Table of Contents

1. Message from the Executive Director ............................................................. 1

2. The Waterloo Institute for Sustainable Energy ............................................... 3
   2.1 Mission, Vision and Strategic Objectives .................................................. 4
   2.2 WISE People ............................................................................................... 5
   2.3 WISE by the Numbers ................................................................................ 11

3. Accomplishments and Impact ........................................................................... 13
   3.1 Collaborate: Fostering Interdisciplinary Research and Training ............... 15
      3.1.1 WISE Research ..................................................................................... 18
         3.1.1.1 Energy Generation ......................................................................... 18
         3.1.1.2 Energy Storage ............................................................................. 24
         3.1.1.3 Smart Energy Networks ................................................................. 27
         3.1.1.4 Sustainable Mobility ..................................................................... 32
         3.1.1.5 Global Energy Access ................................................................... 35
      3.1.2 Training and Student Development ..................................................... 39
   3.2 Reach out: Delivering High Value Partnerships .......................................... 44
      3.2.1 Successful Funding Partnerships ......................................................... 47
      3.2.2 Funding Proposals in Development ..................................................... 100
   3.3 Influence: Mobilizing Knowledge for a Sustainable Society ....................... 116
      3.3.1 Conferences and Workshops ................................................................. 119
      3.3.2 Public Lecture Series ......................................................................... 131
      3.3.3 Media Exposure ................................................................................... 137
      3.3.4 Selected WISE Member Publications ............................................... 143

4. Future Directions ................................................................................................ 148
   4.1 Context ......................................................................................................... 149
   4.2 Priority Areas ............................................................................................... 150
      4.2.1 Smart Energy Infrastructure ................................................................. 150
      4.2.2 Inclusive Energy Transformation ......................................................... 151
      4.2.3 Affordable Energy for Humanity ......................................................... 152
      4.2.4 Geothermal Energy ............................................................................ 153
      4.2.5 Interdisciplinary Energy Research ....................................................... 154

5. Financial Summary ............................................................................................. 155
   5.1 Financial Summary ....................................................................................... 156
   5.2 Use of Funds (Fiscal 2014–Fiscal 2019) ....................................................... 158
   5.3 Budget Request (Fiscal 2020–Fiscal 2024) .................................................... 159

6. Appendices .......................................................................................................... 161
   Appendix I: Letters of Support ........................................................................ 162
   Appendix II: Research Spotlights ..................................................................... 216
   Appendix III: Research Labs ........................................................................... 26
   Appendix IV: Public Lecture Series Posters ..................................................... 280
   Appendix V: Member Publications .................................................................. 296
   Appendix VI: Student Posters .......................................................................... 353
   Appendix VII: Highly Qualified Personnel ..................................................... 373
   Appendix VIII: Visitors ................................................................................... 428
   Appendix IX: WISE Contribution to UW Strategic Plan .................................... 465
1. MESSAGE FROM THE EXECUTIVE DIRECTOR
MESSAGE FROM THE EXECUTIVE DIRECTOR

Dear Senate Graduate & Research Council,

I am pleased to submit this report summarizing our achievements over the past five years of research excellence, energy policy leadership and development of the scientific and technical capacity to support national and global initiatives. As we celebrate ten years of our operation as an Institute, we recognize the achievements of our members who have made significant contributions to the advancement of energy research in Canada and globally.

Although we are a small group in the global context, the impacts of our work are noticeable because we work effectively by joining hands across disciplines and build bridges over institutional barriers. Our success stories are a testament to the collective strengths of our faculty and our efforts to engage with funding agencies and external partners to grow the scope and scale of energy research at the University of Waterloo.

As an Institute, we have been successful in supporting our faculty members across all faculties and continue to foster a strong culture of collaboration across departments to engage in interdisciplinary research projects. The alignment of specific interests of faculty members with the needs of the broader energy sector has created a vast network of positive relationships and engagement both within the university and with external agencies. The Institute has established a solid reputation within the energy community nationally and internationally.

Our existing fossil-fuel based energy system delivers light but also casts dark shadows over the health of our environment. Greenhouse gas emissions threaten the integrity of the climate and the biophysical ecosystem. We are driven by a compelling desire to develop energy solutions that will help achieve the transition of the global energy economy to one with a lower carbon footprint.

Ensuring access to affordable energy is a key criterion for economic and social well-being. Delivering clean energy to every global citizen without compromising the long-term sustainability of the environment is an equally compelling challenge. The twin goals form the nexus of our work. Collectively, we are animated and committed to developing the right solutions for meeting this challenge: a clean environment with affordable energy access for all.

In the following pages, you will read a summary of the accomplishments of our researchers and students through their publications and presentations. We are proud of the efforts of our faculty and their unflinching commitment to work collaboratively.

I invite you to read more about the next chapter in our journey, outlined in the ‘Future Directions’ section.

Jatin Nathwani
2. THE WATERLOO INSTITUTE FOR SUSTAINABLE ENERGY
### 2.1 Mission, Vision and Strategic Objectives

WISE was founded in April 2008, building on the University’s longstanding strengths in engineering, science and environmental research.

WISE advances the broader priorities of the University of Waterloo, including research excellence, interdisciplinarity, internationalization, experiential learning, and entrepreneurship. Our commitment in this regard includes the submission of a special contribution to the current UW Strategic planning process ‘Bridge to 2020’ (see appendix IX).

The institute provides a focal point for energy research at Waterloo and we work to create the best possible research platforms for faculty to test their ideas, engage with their peers, and partner with external organizations to accelerate the pace of research, development and deployment of practical solutions. In the ten years since our founding, WISE has become the face of sustainable energy research at Waterloo, and has established itself as a globally networked and recognized centre for research within the sustainable energy sector.

Our **vision** is simple: clean energy, accessible and affordable for all.

Our **mission** is to conduct original research and develop innovative solutions and policies to help transform the energy system for long-term sustainability.

WISE activities continue to be guided by three **strategic objectives**:

1. **Collaborate**: To expand opportunities for interdisciplinary sustainable energy research at Waterloo and improve research productivity. This is achieved through supporting a diverse group of energy researchers from across the faculties (WISE members) in scoping new projects, developing the funding and human resources to ensure their success, and assisting with communication about research outcomes. In addition to this, WISE plays a central role in supporting students to become future sustainable energy sector leaders through a variety of research, fellowship, and experiential education programs.

2. **Reach Out**: To promote engagement of external organizations, we work closely with government agencies, civil society organizations, and private sector companies to develop sustainable energy research at UW. This is achieved through partnership building activities that deliver significant new sources of research funding, establish long-term relationships with peer institutions, and provide platforms for our researchers to share their findings.

3. **Influence**: To establish WISE as an authoritative source of energy insights and analysis, translate important scientific discoveries for a wide audience, and inform energy policy choices. This is achieved through annual events, publications, media exposure, and engagement with high-level decision-makers and thought leaders.
2.2 WISE People

Staff

Jatin Nathwani
Executive Director

Armughan Al-Haq
Manager, Programs and Partnerships

Nigel Moore
Manager, Global Programs and Initiatives

Laurie Larochelle
Administrative Assistant

Jessica Strickler
Communications Specialist

Advisory Council

David McFadden
Chair, International Practice & Partner, Gowling Lafleur Henderson LLP

Andrew Teichman
Former Executive Director of Investments, OPG Ventures Inc.

Paul Murphy
Chair of the Advisory Board, Advanced Energy Centre, MaRS Discovery District

George Greene
Chair, Stratos Inc

Bruce Campbell
Former President & CEO, IESO

William Smith
Senior Vice President Operations & Engineering, Terrestrial Energy

Céline Bak
President, Analytica Advisors

Steve Dorey
Former Chair, Energy Council of Canada Studies Committee

John Wilkinson
Senior Vice President Sustainability, Greenfield Global

Serge Imbrogno
Deputy Minister of Energy, Ontario Government

Velma McColl
Principal, Earnscliffe Strategy Group

Carmine Marcello
Executive Director, Hetherington Kearney Group

Colin Andersen
Principal, CACS and Chair, Energy Council of Canada

Senior Executive Fellows

Yves Lostanlen
CEO, SIRADEL North America (ENGIE)

Don McCutchan
Partner & International Policy Advisor, Gowling WLG LLP

Chris Henderson
President, Lumos Energy

Catherine Jackson
Founder, Jackson Principled Governance

Neil B. Freeman
Principal & CEO, NBF Group Inc.

Sankaran Ramalingam
National President, Energy & Fuel Users’ Association of India

Thomas Gottschalk
CEO, Mobisol Group

Zohrab Mawani
Co-Founder & President, oneGRID Corporation
Internal Board of Management

The Internal Board of Management provides operational oversight and approval.

The IBM Directors include:

- **WISE Executive Director**
- **Deans of Engineering, Environment and Science**
- **Eight regular WISE faculty members from the five UW faculties**

<table>
<thead>
<tr>
<th>Charmaine Dean (Chair)</th>
<th>Jean Andrey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vice President, University Research</td>
<td>Dean of Environment</td>
</tr>
<tr>
<td>Peal Sullivan</td>
<td>Bob Lemieux</td>
</tr>
<tr>
<td>Dean of Engineering</td>
<td>Dean of Science</td>
</tr>
<tr>
<td>Keith Hipel</td>
<td>Heather Douglas</td>
</tr>
<tr>
<td>Professor, Faculty of Engineering</td>
<td>Professor, Faculty of Arts</td>
</tr>
<tr>
<td>Department of Systems Design Engineering</td>
<td>Department of Philosophy</td>
</tr>
<tr>
<td>Kankar Bhattacharya</td>
<td>Giovanni Cascante</td>
</tr>
<tr>
<td>Professor, Faculty of Engineering</td>
<td>Professor, Faculty of Engineering</td>
</tr>
<tr>
<td>Department of Electrical and Computer Engineering</td>
<td>Department of Civil and Environmental Engineering</td>
</tr>
<tr>
<td>Neil Craik</td>
<td>Olaf Weber</td>
</tr>
<tr>
<td>Professor, Faculty of Environment</td>
<td>Professor, Faculty of Environment</td>
</tr>
<tr>
<td>School of Environment, Enterprise and Development</td>
<td>School of Environment, Enterprise and Development</td>
</tr>
<tr>
<td>Maurice Dusseault</td>
<td>Jatin Nathwani</td>
</tr>
<tr>
<td>Professor, Faculty of Science</td>
<td>Professor and Ontario Research Chair in Public Policy for Sustainable Energy</td>
</tr>
<tr>
<td>Department of Earth and Environmental Sciences</td>
<td>Faculty of Engineering and Faculty of Environment</td>
</tr>
</tbody>
</table>

UW WISE Members

**FACULTY OF APPLIED HEALTH SCIENCES**

Philip Bigelow, Associate Professor, Associate Director Graduate Research Programs, Public Health and Health Systems, University of Waterloo

**FACULTY OF ARTS**

Paul Doherty, Continuing Lecturer, Anthropology, University of Waterloo

Heather Douglas, Associate Professor, Philosophy, University of Waterloo

Ranjini Jha, Professor, School of Accounting and Finance, University of Waterloo

Alain-Desire Nimubona, Associate Professor, Economics, University of Waterloo

Anindya Sen, Associate Professor; Associate Chair, Graduate Studies, Economics, University of Waterloo
FACULTY OF ENGINEERING

William Anderson, Professor and Director of Admissions, Chemical Engineering, University of Waterloo

Dipanjan Basu, Associate Professor, Civil and Environmental Engineering, University of Waterloo

Kankar Bhattacharya, Professor, Electrical and Computer Engineering, University of Waterloo

Paul Calamai, Professor, Systems Design Engineering, University of Waterloo

Claudio Cañizares, Professor and HyroOne Endowed Chair, Electrical and Computer Engineering, University of Waterloo

Giovanni Cascante, Professor and Associate Chair, Graduate Studies, Civil and Environmental Engineering, University of Waterloo

Zhongwei Chen, Assistant Professor, Chemical Engineering, University of Waterloo

Pu Chen, Professor, Chemical Engineering, University of Waterloo

Chih Hsiung (Perry) Chou, Canada Research Chair in Biomanufacturing and Editor of Biotechnology Advances; Professor, Chemical Engineering, University of Waterloo

Michael Collins, Associate Professor, Mechanical and Mechatronics Engineering, University of Waterloo

James Craig, Assistant Professor, Civil and Environmental Engineering, University of Waterloo

Eric Croiset, Professor, Chemical Engineering, University of Waterloo

Cecile Devaud, Associate Professor, Mechanical and Mechatronics Engineering, University of Waterloo

Peter Douglas, Associate Dean Undergraduate Studies and Professor; Chemical Engineering, University of Waterloo

Ali Elkamel, Professor, Chemical Engineering, University of Waterloo

Ehab El-Saadany, Professor and Tier 2 Canada Research Chair; Electrical & Computer Engineering, University of Waterloo

Ramadan El-Shatshat, Lecturer, Director of the Electric Power Engineering Program, Electrical and Computer Engineering, University of Waterloo

Xianshe Feng, Professor, Chemical Engineering, University of Waterloo

Michael Fowler, Associate Professor, Chemical Engineering, University of Waterloo

Roydon Fraser, Professor, Mechanical and Mechatronics Engineering, University of Waterloo

Mel Gabriel, Adjunct Assistant Professor, Management Sciences/Applied Operations Research & Management of Technology, University of Waterloo

Vincent Gaudet, Professor, Electrical and Computer Engineering, University of Waterloo

Bissan Ghaddar, Assistant Professor and Adjunct Assistant Professor, Management Sciences, University of Waterloo

Lukasz Golab, Assistant Professor and Canada Research Chair, Management Sciences, University of Waterloo
Wojciech Golab, Assistant Professor, Electrical and Computer Engineering, University of Waterloo

Irene Goldthorpe, Assistant Professor, Electrical and Computer Engineering, University of Waterloo

Jeff Gostick, Assistant Professor, Chemical Engineering, University of Waterloo

Robert Gracie, Assistant Professor, Civil and Environmental Engineering, University of Waterloo

Feridun Hamdullahpur, University President and Vice-Chancellor; Professor, Mechanical and Mechatronics Engineering, University of Waterloo

Keith Hipel, Professor, Systems Design Engineering, University of Waterloo

Anming Hu, Research Assistant Professor, Mechanical and Mechatronics Engineering, University of Waterloo

Robert Hudgins, Professor Emeritus, Chemical Engineering, University of Waterloo

Shesha Jayaram, Professor, Electrical and Computer Engineering, University of Waterloo

Beth Jewkes, Professor, Management Sciences, University of Waterloo

David Johnson, Associate Professor, Mechanical and Mechatronics Engineering, University of Waterloo

Mehrdad Kazerani, Professor, Electrical and Computer Engineering, University of Waterloo

Behrad Khamesee, Professor, Mechanical and Mechatronics Engineering, University of Waterloo

Nasser Lashgarian Azad, Associate Professor, Systems Design Engineering, University of Waterloo

Hyung-Sool Lee, Assistant Professor, Civil and Environmental Engineering, University of Waterloo

Yuri Leonenko, Associate Professor, Geological Engineering and Geography; Environmental Management, University of Waterloo

Xianguo Li, Professor, Mechanical and Mechatronics Engineering, University of Waterloo

Yuning Li, Associate Chair Graduate Studies and Professor, Chemical Engineering, University of Waterloo

Fue-Sang Lien, Professor, Mechanical and Mechatronics Engineering, University of Waterloo

David Mather, Lecturer, Mechanical and Mechatronics Engineering, University of Waterloo

John McPhee, Professor, Systems Design Engineering, NSERC/Toyota/Maplesoft Industrial Research Chair, University of Waterloo

Christine Moresoli, Professor, Associate Dean Co-op Education & Professional Affairs, Chemical Engineering, University of Waterloo

Sriram Narasimhan, Assistant Professor, Canada Research Chair, Civil and Environmental Engineering, University of Waterloo

Flora Ng, Professor, Chemical Engineering, University of Waterloo

Amer Obeidi, Adjunct Professor, Systems Design Engineering Department, University of Waterloo
Section II: The Waterloo Institute for Sustainable Energy

Qinmin Pan, Professor, Chemical Engineering, Soochow University, China/University of Waterloo

Mahesh Pandey, Professor and Industrial Research Chair, Civil and Environmental Engineering, University of Waterloo

Wayne Parker, Professor, Civil and Environmental Engineering, University of Waterloo

Mehrdad Pirnia, Graduate Attributes Lecturer, Management Sciences, University of Waterloo

Sahar Pirooz Azad, Assistant Professor, Electrical and Computer Engineering, University of Waterloo

Kumaraswamy Ponnambalam, Professor, Systems Design Engineering, University of Waterloo

Omar Ramahi, Professor, Electrical and Computer Engineering, University of Waterloo

Garry Rempel, Professor, Chemical Engineering, University of Waterloo

Luis Ricardez-Sandoval, Associate Professor, Chemical Engineering, University of Waterloo

Catherine Rosenberg, Professor and Tier 1 Canada Research Chair for the Future Internet, Electrical and Computer Engineering, University of Waterloo

Rebecca Saari, Assistant Professor, Civil and Environmental Engineering, University of Waterloo

Magdy Salama, Professor, University Research Chair, Electrical and Computer Engineering, University of Waterloo

Armaghan Salehian, Associate Professor, Mechanical and Mechatronics Engineering, University of Waterloo

Andrei Sazonov, Associate Professor, Electrical and Computer Engineering, University of Waterloo

Gerry Schneider, Professor, Mechanical and Mechatronics Engineering, University of Waterloo

Xuemin (Sherman) Shen, Professor and University Research Chair, Electrical and Computer Engineering, University of Waterloo

David Simakov, Assistant Professor, Chemical Engineering, University of Waterloo

John Simpson-Porco, Assistant Professor, Electrical & Computer Engineering, University of Waterloo

Siva Sivoththaman, Professor and Ontario Research Chair, Electrical and Computer Engineering, University of Waterloo

John Straube, Associate Professor, Civil and Environmental Engineering, University of Waterloo

Zhongchao Tan, Associate Professor, Mechanical and Mechatronics Engineering; Civil and Environmental Engineering, University of Waterloo

Susan Tighe, Professor, Civil and Environmental Engineering, University of Waterloo

Robert Varin, Professor, Mechanical and Mechatronics Engineering, University of Waterloo

Lan Wei, Assistant Professor, Electrical and Computer Engineering, University of Waterloo

John Wen, Professor, Mechanical and Mechatronics Engineering, University of Waterloo
Section II: The Waterloo Institute for Sustainable Energy

Aiping Yu, Assistant Professor, Chemical Engineering, University of Waterloo

Jian Zhang, Associate Professor, Bioreactor Engineering, East China University of Science and Technology

Boxin Zhao, Associate Professor, Chemical Engineering, University of Waterloo

Weihua Zhuang, Professor, Electrical & Computer Engineering, University of Waterloo

Philip Beesley, Professor, School of Architecture, University of Waterloo

Terri Meyer-Boake, Professor, School of Architecture, University of Waterloo

FACULTY OF ENVIRONMENT

Neil Craik, Associate Professor, School of Environment, Enterprise and Development (SEED), University of Waterloo

Robert Feick, Associate Professor, School of Planning, University of Waterloo

Komal Habib, Assistant Professor, Industrial Ecology, University of Waterloo

Jennifer Lynes, Associate Professor, Program Director Environment and Business Undergraduate Program, Environment and Resource Studies, University of Waterloo

Paul Parker, Professor and Associate Dean, Strategic Initiatives, Geography and Environmental Management, University of Waterloo

Ian Rowlands, Professor and Associate Vice-President, International, School of Environment, Resources and Sustainability, University of Waterloo

Olaf Weber, Professor, School of Environment, Enterprise & Development (SEED), University of Waterloo

Steven Young, Associate Professor, School of Environment, Enterprise and Development (SEED), University of Waterloo

FACULTY OF MATHEMATICS

Ihab Ilyas, Professor, Cheriton School of Computer Science, University of Waterloo

Srinivasan Keshav, Professor and Cisco Chair, Cheriton School of Computer Science, University of Waterloo

FACULTY OF SCIENCE

Trevor Charles, Professor, Associate Chair, Graduate Studies, Biology, University of Waterloo

Maurice Dusseauult, Professor, Earth and Environmental Sciences, University of Waterloo

Holger Kleinke, Professor, Interim Executive Director, Chemistry, University of Waterloo

Seyed Bijan Mahbaz, Research Associate, Geomechanics Group, University of Waterloo

Linda Nazar, Professor, Chemistry, University of Waterloo

Mark Pritzker, Professor, Chemistry, University of Waterloo

Eric Prouzet, Associate Professor, Chemistry, University of Waterloo

Pavle Radovanovic, Professor, Chemistry, University of Waterloo
Understanding our Members

2.3 WISE BY THE NUMBERS

**Our People**
- 104 University of Waterloo Members
- 145 AE4H Members

**Scholarly Output**
- 2,785 Publications
- 772 Graduate Theses

**Industry – Academic Events**
- 24 Events and Workshops
- 65 Public Lecture Series
- 3,830 Registered Attendees
- 86 Successful Funded Projects

**Secured Funding**
- $102.1 Million Secured by WISE Faculty Members
- $23.1 Million Secured by WISE Management
Section II: The Waterloo Institute for Sustainable Energy

How Members Engage With WISE

- Be a WISE Ambassador at events: 35
- Co-supervise students with WISE Faculty: 45
- Guide WISE on matters of strategy: 42
- Provide insights into funding opportunities: 37
- Share industry, research, global connections: 44
- Collaborate with other researchers: 53
- Present at a WISE seminar: 49
- Identify external guest lecture candidates: 43
- Serve on a WISE committee: 62
- Share items of interest with WISE members: 58

What Faculty Value About Membership

- Keep up to date on WISE news: 56
- Keep up to date on collaboration opportunities: 59
- Organize workshops and events: 35
- Secure online collaboration tools: 28
- Participate in interdisciplinary research proposals: 53
- Attract research funding: 50
- Increased access to labs and facilities: 26
- Raise profile of research: 30
- Connect with other researchers: 49
- Build research partnerships with industry: 49
3. ACCOMPLISHMENTS AND IMPACT
Section III: Accomplishments and Impact

Collaborate

Interdisciplinary Research & Training
- Generation
- Sustainable Mobility
- Smart Energy Networks
- Storage
- Universal Access
- Student Internships/Fellowships

Events
- Conferences
- Workshops
- Innovation Labs
- Public Lecture Series

Publications

Media Exposure

Reach Out

WISE-led partnerships with
- Funding Councils
- Industry
- Academia
- Non-Profit

Influence

$23.1M
3.1 Collaborate: Fostering Interdisciplinary Research and Training
**Collaborate:**

*Fostering Interdisciplinary Research and Training*

Our research advances knowledge across several domains, informs energy policies, and helps put Waterloo centre-stage in the development of the clean energy economy.

WISE encourages interdisciplinary research collaboration on sustainable energy topics that range from technology through to economics and policy development. We are the central node that brings together over 100 WISE members from across all UW faculties and diverse departments to catalyze research collaboration on pressing energy sector challenges. We assist our members in acquiring funds and developing partnerships to support their research, disseminate the results of this work to key audiences both within and outside academia, and support the development of the next generation of sustainable energy leaders and change agents from the University of Waterloo. In a landscape that puts a premium on cross-disciplinary collaboration, WISE is the indispensable catalyst advancing sustainable energy research at UW.

In addition to supporting our members own research, WISE itself has championed a number of initiatives. Over the past five years, these have included a multi-million dollar research program to explore the feasibility of salt caverns as locations for compressed air energy storage, a variety of sustainable mobility initiatives related to electric vehicles and EV charging, industry-academia partnerships in the area of smart grids and smart energy networks, and a global initiative that catalyzes innovation in off-grid renewable energy technology to address the unmet energy needs of those living in energy poverty. Through these projects and others, WISE takes an active role in developing new opportunities to enhance UW’s research excellence.

WISE recognizes the role of the University as an incubator for the next generation of energy sector leaders. WISE currently manages multiple externally funded programs that allow Waterloo’s undergraduate, Masters and PhD students to conduct interdisciplinary research with a focus on sustainable energy and undertake internships with cutting edge sustainable energy enterprises within our network. WISE also responds to the growing prominence of entrepreneurship in the energy sector—and student interest in venture creation—through mentoring student teams and start-ups. We have been actively involved in on-campus social innovation competitions related to sustainable energy, and meet regularly with UW-based energy start-ups to provide them with advice and networking opportunities.
“WISE has played an incredibly supportive role in my research in the last eight years. Indeed, I think that I could not do the work I am doing now if it were not for WISE.”

Srinivasan Keshav
Professor, ACM Fellow, IEEE Senior Member David R. Cheriton School of Computer Science

“Since its inception, WISE has successfully brought together scores of academics and researchers from different departments, and faculties, and from Universities across the globe to collaborate under the umbrella of sustainable energy, and addressed diverse and critical issues.”

Kankar Bhattacharya
Professor, ECE Department
Ph.D., P.Eng., FIEEE

“WISE’s international, cross-discipline and collaborative approach to energy research promotes truly forward-thinking that is shaping the future of the electricity sector in Ontario.”

Peter Gregg
President and CEO
Independent Electricity System Operator (IESO)
3.1.1 WISE Research

Between 2013 and 2018, WISE has played a pivotal role in developing research projects across a range of academic disciplines and knowledge domains. A variety of projects involving the WISE team and our members are described below, aligned in five primary domains: Energy Generation, Energy Storage, Smart Energy Networks, Sustainable Mobility, and Universal Energy Access.

3.1.1.1 ENERGY GENERATION

Solar

Over the past several years, the cost of solar energy systems and their components have declined by a large margin, paving the way to a cleaner, more sustainable energy future.

FLEXIBLE SOLAR CELLS

Conventional solar photovoltaic (PV) systems are being augmented by promising new materials and technologies. The possibility of using flexible large scale substrates opens the door to multiple advanced application opportunities such as smart textiles, photovoltaic window shades and options for building integrated solar technologies.

Research led by Professor Siva Sivoththaman (Electrical and Computer Engineering) is focused on graphene-decorated nanocomposites for printable electrodes in thin wafer devices for future solar cells. The synthesis of nanocomposites by incorporating graphene nanopowders as well as silver nanowires into epoxy-based electrically conductive adhesives (ECA) is being explored to improve electrical conductivity and to develop alternate printable electrode materials that induce less stress on the wafer. Low curing temperature, good thermal resistance, reasonably high conductivity, and low residual stress in the ECA/graphene nanocomposite makes this material a promising alternative in screenprinted electrode formation in thin substrates.

Professor Irene Goldthorpe (Electrical and Computer Engineering) has completed work on Al-doped ZnO/Ag-nanowire composite electrodes for flexible three-dimensional nanowire solar cells. The power conversion efficiency (PCE) of the three-dimensional solar cells improved by up to 60 per cent compared to using AZO electrodes alone due to enhanced coverage of the top electrode over the 3-D structures, decreasing the series resistance of the device by five times. The composite layer also showed a 10 times reduction in sheet resistance compared to the AZO thin-film contact under applied mechanical strain.

NEXT GENERATION QUANTUM DOT TECHNOLOGY

Solar PV Quantum dots (QDs) are semi-conductors on a nanometer scale. They are an emerging class of functional material being developed for novel solar energy conversion strategies. First and second generation PV cells have best-cell PCEs that are asymptotically approaching the Shockley-Queisser (SQ) limit; for example, the record for c-Si based solar cells is currently at 25 per cent, while for GaAs the record is 28.3 per cent. Third generation PV can have a higher limiting conversion efficiency through bypassing one of the assumptions of the SQ analysis and recovering either some of the
energy lost via thermalization or providing pathways to harvest those photons not absorbed in a standard solar cell. In addition to the efficiency considerations, third generation solar cells promise low manufacturing costs.

Professor Sivoththaman’s team has examined the toxicity and safety aspects of nanoparticle spread in third generation photovoltaic device processing environments. Detection of aerosolized nanoparticles was experimentally verified using gold nanoparticle adsorbent, followed by spectroscopic measurements. Results from in-vitro cytotoxicity study with HeLa cell cultures and fluorescent plate reading confirms that core/shell ‘CdSe/ZnS’ QDs are responsible for cell death following exposure.

SOLAR ROADWAYS

Professor Susan Tighe (Civil and Environmental Engineering) has conducted a finite element analysis to predict how her solar road based prototype would perform in real-world conditions. Using modelling software, her team tested the panel’s durability on four structural bases typically used in Ontario pavement: concrete, asphalt, granular and subgrade. For each, they applied the maximum wheel and axle loads allowed under Canadian regulations to different areas on the panels, checking whether they would crack or fail under the pressure.

In all cases, there were no cracks and the strain put on the transparent and base layers of the panels fell well below their endurance limits, demonstrating that the prototype is road-worthy.

Additional reinforcement provided by the solar panels helped distribute tire loads, actually maintaining or improving the structural performance of the base they’re installed on. The results suggest that researchers can move their trials out of the lab and into the field – paving the way for a network of solar highways.

WIND

The role of wind power in the reduction of CO₂ emissions is well recognized. Wind power generation has shown remarkable growth worldwide and in Canada with generation capacity increasing dramatically over the past decade.

WIND POWER FORECASTING

One of the challenges for wind farm operators is to determine the amount of electricity that can be produced by wind turbines on any given day to meet the desired energy demand as wind speeds vary from hour to hour.

Professor Fue-Sang Lien (Mechanical and Mechatronics Engineering) and his team of graduate students have developed a model for feeding the best statistical and meteorological data into an interconnected framework of artificial neural networks to forecast wind speed and turbine power. The result is an advanced 72 hour accurate forecast that will help operators and utilities to manage the power supply more efficiently.

WIND TURBINE PERFORMANCE ANALYSIS

Wind turbines frequently operate in multifaceted atmospheric conditions due to continually changing wind direction and magnitude. These conditions can impact the performance of the wind turbines due to unstable airloads on the blades that can result
in turbine rotors that are misaligned with the wind (yawed). Prof. David Johnson (Mechanical and Mechatronics Engineering) and his group are analyzing different technical parameters of various blade designs by studying the wind turbine rotor under yaw loads.

HEALTH AND SOCIAL CHALLENGES OF WIND FARMS

Challenging issues for social and community acceptance of wind power development include noise and suspicion of negative health impacts. To meet regulatory requirements for noise levels, new predictive tools are required in support of new wind farm development.

Professor Johnson has developed tools based on computational fluid dynamics studies to predict the far field sound. Validation of these predictive tools with experimental measurements of 2D airfoil self-noise measurements obtained at the University of Waterloo Wind Energy Research wind turbine field site shows good agreement with the measured experimental data. Professor Johnson also contributed to the Canadian Council of Academies Expert Panel on Wind Turbine Noise and Human Health, which published its report in 2015.

Professor Lien and his team of graduate students have also investigated noise emission and the power output from a small horizontal axis wind turbine by using coarse-resolution computational fluid dynamics (CFD) simulations. Professor Lien’s team has shown that a computational modeling/simulation framework involving coupled aerodynamic and aero-acoustic components can be used to address a specific industrial challenge: namely, a physics-based prediction of the noise generated by a full scale wind turbine.

Geothermal

INTERMEDIATE GRADE GEOTHERMAL ENERGY

Intermediate grade geothermal energy is an abundant, low carbon base load energy source that does not require high temperature gradients or heat sources and can be extracted by using the latest drilling technology at an affordable cost. The typical range of intermediate grade geothermal energy is 80-150°C found several kilometers beneath the Earth’s surface.

Professors Dipanjan Basu (Civil and Environmental Engineering), Roydon Fraser (Mechanical and Mechatronics Engineering), and Maurice Dusseault (Earth and Environmental Science) have collaborated to assess the geothermal resources in Canada with an eye to harvesting this energy.

Geothermal has emerged as a significant carbon-free energy resource to help Canada transition towards a low carbon energy economy consistent with Canada’s international obligations to reduce the GHG emissions for meeting the climate challenge. Geothermal energy is a ubiquitous energy resource that can provide a continuous – non intermittent – source of base load electricity or heating to meet end user requirements. Geothermal energy’s positive environmental attributes –low GHG emissions and low water usage requirements as part of closed cycle configurations – coupled with the potential for meeting energy requirements in northern Canada and to serve distant isolated communities is another strategic advantage. If geothermal energy resource is developed to it fullest potential to serve a wide range of end user requirements across a range of
geothermal technology options, then its strategic national importance lies within three intersecting goals: environmental sustainability, economic prosperity through a transition from fossil fuel extraction to direct heat and electricity extraction and reduction of dependence on foreign energy resources.

WISE has been also instrumental in providing leadership to two major global energy summits in co-operation with the Waterloo Global Science Initiative (a partnership of UW and the Perimeter Institute. WGSI's first major report – The ‘Equinox Energy 2030 Blueprint’ (2012) – specifically identified advancement of geothermal energy as a credible pathway for an energy future without fossil fuels. A second Summit produced the OpenAccess Energy Blueprint – which identified remote off-grid communities in Canada as potential sites for geothermal energy deployment. WISE has therefore made specific efforts to advance geothermal research at UW over the past 5 years, in accordance with the opportunities identified at the WGSI summits, and engaged consistently with a variety of emerging sector players from across the country, including through hosting a geothermal symposium event in Waterloo to advance national-level collaboration.

GROUND SOURCE HEAT PUMP SYSTEMS

Ground Source Heat Pump Systems (GSHPs) are among the most efficient and sustainable methods to provide space heating, cooling, and hot water to residential and commercial buildings. The technology has a great potential to reduce carbon emissions and address energy demands of the different dwelling types in Canada by delivering energy access to residential and commercial buildings at a low cost. Prof. Basu leads the project to identify the technical constraints and to perform a detailed life cycle assessment of GSHPs in Northern Ontario.

GEOTHERMAL PILE FOUNDATIONS

Prof. Basu is also investigating the feasibility of using helical piles to extract shallow geothermal energy. These pre-fabricated piles can be quickly installed under a variety of subsurface conditions, and are attractive foundation option for 1-3 storey residential buildings. However, these piles have never been used to extract shallow geothermal energy from the ground. If successful, geothermal helical piles will be cost-effective building solution that serves the dual purpose of providing structural support and providing space heating, cooling, and hot water to a variety of residential buildings.

This technology will not only help in reducing the carbon footprint of future building stock but also minimize the energy expenditure for consumers. In this technology, energy is extracted from the ground when in heating mode, and energy is released to the ground when in cooling mode.

Bioenergy

Bioenergy has the potential to make an important contribution to meeting growth in energy demand in an environmentally responsible manner, while at the same time providing opportunities for social and economic development in rural communities.
THERMAL AND THERMOCHEMICAL TECHNOLOGIES

A thermal conversion is the use of heat, with or without the presence of oxygen, to convert biomass materials or feedstocks into other forms of energy. Thermal conversion technologies include direct combustion, pyrolysis, and torrefaction. A key thermochemical conversion process is gasification.

Professors Ali Elkamel and William Anderson (Chemical Engineering) are developing a conceptual design of a peat gasification process to produce electricity and methanol. Two types of gasifiers (updraft fixed-bed and dual fluidized-bed) and two types of methanol synthesis reactors (gas-phase and liquid-phase) are paired to create four design alternatives that are modeled through this research. The chosen design is then refined with detailed modeling of the power generation section and energy integration. The final design consumes 1,000 tonne peat/day, produces 214 tonne methanol/day, and generates 56 MW of electricity with GHG emissions reduced by 22 per cent compared with traditional alternatives.

BIOLOGICAL AND BIOCHEMICAL TECHNOLOGIES

Micro-organisms can be regarded as biochemical “factories” for the treatment and conversion of biological materials. Fermentation technologies, with the assistance of biological engineering, are leading to breakthrough processes for creating fuels and fertilizer, and other products useful in agriculture and the energy sector.

Research conducted by Professor Hyung-Sool Lee (Civil and Environmental Engineering) involves production of hydrogen from sugar beet juice using an integrated biohydrogen process of dark fermentation and microbial electrolysis. Professor Lee is also focusing on the concept of microbial fuel cells with emphasis on three key areas: (i) Adding an electron scavenger to the system to prevent the efficiency drop that occurs when the electrons produced from bacteria are grabbed on route to the anode, (ii) Using large quantities of Geobacter sp. to increase the current density within the fuel cells, and (iii) Reducing the internal resistance by designing fuel cells with a high surface-to-volume ratio and adjusting the distance between electrodes.

Professor Flora Ng (Chemical Engineering) has turned to acid catalysts to create a cost-effective and green alternative. She is performing several analytical studies to evaluate the feasibility of producing biodiesel from high-FFA (free fatty acids) feedstock without the problem of soap by-products by using a novel solid acid catalyst and converting the oil’s triglycerides and FFAs into biodiesel in a single-step process. One of her key focused areas is to produce biodiesel with glyceride levels and acid numbers that met international biodiesel standards by adding a water-stripping step.

Piezoelectricity

Piezoelectric energy harvesting is a groundbreaking technology that can be used to transfer energy wirelessly from one location to another. This is a method of capturing minute amounts of energy in the form of heat, light, sound, vibrations, and electromagnetic fields. Such electromagnetic energy is abundantly available from sunlight, radio waves, and infrared radiation.
ELECTROMAGNETIC ENERGY WIRELESS TRANSFER

Professor Omar Ramahi (Electrical and Computer Engineering) and his team have proposed the concept of etching to harvest up to 97 per cent of the electromagnetic energy that falls onto the surface of sheets of copper by etching repeating patterns on a sheet of metamaterial and adjusting the dimensions of the patterns. The ultra-efficiency of the process makes it a potential low cost option for energy harvesting.

PIEZOELECTRIC MICROELECTROMECHANICAL SYSTEMS (MEMS)

The goal of MEMS is to create a self-sustainable integrated system for smart grid monitoring and active management of electrical demand. In this way, issues related to grid capacity, reliability and efficient distribution of power can be monitored and controlled through sensing units as they have the capability to measure current and identify failures across the grid.

Compared with the traditional technology, the MEMS technological concept is highly competitive due to its non-invasive properties, low maintenance and significantly reduced costs. Professor Armaghan Salehian (Mechanical and Mechatronics Engineering) and her research team are developing a system-on-chip solution to monitor electric power in smart grids using a piezoelectric based MEMS current sensor. In addition to a much smaller footprint, once developed, the proposed technology will have many advantages over its opponents in the market including superior accuracy for high current measurements — a limitation for available technologies due to their saturation problems.

Carbon Dioxide Capture and Storage

Carbon dioxide capture and storage (CCS) technologies are an attractive option to limit CO2 emissions from fossil fuel power plants. If the technology can be developed cost-effectively, CCS can be a vital tool in mitigating meeting the goals of greenhouse gas (GHG) emissions from the power sector and large industrial operations.

CO2 CAPTURE FROM COAL-FIRED POWER PLANTS

Professors Eric Croiset, Peter Douglas, and Luis Ricardez-Sandoval's (Chemical Engineering) research includes dynamic modelling of a CO2 capture and purification unit for an oxy-coal-fired power plant. They have concluded that oxy-combustion is a promising pathway to capture CO2 from coal fired power plants and can compete favourably with other CO2 capture technology pathways, such as post-combustion and pre-combustion. Future research will focus on validating a dynamic model of the CO2CPU for control design purposes.

Professors Croiset, Douglas, and Elkamel have also collaborated on a project using short-term resource scheduling for assessing effectiveness of CCS within the electricity generation subsector.
3.1.1.2 ENERGY STORAGE

THE NEED FOR STORAGE

Energy storage technologies provide valuable support to power grids as backup power, load leveling, frequency and voltage regulation, and energy management services. Rapid development of variable renewable energy resources (wind and solar in particular) suggests a growing role for storage to accommodate the intermittency of generation. The need for balancing services, rapid generation ramping, and moving energy from times of excess to times of high demand are expected to increase with high levels of wind and solar energy penetration. Practical energy storage solutions comprise a range of technologies: electrochemical (batteries and capacitors), compressed air, pumped hydro and indirect options such as power-to-gas and hydrogen.

BATTERY STORAGE

Batteries can play a significant role in managing variability and supporting the decentralized nature of renewable energy technologies to ensure a reliable electricity supply. At high levels of penetration, the fluctuations of energy output increases the risk for reliable operation of the grid. The physics of power flows requires supply and demand of electricity must be balanced at all times. This storage technology can be used for both short (seconds-minutes) and long-term (hours-seasons) applications, and benefits from being highly scalable and efficient.

Battery storage in the power sector needs to overcome several barriers before it can be integrated as a mainstream option. One barrier is the lack of monetary compensation schemes available for the benefits of battery storage systems. Cost competitiveness, validated performance, regulatory hurdles, and safety are others.

Professor Linda Nazar (Chemistry) has made significant advances on the characterization techniques commonly employed for battery evaluation. The recent work is a study of methods and protocols for electrochemical energy storage materials. This project involves a comprehensive analysis of electrode preparation, coin cell assembly, electrochemical evaluation techniques, operando X-ray diffraction, operando pair distribution function analysis, operando X-ray absorption spectroscopy, and X-ray photoelectron spectroscopy techniques. Professor Nazar was named an Officer for the Order of Canada in recognition of her excellence in research. She holds the Canada Research Chair in Solid State Energy Materials, and is a Fellow of the Royal Society of Canada.

Professor Nazar has also developed a concept for aqueous batteries to provide cost-effective, durable, and safe options to battery storage. Utilizing zinc as the negative electrode addresses the issues of low energy density, slow charge and discharge speeds and inability to hold a charge over many cycles. Other issues have been tackled by building a better positive electrode. Professor Nazar and her team has created nanobelts of vanadium oxide bronze with metal ions and structural water sandwiched between sheets of oxide. The result is a compact electrode structure that allows aqueous batteries to charge and discharge quickly and this technology retains more than 80 per cent of its capacity over 1,000 cycles. The nanobelts are also easy to fabricate on a large scale. At
Section III: Accomplishments and Impact

a cost of less than US$65 per kilowatt-hour, these batteries offer a highly affordable solution for grid-scale storage.

Professor Zhongwei Chen (Chemical Engineering) is working on an anode material that can maximize the performance of a lithium ion battery (LIB) in energy storage options. LIB can play a vital role as renewable energy storage devices for applications in electric vehicles and portable electronics. Currently, lithium-ion batteries are extensively employed in portable electronic devices with their expanded applications has expanded to the electric vehicle market. Battery technologies beyond Li-ion batteries, such as lithium-sulfur (Li-S), sodium-ion (Na-ion), and magnesium (Mg) batteries, have gained much attention from the research communities and industry as they offer advantages for sustainability, cost-effectiveness and high capacity performance. Commercial LIBs employ graphite as the anode material with a low capacity unable to satisfy the energy demand of emergent systems. There is a need to develop new anode materials with high capacity and reliability as well as low fabrication cost for practical applications. LIBs that utilize the anode material developed by Prof. Chen and his team can deliver a high volumetric capacity and exhibit superior cycle stability over 1500 cycles as well as a high capacity retention of 85%. Excellent battery performance combined with the simplistic, scalable, green chemistry approach makes this material a promising candidate for LIB applications.

COMPRESSED AIR ENERGY STORAGE

Solar and wind energy are increasingly being integrated into power grids, however, their intermittent and variable nature of output requires large-scale (gigawatt-level), cost-effective storage to help balance local and regional generation sources to enable a larger share of renewable energy generation into the power grid.

Compressed Air Energy Storage (CAES) is a solution that offers a variety of socio-economic and environmental benefits for the energy economy as a whole. The CAES storage reservoir can be constructed in pre-existing formations i.e. salt caverns, aquifers and abandoned mines. As a result, the capital cost of adding an incremental amount of storage capacity can be much lower than for other comparable storage technologies. Not only is CAES financially practical for bulk storage, it is a promising storage solution that:

- **Accommodates Large Scale Integrated Renewables** through the ability to store and combine intermittent solar and wind power in underground salt caverns
- **Enhances Grid Performance** by providing stability, reliability, and additional peak capacity to the grid infrastructure
- **Leads to Environmental Sustainability** by maximizing environmentally friendly forms of electricity generation
- **Contributes to Economic Benefits** since this technology would allow cost effective operation of wind resources when demand during the night is low

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.

Over the past three years, WISE has taken on an ambitious project to assess and deploy CAES technology in Canada. This work is led by Professor Dusseault, Professor Fraser
and Professor Giovanni Cascante (Civil and Environmental Engineering), along with a team of investigators from the University of Waterloo, including Prof. Basu and Profs. Claudio Cañizares and Kankar Bhattacharya (Electrical and Computer Engineering), Jatin Nathwani (WISE), researchers from the University of Alberta and the University of Calgary, and industry partners including Hydro One Networks Inc., Ontario Power Generation (OPG), Union Gas Limited, NRStor Inc., Compass Minerals and Rocky Mountain Power (RMP).

An initial assessment showed that CAES in salt caverns is a technically feasible and financially viable technology. In addition, it is concluded that CAES integrates well with battery energy storage because they occupy different response-time regions and are of different scales of output over demand times (seconds to days).

Following this assessment, WISE partnered with NRStor and Hydrostor to initiate Canada's first CAES in Salt Caverns project in the city of Goderich, Ontario. This $7.2 million CAES facility has a planned installed capacity of 1.75 MW (7MWh) and will be operating under a contract with the Independent Electricity System Operator (IESO). In addition, NRStor Goderich intends to provide energy and operating reserve services to the IESO markets. This project is expected to be the world's first commercial fuel-free CAES facility when completed.

**FLYWHEELS**

Flywheel energy storage systems (FESS) offer several unique advantages as an energy storage solution with attributes of a high cycle life, long operational life, high round-trip efficiency, high power density, low environmental impact, and ability to store megajoule (MJ) levels of energy with no upper limits when configured in banks.

Flywheels are mechanical devices that spin at high speeds, storing electricity as rotational energy. This energy is later released by slowing down the flywheel's rotor, releasing quick bursts of energy (i.e. releases of high power and short duration).

Professor Magdy Salama (Electrical and Computer Engineering) and his team have proposed a unique approach, using a flywheel to store excess electricity during off-peak periods and also reduce voltage fluctuations. The system consists of a flywheel, a permanent magnet synchronous machine and three-phase back-to-back converters. The researchers put it to the test in a simulation of a residential distribution network that includes photovoltaic panels. The results show that incorporating a flywheel energy storage system can compensate for the fluctuations in output power, thus reducing the need for an automatic voltage regulator. Thus, more electricity produced by solar panels is actually used, extracting maximum benefit from each ray of sunshine.

**HYDROGEN ‘POWER-TO-GAS’ TECHNOLOGIES**

Hydrogen-based energy storage technologies show tremendous potential across a variety of applications, but face significant challenges related to the design of efficient and low-cost hydrogen production, transmission and storage technologies.

Professors Michael Fowler and Ali Elkamel (Chemical Engineering) are developing strategies to decarbonize transportation through the use of power-to-gas. Power-to-Gas is a technology that generates hydrogen by electrolysis. It can be used to provide a number of energy services including energy storage, ancillary services for the electrical grid and, the production of hydrogen for industrial processes and transportation fuel. The purpose of this work is to provide an incentive for using power-to-gas technology for oil
Section III: Accomplishments and Impact

refining processes in an effort to reduce the carbon footprint in refining industry and ultimately the transportation sector.

This work also highlights the optimal size and operation of hydrogen production facilities that include polymer electrolyte membrane (PEM) electrolyzers to meet the proposed refinery demand. The researchers note that power-to-gas is an economically feasible approach to produce hydrogen. The use of PEM electrolysis to provide hydrogen results in a significant reduction of emissions.

BUSINESS MODELS FOR GRID-SCALE STORAGE

The choice of appropriate business model, complexity of regulatory and policy environment, ownership and governance structure of storage assets, financing strategies, managing revenue streams, and associated operational risks are critical for providing an accurate assessment of the viability of the emerging energy storage technologies.

Professor Nathwani and doctoral student Kourosh Malek have developed a typology of business models by employing a set of technology management frameworks in the context of energy storage technologies for power grid applications. The business model framework is tailored to provide a customized analysis platform for adopting emerging energy storage technologies. Several case studies were undertaken to validate the business model framework and the energy storage valuation analysis. For industry looking to adapt new energy storage technologies, this analysis provides unique insights through a multi-dimensional considerations of cost, efficiency, reliability, best practices and policy instruments.

3.1.1.3 SMART ENERGY NETWORKS

A smart energy network (SEN) uses clean energy technologies coupled with information and communication technologies (ICT) to improve the reliability and cost performance of the overall systems. SENs allow integration of all available energy sources, including electricity, natural gas, heat, bioenergy, solar PV, wind, geothermal, and storage.

The value proposition of smart energy networks relies on the integration of disparate and diverse components through ICT. The potential and promise of ICTs utilizing big data to enable optimal performance of a networks is a focus of extensive research activity at WISE. Convergence of ICT with multiple networks including sustainable mobility and transportation offers the potential for large benefits to consumers if demand and supply can be matched through real-time feedback. Eliminating or reducing the demand for services at peak times allows flexibility in the planning and operation of the infrastructure and helps achieve a lower societal cost.

CANADIAN LEADERSHIP IN SENs RESEARCH AND SMART GRID TECHNOLOGY

The electricity grid is a complex web of interconnected physical systems that comprise the generation, transmission, and distribution infrastructure. It is an ecosystem of asset owners, manufacturers, service providers, consumers, prosumers and diverse stakeholders. To modernize the grid is to make it “smarter” and more resilient through the use of cutting-edge technologies, equipment, and controls that communicate and work together to deliver electricity more reliably and efficiently.
Smart grids are a key enabler for consumers and businesses to better manage their own energy consumption and costs through easier access to data. Utilities also benefit from a modernized grid, including improved security, reduced peak loads, increased integration of renewables, and lower operational costs.

In the fall of 2003, WISE members, led by Prof. Nathwani, were joined by 65 leaders in government, utilities, business, civil society and academia to initiate a discussion about the potential role of integrated, multiple-fuel, and communicative systems in Canada’s energy future. The event marked the beginning of a long history of WISE activities to pioneer the concept and advance SENs in Canada.

Pioneering work has been initiated by Professors Croiset, Elkamel, and Douglas (Chemical Engineering), who have undertaken a collaboration with Union Gas, Horizon Utilities, Natural Resources Canada (NRCan), Canadian Gas Association (CGA), Canadian Electricity Association (CEA), Continental Automated Buildings Association (CABA), National Research Council (NRC) of Canada, and Quality Urban Energy Systems of Tomorrow (QUEST) to develop an extensive set of smart energy network models available for application on demonstration projects.

Professors Ian Rowlands and Paul Parker (Faculty of Environment) with Professors Cañizares and Bhattacharya (Electrical and Computer Engineering) have completed a major project on the ‘Energy Hub Management System’ (EHMS). The EHMS portal allows real-time management of energy demand, production, storage and import and export from different locations and types of facilities such as manufacturing, farm, retail stores and residential homes.

Professor John Simpson-Porco (Electrical and Computer Engineering) has also developed a ‘plug and play’ form of decentralized control by adding a distributed averaging proportional-integral (DAPI) controller that makes micro-grid more stable — and in the process enhances the integration of renewable energy resources.

Professor Cañizares and Bhattacharya work on the development of a freeware Smart Residential Load Simulator facilitates the study of residential energy management systems in smart grids. The tool provides a complete set of user-friendly graphical interfaces to model and study smart thermostats, air conditioners, furnaces, and household appliances. Wind and solar power generation as well as battery sources are also modeled allowing impact of different variables such as ambient temperature and household activity levels to be quantified for optimal use of energy. The simulator enhances understanding of how these contribute to peak demand, providing individual and total energy consumption and costs. This freeware platform is a useful tool for researchers and educators to validate and demonstrate models for energy management and optimization, and can also be used by residential customers to model and understand energy consumption profiles in households.

Professor Salama’s novel incentive-based distribution system expansion planning (IDSEP) model enables an LDC and distributed generation (DG) investors to work in a collaborative way for mutual benefit. Using the proposed model, the LDC would establish a bus-wise incentive program (BWIP) based on long-term contracts, which encourage DG investors to integrate their projects at specific system buses to benefit both parties. The model guarantees that the LDC will incur minimum expansion and operation costs while concurrently ensuring the feasibility of DG investors’ projects. The intermittent nature of both system demand and wind- and PV-based DG output power is handled probabilistically, and a number of DG technologies are taken into account.
Dr. Kumaraswamy Ponnambalam (Systems Design Engineering) and Dr. Ehab El-Saadany (Electrical and Computer Engineering) have developed a two-stage stochastic centralized dispatch scheme for AC/DC hybrid smart grids to reduce the expected high operating cost while satisfying the operational and technical constraints of interaction among several components of smart grid. The scheme will coordinate the operations of a number of distributed energy resources (DERs) and ensures the harmonized charging of EVs and models to address degradation of batteries over time. The approach, if successful, will also solve scheduling problems associated with an intermittent supply, variable demand and fluctuating real time energy pricing issues.

Professors Sherman Shen and Kankar Bhattacharya (Electrical and Computer Engineering) are working on areas of Information and Communications Technologies (ICT) in Smart Grid applications that will result in significant benefits to Canadian users and will foster a vital competitive edge to Canadian ICT and power industries in the international market place. The end goal is to develop innovative information and communication solutions for the smart power grid in order to facilitate integration of renewable energy sources and energy storage devices in microgrids, planning of electric vehicle (EV) charging infrastructure including vehicle-to-grid (V2G) systems to balance power generation and demand. In addition, novel cyber-physical security and customer privacy protection techniques will be developed to enhance smart grid communications. The research outcomes will help to increase the market share of renewable energy in Canada.

Professor Nathwani, as a founding member of the Ontario Smart Grid Forum (chaired by the IESO and now renamed the Energy Transformation Network Ontario) has been an active contributor since 2008 to the development of legislation, government policy, and the support of innovation for Smart grid technologies in Ontario.

THE ‘INTERNET OF THINGS’ AND THE ‘INTERNET OF ENERGY’

The Internet of Things (IOT) is a network of interoperable embedded sensors, computers and communication devices that enrich and transform the way energy is generated, transmitted, distributed, and delivered to the end user. The internet of energy (IOE) represents a new reality in the energy sector with significant potential for disruption of the existing business models of the distribution. The interactions of ubiquitous sensors, devices, and diversity of systems allowing real-time decisions by many participants has the benefit of enhancing efficiency, effectiveness and productivity of the entire energy supply chain and this shifts control from producers to users.

Professors Catherine Rosenberg (Electrical and Computer Engineering) and Srinivasan Keshav (Cheriton School of Computer Science) continue to advance their research in low power connected devices (sensors, actuators); use of an energy storage system (ESS) to integrate solar energy generators into the electrical grid; designing and operation of hybrid energy storage systems; developing practical strategies for storage operation in energy systems; interaction between personal comfort systems and centralized HVAC systems in office buildings; multiple time-scale model predictive control for thermal comfort in buildings; integration of renewable generation and elastic loads into distribution grids; and optimal design of solar PV farms with storage.

A number of IoE research initiatives are being advanced at WISE, including:

- Low power connected devices (sensors, actuators)
Use of an energy storage system (ESS) to integrate solar energy generators into the electrical grid
Developing practical strategies for storage operation in energy systems
Interaction between personal comfort systems and centralized Heating, Ventilation and Air Conditioning (HVAC) systems in office buildings
Multiple time-scale model predictive control for thermal comfort in buildings
Integration of renewable generation and elastic loads into distribution grids

The objective of this research is to develop innovative information and communication solutions that facilitate integration of renewable energy sources and energy storage devices in smart-grids and micro-grids. In addition, novel cyber physical security and customer privacy protection techniques, and peer-to-peer energy sharing schemes are being explored to enhance smart grid efficiency and communications.

In addition, Professor Rosenberg, in collaboration with Professor Abinav Kumar (IIT, Hyderabad, India), have developed a project on ‘Energy and Throughput Trade-Offs in Cellular Networks Using Base Station Switching’. The information and communication technology (ICT) sector is responsible for approximately two per cent of the global CO₂ emissions. Within ICT, cellular networks are one of the biggest contributors. Base stations (BSs) operations consume up to 80 per cent of the energy required for the operation of a cellular network. The research highlighting a complex interplay between coverage, power management, scheduling, and interference and recommendations are developed to take into account a strategy for saving energy to enable base station switching.

ARCHITECTURE OF 5G NETWORKS IN THE POWER SECTOR

5G Technology is the fifth Generation Mobile technology. 5G technology has the potential to unleash the next wave of smart grid or “intelligent” features to improve efficiency and cost performance. By allowing many unconnected, energy consuming devices to be integrated into the grid through low-cost connections, 5G enables these devices to be more accurately monitored to support better forecasting of energy needs. By connecting these devices using a smart grid, demand side management can be enhanced to support load balancing, helping reduce electricity peaks and ultimately reduce energy costs. Capturing this data through 5G connections will further enable large cities with high density urban growth to plan for energy infrastructure spending more efficiently and reduce downtime.

The business potential of introducing 5G in the energy domain is exceptionally high; it provides support not only to the critical machine type communication (MTC) applications of energy grid protection and control, but also to the massive volume of MTC type applications of the emerging smart metering data. The ongoing evolution of the power grid into a grid supporting a much more distributed generation and storage of power as well as micro-grids would be a clear beneficiary of the high performance with a very flexible communication architecture provided by 5G.

Professor Rosenberg, Cisco Research Chair in 5G Systems, is leading a multidisciplinary team of experts to help the industry leaders to prepare for the introduction of 5G. She will be working on a family of 5G technologies related to new frequency bands, which will enable faster data transfer and reduced delays for greatly improved wireless service.
REGIONAL ENERGY HUBS AND TRADING

Greater optimization of underutilized generation capacities over a wide geographic area through additional transmission interconnectors can support emissions reduction and energy transition strategies across several independent jurisdictions and countries. Transmission investment, however, is not explicitly identified as a powerful enabler of global energy transitions within the compass of clean energy policy debates.

Professor Nathwani and Post doctoral fellow Dr Burak Guler have argued for larger investments to be made in transmission capacity that allow greater inter-regional electricity trade through grid development on a continent wide basis. This will allow more effective and lower cost fuel switching among countries through a physically connected market. A conceptual framework of “Regional Energy Hubs” has been developed including a cost minimization model in support of a transmission investment strategy that integrates several key factors including geography, economics, and environmental factors.

BLOCKCHAIN FOR THE ENERGY SECTOR

Blockchain applications have the potential to create substantial new value in the energy sector. The blockchain ledger is currently used to reduce transaction costs, pinpoint origins of energy, increase the efficiency of exchanges, and maintain more proficient records. This technology also gives consumers the opportunity of distinguishing where energy is coming from – renewables or traditional fossil fuel based power generating plants. In the past, electric grids used to measure electricity as net amounts and don’t allow consumers to pick and choose. Now, the consumers are empowered to choose their preferred energy generation option and switch providers. The technology overcomes a process that is currently full of technical and financial constraints.

Professor Keshav and colleagues have developed a prototype blockchain solution called Canopus with capability of handling more than one million transactions per second in support of the Renewable Energy Certificates (REC) trading. The goal is to reduce the cost of certification, eliminate onerous auditing and avoid non-market price controls, so that even a small-scale green generator could de-risk investments. Today’s blockchains cannot support the addition of more than a few hundred certificates or trades (we can call them both “transactions”) per second. This is because blockchain servers require agreement on the contents of each block with endemic server and communication failures and the presence of malicious servers. This is known as the difficult “consensus problem.”

Currently, BitCoin, the best-known blockchain, supports only about 10 transactions per second and HyperLedger, IBM’s competing solution, under 1,000 transactions per second. Professor Keshav’s Canopus prototype takes a server’s location on the internet cloud into account, minimizing communication between geographically distant servers.

By keeping most communications local and fast, blockchain servers can process far more transaction records each second than a traditional consensus protocol that doesn’t take location into account. This improvement in scaling allows even mom-and-pop green generators to obtain certificates and participate in energy transactions. In long term, this work will encourage homeowners and small businesses to invest in renewable energy technologies to become green generators. It would also encourage Ontario’s electricity consumers to become 100 per cent green.
3.1.1.4 SUSTAINABLE MOBILITY

Electric Vehicles (EVs) are increasingly recognized as a viable transport alternative to internal combustion gasoline engines. The Canadian government has created incentives and policies in support of EVs and deployment of EV charging infrastructure. However, the sporadic growth of the EV industry has given rise to numerous technical challenges, and may create challenges for the operation of energy distribution systems.

At WISE, more than two dozen members conduct research involving electric vehicles. Their objectives are to develop innovations to enhance the performance of EVs and improve their component technologies, as well as to scope and address challenges related to augmented demand for electricity resulting from increased penetration of EVs.

VEHICLE TO GRID TECHNOLOGIES

The term “vehicle-to-grid” describes the use of car batteries as a source of power that can be used for grid services, such as frequency regulation when the car is not in the drive mode. The idea has significant appeal because the battery capacity of electric vehicles is not in use for 95 per cent of the time. The goal is to “develop driver-centered business models” to support a rapid roll out of vehicle-to-grid (V2G) technologies, allowing millions of electric car batteries to become a vital part of the power grid.

WISE researchers are actively involved in addressing challenges and opportunities that arise when EVs become part of the electricity grid.

Professors Sherman Shen and Weihua Zhuang (Electrical and Computer Engineering) work on electric vehicle integration and Vehicle-to-Grid (V2G) system optimization which has the potential to revolutionize the role of energy storage and information and communication technology (ICT) in the energy sector. With high EV penetration, the battery storage of EVs can be leveraged to improve the efficiency and reliability of electricity delivery via V2G systems. The V2G system enables bidirectional energy delivery, which allows the EV to either draw energy from or feed energy back to the grid. In other words, EVs can facilitate two types of services to the grid, namely, load shaving services and ancillary services to the grid.

Professor El-Saadany (Electrical and Computer Engineering) has developed a new energy management system (EMS) for incorporating aggregated Plug-in Electric Vehicles (PEV) in parking lots. Demand response (DR) capability allows end-use customers to modifying electricity usage based on incentive payments to encourage lower electricity use at times of high prices.

Professor Salama (Electrical and Computer Engineering) has designed a model of charging plug-in hybrid electric vehicles using photovoltaic electricity in residential distribution systems and developed a comprehensive planning model for the electric vehicle charging infrastructure in Ontario.

Professor Bhattacharya’s (Electrical and Computer Engineering) studies include: smart plug-in hybrid (PEV) charging station operation and design, evaluation of distribution system impacts, effect of PEV penetration on distribution system planning and time-of-use electricity prices, smart charging PEVs in an isolated microgrid, and adequacy assessment of power systems with PEV charging loads.

Professors Fraser and Fowler (Faculty of Engineering) have initiated a pilot project on UWaterloo campus along with various faculty members from Management Sciences,
Section III: Accomplishments and Impact

Environment, and Accounting and Finance, to study the impact of high-voltage, direct current (HVDC) charging stations on the distribution grid and battery life of electric vehicles.

Professor Fraser, Professor Fowler, and Professor Young (Faculty of Environment) have worked together on the reuse of electric vehicle lithium ion battery packs in energy storage system applications. Their work concluded that Li-ion battery packs present opportunities for powering both mobility and stationary applications.

Professors Cañizares and Rosenberg’s (Electrical and Computer Engineering) award winning paper on ‘Day-ahead dispatch of distribution feeders’ addresses the issues related to high PEV charging penetration levels.

Professors Cañizares and Kazerani (Electrical and Computer Engineering) have developed the concept of a bidirectional smart charger that give drivers the option of charging when power is plentiful (and rates are cheaper) and earning discounts or rebates by supplying electricity from their vehicles back to the grid when they don’t need it.

Professor Kazerani and Cañizares (Electrical and Computer Engineering) have also completed a project on modeling and testing of a bidirectional smart charger for distribution system EV integration. A practical case study demonstrates and tests the proposed smart charger and model, investigating the provision of V2G for active and reactive power in a low voltage (LV) residential distribution network. The results confirm the advantages of the charger model for developing V2G strategies in distribution networks. This project developed a prototype and an average model of a single-phase, two-stage, level one bidirectional smart charger comprising of a full bridge ac/ dc converter and a bidirectional buck-boost converter.

**EV CHARGING STATIONS**

An important constraint to the deployment of EVs in Canada is the lack of public EV battery charging infrastructure across the country.

In collaboration with WISE and faculty members from Management Sciences, Environment, and Accounting and Finance Professors, Roydon Fraser and Michael Fowler (Faculty of Engineering) have initiated a pilot project on the UW campus to study the impact of high-voltage, direct current (HVDC) charging stations on the local distribution grid and examined data related to the battery life of EVs.

This project has seen UW become the first academic institution in Canada to deploy a HVDC fast charging facility, located in the parking lot of the Engineering 6 (E6) Building. Construction of one level II charger, one level III charger, and one Tesla charger was completed in 2018.

Additionally, Prof. Salama and PhD student Yassir Alhazami have developed a planning model to implement EV charging infrastructure in electric power distribution systems. The results of this study will help to identify ideal locations for charging stations throughout the country and thereby optimize the electricity grid to meet growing EV charging demands. The findings will support the development of sustainable and profitable business models for EV charging infrastructure owners.
DRIVE4DATA

Drive4Data (D4D) is the first initiative of its kind in Canada, providing a trove of data to advance electric vehicle research while supporting local EV owners in the optimum use of their EVs. This initiative was founded in 2012 as a collaboration between WISE and Grand River CarShare, and involves collection of mileage, battery charging and energy use data from hundreds of EV owners in the Waterloo region. The data are relayed to WISE for research purposes, helping to advance a variety of UW faculty-led research initiatives on electric vehicles, from battery technology to smart grid management.

Drive4Data participants have a small wireless device about the size of a cell phone installed in their car, and benefit from access to detailed reports on their vehicle’s performance, including the travelled distance, charging schedule, fuel and electricity usage and performance against similar vehicles. Drivers can access detailed reports on their vehicle’s performance, including the distance they’ve travelled, charging schedule, fuel and electricity usage, performance against similar vehicles, and status of battery charge under hot and cold conditions.

The installation of the smart chargers on campus enhances our capacity to allow a larger number of vehicles to be included in the D4D program. Data mining and analytics will support the next generation of modelling tools and algorithms.

Financial support from Waterloo North Hydro, Kitchener-Wilmot Hydro, Cambridge and North Dumfries Hydro, and the Community Environmental Fund administered by the Regional Municipality of Waterloo make this project possible.

ELECTRIC BICYCLES

E-Bikes are becoming the world’s fastest growing mode of low-carbon urban transportation. In September 2014, Prof. Keshav initiated the Webike project, deploying a fleet of approximately 30 sensor-equipped electric bicycles to UW faculty, staff, and students.

The Webike project had two main phases. In the first, a survey was disseminated to UW faculty, staff, and students to select suitable participants. The second phase consisted of a three year field test. E-bikes were purchased from eProdigy Bikes, an e-bike manufacturer based in Vancouver, and instrumented with sensors. Participants were then given e-bikes and appropriate training by a local partner, Cycle Electric.

Over 200 GB of anonymized usage data (GPS location, accelerometer readings and battery state) were collected from September 2014 until the culmination of the tests in 2017, and participants were asked to fill out user surveys every three to six months.

Insights from the project have contributed to increased understanding of the potential scope and impact of e-bikes on transportation infrastructure in Canada. The project also evaluated the feasibility of solar powered e-bikes as a cost-effective off-grid transportation solution, and suggested that e-bike batteries could be used as a source of power for high efficiency appliances such as refrigerators and lighting in developing countries.
3.1.1.5 GLOBAL ENERGY ACCESS

There are currently 1.2 billion people in the world who still do not have access to electricity. While this number is currently falling, it is estimated that without significant innovation, aggressive investment and invigorated political will, the world will not achieve universal energy access by 2030 — a target now enshrined as UN Sustainable Development Goal 7: Universal Access to Affordable, Reliable, Sustainable and Modern Energy.

In September 2015, WISE launched the Affordable Energy for Humanity (AE4H) initiative in partnership with the Karlsruhe Institute of Technology (KIT) and a global consortium of leading experts in the fields of sustainable energy and international development. This ‘global change initiative’ undertakes research, advocacy and knowledge transfer activities to advance Sustainable Development Goal 7: ensuring access to affordable, reliable, sustainable and modern energy for all by 2030.

Through founding this new initiative, WISE has made a commitment to advancing the global energy access agenda. At the heart of this commitment is the recognition that access to an affordable supply of clean electricity is a fundamental stepping stone to human development in the 21st century. AE4H puts WISE at the center of a global movement that aims to leverage the potential of cutting edge sustainable energy technologies to improve the quality of life of the third of humanity that lives without reliable access to electricity.

Since it was established in 2015, the AE4H consortium has grown to include over 140 members from 50+ institutions in 25 countries. Scientific Advisors representing the world’s foremost post-secondary research institutions on the topic have also joined the initiative.

"Energy as a sustainable development multiplier"
Section III: Accomplishments and Impact

AE4H LEADERSHIP

<table>
<thead>
<tr>
<th>Co-Directors</th>
<th>Scientific Advisors</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Waterloo</td>
<td>Karlsruhe Institute of Technology</td>
</tr>
<tr>
<td>Jatin Nathwani</td>
<td>Joachim Knebel</td>
</tr>
<tr>
<td>Executive Director, Waterloo Institute of Sustainable Energy</td>
<td>Head of Division II, Electrical and Mechanical Engineering</td>
</tr>
</tbody>
</table>

RESEARCH DOMAINS

Four key domains of research support an interdisciplinary approach to energy access research. AE4H partners are engaged in a number of projects across all four domains. Brief descriptions of members’ exemplar projects are included below.

**Domain I: Generation, Devices, and Advanced Materials**

**Exemplar activity: Testing a Novel Hybrid Renewable Energy System**

This project aims to develop a simple, economically viable and robust Hybrid Renewable Energy System (HRES) for off-grid electrical energy supply. The HRES is based on renewable and non-renewable energy sources, in combination with battery storage system, and is being tested in diverse geographical locations including Uganda and Canada.

The project is being carried out by the Competence E (energy) lab at KIT, led by PhD student Mohamed Mamdouh Elkadragy under the supervision of Prof. Nathwani (WISE).
and Knebel (KIT). The system itself will be tested in an off-grid house in Canada owned by an expert in off-grid renewable energy systems, George Colgate, who has collaborated with WISE as a participant in a global summit on energy poverty held in Waterloo. Results of this work are disseminated by WISE through a variety of media, and WISE researchers have co-authored findings with the KIT team.

**Domain II: Microgrids for Dispersed Power**

**Exemplar Activity: Partnership with Renewable & Appropriate Energy Laboratory, UC Berkeley**

Directed by Prof. Daniel Kammen, RAEL is a unique research, development and project implementation lab located at the University of California, Berkeley, focussed on the design and implementation of renewable energy systems in regions facing energy poverty. RAEL projects range from small community-driven initiatives in remote locations, to large projects that assess national electrification plans. A number of RAEL researchers have contributed to AE4H initiatives since 2015, including participating in AE4H events, writing joint papers, and collaborating on funding proposals. Prof. Kammen in co-editing an IEEE special issue on ‘Electricity of Everyone’ with WISE Executive Director Jatin Nathwani and WISE researcher Prof. Claudio Canizares. Prof. Kammen is a Scientific Advisor to AE4H and has contributed to a number of funding proposals that have been submitted by the consortium, including two successful applications for funding to support international ‘innovation labs’ hosted by AE4H that bring members together to catalyze new projects.

**Domain III: ICT for Energy System Convergence**

**Exemplar Activity: Self-serve Pre-Paid Emissions-free Energy Delivery (SPEED)**

Professor Srinivasan Keshav and undergraduate research assistant Kayla Hardie designed a simple and robust standalone device called SPEED, which is a standalone system to charge cell phones and other small electronic devices with solar energy. SPEED enables small businesses to sell emissions-free charging services at an affordable price. The prototype system employs RFID tracking and a user-friendly interface accessible via WI-FI, allowing shopkeepers to easily register new clients, track existing customers, and check the performance of the system.

**Domain IV: Environmental and Human Dimensions of Energy Transitions**

**Exemplar Activity: The Social Value of Energy**

WISE has collaborated with ASU’s Grassroots Energy Innovation Lab, led by Professor Clark Miller, to develop a framework for understanding the broader social impacts of energy access initiatives. The goal of this work is to contribute to ongoing policy developments at national, international and sub-national levels which aim to use energy access as a lever advance economic and social development. A working paper entitled ‘Poverty Eradication through Energy Innovation: A Multi-Layer Framework for Social Value Creation’, which was published jointly by both institutions. This working paper has also been submitted to UN in support of the 2019 Global Development Progress Report. Following from this work, ASU and KIT researchers have initiated a field research project that utilizes the framework to assess the impact of ongoing electrification initiatives
across a variety of locations in the Global South. This project is being carried out jointly by AE4H members from ASU, KIT and WISE.

**ENERGY POVERTY IN REMOTE COMMUNITIES IN CANADA**

Far away from the Canadian electricity grid, about 250 communities, many of whom are mostly indigenous, rely solely on diesel generators to meet their needs for electricity and heat. In many cases, this aging energy infrastructure is woefully insufficient in meeting energy needs. Blackouts are frequent and many communities face ‘load restriction’ – generators operate at maximum capacity and therefore no additional loads (such as new homes or community facilities) can be connected.

Diesel fuel is enormously expensive in these locations due to transport costs. It also causes local air and noise pollution, and results in recurrent spills which are expensive to clean up and environmentally damaging. According to Indigenous and Northern Affairs Canada, there are over 1,400 sites contaminated by diesel spills on First Nations reserves across Canada.

Between 2015 and 2018 WISE has collaborated with the Waterloo Global Science Initiative and other Canadian partners to host a global summit on the topic of energy poverty in 2016, with an explicit focus on off-grid indigenous communities in Canada. Prof. Nathwani and WISE Manager Nigel Moore, along with UW post-doctoral researcher Marriano Arriaga, developed a position statement following the summit, which was published as a special section of the final summit report. The ‘Plan-for-Plenty’ position is an urgent call to action targeting government and other actors in Canada to provide a step-change of investment in support of clean, reliable and affordable energy for underserved communities, and the implementation of these projects through indigenous leadership. WISE continues to push this message through engagement with policymakers, and through partners including the Indigenous Clean Energy Network – a national organization that supports indigenous knowledge sharing on renewable energy.

WISE researchers have also developed and implemented concrete solutions that provide emissions-free energy to off-grid communities in Canada. Professors Claudio Cañizares, Ehab El-Saadany, Paul Parker, Mehrdad Kazerani, Kankar Bhattacharya and David Johnson, in collaboration with NRCan, Hatch, Wenvor, and Hydro One, participated in a project to introduce a renewable micro-grid system in Kasabonika Lake First Nation, an isolated community in northern Ontario only accessible by air or winter roads. The Waterloo team’s work focussed on micro-grid controller development, energy management system planning and community engagement. Solar and wind technologies were deployed to augment the use of diesel. WISE researchers worked with the community and industry partners to develop energy plans and models for higher rates of renewable energy penetration on the community’s grid.

WISE has also partnered with the World Wildlife Foundation (WWF) and Innovus power, to study alternatives to existing diesel systems in the Canadian Arctic. Led by Prof. Claudio Cañizares, these studies indicated significant potential for cost savings and GHG emission reductions across a range of communities that currently rely entirely on diesel systems for heat and power. The aim of this work is to develop strategies to optimize the dispatch of carbon-free power at the lowest cost possible in remote locations across Canada.
3.1.2 Training and Student Development

Energy Council of Canada Energy Policy Research Fellowship Program

In 2013, WISE established an agreement with the Energy Council of Canada (ECC) to enhance and promote energy policy research, with a particular focus on thematic areas that align with the priorities of the ECC, and its member organizations across the country.

ECC is a not-for-profit organization made up of representatives of Canada’s energy sector. It is a vehicle for strategic thinking, collaboration and action by senior executives in the private and public sectors having a broad interest in national, continental and global energy policy issues.

ECC has provided a total cash contribution of $500,000 commencing April 1, 2013 continuing to and including September 30, 2023 in support of the ECC Energy Policy Research Fellowship. The program funds University of Waterloo graduate students (both Masters and PhD) to undertake research activities on energy policy-related topics, with a particular focus on contemporary clean energy issues.

This program is managed and administered by Professor Nathwani - Executive Director WISE - with ECC fellows becoming an important source of energy and insight for a variety of other WISE activities. ECC fellows are supported by WISE throughout the duration of their fellowship and until completion of their graduate studies at UW. Examples include participation at WISE events, research assistanship at WISE including drafting reports and working papers, mentorship, networking assistance, and other activities.

Since the program’s inception in 2013, WISE has supported 17 ECC Student Fellows who have received a total of $319,500 for their research.

The following graduate research projects have been supported by the program to date:

- Development of a utility grade controller for remote microgrids with high penetration renewable generation
- Accelerating progress in renewable energy using a technology-centered co-evolutionary framework
- Examining the potential for smart meter data streams
- Creation of a comprehensive engagement and planning framework for the integration of renewable energy in remote communities
- Technically detailed co-evolutionary model to guide energy innovation policy
- Applying social theories to conservation initiatives
- Wind turbine opposition in Ontario
- Investigate the effectiveness of interventions used in the EHMS project: Residential consumption shifts
- Integrating distributed renewable energy generation into the Canadian electricity distribution system
- Canada’s lower carbon energy futures: Multi-level sociotechnical scenarios under the new scenario framework for climate change research
- Engaging residential consumers using smart grid tools
Section III: Accomplishments and Impact

- The socio-technical dimensions of carbon management for bridging to a lower carbon energy future
- Applying social theories to conservation initiatives
- Enabling energy transitions: evaluating the effectiveness of past and present energy transition policies to guide Canada’s transition to a low carbon future
- Informing the design, implementation and evaluation of the Decarbonize Waterloo Region process
- Methodology for improving the net environmental impacts of new buildings through product recovery management
- Intra-household dynamics and residential energy conservation policies
- Renewable energy to advance off-grid community sustainability: a comparative energy policy analysis between Alaska and Canada’s North
- Carbon management: bridging to a lower carbon energy future

Queen Elizabeth Scholars for Energy Access Program

WISE has been awarded $300,000 from the Queen Elizabeth II Diamond Jubilee Scholarship Program (funded jointly by the Rideau Hall Foundation, Community Foundations of Canada, and Universities Canada) to prepare UW students for leadership in the emerging off-grid renewable energy sector, with a focus on the developing world.

Between 2018 and 2021, approximately 40 UW students will undertake international internships at sustainable energy social enterprises with in the AE4H network.

Participation of the AE4H global network of partners and St. Paul’s Greenhouse allows opportunities for students to engage with global knowledge networks and develop their own social ventures related to energy access. On campus programming includes social innovation competitions, guest speaker events, and other activities related to this critical and growing development sector that crosses disciplinary boundaries.

Three cohorts of UW students have participated in the program since May 2018, interning at cutting edge social enterprises within the AE4H network, with whom WISE has developed reciprocal relationships.

The program is open to all co-op students and Masters students with a required internship component in their degree. Students from the following programs have participated to date:

- Mechtronics Engineering
- Geological Engineering
- Mechanical Engineering
- Computer Engineering
- Biomedical Engineering
- Civil Engineering
- Environment, Resources and Sustainability
- Planning
- Geography and Environmental Management
- Masters of Development Practice
In February 2016 WISE hosted ‘Rethinking Design for Energy Access’ on the UW campus, inviting students to take part in interactive discussions with experts about the exciting opportunities and challenges facing innovators whose work lays at the boundary between energy and international development. This event was meant to galvanize student interest in universal energy access and the AE4H initiative. It was held in partnership with the Waterloo Global Science Initiative, and two AE4H members were invited to speak to students: Steve Katsaros, Founder & CEO of Nokero Solar, and Iana Aranda, President of Engineering for Change. A unique mix of engineering and international development students participated in the workshop. Videos are available on the AE4H website.

The following design questions were considered as part of the discussion:

- Should we promote technologies even if they hurt the environment?
- Should technology for global development always be the cheapest solution?
- Should we make products that are localized or standardized?
Section III: Accomplishments and Impact

- Is technology appropriate if it violates cultural norms?
- Is it more important for technologies to be affordable or durable?
- Should we design for aid or for trade?

**Mentoring UW student teams participating in the Hult Prize Social Innovation Competition**

The Hult Prize is the world's largest student Social Enterprise competition. Teams from all over the world compete annually for a $1 Million grand prize to put their social enterprise idea into action.

Through the AE4H initiative, WISE actively mentoring a number of Hult Prize teams from the University of Waterloo during their 2017-2018 competition, entitled “Harnessing the Power of Energy to Transform 10 Million Lives”.

WISE organized a speed mentoring event for UW teams, with AE4H members Srinivasan Keshav (Waterloo), Malcolm McCulloch (Oxford), Uche Onuora (HITCH), Michael Sinclair (Ecobee) and Nigel Moore (WISE) serving as mentors at the event.

One of our teams, Circadian Energy, placed in the top three in the Waterloo competition and went on to represent the University at a national event in Toronto. Circadian subsequently joined the Velocity incubator program and are refining their energy sharing technology and business plan, which aims to provide off-grid electrification to underserved communities in East Africa. WISE continues to work with the Circadian Energy team as they launch their business.

**Incubating Off-grid Internet start-up HITCH**

HITCH is a Smart Wireless Mesh Router & Predictive Content Caching Software Platform that pre-downloads relevant online content once, so many users can access the same information quickly without an Internet connection. Globally, over 4 billion people don't have sustainable (available, affordable & accessible) broadband.

HITCH was founded by ICT expert Uche Onuora. After completing his Master of Business, Entrepreneurship and Technology at UW’s Conrad Centre, Uche joined Velocity to continue to develop HITCH technology and prepare it for deployment in his native Nigeria. One of the key challenges facing HITCH is lack of consistent access to electricity to run its devices. WISE, through the AE4H initiative, has therefore been supporting HITCH in refining their prototype technology so that it can operate without electricity for long periods of time, and in conducting initial field tests in Nigeria in 2017-2018. HITCH devices have now been present in 10 schools for a 3-month trial period to
intelligently deliver affordable educational video content straight to classrooms. A roll-out to 50 additional schools in now underway.

**Student Engagement at WISE Events**

WISE encourages student participation at all of our regular events, providing open space for graduate and undergraduate students and young entrepreneurs to present posters during designated poster sessions. These events, which occur 2+ times per year at various WISE events, allow UW students to network with sustainable energy leaders on campus, from the Waterloo Region, and beyond.

*Please see Appendix VI for student posters*
3.2 Reach Out: Delivering High Value Partnerships
Reach out:
Delivering High Value Partnerships

WISE is Waterloo’s ‘front door’ for all things sustainable energy – the first stop for those from outside of the University to get to know Waterloo’s cutting edge research on this topic.

We work closely with utilities, the private sector, government and non-profit organizations to ground our work in real-world issues. We facilitate partnerships between WISE and our stakeholders that advance along the full spectrum of energy R&D, education and training, networking, and commercialization activities. We advise our UW faculty experts about new partnership and research funding opportunities and provide them with support at every stage to ensure that their proposals have the greatest chance of success.

A central role that WISE plays is in developing relationships with a diverse array of prospective funders and partner organizations. These relationships have resulted in a significant and consistent flow of research dollars into the University, from both traditional sources such as the tri-councils, as well as through multi-year, multi-million dollar partnerships with energy sector companies that help fund our members' research. WISE also helps to secure funding of physical assets such as cutting edge research laboratories and equipment, giving UW faculty experts the tools they need to advance knowledge in their domain.

WISE has successfully built deep long-term reciprocal relationships with industry partners including both small renewable energy start-ups and large established multinational energy sector players. We have also championed formal research collaborations between UW and a variety of leading Universities at home and abroad, from MIT to Oxford, Berkeley and beyond. We are a valued partner of a number of forward thinking non-profit organizations that we work with to promote responsible and informed public dialogue and policy related to sustainable energy.

WISE’s consistent engagement with a multiplicity of leading energy sector players both domestically and internationally help us to understand the bigger picture of where the energy sector is going, and as a result, to communicate these trends to our members. Our members benefit from working with us not only due to increased access to funding, but also from exposure to new ideas and concepts that we help bring into our research community.
“I have been struck by the constructive ambition of WISE, as it works effectively with many international peers to achieve global impact.”

Ian H. Rowlands
PhD Associate Vice-President, International Professor
School of Environment, Resources and Sustainability

“WISE has played an important role supporting my research through the coordination of workshops, promotion of research activities at Waterloo, and coordinating initial contact with potential industrial sponsors.”

Michael Fowler
Professor
Chemical Engineering

“The AE4H Global Change Initiative is an impressive effort that will not only create positive change in the lives of Ontarians but also has the potential to create new enterprises and markets for Ontario and Canadian entrepreneurs.”

Serge Imbrogno
Former Deputy Minister of Energy
Government of Ontario
3.2.1 Successful Funding Partnerships

Between 2013 and 2018, WISE has been directly involved in the development of 86 successfully funded projects worth a total of $23,084,193. These projects have been developed in partnership with a wide range of funding agencies, industry partners, and academic collaborators, with whom WISE has played a leading role in building relationships on behalf of UW faculty and students.

1. A Compressed Air Energy Storage (CAES) Demonstration Project

Abstract: There is a unique opportunity in Goderich, ON to combine fuel-free compressed air energy storage (CAES) with salt caverns. Energy storage developer NRStor, alongside technology supplier Hydrostor and research partners at the University of Waterloo, will build a 1.75 MW CAES facility providing the Ontario electricity grid with 4 hours of energy storage. The facility will use proprietary technology to store electricity in the form of compressed air and heat. This demonstration project will prove the market operations of fuel-free CAES and will open up opportunities for Canadian companies to deploy locally developed and manufactured CAES technology around the world.

This Project is in addition to and linked to the First Phase of the successful Project approved in 2015. (see below).

Academic Investigator(s):
- Main PI: Prof. Maurice Dusseault (Earth and Environment Sciences, UW)
- Co-PI: Prof. Roydon Fraser (Mechanical and Mechatronics Eng., UW), and Prof. Giovanni Cascante (Civil and Environmental Eng., UW)

Industry Partner(s): NRStor Inc., and Hydrostor Inc.
Other Academic Institution(s): N/A
Funding Agencies: Ontario Centres of Excellence (OCE), and Sustainable Technology Development Canada (SDTC)
Grant Name: TargetGHG Collaborative Technology Development Program
Date Approved: 2017
Total Project Value: $7,200,000

2. The Greening Growth Partnership

Abstract: The Greening Growth Partnership brings together a network of more than 50 Canadian and international scholars, and over 40 government, civil society, business and research institution partners. Funded through a Social Sciences and Humanities Research Council (SSHRC) Partnership Grant and the contributions of partners, this partnership works to produce targeted research and effective knowledge translation and mobilization, to inform environment-economy policy innovation in Canada.

Academic Investigator(s):
- Main PI: Stewart Elgie (Smart Prosperity Institute)
- UW Collaborators: Prof. Jatin Nathwani (Management Sciences), Nigel Moore (WISE Manager)
3. Resilient and Sustainable Energy for Northern Canada

Abstract: The objective is to demonstrate quantitatively that a system combining shallow and deep geothermal energy is feasible to provide robust, reliable, and resilient power and heat for military establishments in Canada’s North (N of 60°, including QC and Labrador). Novel concepts include efficient deep drilling, enhanced repository development methods, heat storage (summer), and efficient thermodynamic processes to provide heat and energy from a two-scale system – shallow heat-pump and deep heat repositories. We show that geothermal is the only non-carbon option able to provide sustained energy and heat the whole year; furthermore, this technology will have broad civilian applications in the north, and likely the south of Canada.

Academic Investigator(s):
- Main PI: Prof. Maurice Dusseau (Earth and Environmental Sciences, UW)
- Co-PIs: Prof. Yuri Leonenko (Earth and Environmental Sciences, UW), Prof. Roydon Fraser (Mechanical and Mechatronics Eng., UW), and Prof. Robert Gracie (Civil and Environmental Eng., UW)

Industry Partner(s) and Other Organization(s): Geosource Energy Inc., Egmond Associates Ltd., and Natural Resources Canada (NRCan)
Section III: Accomplishments and Impact

Other Academic Institution(s): University of Manitoba, and Institut national de la recherche scientifique (INRS)

Funding Agencies: Defence Research and Development Canada (DRDC)

Grant Name: Innovation Call For Proposals (CFP) 2017

Date Approved: 2017

Total Project Value: $1,848,209

4. Hydro One Endowed Chair, Claudio Canizares

Abstract: As Hydro One chair, Cañizares supports research in smart grid power distribution and management, alternative energy and sustainability projects, along with graduate student investigations. The chair contributes significantly to work on how to integrate clean energy technologies into the grid as well as address specific issues of the electricity sector through research, development and deployment projects.

The Waterloo Institute for Sustainable Energy (WISE) oversees the Hydro One Chair agreement, which is part of a broader funding agreement between Hydro One and WISE.

Academic Investigator(s):

- Main PI: Prof. Claudio Canizares (Electrical and Computer Eng., UW)
- Co-PI: Prof. Jatin Nathwani (Management Sciences, UW)

Industry Partner(s): Hydro One

Other Academic Institution(s): N/A

Funding Agencies: Hydro One

Grant Name: WISE-Hydro One MOU

Date Approved: 2010

Total Project Value: $1,500,000

5. Compressed Air Energy Storage in Salt Caverns in Canada

Abstract: As renewable resources such wind and solar are increasingly integrated into the 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 not only can 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. We propose 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.

Academic Investigator(s):

- Main PI: Prof. Maurice Dusseault (Civil and Environmental Eng., UW)
- Co-PIs: Prof. Claudio Canizares (Electrical and Computer Eng., UW), Prof. Roydon Fraser (Mechanical and Mechatronics Eng., UW), Prof. Jatin Nathwani (Management Sciences, UW), Prof. Kankar Bhattacharya (Electrical and Computer Eng., UW),
Section III: Accomplishments and Impact

Prof. Dipanjan Basu (Civil and Environmental Eng., UW), Prof. Andy Knight, Electrical and Computer Eng., UC), Prof. Hamid Zareipour (Electrical and Computer Eng., UA), and Prof. Nicholas Harris (Earth and Atmospheric Sciences, UA).

Industry Partner(s): Hydro One, Ontario Power Generation, Union Gas, NRStor, Compass Minerals, and Rocky Mountain Power
Other Academic Institution(s): University of Calgary and University of Alberta
Funding Agencies: NSERC, OCE, and Alberta Innovates
Grant Name: Alberta-Ontario Innovation Program/NSERC Collaborative Research and Development (CRD)
Date Approved: 2015
Total Project Value: $1,370,417

6. Management and Control of Energy Use in Homes and Buildings

Abstract: The household and building sectors are a significant consumer of energy in Canada, residential energy use alone accounting for 22.8% of energy use in 2008, with heating, lighting, and appliances accounting for 12.6% of the total, according to Statistics Canada. The energy consumption by these sectors have been rising over time, growing 11% between 2000 and 2008. As energy costs rise and the carbon footprint of energy sources becomes a growing concern, there is an imperative need to intelligently control the use of energy in homes and buildings, eliminating waste while minimally affecting user comfort.

Meeting these goals requires careful control over energy consumption by appliances, heating and cooling systems, and lighting (the three main uses of energy), taking user preferences into account. The recent rapid decrease in the cost of solar panels raises the further possibility of simultaneously reducing carbon footprint, transmission and distribution losses, and operational cost by integrating these elements into homes and buildings. However, these generation resources are time-varying, requiring the careful sizing, integration, and control of associated (expensive) electricity storage.

From the perspective of computer systems research, managing energy consumption requires the design and implementation of an underlying control framework that is composed from wireless sensors and actuators, coupled with computation. Our overall goal, therefore, is to exploit low-cost pervasive computing and ubiquitous wireless communication for the management and control of energy use in buildings and homes, drawing on our past decades of experience in the design, implementation, operation, and management of computer networks such as the Internet.

Academic Investigator(s):
- Main PI: Prof. Srinivasan Keshav (Cheriton School of Computer Science., UW)

Industry Partner(s): CISCO Canada Inc.
Other Academic Institution(s): N/A
Funding Agencies: NSERC
Grant Name: NSERC Collaborative Research and Development (CRD) Grant
Date Approved: 2013
Total Project Value: $1,330,675
7. Optimal Microstructures and Thermomechanical Properties of Ceramic Heat Carrier Balls for Waste to Energy Conversion

Abstract: Recently a research initiation has been developed by the University of Waterloo, InnoTech Alberta and Lockheed Martin Canada (LMC), which aims to develop a new and unique renewable based energy solution to the remote communities of Canada. Its major objectives are, to collect and analyze data of biomass feedstock available in designated remote regions in Alberta and Ontario and to develop critical process and material properties allowing an efficient conversion of these feedstocks to bioenergy. Quantitative assessments on energy, economic and environmental benefits to the remote communities will be performed. Serving for this purpose, this CRD project aims to maximize the energy conversion efficiency and minimize the operating cost, both being critical to achieve a meaningful assessment on the proposed technology's performance, through identification of a cutting edge material for heat carrier balls which play a central role in biomass to syngas conversion. The development and commercialization of WtE technology will help the remote communities reduce their energy cost and achieve Canada's pledged GHG reduction goals, through biomass utilization, technology advancement and HQP training.

Academic Investigator(s):
- Main PI: Prof. John Wen (Mechanical and Mechatronics Eng., UW)

Industry Partner(s): Lockheed Martin Canada Inc.
Other Academic Institution(s): N/A
Funding Agencies: NSERC, Innotech Alberta, and OCE
Grant Name: NSERC Collaborative and Research Development (CRD)
Date Approved: 2016
Total Project Value: $1,035,284

8. CISCO Research Chair in Smart Grid, Srinivasan Keshav

Professor Srinivasan Keshav of the Cheriton School of Computer Science has been named the Cisco Chair in Smart Grid. Cisco is providing $1 million over five years to establish the chair, which will focus on research in the full integration of information science and technology concepts for power grid in order to enhance the security, reliability and effective performance of key components, such as storage and renewable resources. This research will help define the next generation electricity grid, or ‘future grid’, developing concepts, techniques and technologies to drive collaboration, productivity and efficiency in the energy sector in Canada.

Academic Investigator(s):
- Main PI: Prof. Srinivasan Keshav (Cheriton School of Computer Science., UW)
- Co-PI: Prof. Jatin Nathwani (Management Sciences, UW)

Industry Partner(s): CISCO Canada Inc.
Other Academic Institution(s): N/A
Funding Agencies: CISCO Canada Inc.
Grant Name: CISCO Research Chair in Smart Grid
9. Internships at Energy Access Social Enterprises for University of Waterloo Students

Abstract: In order to deliver on Sustainable Development Goal (SDG) 7 and solve the energy poverty crisis by 2030, social enterprises that work in the clean energy sector will need a massive infusion of human talent, particularly from science, technology, engineering, and mathematics (STEM) and business/entrepreneurship related fields. Canadian students such as those at the University of Waterloo, have an incredible opportunity to become global leaders in the emerging energy access sector. Unfortunately, they are limited by a dearth of opportunities to experience firsthand both the context of energy access (whether in indigenous communities in Canada or abroad), and what it is like to work in a social enterprise. The project will therefore create invaluable international experience opportunities for 40 University of Waterloo students to learn about the increasingly important roles that social enterprise, entrepreneurship and clean energy technology are playing in the global effort to deliver on the SDGs.

Academic Investigator(s):

- Main PI: Prof. Jatin Nathwani (Management Sciences, UW)
- Co-PI: Nigel Moore, WISE Manager
- UW Collaborators: Tania Del Matto, St.Paul's Greenhouse; Grainne Ryder, SEED; Lisa ter Woort, CECA

Industry Partner(s): Mobisol, Nokero Solar, ME SolShare, HITCH, EarthSpark International, Burro Brand, Steama.co, ENVenture

Other Academic Institution(s): N/A

Funding Agencies: The Rideau Hall Foundation, Universities Canada, Community Foundations of Canada

Grant Name: Queen Elizabeth II Diamond Jubilee Scholarship Program - 2017

Date Approved: 2018

Total Project Value: $824,350

10. Advanced Information and Communication System for Smart Grid

Abstract: This strategic project will develop innovative information and communication solutions for the smart power grid, in order to facilitate the integration of renewable energy sources and energy storage devices in microgrids, planning of electric vehicle (EV) charging infrastructure, and provision of cyber-physical security and user privacy. Mathematical models will be developed to characterize the intermittency in renewable energy generation, buffering dynamics of energy storage devices, and mobility of EVs. The planning and operation of microgrids will be optimized based on the mathematical models, such that the overall utilization and reliability of the microgrids are maximized. Intelligent transportation based vehicular communications will be exploited to facilitate information exchange on real-time vehicle mobility and energy demand for EV integration. Vehicle-to-grid (V2G) systems will be investigated to improve microgrid
reliability, using EV batteries for energy storage to balance power generation and demand. In addition, novel cyber-physical security and customer privacy protection techniques will be developed to enhance smart grid communications.

**Academic Investigator(s):**

- Main PI: Prof. Xuemin Shen (Electrical and Computer Eng., UW)
- Co-PI: Prof. Kankar Bhattacharya (Electrical and Computer Eng., UW), Prof. Jon Mark (Electrical and Computer Eng., UW)

**Industry Partner(s):** Waterloo North Hydro (WNH)

**Other Academic Institution(s):** N/A

**Funding Agencies:** NSERC

**Grant Name:** Strategic Projects - Group

**Date Approved:** 2016

**Total Project Value:** $530,100

11. **Operation, Communication and Information Management for Smart Electricity Grids**

**Abstract:** Electric utilities worldwide are embracing a 'Smart Grid' vision of transformational change. This vision includes full modernization and automation of electric power networks. This vision also encompasses major elements from advanced metering, power electronics and information management to renewable and distributed energy resources, and home and electric vehicle energy management. The Smart Grid vision seeks to bring together and connect, in an inter-operable way, diverse technologies- advanced applications and use of distributed energy resources, communications, information management, automated controls. Doing so, the Smart Grid enables a self-healing, more reliable, less constrained, safer and more efficient grid. Intelligent meters, products and displays also empower customers to use electricity more efficiently.

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 are therefore linked between the three important pillars- the power system, the communication system, and the information system.

**Academic Investigator(s):**

- Main PI: Prof. Kankar Bhattacharya (Electrical and Computer Eng., UW)

**Industry Partner(s):** Hydro One, ABB Corporate Research, and IBM Canada Ltd

**Other Academic Institution(s):** N/A

**Funding Agencies:** Hydro One, and NSERC

**Grant Name:** WISE-Hydro One MOU, and NSERC Strategic Projects - Group
Date Approved: 2013
Total Project Value: $516,596

12. Impact of Electric Vehicles on the Grid

Abstract: Several powerful forces are gathering to make fundamental and irrevocable changes to the century-old grid. The next-generation grid, often called the `smart grid,' will feature distributed energy production, vastly more storage, tens of millions of stochastic renewable-energy sources, and the use of communication technologies both to allow precise matching of supply to demand and to incentivize appropriate consumer behavior. These changes will have the effect of reducing energy waste and reducing the carbon footprint of the grid, making it smarter and greener.

Our proposal focuses on one aspect of the smart grid: the integration of electric vehicles (EVs). This is an important technical challenge because the introduction of EVs will greatly affect the distribution network but, if properly controlled, can serve to mitigate other elements of the smart grid.

The collaborative research project proposed here has three thrusts: modelling, control, and prototyping. First, we will use advanced modeling techniques, such as exact simulation of distribution networks using both proprietary and open-source simulators, to study the effect of EVs on distribution networks. Our modeling approach, unlike past efforts, will take into account the stochastic nature of EV loads. We will also use advanced telemetry technique to construct mobility models for EVs. Finally, we will model the effect of advanced Lithium-air batteries on the EV ecosystem. Second, we will study techniques to control the charging current delivered to each EV in a fleet. In doing so, we hope to simultaneously meet the needs of the grid and the EV fleet owner. Our second project in the area of control is to use game theory to study control techniques for EVs in residences. We will also design control mechanisms for EV billing and to prevent unauthorized EV charging. Third, we will design a smart charger that could control the charge current and also communicate with the grid to decide whether to allow charging, at what rate to charge, and whom to bill for the electricity. These issues are clearly inter-related and hence can only be addressed together.

The commercial and economic reasons for this research are compelling. This is reflected by a strong commitment from our industrial partners, Hydro One and IBM.

Academic Investigator(s):
- Main PI: Prof. Catherine Rosenberg (Electrical and Computer Eng., UW)

Industry Partner(s) and Other Organization(s): Hydro One, IBM Canada Ltd, and Ministry of Economic Development and Trade

Other Academic Institution(s): N/A
Funding Agencies: NSERC
Grant Name: NSERC Collaborative Research and Development (CRD)
Date Approved: 2014
Total Project Value: $360,000
13. Memorandum of Understanding – Changfeng Energy

Abstract: This agreement between Changfeng Energy Inc. & its subsidiaries (“Changfeng Energy”) and the University of Waterloo (“UW”) will enhance the capacity for training and research in the low energy building sector, and smart cities network infrastructure. Building on the expertise of the University of Waterloo faculty members and the management team of Changfeng Energy Inc. & its subsidiaries, this agreement is to advance active collaboration and to promote development of innovative solutions to the emerging challenges of integrating clean energy technologies into the building structure and to address specific issues related to smart city infrastructure for Haitang Bay in the city of Sanya, Hainan Province, and beyond Hainan Province across China. The goal is to advance research and development, and support for the training of highly qualified personnel and specific initiatives in support of deployment of smart energy/smart infrastructure concepts.

Academic Investigator(s):
- Main PI: Prof. Jatin Nathwani (Management Sciences, UW)

Industry Partner(s): Changfeng Energy
Other Academic Institution(s): N/A
Funding Agencies: N/A
Grant Name: N/A
Date Approved: 2017
Total Project Value: $300,000


Abstract: With few exceptions, there is at present no way to directly control the flow of power between generators and consumers in a power grid, so in order to maintain grid stability and prevent blackouts transmission lines are limited in their power carrying capacity. When transfer capacity needs to be increased because of greater consumer demand, one way to do this is by building new transmission lines, which is both very costly and time consuming. If, however, power flow in the system is controlled, it is possible to more evenly balance the load between the various existing lines, and thus allow system operators to increase the transfer capacity of the system as a whole. This increased transfer capacity may be enough to eliminate the need for a new transmission line.

The inability of system operators to control the flow of power through electric grids will take on even more significance as utilities move forward in their development of the "smart grid". Renewable and distributed energy generation, the installation of "smart meters" in homes and businesses, greater use of electric transportation will place an even greater strain on the grid. Without both an increase in grid capacity and the ability to better control power flow, we will not be able to tap the full potential of these new developments.

This proposed project aims to evaluate in detail the role a new converter-based transmission control technology, the Hybrid Power Flow Controller (HPFC), can play in a smart grid designed to maximize the transfer capacity and stability in Ontario's electric
power grid, with a focus on reducing dispatch costs and increasing access to the renewable energy in Ontario’s power system. The key advantage of the HPFC, which was invented in 2003 at the University of Toronto, is in its unique ability to retrofit components (voltage support capacitors) that are often already on the grid, making it a more cost-effective alternative to existent Flexible AC Transmission System (FACTS) technologies.

Academic Investigator(s):
- Main PI: Prof. Claudio Canizares (Electrical and Computer Eng., UW)

Industry Partner(s): Hydro One

Other Academic Institution(s): N/A

Funding Agencies: Hydro One, NSERC

Grant Name: WISE-Hydro One MOU, and NSERC Collaborative and Research Development (CRD) Grant

Date Approved: 2013

Total Project Value: $224,500

15. Active Distribution Systems: Modeling, Planning and Control Design

Abstract: The energy sector is moving into the era of Smart Grids (SGs). The main concept in a typical SG is the evolution of a centralized, partially-automated, producer-controlled network to a decentralized network that minimizes the environmental adverse impacts; maximizes grid reliability and performance; and enables real-time interactions between customers, network operators and power producers. To achieve this vision, the state-of-the-art planning, design, operation, and control strategies should be adopted to integrate conventional power grid components, distributed and renewable generation, energy storage devices, advanced grid control devices, power electronic converters, automated sensing and metering devices, and information and communication technologies.

A natural evolution of the SG concept is the transformation of a conventional distribution system into an Active Distribution System (ADS). The latter hosts distributed and renewable generation and is equipped with embedded low- and high-level energy management and control algorithms. Substantial research efforts are needed to achieve the SG and ADS vision and overcome integration issues.

The proposed research work aims to the development of modeling, planning and control tools and algorithms that will facilitate timely and safe integration of ADS devices into existing networks. With close co-operation with the industrial partner of this project (Hydro One Networks and Natural Resources Canada), the proposed research work will help to facilitate the safe transformation of Hydro One Networks distribution system into intelligent ADSs through better understanding of requirements and upgrades, and providing assessment tools, planning algorithms and control design procedures.

Academic Investigator(s):
- Main PI: Prof. Magdy Salama (Electrical and Computer Eng., UW)

Industry Partner(s) and Other Organization(s): Hydro One, and Natural Resources Canada (NRCan)
16. Probabilistic Planning and Billing Management

Abstract: The project is structured in the form of three thrusts that encompass six research projects. The first thrust is on modeling. In this context we define three projects. First, we will use advanced modeling techniques to study the effect of EVs on distribution networks. Our modeling approach, unlike past efforts, will take into account the stochastic nature of EV loads. In the second project, we will develop smartphone applications and machine learning techniques to build large-scale accurate models of vehicle usage. Our models will allow us to study techniques to account for “range anxiety” when using EVs. Third, we will use mathematical models to study the potential benefits from using next-generation Lithium-air batteries that are being developed by our partner, IBM.

The second thrust is on control. We define two projects in this area. First, we will develop optimal algorithms to control the rate of charging of EVs and fleets of electric vehicles. Second, we will customize EV charge/discharge in homes depending on the profile of energy use in each household and the availability of distributed generation assets.

The third thrust is to design and prototype a smart charger that could control the charge current and also communicate with the grid to decide whether to allow charging, at what rate to charge, and whom to bill for the electricity.

Academic Investigator(s):

- Main PI: Prof. Catherine Rosenberg (Electrical and Computer Eng., UW)

Industry Partner(s): Hydro One

Other Academic Institution(s): N/A

Funding Agencies: Hydro One

Grant Name: WISE-Hydro One MOU

Date Approved: 2013

Total Project Value: $180,000

17. Increasing renewable generation connectivity in the transmission system of Ontario through use of innovative DG controls

Abstract: To increase the renewable generation connectivity, innovative DG controls are proposed for each of the three operational modes: normal, fault, and transient-stability.

During normal mode, a DG interface is presented based on cascaded multilevel inverter topology for medium voltage distribution networks. The interface enables the elimination of the needed transformer for coupling to the medium voltage network, which reduces the losses, size and weight of the DG unit. A decoupled control system is presented with
the ability to operate the DG with unity power factor, constant power factor, or constant voltage.

In the case of faults, a novel fault current management (FCM) technique is suggested for inverter-based distributed generators (IB-DGs). At the point of connection to a power system, many distributed generators (DGs) require power electronic (PE) interfaces, which are normally idle during faults. The proposed FCM method employs these PE interfaces for control of the fault current. For this purpose, operation of IB-DGs is modified to FCM mode at the moment of fault and new current references are applied.

Through transient stability studies, this project presents a novel technology of utilizing Photovoltaic (PV) Solar Farms in the nighttime. New controls are developed for the solar farm inverters to operate as STATCOM—a Flexible AC Transmission System (FACTS) Controller, using the entire inverter capacity in the night for accomplishing an improvement of power transfer capacity. During the daytime, the same objective can be achieved to a substantial degree with the inverter capacity remaining after real power generation. This technology is termed PV-STATCOM.

**Academic Investigator(s):**
- Main PI: Prof. Magdy Salama (Electrical and Computer Eng., UW)

**Industry Partner(s):** Hydro One
**Other Academic Institution(s):** N/A
**Funding Agencies:** Hydro One
**Grant Name:** WISE-Hydro One MOU
**Date Approved:** 2013

**Total Project Value:** $150,000

---

18. Dynamic Interactions in Active Distribution Systems: Modeling, Analysis and Suppression via Control Design

**Abstract:** Driven by economic, technical and environmental reasons, the interest in distributed and renewable generation (DG) is increasing. According to a conservative estimate by the U.S. Department of Energy, the worldwide growth of the capacity of DG is 20 GW per year over the next decade. Beside conventional rotary-machine-based DG units, potential renewable and clean energy sources, such as fuel cells, photovoltaic arrays, micro-turbines, full-scale wind turbines, variable-speed efficient diesel generators and energy storage devices are interfaced to the grid via power electronic converters. On the other hand, driven by the urgent need to improve the reliability and efficiency, power distribution systems are moving towards an extensive use of electronic distribution system control devices, such as power-quality control devices, smart capacitor banks, grid reconfiguration systems and other smart-grid technologies. With high penetration of these newly emerging devices, future distribution systems can be seen as converter-dominated distributed power grids with hybrid continuous-discrete control devices, self-healing algorithms and embedded intelligence, or simply Active Distribution Systems.

Some of Hydro One lines are already at capacity and yet the need for power is increasing greatly. New renewable generation is envisioned for the urban areas such as GTA but the constraint lies in the transmission and distribution system. While the transmission capacity has many pain to be enhanced, the short circuit current levels in the distribution
systems with the proposed enhanced renewable generation, must be controlled to avoid
damage to system components and to obviate any major system reconfiguration. The
proposed project aims to the development of modeling, planning and control tools and
algorithms that will facilitate timely and safe integration of ADS devices into existing
networks.

Academic Investigator(s):

- Main PI: Prof. Magdy Salama (Electrical and Computer Eng., UW)

Industry Partner(s): Hydro One
Other Academic Institution(s): N/A
Funding Agencies: Hydro One
Grant Name: WISE-Hydro One MOU
Date Approved: 2013

Total Project Value: $150,000

19. EV Charging Infrastructure on UW Campus

Abstract: In April 2016, Waterloo became the first Canadian university to install smart
charging infrastructure for electric vehicles (EVs). That’s good news for anyone on
campus who wants to charge up for free. It’s even better news for the 21 WISE faculty
whose research focuses on EVs. Unlike regular chargers, these units optimize charging
patterns based on demand levels and time-of-use electricity costs. They also collect a
wealth of detailed data to help investigators shed light on critical issues of grid
management and next generation EV design.

Academic Investigator(s):

- Main PI: Prof. Jatin Nathwani (Management Sciences, UW)
- Co-PI: Prof. Roydon Fraser (Mechanical and Mechatronics Eng., UW), Prof. Nasser
  Azad (Systems Design Eng., UW), Prof. Michael Fowler (Chemical Eng., UW), Prof.
  Weihua Huang (Electrical and Computer Eng., UW), Prof. Sheshakamal Jayaram
  (Electrical and Computer Eng., UW), Prof. Mehrdad Kazerani (Electrical and
  Computer Eng., UW), Prof. Amir Khajepour (Mechanical and Mechatronics Eng.,
  UW), Prof. Kumaraswamy Ponnambalam (Systems Design Eng., UW), Prof.
  Armaghan Salehian (Mechanical and Mechatronics Eng., UW), Prof. Sherman Shen
  (Electrical and Computer Eng., UW), Prof. Lan Wei (Electrical and Computer Eng.,
  UW), Prof. Ramandan El Shatshat (Electrical and Computer Eng., UW), Prof. John
  McPhee (Systems Design Eng., UW), Prof. Steven Young (School of Environment,
  Enterprise and Development), Prof. Paul Parker (School of Environment, Enterprise
  and Development), and Prof. Ranjini Jha (School of Accounting and Finance)

Industry Partner(s): N/A
Equipment Supplier(s): AddEnergie, Tesla, and Fluke
Other Academic Institution(s): N/A
Funding Agencies: University of Waterloo
Grant Name: N/A
Date Approved: 2016

Total Project Value: $105,000
20. Non-destructive Condition Assessment of Wood Poles using Ultrasonic Waves

Abstract: The efficient condition assessment of wood poles for maintenance, replacement, and monitoring programs of wood infrastructure is an essential task for ensuring the reliability of the electrical network. In this project, an integrated assessment method is proposed; which complements the traditional visual and sounding inspection methods by assessing the early-decay condition of a wood pole. This new nondestructive technique for the evaluation of in-service wood poles is based on ultrasonic waves. The main tool developed is called UPole-Testing; which includes an ultrasonic system and a computer software for automatic data processing. The system generates and updates a database with the condition assessment of all poles tested in a given network. The new method is able to detect early decay and its location inside a wood pole as well as to determine the end-of-life (EOL) of in-service wood poles. The new method can be used to (a) increase the reliability of the new and old distribution and transmission lines by assessing early decay, (b) reduce maintenance costs by optimizing the schedule of wood pole replacement and rehabilitation, and (c) provide a safe environment for the public and operation personnel and the public in general by addressing unexpected pole failures (EOL).

Academic Investigator(s):

• Main PI: Prof. Giovanni Cascante (Civil & Environmental Eng., UW)

Industry Partner(s): Hydro One
Other Academic Institution(s): N/A
Funding Agencies: Hydro One
Grant Name: WISE-Hydro One MOU
Date Approved: 2013

Total Project Value: $100,000


Abstract: Energy harvesting has been an important research topic in the field of green energy technology. Different mechanisms were reported in the literature for converting a variety of energy into electricity energy. Among them to mention, a thermoelectric energy harvester converts the heat into electrical energy. A piezoelectric energy harvester converts the mechanical strain into electrical energy. Permanent magnet structures in presence of vibrational motion are a popular source for energy harvesting. During the course of the project, one PhD student, one Postdoctoral researcher, one undergraduate research assistant, and two capstone project students will be engaged in the project. They will be trained in a number of key areas, including magnetic energy harvesting system design, finite element analysis, and prototype manufacturing.

Academic Investigator(s):

• Main PI: Behrad Khamesee (Mechanical and Mechatronics Eng., UW)

Industry Partner(s): Mag-Tech Renewable Energies Inc.
Other Academic Institution(s): N/A
Funding Agencies: NSERC
Grant Name: NSERC Collaborative Research and Development (CRD)  
Date Approved: 2017  
Total Project Value: $83,500

22. The Energy Hub Management II: Empowering LDCs to Enable the Smart Grid

Abstract: The intention is to research, design, develop, deploy and evaluate a new generation of LDC energy management systems to interact with customers’ energy management systems and thus allow the realization of a smart grid. Specifically, develop the “macrohub” box (a high-end desktop computer), a proposed system and communication architecture, containing the appropriate software (mathematical models and algorithms) and communication capabilities to exchange information and control signals with both the LDC and customer monitoring and control equipment.

Academic Investigator(s):
- Main PI: Prof. Claudio Canizares (Electrical and Computer Eng., UW)

Industry Partner(s): Hydro One  
Other Academic Institution(s): N/A  
Funding Agencies: Hydro One  
Grant Name: WISE-Hydro One MOU  
Date Approved: 2013  
Total Project Value: $75,000


Abstract: Delivering training to Colas staff to help them understand requirements of Sustainability and best industry practice. The project consists of ISO 9001 (international standard that specifies requirements for a quality management system (QMS), OHSAS 18001 (international standard which provides a framework to identify, control and decrease the risks associated with health and safety within the workplace), and Quality Management and Control Webinars.

Academic Investigator(s):
- Main PI: Prof. Jatin Nathwani (Management Sciences, UW)

Industry Partner(s): Colas Canada Inc.  
Other Academic Institution(s): N/A  
Funding Agencies: N/A  
Grant Name: N/A  
Date Approved: 2017  
Total Project Value: $68,000
24. Highly Efficient, Self-Powered Traffic Event Detection System

Abstract: Real-time traffic monitoring and control is essential for efficient operation of modern transportation networks. Effective Intelligent Transportation Systems (ITS) and transit strategies reduce travel time, improve safety, and reduce pollutant emissions. However, the cost of traffic sensor and installation is currently prohibitive. It is proposed that a several cable-free traffic sensor can be sold and installed in each intersection, which can greatly expand traffic data coverage in a budget constrained traffic network. The challenge is to design a power optimized, yet fully functional, traffic sensor platform, using alternative power generation rather than cables.

Academic Investigator(s):
Main PI: Prof. Kumaraswamy Ponnambalam (Systems Design Engineering, UW)

Industry Partner(s): Miovision

Other Academic Institution(s): N/A

Funding Agencies: NSERC and OCE

Grant Name: NSERC Engage + OCE VIP 1

Date Approved: 2016

Total Project Value: $65,000

25. Accelerating Energy Access Solutions: Field-Based Knowledge, Fundamental Research, and the Role of Incubation Platforms

Abstract: The primary outcome from the project will be a workshop to be held at IASS in Potsdam, Germany. The workshop will bring together all of the partners alongside other selected individuals with deep experience in developing innovation platforms and projects in the fields of sustainability and development, with a focus on energy access. The workshop will feature presentations of a variety of innovation models employed by partners and a discussion of best practices through comparative analysis of the models and their relative successes and failures across a range of factors. The workshop will also provide a venue to partners to discuss potential further funding opportunities from major EU, North American and global philanthropic sources. The purpose of securing additional funding will be to grow the AE4H initiative through implementation of the best practices identified at the workshop.

Academic Investigator(s):
- Main PI: Prof. Jatin Nathwani (Management Sciences, UW)
- Co-PI: Nigel Moore, WISE Manager
- UW Collaborators: Neil Craik, Ian Rowlands, Srinivasan Keshav; Claudio Canizares, Bissan Ghaddar, Mehrdad Kazerani

Industry Partner(s) or Other Organizations: The Waterloo Global Science Initiative

Other Academic Institution(s): The Karlsruhe Institute of Technology, The University of Oxford, The University of California, Berkeley, Carnegie Mellon University, Ashesi University, Aalto University, The University of Southampton, Penn State University, The Institute for advanced sustainability Studies

Funding Agencies: University of Waterloo + Matching funds from academic partners (KIT & WGSI)

Grant Name: International Research Partnership Grant
26. R&D of Control Platform for Integration of Renewable Energy in Remote Communities

Abstract: The main objective of the proposed project is to develop a robust microgrid system in collaboration with key partners (utility, community, equipment suppliers) that can be installed in remote communities in Canada, which will ultimately reduce the dependence on and the environmental impacts of diesel generation in these communities. This aligns with the ecoEII objectives of advancing Canada’s commitment to reducing the environmental impact and GHG associated with energy production, supporting the development of next generation hybrid wind diesel technologies, and contributing to Canadian competitiveness in the clean tech sector.

Academic Investigator(s):
- Main PI: Prof. Claudio Canizares (Electrical and Computer Eng., UW)

Industry Partner(s): Hydro One
Other Academic Institution(s): N/A
Funding Agencies: Hydro One
Grant Name: WISE-Hydro One MOU
Date Approved: 2013
Total Project Value: $60,000

27. Smart Grid Load Balancing & Energy Storage by Power-to-Gas via Methanation in Ontario and Germany

Abstract: Currently, power generation mainly relies on fossil fuel combustion that provides a cheap source of power but results in excessive CO₂ emissions. Alternatively, energy can be generated from renewable sources, which is particularly relevant when the electrical grid is unreliable or inaccessible. Solar and wind energy is abundant but efficient utilization of these renewable resources is challenging because of their unreliable nature. Transient fluctuations in solar and wind power supply result in significant grid load variations, leading to the supply-demand mismatch. Smart Grid load balancing can compensate for these fluctuations via energy transmission and storage. Off-peak power can be stored in batteries for later redistribution but scalability of this approach is questionable because of energy density, durability and cost limitations. An alternative route is to store surplus electricity in form of chemical energy using a Power-to-Gas (PtG) system integrated into a Smart Grid. In the PtG concept shown in Fig. 1, an electrolyzer is used to store renewable energy in H2 which is then reacted with CO₂ (from biogas, flue gas, etc.) to make renewable natural gas (RNG) in a thermocatalytic process of methanation. In addition to grid load balancing, this approach provides a benefit of CO₂ emissions reduction! RNG can be injected into the existing natural gas infrastructure that provides enormous storage and transportation capacities; it is a scalable technology. Ultimately, distributive PtG systems could enable widespread use of smart grid technologies.
The ultimate goal is to develop a highly efficient PtG system which can be integrated into a Smart Grid for distributed energy storage and load balancing via converting renewable electricity into energy content of RNG.

**Academic Investigator(s):**
- Main PI: Prof. David Simakov (Chemical Eng., UW)

**Industry Partner(s):** CISCO Canada Inc.
**Other Academic Institution(s):** N/A
**Funding Agencies:** CISCO Canada Inc.
**Grant Name:** WISE-CISCO Systems Smart Grid Research Fund
**Date Approved:** 2013

**Total Project Value:** $52,000

### 28. Distributed Generation Multi-Agent Voltage and Reactive Power Control

**Abstract:** In the third work, a two ways communication-based distributed control has been proposed to provide proper voltage and reactive power control in active distribution networks. The proposed control scheme is defined according to the concept of multiagent technology, where each voltage and reactive power control device or distributed generation (DG) unit is considered as a control agent. An intelligent Belief-Desire-Intention (BDI) model is proposed for the interior structure of each control agent. The Foundation for Intelligent Physical Agents (FIPA) performatives are used as communication acts between the control agents. First, the distributed control scheme is applied for voltage regulation in distribution feeders at which load tap changer (LTC) or step voltage regulators are installed at the beginning of the feeder. In this case, the proposed control aims to modify the local estimation of the line drop compensation circuit via communication. Second, the control scheme is modified to take into consideration the case of multiple feeders having a substation LTC and unbalanced load diversity. To verify the effectiveness and robustness of the proposed control structure, a multiagent simulation model is proposed. The simulation results show that distributed control structure has the capability to mitigate the interferences between DG units and utility voltage and reactive power control device.

**Academic Investigator(s):**
- Main PI: Prof. Ehab El-Saadany (Electrical and Computer Eng., UW)

**Industry Partner(s):** Hydro One
**Other Academic Institution(s):** N/A
**Funding Agencies:** Hydro One
**Grant Name:** WISE-Hydro One MOU
**Date Approved:** 2013

**Total Project Value:** $50,000
29. Developing a Stabilizing Control for Microgrid Systems

Abstract: The IEEE standard 1547.4 enumerates a list of potential benefits for the islanded microgrid operation. However, the microgrid isolation from the main grid creates special technical challenges that have to be comprehensively investigated in order to facilitate a successful implementation of the islanded microgrid concept. First, for the steady-state analysis of islanded microgrid systems, a novel and generalized algorithm is proposed to provide accurate power flow analysis of islanded microgrid systems. Secondly, the consideration of a system maximum loadability criterion in the optimal power flow (OPF) problem of islanded microgrid systems is proposed. Such consideration allows for an increased utilization of the islanded microgrid limited generation resources when in isolation from the utility grid. Next, a new probabilistic algorithm for enabling the decentralized operation of islanded microgrids, including renewable resources, in the absence of a microgrid central controller (MGCC) is proposed. The proposed work takes into consideration the variety of possible islanded microgrid configurations that can be initiated in a distribution network (multi-microgrids), the uncertainty and variability associated with the output power of renewable DG units as well as the variability of the load, and the special operational philosophy associated with islanded microgrid systems.

Academic Investigator(s):
- Main PI: Prof. Ehab El-Saadany (Electrical and Computer Eng., UW)

Industry Partner(s): Hydro One

Other Academic Institution(s): N/A

Funding Agencies: Hydro One

Grant Name: WISE-Hydro One MOU

Date Approved: 2013

Total Project Value: $50,000

30. Affordable Energy for Humanity Innovation Lab

Abstract: The primary outcome from the project will be a workshop (referred to as an ‘Innovation Lab’) to be held in Waterloo at the Balsillie School for International Affairs. This 2.5 day event will take place June 19th-21st 2019. The Innovation Lab follows a non-traditional format developed specifically by AE4H as a means to catalyze meaningful collaboration across our global consortium of partners. Innovation Labs encourage our partners to engage in deep conversations about the challenges that they face, the opportunities for innovation and collaboration that they see, and possible sources of funding to support future work across the consortium that address these issues. Given the range of positive outcomes from our inaugural innovation lab in 2017, we expect significant positive outcomes this time around as well, particularly with regard to identification and pursuit of funding opportunities.

Academic Investigator(s):
- Main PI: Prof. Jatin Nathwani (Management Sciences, UW)
- Co-PI: Nigel Moore, WISE Manager
- UW Collaborators: Srinivasan Keshav; Claudio Canizares, Bissan Ghaddar, Mehrdad Kazerani

Industry Partner(s): N/A
31. Energy Harvesting for Sensors in Smart Grids

Abstract: A key part of North American and European plan for a clean energy future is the development of smart grid and a modern electricity system using more advanced monitoring, communication and control technologies to build more flexible, reliable and efficient electricity systems. Hence, there has been increasing interest in exploring new technologies for real-time monitoring and active management of electrical demand in the grid distributed over large geographic regions. The proposed research will provide a self-contained, innovative and economic single chip solution for smart grid monitoring. The MEMS-based proposed technology to monitor the grid has a number of distinct advantages such as two-way communication with self-healing network topology, and an energy harvesting device that allows a self-powered and maintenance free sensor. Also, the target design is about 50 times smaller than any of the existing sensing devices in the market today. Professors Salehian, Nairn and Wei with the MME and ECE departments have initiated collaborations with a team of researchers at the University of Bordeaux in France and Delft University of Technology in the Netherlands on this topic. The team of researchers have received funding from several sources in the past such as WISE, a previous CISCO funding opportunity, International Research Partnership Grants-European Union, and the Bordeaux-Waterloo Research Grants. This research currently involves 4 UW graduate students and an engineer at the University of Bordeaux Material Systems and Integration lab. The students will benefit from a multidisciplinary training throughout the course of this project and will obtain essential skillsets for MEMS fabrication, circuit design, and structural vibration modelling and testing. They will also gain fundamental knowledge in the areas of materials science, physics, electronic devices and circuits.

Academic Investigator(s):
- Main PI: Prof. Armaghan Salehian (Mechanical and Mechatronics Eng., UW)
- Co-PIs: Prof. Lan Wei (Electrical and Computer Eng., UW), and Prof. David Nairn (Electrical and Computer Eng., UW)

Industry Partner(s): CISCO Canada Inc.
Other Academic Institution(s): University of Bordeaux (France), and Delft University of Technology (Netherlands)
Funding Agencies: CISCO Canada Inc.
Grant Name: WISE-CISCO Systems Smart Grid Research Fund
Date Approved: 2013
Total Project Value: $46,000
32. Non-Destructive Testing of Utility Wood Poles

**Abstract:** Wood poles are widely used in Canada to support electric transmission and distribution lines. Since wood is a raw material, the material properties are affected by environmental conditions. Factors such as temperature, moisture, bacteria or fungi may induce the development of internal decay in the poles. Decayed areas could reduce the strength of a pole significantly, making it vulnerable to extreme weather conditions. In order to avoid sudden failures of wood poles, ensure the reliability of the electrical network and develop effective maintenance programs, Waterloo North Hydro needs to assess the internal condition of wood poles reliably.

**Academic Investigator(s):**
- Main PI: Prof. Mahesh Pandey (Civil and Environmental Eng., UW)

**Industry Partner(s):** Waterloo North Hydro (WNH)

**Other Academic Institution(s):** N/A

**Funding Agencies:** NSERC

**Grant Name:** NSERC Engage

**Date Approved:** 2016

**Total Project Value:** $43,600

33. Intermediate Grade Geothermal Energy

**Abstract:** The Enhanced geothermal energy (EGS) is an abundant, low-carbon base-load energy source that does not require high temperature gradient or heat source (intermediate-grade geothermal energy). This heat can be extracted by using the contemporary innovative drilling technology. By drilling deep into the ground, HDR EGS can enable access to an even larger scale heat resource in most parts of the planet. The potential for EGS is vast - a recent Massachusetts Institute of Technology report estimated that 2% of the heat below the continental United States could provide 2,500 times the country’s total annual energy use (MIT, 2006). The research project will consist of a numerical approach using the finite element method to perform a fully coupled thermo-hydro-mechanical finite element analysis to investigate the strain, stress and displacement field. The research activities will include the assessment of different parameters and their effects on induced seismicity.

**Academic Investigator(s):**
- Main PI: Prof. Dipanjan Basu (Civil and Environmental Eng., UW)

**Industry Partner(s):** Borealis Geopower

**Other Academic Institution(s):** N/A

**Funding Agencies:** NSERC

**Grant Name:** NSERC Engage

**Date Approved:** 2015

**Total Project Value:** $42,100
34. Integration and Impact Assessment of AC/DC Hybrid Distribution Grids

**Abstract**: The current infrastructure of the distribution system owned and managed by Newmarket-Tay Power Distribution Ltd (NTPDL) is not designed to accommodate the new emerging DC technologies. The widespread implementation of DC technologies such as renewables, storage systems, and plug-in electric vehicles (EVs) have created a demand for more AC/DC and DC/DC conversions. The number of conversion systems will continue to escalate rapidly as additional DC technologies, such as distributed energy resources and modern loads, are adopted. An AC/DC hybrid infrastructure is a promising configuration for future smart grids. Such a configuration allows NTPDL distribution system to efficiently manage AC/DC distrusted energy resources and reliably deliver power to load centres, along with the resulting formation of AC/DC distribution systems. UW researchers will collaborate with NTPDL to investigate the newly structured AC/DC hybrid distribution system characterized by plug-and-play features.

**Academic Investigator(s):**
- Main PI: Prof. Kumaraswamy Ponnambalam (Systems Design Eng., UW)

**Industry Partner(s):** Newmarket-Tay Power Distribution Ltd (NTPDL)

**Other Academic Institution(s):** N/A

**Funding Agencies**: NSERC

**Grant Name**: NSERC Engage Grant

**Date Approved**: 2017

**Total Project Value**: $39,700

35. Ground Source Heat Pump (GSHP) Systems in Ontario

**Abstract**: The research project will involve developing multiple optimized GSHP models for a range of residential and commercial buildings in northern Ontario spanning over 800 to 500,000 square feet. The modeling will involve optimization and LCA, and these tasks will be performed using the Ground Loop Design (GLD) software and GaBi LCA software, respectively. These models will help to optimize the entire life cycle cost, which includes the cost of installation, operation, maintenance, and disposal. The underlying challenge in this research is to integrate the different components and optimize their contributions considering a life cycle (cradle to grave) approach to develop an efficient GSHP system.

**Academic Investigator(s):**
- Main PI: Prof. Dipanjan Basu (Civil and Environmental Eng., UW)

**Industry Partner(s):** GeoSmart Energy Inc.

**Other Academic Institution(s):** N/A

**Funding Agencies**: NSERC

**Grant Name**: NSERC Engage Grant

**Date Approved**: 2016

**Total Project Value**: $39,300
36. Smart Meter Data Mining

Abstract: The widespread availability of smart metering systems makes it possible to model and predict energy usage using data mining and machine learning techniques. As a result, utilities and private-sector partners are seeking ways to leverage smart meter analytics in order to improve grid efficiency and stimulate new energy service businesses. In this project, we will investigate how data mining techniques can be used to provide meaningful feedback to consumers and recommendations for saving energy.

Academic Investigator(s):
- Main PI: Prof. Lukasz Golab (Management Sciences, UW)

Industry Partner(s): CISCO Canada Inc.
Other Academic Institution(s): N/A
Funding Agencies: CISCO Canada Inc.
Grant Name: WISE-CISCO Systems Smart Grid Research Fund
Date Approved: 2013

Total Project Value: $39,000

37. Stochastic Modeling and Optimization for PEV Charging Station Operation in Smart Distribution Systems

Abstract: The significant research effort has been made in both academia and industry to enhance the sustainability of the power system, specifically by introducing more renewable energy sources and demand side management programs for electricity production and consumption. It is envisaged that these new technologies and applications will be harnessed in the future smart grid, facilitated by two-way communication.

In this project, stochastic modeling and optimization techniques will be developed for coordination of multiple PEV charging station operation in a smart distribution system operated by a local distribution company (LDC). The two-way communication functionality of smart distribution system will be leveraged to establish a communication link between the LDC and the charging station operator. Historical traffic statistics will be used to construct a queuing network model to evaluate the charging demand of charging stations, based on which an optimal decision on charging station operation can be made.

Academic Investigator(s):
- Main PI: Prof. Kankar Bhattacharya (Electrical and Computer Eng., UW)

Industry Partner(s): CISCO Canada Inc.
Other Academic Institution(s): N/A
Funding Agencies: CISCO Canada Inc.
Grant Name: WISE-CISCO Systems Smart Grid Research Fund
Date Approved: 2013

Total Project Value: $39,000
38. Technical Feasibility of Helical Piles to Extract Shallow Geothermal Energy

Abstract: Almita Piling Inc. (located at Edmonton, AB) will collaborate with the University of Waterloo Professor Dipanjan Basu (Principal Investigator, PI) to investigate the feasibility of using helical piles to extract shallow geothermal energy. These prefabricated piles can be quickly installed under a variety of subsurface conditions, and are attractive foundation option for 1-3 storey residential buildings. However, these piles have never been used to extract shallow geothermal energy from the ground. If successful, geothermal helical piles will be a cost-effective building solution that serves the dual purpose of providing structural support and providing space heating, cooling, and hot water to a variety of residential buildings. This technology will not only help in reducing the carbon footprint of future building stock but also minimize the energy expenditure for consumers. In this technology, energy is extracted from the ground when in heating mode, and energy is released to the ground when in cooling mode.

Academic Investigator(s):
- Main PI: Prof. Dipanjan Basu (Civil and Environmental Eng., UW)

Industry Partner(s): Almita Piling Inc.
Other Academic Institution(s): N/A
Funding Agencies: NSERC
Grant Name: NSERC Engage Grant
Date Approved: 2017
Total Project Value: $39,000

39. Developing an Energy Harvesting Generator with Permanent Magnets

Abstract: MagTech Inc. is an entrepreneurial company focusing on permanent magnetic power and shielding as a renewable environmentally friendly energy source. They have already begun working on the development of such permanent magnet generators. However, scientific foundational research is required for this work which will be achieved by teaming up with experts at the University of Waterloo. MagTech Inc. will collaborate with Prof. Behrad Khamesee and his team to assist in research activities i.e. modeling including analytical and numerical approaches using finite element method to perform magnetic analysis and optimization of a magnetic generator initially developed by MagTech.

Canadian economy.

Academic Investigator(s):
- Main PI: Prof. Behrad Khamesee (Mechanical and Mechatronics Eng., UW)

Industry Partner(s): Mag-tech Renewable Energies Inc.
Other Academic Institution(s): N/A
Funding Agencies: NSREC
Grant Name: NSERC Engage Grant
Date Approved: 2016
Total Project Value: $37,500
40. Advancing Geothermal Drilling Techniques in Canada

Abstract: Energy decarbonization and energy storage are key elements in the world’s energy future. In Canada, the cold climate means that a great need for reliable heat and electrical power exists. In the North, diesel fuel, imported at great cost, generates all heat and power. Indigenous communities depend on this costly, carbon-rich source that is also a fire hazard and potential pollutant. Geothermal energy in deep rock masses promises to provide heat and power to remote communities, enhancing their life quality and opening new possibilities for community activities. Deep in the earth, the rock is hot enough to extract beneficial energy. In low permeability rock, this requires several boreholes, carefully placed through directional drilling, and connected through hydraulic fracturing. New drilling techniques are emerging for deep hard rock - hammer drilling with reverse circulation. After fracturing to establish communication between optimally placed well pairs, fluid circulates through the rockmass to bring heat to the surface, used for power and heating. Dr. Dusseault will work with Scientific Drilling International (Canada) Inc. to advance technologies for directional drilling of deep geothermal boreholes in hard rock (low porosity sedimentary rocks, igneous rocks). Assessment of directional drilling methodologies with hammer drilling methods is a basis of study, as well as evaluation of geothermal efficiency potential for different well placements, needed to decide on the best well placement strategies. Well designs and various monitoring approaches will be examined for these issues, with the goal of reducing drilling costs and making geothermal energy more accessible for Canadians.

Academic Investigator(s):
- Main PI: Prof. Maurice Dusseault (Earth and Environmental Sciences, UW)

Industry Partner(s): Scientific Drilling International Inc. (Canada)
Other Academic Institution(s): N/A
Funding Agencies: NSERC
Grant Name: NSERC Engage Grant
Date Approved: 2017
Total Project Value: $36,000

41. Voltage wWaveforms Effects on Power System Insulation Under High Frequency and Fast Transients

Abstract: In an effort to make the power system network more reliable and sustainable, there have been ongoing changes in the existing grid, which in turn has resulted in, the increased usage of power electronic devices. As such, increased switching could create many issues pertaining to voltage waveform quality; like, initiating severe stresses on the electrical insulation system in various power system components. The research undertaken investigates the effects of distorted voltage waveforms composed of fundamental and harmonics at different distortion levels in two separate parts.

In part A, the effect of the harmonics’ injection, as a consequence of the distributed generation interface to the grid, on the degradation of the transformer insulation system is studied. Experiments on degrading transformer paper insulation samples with harmonic-polluted voltages are performed. Dissipation factor increment ratio is used as a measure of the aging effect on insulation. It has been found that the dissipation factor
increment ratio of the transformer paper insulation is significantly higher, when stressed with distorted voltage waveforms compared to the power frequency voltage stresses.

In part B, the experimental work analyzes the cable termination degradation process when exposed to steep front non-sinusoidal voltage waveforms. The partial discharge (PD) measurements are carried out before and after the accelerated aging experiment to study the insulation degradation under high frequency medium voltage stresses. In addition, both the surface potential distribution measurements using an electrostatic voltmeter along with the surface temperature measurements using infra-red camera are used in the analyses.

Academic Investigator(s):
- Main PI: Prof. Sheshakamal Jayaram (Electrical and Computer Eng., UW)

Industry Partner(s): Hydro One
Other Academic Institution(s): N/A
Funding Agencies: Hydro One
Grant Name: WISE-Hydro One MOU
Date Approved: 2013
Total Project Value: $36,000

42. Permafrost Thermosyphon

Abstract: Sigma Energy Storage is developing sustainable technologies to access the methane trapped in permafrost (clathrate form) and use it as an energy source for remote northern communities. There is no known existing methodologies allowing to utilize such resources of methane due to potentially high costs of production and lack of knowledge on how it can be done. Many Canadian northern regions, especially remote communities have very high costs of transporting fuel. Therefore, methane production from clathrate may be economically feasible and more sustainable than transporting fossil fuels.

Prof. Leonenko is collaborating with Sigma Energy Storage to investigate approaches to produce methane from clathrate. This involves feasibility study of using geothermal energy to locally heat and melt permafrost in a controlled way to release, produce and capture methane. Sigma Energy Storage will integrate these new developed techniques to its portfolio of technologies addressing new and sustainable forms of energy production and storage, yielding more cost effective and environmentally friendly energy systems in the Canadian economic, climatic, and geological context.

Academic Investigator(s):
- Main PI: Prof. Yuri Leonenko (Earth and Environmental Sciences, UW)

Industry Partner(s): Sigma Energy Storage
Other Academic Institution(s): N/A
Funding Agencies: NSERC
Grant Name: NSERC Engage Grant
Date Approved: 2018
Total Project Value: $36,000
43. Developing Intermediate Grade Geothermal Energy for Canada

**Abstract:** There are only a few sites in Canada in British Columbia and the Yukon with reasonable access to high-grade geothermal energy. However, warm fluids (60-120°C) in permeable sedimentary rock represent a vast intermediate-grade geothermal energy (IGGE) source in the basins of Western Canada. Elsewhere, at depths of 4-8 km in the igneous rocks that underlie all of Canada, there are also huge quantities of IGGE. Improvements in drilling technologies in sedimentary and igneous rocks promise to revolutionize our ability to economically drill boreholes, and new concepts in hydraulic fracturing will allow linking of parallel wells at depth. This will open the possibility of widespread use of zero-carbon IGGE, but its advantages may be most apparent in Canada North, where the only reliable source of energy is currently fossil fuel, shipped in at great expense. IGGE can provide this, and it can also provide electrical power. In partnership with the DEEP project in Saskatchewan, a fluids-based IGGE project, the ENGAGE grant will explore one large important theme. Large scale heat extraction through fluids circulation reduces the rock mass temperature, which in turn causes thermoelastic shrinkage. This leads to large-scale stress redistribution, generating regions of stress increase, and regions of stress decrease. Stress changes will lead to an increase in induced seismicity, but its magnitude and rate are currently challenging to predict. Our work will initiate research into this by developing appropriate mathematical models with the DEEP project that can simulate the process of stress redistribution through extraction of geothermal energy, aiding in the design and operation of such projects.

**Academic Investigator(s):**
- Main PI: Prof. Maurice Dusseault (Earth and Environmental Sciences, UW)

**Industry Partner(s):** Deep Earth Energy Production

**Other Academic Institution(s):** N/A

**Funding Agencies:** NSERC

**Grant Name:** NSERC Engage Grant

**Date Approved:** 2016

**Total Project Value:** $35,000

44. Technical and Life Cycle Cost Assessment of Zero-Emission Transport Refrigeration Units

**Abstract:** The development of an efficient and green stationary, thermal system for medium to heavy duty service vehicles has the potential to provide significant technological and sustainability advantages in the next-generation Air Conditioning and Refrigeration (A/C-R) for transportation. This proposal is built with partnership with VoltaAir Technology Inc. and primarily aims to develop a Life Cycle Cost modeling platform for VoltaAir’s battery powered A/C-R system.

**Academic Investigator(s):**
- Main PI: Prof. Sanjeev Bedi (Mechanical and Mechatronics Eng., UW)

**Industry Partner(s):** VoltaAir Technology Inc.

**Other Academic Institution(s):** N/A
Section III: Accomplishments and Impact

**45. HITCH - Smart Mesh Routers for Community Broadband & Off-Grid Renewable Energy Access in Remote Areas**

**Abstract:** Broadband demand for video and other services is exploding globally. Service providers struggle to maintain legacy systems, and upgrades to emerging technologies at a pace that matches deployment and maintenance ROI requirements; as well as extend coverage to underserved users in various markets. Also, demand for off-grid renewable energy to support livelihoods in remote areas, outstrips current supply options, and is a persistent sustainable development prerequisite. Conventional thinking posits that over time, broadband and off-grid energy access will become available, affordable, and accessible to these users.

HITCH is a solar-powered smart wireless router AND predictive video caching platform. Users need impactful Videos and HITCH delivers these to their handheld mobile devices, via WiFi. Routers also provide affordable off-grid energy access, via built-in ports for charging mobile and other personal devices, powered by solar & battery capacity.

This funding will enable us to develop, test, and finalize the HITCH product, prior to a market launch in emerging markets. Our goal is to build out a unique impact platform, with a sustainable model for scaling a hybrid service offering, which delivers a core video content AND off-grid energy access solution for remote communities. We will also write a report for WISE at the end of the co-op student’s term, which will describe what we accomplished and how it relates to energy access.

**Academic Investigator(s):**
- Main PI: Prof. Jatin Nathwani, (Management Sciences)
- Main PI: Prof. Mahesh Pandey (Civil and Environmental Eng., UW)

**Industry Partner(s):** CISCO Canada Inc., HITCH (by flexfinity)

**Other Academic Institution(s):** N/A

**Funding Agencies:** CISCO Canada Inc.
**Grant Name:** WISE-CISCO Systems Smart Grid Research Fund
**Date Approved:** 2013

**Total Project Value:** $28,072

---

**46. A Novel Self-Contained Piezo-Magnetic Sensor for Failure Detection in Power Grids**

**Abstract:** Grid capacity, reliability and efficient distribution of power have been among major challenges for traditional Ontario power grids in the past few years. Reliable distribution within these power grids will continue to depend on development of lighter and more efficient sensing units with much smaller maintenance costs in order to detect grid failures. The objective of this research is to develop light-weight, more reliable and
self-contained sensing units with much higher packaging efficiencies compared to the available sensors in the market to detect power outages and cascading failures in grids. The proposed sensor employs hybrid design which includes a piezoelectric and a magnetic part. The sensor will be connected to a harvester unit that harvests remotely (on a non-contact base) minimal and sufficient amount of power (microwatts) from the transmission lines to feed the sensor. The harvester energy will power the sensing unit to wirelessly transmit the sensor readings to a remote central monitoring unit. The proposed technology will be the first single chip Micro-Sensor solution with several advantages such as being self-contained which means that it will not rely on batteries for its operation while being about 50 times smaller and cheaper than any existing device in the market today. The maintenance costs will be reduced significantly due to the sensor being self-contained. The harvested energy will be stored in a super-capacitor to power the sensor.

Academic Investigator(s):
- Main PI: Prof. Armaghan Salehian (Mechanical and Mechatronics Eng., UW)

Industry Partner(s): CISCO Canada Inc.
Other Academic Institution(s): N/A
Funding Agencies: CISCO Canada Inc.
Grant Name: WISE-CISCO Systems Smart Grid Research Fund
Date Approved: 2013
Total Project Value: $26,000

47. Efficient Analysis of Smart Meter Energy Data

Abstract: Smart grids have joined a growing list of “big data” sources in the Internet of Things, opening the door wider than ever to analysis of energy consumption data. Many of the analytical techniques explored in this context are driven by the promise of tangible economic benefits, for example through reductions in peak power consumption for energy providers, and the monthly bill for energy consumers. The profit motive, in turn, helps steer business decisions and consumer behaviors in the direction of environmental sustainability by reducing the byproducts of electricity production, including greenhouse gases, emissions that contribute to smog and acid rain, as well as long-lived radioactive waste. Information technology plays a critical role in energy analytics by extracting insights quickly from large data sets, but inefficient information systems work against the profit and sustainability motives by wasting time and electricity. The proposed research seeks efficiency gains along two axes: (1) reductions in CPU cycles and IO through incremental algorithms that operate efficiently on dynamically growing data sets such as time series; and (2) improvements in energy efficiency through parallel computation on general-purpose graphics processing units (GPGPUs). The algorithms and software prototypes arising from this research have potential for both economic and environmental benefit by reducing the capital costs and electrical energy costs associated with common energy analytics tasks.

Academic Investigator(s):
- Main PI: Prof. Wojciech Golab (Electrical and Computer Eng., UW)

Industry Partner(s): CISCO Canada Inc.
48. Accelerating Progress in Renewable Energy Using a Technology-Centered Co-Evolutionary Framework

Abstract: A review will be conducted in regards to the literature comparing national renewable energy policies and their impact on global technological progress (US, China, Germany/EU, Japan, and Canada’s provinces) including policy prescriptions based on prevailing analyses. Using existing frameworks to draw historical lessons, this review will compile and infer best-in-context-practices and policy options for Canada. This synthesizing report will be a discrete outcome. Complexity literature, Arthur in particular, will be used to develop the first iterations of the proposed framework. The application specifically to energy technology will be aided by the use of technical literature to test and develop the framework. This preliminary framework will be used to critique the existing co-evolutionary models and articulate how the inner workings of technological systems can be drawn into these models. This will include detailing how ad-hoc understandings are currently used, what implicit assumptions exist, and examples of specific missing insights into technological systems, particularly regarding their interactions with other systems. This critique will be a second discrete outcome. Results will be put into the necessary forms to be extensively communicated through both academic and popular mediums.

Student Researcher:
• Yonatan Strauch (School of Environment, Resources and Sustainability, Faculty of Environment)

Supervisor:
• Prof. Stephen Quilley (School of Environment, Resources and Sustainability, Faculty of Environment)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
Award Type: PhD Fellowship
Date Approved: 2014
Total Project Value: $25,000

49. Development of a utility grade controller for remote microgrids with high penetration renewable generation

Abstract: The research will investigate the energy systems in remote communities (including Kasabonica Lake First Nation (KLFN)), the priority that First Nations place on
renewables, the renewable energy resources and technologies available, the development of engagement strategies and the design of policies to:

(a) Promote a holistic approach to community energy planning that considers not only the consumption of electricity, but also thermal energy, conservation opportunities and the use of renewables to reduce fossil fuel consumption.

(b) Engage communities to maximize benefits for remote communities, including the creation of local economic development and employment opportunities through increased access to energy.

Renewable energy that is produced locally can contribute to employment generation, the creation of profitable enterprises at the local level, local skill development and the empowerment of local communities to manage their resources.

**Student Researcher:**
- Konstantinos Karanasios (Geography and Environmental Management, Faculty of Environment)

**Supervisor:**
- Prof. Paul Parker (School of Environment, Enterprise and Development, Faculty of Environment)

**Funding Partner(s):** Energy Council of Canada (ECC)
**Other Academic Institution(s):** N/A
**Funding Agencies:** N/A
**Award Type:** PhD Fellowship
**Date Approved:** 2014
**Total Project Value:** $25,000

### 50. Integrating Distributed Renewable Energy Generation into the Canadian Electricity Distribution System

**Abstract:** The preparatory work for this project will include: (1) A literature review of current thinking related to the Utility Death Spiral, (2) A review of laws regulating electrical utilities across Canada. This will include reviewing the provincial and territorial regulations to provide appropriate context for different jurisdictions, (3) Interviews with stakeholders in the electrical distribution field, proponents of renewable energy integration, and academics studying these issues, and (4) A review of distributed renewable generation in Canada and the expected trends for growth.

Based on this research, a white paper will be produced that provides an analysis of the likelihood that a Utility Death Spiral will occur in Canada and evaluates approaches for managing this potential challenge. This analysis of policy options will weigh the social, financial, and regulatory impacts of various approaches.

**Student Researcher:**
- Dane Labonte (School of Environment, Resources and Sustainability, Faculty of Environment)
Section III: Accomplishments and Impact

51. Optimization and Machine Learning for Smart Grid Applications

**Abstract:** The extraction of energy from renewable sources is rapidly growing. The rapid development of Information and Communication Technologies (ICT), including those in smart meters, cloud computing, big data analytics, and machine learning algorithms, can modernize the electric grids into smart grids. Smart grids increase the electric energy efficiency by meeting the dynamic demand responses and reducing the power loss from generation to consumption and through utilizing new supplies of renewable green energy, including wind and solar, and the ever-increasing use of Microgrid, electric vehicles (EVs) and smart appliances.

The project consists of four different components: (1) Wind and solar energy output forecasting using supervised learning, (2) microgrid consumer demand analysis using unsupervised classification, (3) dynamic pricing schemes (4) optimal scheduling of mobile EV energy storage taking into account energy demand and supply. The four components are coupled together in a holistic optimization framework to balance energy supply and demand taking into account the EV as an energy storage as well as a power supply.

**Academic Investigator(s):**
- Main PI: Prof. Bissan Ghaddar (Management Sciences, UW)

**Industry Partner(s):** CISCO Canada Inc.

**Other Academic Institution(s):** N/A

**Funding Agencies:** CISCO Canada Inc.

**Grant Name:** WISE-CISCO Systems Smart Grid Research Fund

**Date Approved:** 2013

**Total Project Value:** $19,500

52. Investigate the Effectiveness of Interventions Used in the EHMS Project: Residential Consumption Shifts

**Abstract:** This research will investigate the effectiveness of the interventions used throughout the EHMS project in terms of residential electricity consumption shifts in both overall and peak consumption levels. This proposed research correlates to the energy policy topic of ‘smart cities and energy networks’ focusing on consumer engagement of
smart grid systems. This research will provide insight on appropriate methodologies to promote residential conservation behaviour using smart grid project interventions.

**Student Researcher:**
- Bronwyn Lazowski (Department of Geography & Environmental Management (GEM))

**Supervisor:**
- Prof. Paul Parker (School of Environment, Enterprise and Development, Faculty of Environment)

**Funding Partner(s):** Energy Council of Canada (ECC)
**Other Academic Institution(s):** N/A
**Funding Agencies:** N/A
**Award Type:** Master to PhD Fellowship
**Date Approved:** 2016
**Total Project Value:** $19,000


**Abstract:** The Council for Clean & Reliable Energy (CCRE) in partnership with the Waterloo Institute for Sustainable Energy (WISE), a leading Canadian innovation centre at the University of Waterloo, is hosting the Annual Technology Innovation and Policy Forum. The purpose is to advance our understanding of the role of emerging smart grid technologies and to identify opportunities for reducing cost and improving resilience of the electricity distribution network. The forum brings together technology developers and innovators, leading researchers and entrepreneurs, industry thought leaders, and policy makers to help shape next generation smart energy solutions. Through dialogue and extensive opportunities for discussion, the forum will focus on establishing a common basis for accommodating divergent interests.

**Academic Investigator(s):**
- Main PI: Prof. Jatin Nathwani (Management Sciences, UW)

**Industry Partner(s):** N/A
**Other Academic Institution(s):** N/A
**Funding Agencies:** NSERC
**Grant Name:** NSERC Connect Level II Grant
**Date Approved:** 2017
**Total Project Value:** $16,750

### 54. Frequency Control Strategies for Future Microgrids

**Abstract:** This project proposes a systematic control synthesis framework for an optimal voltage-based frequency control (VFC) in islanded/isolated microgrids. A detailed model of a microgrid is first presented that is both scalable and generic. The problem of voltage-
based frequency control is then formulated as an optimal $H^\infty$ controller synthesis problem for the linearized microgrid model. The validity of model-reduction steps in which the feeders are neglected is discussed, and various centralized/decentralized control architectures are investigated. Multiple simulation studies are finally performed in MATLAB/Simulink to test and compare the performances of the control architectures in a microgrid test system. Simulation results confirm the robustness of the VFC controller with respect to simplifications in the system model, and realistic system changes compared to a non-optimal VFC.

**Academic Investigator(s):**
- Main PI: Prof. John Simpson-Porco (Electrical and Computer Eng., UW)

**Industry Partner(s):** CISCO Canada Inc.
**Other Academic Institution(s):** N/A
**Funding Agencies:** CISCO Canada Inc.
**Grant Name:** WISE-CISCO Systems Smart Grid Research Fund
**Date Approved:** 2013

**Total Project Value:** $16,250

---

55. **Canada’s Lower Carbon Energy Futures: Multi-level Sociotechnical Scenarios under the New Scenario Framework for Climate Change Research**

**Abstract:** Over the next academic year, this project will address two limitations of current approaches to energy futures studies. First, purely quantitative forecasting is too rigid to anticipate transformational developments. Second, global energy futures and national energy futures are currently disjointed; this is no longer acceptable in the face of global climate change. Instead, national energy scenarios could be systematically developed within boundary conditions that are consistent and coherent with global scale energy futures. Through this research project, I will produce such self-consistent qualitative scenarios, which entail not only issues related to energy demand and supply but also interactions of scenario factors across national and global scales and across sectors such as agriculture and water.

**Student Researcher:**
- Herijadi Kurniawan (Department of Geography and Environmental Management)

**Supervisor:**
- Prof. Vanessa Schweizer (Knowledge Integration) and Prof. Johanna Wandel (Geography and Environmental Management)

**Funding Partner(s):** Energy Council of Canada (ECC)
**Other Academic Institution(s):** N/A
**Funding Agencies:** N/A
**Award Type:** Master Fellowship
**Date Approved:** 2016

**Total Project Value:** $16,000
56. Wind Turbine Opposition in Ontario

**Abstract:** This research will take the form of a case study focusing on counties in non-remote part of Ontario with more than ten operating wind turbines, and within these counties specifically the communities with the largest wind farms will be selected. It is assumed that larger wind farms impact more people and the externalities resulting from the development and operation will therefore be more complex and varied. This selection is based on the rationale used to distribute surveys regarding health and perceptions of wind turbines, as part of Dr. Siva Sivoththman’s research as the Ontario Research Chair for Renewable Energy Technologies and Health, which will be used for comparison to case study results. These surveys asked residents living near wind turbines about their views on energy generation, and which aspects of renewable energy development were important for their approval.

**Student Researcher:**
- Tanya Christidis (School of Planning, Faculty of Environment)

**Supervisor:**
- Dr. Geoff Lewis (School of Planning, Faculty of Environment) and Dr. Phil Bigelow (School of Public Health and Health Systems, Faculty of Applied Health Sciences)

**Funding Partner(s):** Energy Council of Canada (ECC)
**Other Academic Institution(s):** N/A
**Funding Agencies:** N/A
**Award Type:** PhD Fellowship
**Date Approved:** 2015

**Total Project Value:** $15,000

57. Creation of a Comprehensive Engagement and Planning Framework for the Integration of Renewable Energy in Remote Communities

**Abstract:** The research will investigate the energy systems in remote communities (including Kasabonia Lake First Nation (KLFN)), the priority that First Nations place on renewables, the renewable energy resources and technologies available, the development of engagement strategies and the design of policies to:

(a) Promote a holistic approach to community energy planning that considers not only the consumption of electricity, but also thermal energy, conservation opportunities and the use of renewables to reduce fossil fuel consumption

(b) Engage communities to maximize benefits for remote communities, including the creation of local economic development and employment opportunities through increased access to energy.

Renewable energy that is produced locally can contribute to employment generation, the creation of profitable enterprises at the local level, local skill development and the empowerment of local communities to manage their resources.

**Student Researcher:**
58. Methodology for Improving the Net Environmental Impacts of New Buildings through Product Recovery Management

Abstract: The aim of this study is to add a Life Cycle Assessment (LCA) perspective to the decision-making methodology involved in adaptive reuse of buildings. LCA accounts for the materials and energy involved in a product and then measures the associated environmental impacts along all its life stages. Energy consumption, carbon emissions and global warming potential are just some of the environmental impacts that can be traced and quantified through LCA. We will investigate how these environmental impacts can be monetized and valued according to the constraints of the natural resources in a specific geographical place. From an economic standpoint, the advantages of monetizing environmental savings are meaningful because, through this kind of metric, it is much easier to compare benefits with costs and make choices across various alternatives. Emphasis will be placed on the increasing value of the environmental resources in a mid-term future. Consequently, it will be possible to create the necessary framework to advance energy policy-making in Canada in regard to Carbon Management: Bridging to a Lower Carbon Energy Future. In other words, through the findings of this study the government will be able to create regulations to incentivize construction projects that promote adaptive reuse as the first construction option. These regulations will be based on the objective monetization of the environmental savings for the community, city, and nation. In this way, the promotion of adaptive reuse could spread, changing the trends in the construction industry. Thus, the adoption of these practices for buildings can contribute to sustainability and climate change through mitigation of CO2 emissions.

Student Researcher:

- Benjamin Sanchez Andrade (Civil and Environmental Engineering, Faculty of Engineering)

Supervisor:

- Prof. Carl Haas (Civil and Environmental Engineering, Faculty of Engineering)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
59. Intra-Household Dynamics and Residential Energy Conservation Policies

Abstract: The proposed research will review and assess the contextual and social factors found to or expected to affect residential energy consumption and conservation at the intra-household level and propose how intra-household factors might be applicable to better understanding the impact of residential energy conservation policies on energy use patterns in Canada and to improving the design of existing or proposed policies.

Student Researcher:
- Ines Havet (School of Environment, Resources and Sustainability, Faculty of Environment)

Supervisor:
- Prof. Ian Rowlands (School of Environment, Resources and Sustainability, Faculty of Environment) and Prof. Andrea Collins (School of Environment, Resources and Sustainability, Faculty of Environment)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
Award Type: PhD Fellowship
Date Approved: 2018
Total Project Value: $15,000

60. Renewable Energy to Advance Off-Grid Community Sustainability: A Comparative Energy Policy Analysis between Alaska and Canada’s North

Abstract: The proposed research project aims to accomplish two goals related to ECC’s energy policy research topics. The first phase of the project will consist of a comparative renewable energy [RE] policy analysis between Alaska and Canada’s territories. This phase of the project aims to identify policy factors which have successfully encouraged RE development in remote/off-grid communities throughout Alaska and to generate policy recommendations for Canada’s North, with direct implications for Theme C: Energy Sector Regulatory Practices and Evolution. The second phase of the project will consist of an empirical analysis focusing on how RE projects contribute to the sustainability of Northern communities, offering important insights for Theme A: Canada’s Transition to Low Carbon Energy System.

Student Researcher:
- Nicholas Mercer (Department of Geography and Environmental Management)
61. Applying Social Theories to Conservation Initiatives

Abstract: This research will advance academic understanding of behavioural modification theory, applied to consumer conservation behaviour, including how to overcome the barriers to adoption. It will also enhance social marketing theory, particularly with respect to the CBSM model, clarifying the relative importance or weighting of model components with respect to the success of conservation initiatives. This is critical for optimizing the effectiveness of conservation programs (e.g., the OPA peaksaver PLUS) and overcoming policy barriers such as negative consumer perceptions of efficiency strategies and technologies such as SMART meters. It also speaks to energy policy-making issues in Canada, by addressing the transformative role that energy literacy in marketing communications can play in influencing consumer conservation decisions and creating a persistent and normative conservation culture. In order to fully incorporate energy conservation into electricity system planning, conservation programs need to consistently achieve their savings targets through consumer behavioural modification; the proposed research is an important step towards accomplishing this objective.

Student Researcher:

- Stephanie Whitney (School of Environment, Resources and Sustainability, Faculty of Environment)

Supervisor:

- Prof. Jennifer Lynes (School of Environment, Enterprise and Development, Faculty of Environment)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
Award Type: PhD Fellowship
Date Approved: 2015
Total Project Value: $13,000
62. Examining the Potential for Smart Meter Data Streams

**Abstract:** Emerging technologies, data sources, and policies may provide the necessary tools to address the issue of energy poverty through improved outreach, education, and conservation incentivization (particularly retrofit assistance program targeting). It is proposed that over the course of a two-year research Master's thesis project, the following initiatives be undertaken though collaboration with relevant stakeholders:

1. A qualitative initial study of existing methods and shortcomings of targeting and participant discovery for conservation incentive, education, and energy-efficiency retrofit programs, particularly the provincial utility-driven Home Assistance Program (HAP) for low-income ratepayers as delivered by agents including Green Communities Canada and GreenSaver;
2. A qualitative and quantitative assessment of the potential for increased energy conservation and cost benefits resulting from the application of machine-learning and data analysis techniques to

**Student Researcher:**
- Gordon Stephen (School of Environment, Enterprise and Development, Faculty of Environment)

**Supervisor:**
- Prof. Ian Rowlands (School of Environment, Resources and Sustainability, Faculty of Environment)

**Funding Partner(s):** Energy Council of Canada (ECC)
**Other Academic Institution(s):** N/A
**Funding Agencies:** N/A
**Award Type:** Master Fellowship

**Date Approved:** 2015

**Total Project Value:** $10,000

63. Thinking Outside the Box: What can energy entrepreneurs in the global south teach Canadian communities about imagining and implementing low carbon energy solutions?

**Abstract:** In this investigation, I will seek to generate knowledge with potential for cross-disciplinary applicability in sustainability, development, political science and business literature. I will disseminate my findings to entrepreneurs and communities across Canada through networks like the Federation of Canadian Municipalities and Canada’s Minister of Small Business. Through my ongoing work in the leadership of Climate Action Waterloo Region, I will disseminate my research results to inform and inspire local stakeholders with the knowledge is created in this project. Those local stakeholders will include the other leaders of Climate Action Waterloo Region, local entrepreneurs and policy makers. I will also seek to disseminate my research in collaboration with local neighbourhoods, schools and other places where energy imagination and agency can take root and grow.

**Student Researcher:**
64. Distributed Energy Resources (DERs): Shaping the Pathways and Policies for a Low-Carbon Energy System

Abstract: The goal of this research is to develop a robust framework for effective utilization of diverse distributed energy resources to reduce the carbon emissions profile of the Canadian energy system. Distributed energy resources have the potential to provide cost-effective solutions over a range of applications and user profiles to help transform the energy infrastructure into a smart and resilient system with information and control technologies (ICTs) providing additional value and support to the system.

Student Researcher:
- Hsiu-Chuan Chang (Management Sciences, Faculty of Engineering)

Supervisor:
- Prof. Bissan Ghaddar (Management Sciences, Faculty of Engineering)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
Award Type: Masters Fellowship
Date Approved: 2018
Total Project Value: $10,000

65. Increasing Societal Awareness About the Impacts of Anthropogenic Climate Change

Abstract: This research will explore the social dimensions of community-based energy transitions to provide new insights necessary in designing innovation policies that support an increasing share of non-carbon sources in the supply system. The purpose of this research is to develop place-based governance frameworks necessary for accelerating renewable energy technology diffusion in underserviced/ vulnerable communities, and foster long-term changes to socio-technical systems. The objectives of this research are to: (1) advance transitions theory by elaborating and linking socio-technical, political, economic, and environmental factors influencing energy transitions;
Section III: Accomplishments and Impact

(2) investigate community-driven trajectories for pathways to low-carbon futures; (3) promote knowledge mobilization and collaboration across different scales; (4) explore learning outcomes of transition activities to facilitate adaptation and resilience, and (5) design policy instruments to support energy project planning and implementation.

Student Researcher:
- Nicholas Palaschuk (School of Environment, Enterprise and Development, Faculty of Environment)

Supervisor:
- Prof. Paul Parker (School of Environment, Enterprise and Development, Faculty of Environment)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
Award Type: PhD Fellowship
Date Approved: 2018
Total Project Value: $10,000


Abstract: The overall objective of the proposed research is to develop frameworks & models that will allow ESS to effectively participate in the electricity markets for flexibility provisions at the wholesale and retail level and to evaluate their system and market impacts. The specific objectives are as follows: (1) Grid Level Participation, and (2) Retail Level Participation.

Student Researcher:
- Nitin Padmanabhan (Electrical and Computer Engineering, Faculty of Engineering)

Supervisor:
- Prof. Kankar Bhattacharya (Electrical and Computer Engineering, Faculty of Engineering)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
Award Type: PhD Fellowship
Date Approved: 2018
Total Project Value: $10,000
67. Mitigating the Systemic Consequences of Stranded Carbon Assets Along the Path of Decarbonization

Abstract: This research seeks to gain a better understanding of how climate related risks and opportunities affect asset pricing and portfolio allocation. Currently, financial institutions do not price environmental risk in the interest rate, either because it is not perceived as material or because the tools to do so are inadequate. First, there is an ongoing debate on whether the impacts of climate change would generate systematic risk across the economy. The complex and pervasive interlinkages of financial institutions could expose investments to indirect environmental impacts from all sectors of the economy. There is, however, a lack of formal theoretical models that integrate environmental externalities into portfolio allocation and pricing decisions. Moreover, relevant data are scarce and there is no consensus on the appropriate methodologies to use. New approaches to asset pricing and allocation theory will be required to integrate the low-carbon transition into financial decision making. This objective is important for doctoral research because it addresses a gap in literature about the materiality of systematic climate related risks on asset pricing and portfolio allocation.

Student Researcher:
- Truzaar Dordi (School of Environment, Resources and Sustainability)

Supervisor:
- Prof. Olaf Weber (School of Environment, Enterprise and Development, Faculty of Environment)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
Award Type: PhD Fellowship
Date Approved: 2018
Total Project Value: $10,000

68. Peer-to-Peer Communication for Distributed Energy Generation and Storage

Abstract: The electrical grid is subject to significant changes, including integration of renewable generation, the widespread installation of smart meters, and the deployment of storage systems. These changes will revolutionize the conventional electrical grid. However, there are still many questions that are left unanswered by the electrical utilities, such as: What is the effect of adding these elements to the grid? How should we size them? What infrastructure is needed to connect these elements? Therefore, in this project our goal was to answer these questions.

Academic Investigator(s):
- Main PI: Prof. Srinivasan Keshav (Cheriton School of Computer Science, UW)

Industry Partner(s): Hydro One
### 69. The Socio-Technical Dimensions of Carbon Management for Bridging to a Lower Carbon Energy Future

**Abstract:** It has been recognized that a danger of short-term, piecemeal approaches to energy transitions is that they may cause path-dependencies that jeopardize long-term success (Morgan, 2016). A federation like Canada needs to especially wary of this, as jurisdictional powers are divided amongst the national government, provinces, and municipalities. Over the last academic year, I have performed research that has made me attuned to the needs of developing cross-sector and cross-scale energy futures. I co-authored an innovative method for developing a multi-scale scenario framework and participated in a research project constructing scenarios for the future of urban transport in Singapore. Through this work, I recognise that (1) transitioning to low-carbon energy futures requires valiant efforts from all sectors and across level of governance; and (2) it requires foresight integration from different agencies such as power & utility, oil & gas (both upstream and downstream), technology & innovation in clean energy, policy and governance, environment, energy market structures and so on. The objective of this research proposal is to pilot an approach to co-create low-carbon energy futures using participatory methods for scenario planning. For the next academic year (Sep 2016 to Dec 2017), the research activities shall include a three-part study.

**Student Researcher:**
- Herijadi Kurniawan (Department of Geography and Environmental Management)

**Supervisor:**
- Prof. Vanessa Schweizer (Knowledge Integration) and Prof. Johanna Wandel (Geography and Environmental Management)

**Funding Partner(s):** Energy Council of Canada (ECC)
**Other Academic Institution(s):** N/A
**Funding Agencies:** N/A
**Award Type:** Master Fellowship
**Date Approved:** 2017

**Total Project Value:** $7,500

### 70. Carbon Management: Bridging to a Lower Carbon Energy Future

**Abstract:** The aim of this study is to add a Life Cycle Assessment (LCA) perspective, to the decision-making methodology for adaptive reuse in order to optimize the environmental and economic performance of this process. Adaptive reuse, identified as a process to improve the financial, environmental and social performance of buildings, involves restoring and in some cases changing the use of existing buildings that are
Section III: Accomplishments and Impact

obsolete or are nearing their disuse stage. To achieve the main goal, the research scope has been divided into three stages. The first one is to create a decision-making methodology for evaluating adaptive reuse. The second one is the optimization of environmental-economic benefits in the process of adaptive reuse. The third one is the extension of the analysis across the building stock to determine the potential environmental benefits in a typical city.

Student Researcher:

• Benjamin Sanchez Andrade (Civil and Environmental Engineering, Faculty of Engineering)

Supervisor:

• Prof. Carl Haas (Civil and Environmental Engineering, Faculty of Engineering)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
Award Type: PhD Fellowship
Date Approved: 2018

Total Project Value: $7,500

71. Enabling Energy Transitions – Evaluating the effectiveness of past and present energy transition policies to guide Canada’s transition to a lower carbon energy future

Abstract: This proposed research project aims to help address the issue of Canada’s transition to a lower carbon economy by providing policy-makers with a framework for evaluating potential energy transition pathways. The framework is premised on the idea that regime-scale (i.e. economy-wide) energy transition policies will be essential to enabling lower carbon transitions in Canada.

Student Researcher:

• Christopher Beninger (School of Environment, Enterprise and Development, Faculty of Environment)

Supervisor:

• Prof. Olaf Weber (School of Environment, Enterprise and Development, Faculty of Environment)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
Award Type: Master Fellowship
Date Approved: 2017

Total Project Value: $7,500
72. Energy Education in the North: Literature review, design features and unit plans

Abstract: The success of new electricity system technologies is dependent on its acceptability to users and the community. The social acceptability of new technologies is dependent upon the local community understanding the technology. Education has been demonstrated as the most effective means to increase awareness and understanding of new technologies. Therefore, the project identified appropriate entry points in the required Ontario curriculum where the understanding of energy systems can be enhanced by additional complementary units to extend what the teachers are required to cover on related topics. Sets of three unit plans were developed for grades 5, 6 and 9. These 9 units provide much greater insight than that currently provided by the standard curriculum. Each unit includes at least one hands-on task to emphasize learning by doing rather than learning by conventional text passages. The modified content and culturally appropriate approach will provide valuable tools for Hydro One support of local education and sensitivity to new technologies.

Academic Investigator(s):
- Main PI: Prof. Paul Parker (School of Environment, Enterprise and Development, UW)

Industry Partner(s): Hydro One
Other Academic Institution(s): N/A
Funding Agencies: Hydro One
Grant Name: WISE-Hydro One MOU
Date Approved: 2013
Total Project Value: $7,000

73. Technically Detailed Co-Evolutionary Model to Guide Energy Innovation Policy

Abstract: A review will be conducted in regards to the literature comparing national renewable energy policies and their impact on global technological progress (US, China, Germany/EU, Japan, and Canada’s provinces) including policy prescriptions based on prevailing analyses. Using existing frameworks to draw historical lessons, this review will compile and infer best-in-context-practices and policy options for Canada. This synthesizing report will be a discrete outcome. Complexity literature, Arthur in particular, will be used to develop the first iterations of the proposed framework. The application specifically to energy technology will be aided by the use of technical literature to test and develop the framework. This preliminary framework will be used to critique the existing co-evolutionary models and articulate how the inner workings of technological systems can be drawn into these models. This will include detailing how ad-hoc understandings are currently used, what implicit assumptions exist, and examples of specific missing insights into technological systems, particularly regarding their interactions with other systems. This critique will be a second discrete outcome. Results will be put into the necessary forms to be extensively communicated through both academic and popular mediums.

Student Researcher:
• Yonatan Strauch (School of Environment, Resources and Sustainability, Faculty of Environment)

Supervisor:

• Prof. Stephen Quilley (School of Environment, Resources and Sustainability, Faculty of Environment)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
Award Type: PhD Fellowship
Date Approved: 2015
Total Project Value: $7,000

74. Innovation in Building Science - Transition to Low Carbon Energy Buildings

Abstract: Canada has an important opportunity to transform the built environment and help the building sector transition to a low-carbon future by enhancing the performance and liveability of buildings. The Waterloo Institute for Sustainable Energy in collaboration with the Department of Civil and Environmental Engineering and School of Architecture at University of Waterloo is hosting its first workshop on ‘Innovation in Building Science’ on Wednesday October 31st, 2018. The NSERC funding support is requested to materialize the necessary activities for the successful completion of the workshop.

Academic Investigator(s):

• Main PI: Prof. Jatin Nathwani (Management Sciences, UW)

Industry Partner(s): N/A
Other Academic Institution(s): N/A
Funding Agencies: NSERC
Grant Name: NSERC Connect Level II Grant
Date Approved: 2018
Total Project Value: $6,470

75. Geothermal Symposium

Abstract: The Waterloo Institute for Sustainable Energy (WISE), a leading innovation centre at the University of Waterloo, is hosting the Geothermal Symposium 2017 under the supervision of Dr. Maurice Dusseault (Professor, Earth and Environmental Sciences) to provide a new platform for industry-academic collaboration in the area of Geothermal Energy in Canada. The purpose is to advance our understanding of the role of geothermal technologies in providing decarbonized energy to Canadian communities, particularly those in remote and cooler climates. The Symposium brings together technology developers and innovators, leading researchers and entrepreneurs, industry thought leaders, and policy makers to help shape a vision of geothermal energy integration into Canada’s energy future.
76. Resource Recovery Partnership Workshop 2017

Abstract: The Canadian Plastics Industry Association (CPIA) in partnership with the Waterloo Institute for Sustainable Energy (WISE), a leading Canadian innovation centre at the University of Waterloo, is hosting the Resource Recovery Partnership Workshop 2017. The purpose is to advance our understanding of the role of circular economy and carbon reduction initiatives to identify opportunities to build fiscal capital through re-designing of ecosystem services infrastructure while respecting environmental limits. The workshop brings together an executive forum designed to encourage the exchange of ideas that will help create a roadmap to guide the future of waste management and resource recovery (including energy demand reduction) research in Canada. The invitation-only workshop focus is collaboration in solid waste research, the exploration of opportunities for partnership, and the integration of efforts across stakeholder groups.

Academic Investigator(s):

- Main PI: Prof. Jatin Nathwani (Management Sciences, UW)

Industry Partner(s): N/A
Other Academic Institution(s): N/A
Funding Agencies: NSERC
Grant Name: NSERC Connect Level II Grant
Date Approved: 2017

Total Project Value: $5,646

77. WISE Energy Day 2018

Abstract: The Waterloo Institute for Sustainable Energy (WISE), a leading innovation centre at the University of Waterloo, is hosting WISE Energy Day 2018 under the supervision of Dr. Jatin Nathwani (Professor, Management Sciences) to provide a strong platform for industry-academic collaboration in the area of power and energy sector in Canada. The purpose is to share emerging knowledge from cutting-edge research to advance our understanding of the role of clean technologies for a low carbon energy future for Canada. The event brings together technology developers and innovators, leading researchers and entrepreneurs, industry thought leaders, and policy makers to help shape a vision of a decarbonized economy.

Academic Investigator(s):

- Main PI: Prof. Jatin Nathwani (Management Sciences, UW)
78. Engaging Residential Consumers Using Smart Grid Tools

Abstract: This proposed research will make several notable contributions. First, most smart grid studies focus on short-term intervention effects, whereas this research will provide a more in-depth understanding of the long-term effects of multiple intervention impacts by analyzing long-term high-resolution consumption data. Second, in the EHMS study, the triangulation of quantitative consumption patterns with qualitative interview data will provide a better understanding of household decision-making processes and intervention preferences at the disaggregated appliance level. Third, limited research on the impact of simple interventions, such as IHDs, on household consumption in Ontario has been completed. The IHD study will provide insight into the long-term impacts of IHDs on residential electricity behaviour. Fourth, with a large control group (2455) and sample group (5575), the IHD study will expand existing studies with smaller sample sizes. Fifth, these studies will build on the limited smart grid intervention studies occurring in Canada and Ontario. Should this application be successful, my doctoral thesis research will highly complement WISE and the Energy Council of Canada’s research objectives. Overall, this research will provide valuable results for shaping smart grid policies, benefiting Canada’s long-term energy conservation goals for a more sustainable future.

Student Researcher:
- Bronwyn Lazowski (Department of Geography & Environmental Management (GEM))

Supervisor:
- Prof. Paul Parker (School of Environment, Enterprise and Development, Faculty of Environment)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
Award Type: Master to PhD Fellowship
Date Approved: 2017
Total Project Value: $5,000
79. Wind Turbine Opposition in Ontario (Renewal)

Abstract: This research will take the form of a case study focusing on counties in non-remote part of Ontario with more than ten operating wind turbines, and within these counties specifically the communities with the largest wind farms will be selected. It is assumed that larger wind farms impact more people and the externalities resulting from the development and operation will therefore be more complex and varied. This selection is based on the rationale used to distribute surveys regarding health and perceptions of wind turbines, as part of Dr. Siva Sivoththman’s research as the Ontario Research Chair for Renewable Energy Technologies and Health, which will be used for comparison to case study results. These surveys asked residents living near wind turbines about their views on energy generation, and which aspects of renewable energy development were important for their approval.

Student Researcher:
- Tanya Christidis (School of Planning, Faculty of Environment)

Supervisor:
- Prof. Geoff Lewis (School of Planning, Faculty of Environment) and Prof. Phil Bigelow (School of Public Health and Health Systems, Faculty of Applied Health Sciences)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
Award Type: PhD Fellowship
Date Approved: 2016
Total Project Value: $5,000

80. Integrating Distributed Renewable Energy Generation into the Canadian Electricity Distribution System (Renewal)

Abstract: As a key component of the Ontario Green Energy Act, the microFIT Program has promoted the expansion of distributed generation, particularly solar PV, to Ontario homeowners, small businesses, municipal, and civil society organizations. Launch in 2009, this program provides a valuable source of data that, when analyzed, could contribute to both academic and policy conversations related to renewable distributed generation.

Student Researcher:
- Dane Labonte (School of Environment, Resources and Sustainability, Faculty of Environment)

Supervisor:
- Prof. Ian Rowlands (School of Environment, Resources and Sustainability, Faculty of Environment)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
81. Applying Social Theories to Conservation Initiatives (Renewal)

Abstract: In collaboration with the IESO and LDCs, I will be investigating the impact of specific components of conservation programmes (e.g. marketing expenditures on awareness campaigns, roving energy managers, community engagement, etc.) on the level of customer participation. Two programmes will be examined in both the province-wide and territory-specific studies – HVAC (residential) and Retrofit (Commercial). The IESO is interested in the relative impact of marketing strategies using different types of media, such as radio, print, and Internet-based promotion on programme participation (measured as the installation of energy-efficient HVAC equipment, or the establishment of Retrofit projects). The LDCs (THESL and Oakville Hydro) are interested in the differences in programme participation amongst different customer segments (size, sector, facility type, etc.) and whether these factors can be attributed to specific programme components or marketing strategies.

Student Researcher:

- Stephanie Whitney (School of Environment, Resources and Sustainability, Faculty of Environment)

Supervisor:

- Prof. Jennifer Lynes (School of Environment, Enterprise and Development, Faculty of Environment)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
Award Type: PhD Fellowship
Date Approved: 2017
Total Project Value: $5,000

82. To inform the design, implementation and evaluation of the Decarbonize Waterloo Region process (Decarbonize WR)

Abstract: This one year participatory action research project links directly to the Energy Council of Canada’s Carbon Management Research Topic. The project will inform the design, implementation and evaluation of the Decarbonize Waterloo Region process (Decarbonize WR), which will culminate in a forum in November 2016. The Decarbonize WR process will facilitate a community roundtable discussion to collaboratively articulate a set of pathways to guide the decarbonization of Waterloo Region’s local energy systems across short, medium, and long term. This extensive crossdisciplinary collaboration will include experts and practitioners from government, NGOs, utilities, businesses, the industry and technology sector, and academia. This participatory action research project will be embedded in the DeCarbonize WR process and has three
specific objectives: (1) Conduct a literature review to investigate best practices from other local level decarbonization processes and analyze them to determine how they can inform the Decarbonize WR process, (2) Conduct pre-forum interviews/focus groups with local key informants to identify opportunities and barriers to a decarbonized energy future in Waterloo Region. This data will help to inform and prime the dialogue at the November 2016 forum, and (3) Analyze the scalability of the Decarbonize WR process and how it might inform similar processes in other Canadian municipalities.

Student Researcher:
- Scott Morton Ninomiya (School of Environment, Enterprise and Development, Faculty of Environment)

Supervisor:
- Prof. Sarah Burch (Geography and Environmental Management)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
Award Type: Master Fellowship
Date Approved: 2017
Total Project Value: $5,000

83. Product Recovery Management Based Methodology for Improving the Net Environmental Impacts of Capital Project Delivery for Buildings

Abstract: The aim of this study is to add a Life Cycle Assessment (LCA) perspective to the decision-making methodology involved in adaptive reuse of buildings, in order to optimize the process. LCA accounts for the materials and energy involved in a product and then measures the associated environmental impacts along all its life stages. Primary energy demand, global warming potential, and water consumption are just some of the environmental impacts that can be traced and quantified through LCA. We will investigate how these environmental impacts can be monetized and valued according to the constraints of the natural resources in a specific geographical place. From an economic standpoint, the advantages of monetizing environmental savings are meaningful because, through this kind of metric, it is much easier to compare benefits with costs and make choices across various alternatives [24]. Emphasis will be placed on the increasing value of the environmental resources in a mid-term future. Consequently, it will be possible to create the necessary framework to advance energy policy-making in Canada in regard to the transition to a low carbon energy economy. In other words, through the findings of this study the government will be able to create regulations to incentivize construction projects that promote adaptive reuse as the first construction option. These regulations will be based on the objective monetization of the environmental savings for the community, city, and nation. In this way, the promotion of adaptive reuse could be spread, changing the trends in the construction industry. Thus, the adoption of these practices for buildings can contribute to sustainability and climate change through mitigation of CO2 emissions.

Student Researcher:
84. Renewable Energy to Advance Off-Grid Community Sustainability: A Comparative Energy Policy Analysis between Alaska and Canada’s North

Abstract: The project will employ a ‘community-based participatory research’ approach; decision-making power/ownership will be shared between NCC and the researcher; NCC will be involved involved in all stages of the research process; emphasis will be placed on co-learning and development of bi-directional research capacity; and new knowledge will be cocreated and disseminated in a manner that is mutually beneficial for both parties. NCC will guide the project in implementing “two-eyed seeing”, a method that combines Indigenous and Western knowledge to address environmental problems. This will be valuable in assessing perceptions of diesel-impacts and envisioning community-driven sustainable energy futures.

In addition, we will utilize energy deployment sustainability theory [EDST], which suggests that energy projects most possess positive substantive and procedural components to maintain viability. Substantive sustainability refers to the tangible economic, environmental, and societal impacts of an energy project. Procedural sustainability refers to how local actors perceive the impacts, how the costs and benefits are distributed throughout society, and whether the project maintains local acceptance.

Student Researcher:

- Nicholas Mercer (Department of Geography and Environmental Management)

Supervisor:

- Prof. Paul Parker (School of Environment, Enterprise and Development, Faculty of Environment)

Funding Partner(s): Energy Council of Canada (ECC)
Other Academic Institution(s): N/A
Funding Agencies: N/A
Award Type: PhD Fellowship
Date Approved: 2018
Total Project Value: $5,000
85. Annual Technology Innovation and Policy Forum 2016 – Microgrids and Distributed Energy: Is there a revolution in the making?

Abstract: The Council for Clean & Reliable Energy (CCRE) in partnership with the Waterloo Institute for Sustainable Energy (WISE), a leading Canadian innovation centre at the University of Waterloo, is hosting the Annual Technology Innovation and Policy Forum. Our goal is to shape the pathways of development for emerging disruptive technologies and understand the impacts of microgrids embedded on a large scale within the existing distribution networks. The forum brings together technology developers and innovators, leading researchers and entrepreneurs, industry thought leaders, and policy makers to help shape next generation smart energy solutions.

Academic Investigator(s):

- Main PI: Prof. Jatin Nathwani (Management Sciences, UW)

Industry Partner(s): N/A
Other Academic Institution(s): N/A
Funding Agencies: NSERC
Grant Name: NSERC Connect Level II
Date Approved: 2016

Total Project Value: $3,350

86. WISE Energy Day 2017

Abstract: The Waterloo Institute for Sustainable Energy (WISE), a leading innovation centre at the University of Waterloo, is hosting WISE Energy Day 2017 under the supervision of Dr. Jatin Nathwani (Professor, Management Sciences) to provide a strong platform for industry-academic collaboration in the area of power and energy sector in Canada. The purpose is to share emerging knowledge from cutting-edge research to advance our understanding of the role of clean technologies for a low carbon energy future for Canada. The event brings together technology developers and innovators, leading researchers and entrepreneurs, industry thought leaders, and policy makers to help shape a vision of a decarbonized economy.

Academic Investigator(s):

- Main PI: Prof. Jatin Nathwani (Management Sciences, UW)

Industry Partner(s): N/A
Other Academic Institution(s): N/A
Funding Agencies: Ontario Centres of Excellence (OCE)
Grant Name: N/A
Date Approved: 2017

Total Project Value: $1,000
3.2.2 Funding Proposals in Development

WISE has developed many funding proposals on behalf of our members that have yet to receive funding. A number of these are in the process of resubmission.

1. Driving a Revolution in ‘Affordable Energy for Humanity’

Abstract:

Energy Access is recognized as a powerful multiplier of the United Nations Sustainable Development Goals (SDGs) with direct links to provision of adequate healthcare, education and food, as well as gender equality and economic empowerment. Providing energy access to the over one billion people on the planet who are currently living without it must be accomplished through the diffusion of clean technology, or else global climate change targets will be imperilled. The dual challenges of development and sustainability make clean energy access for those at the base of the economic pyramid the quintessential sustainable development challenge of the 21st century.

We believe that eradication of energy poverty with clean technology by 2030 (Sustainable Development Goal 7) will require breakthrough solutions that are designed for implementation in a diverse range of local contexts and delivered by a generation of local change-agents and entrepreneurs. If we are to take maximum advantage of the capacity for innovation that exists within university research labs, there is a need to build stronger bridges between local implementers and global knowledge networks. The proposed program operationalizes such an approach, on a global scale.

The proposed program would establish five Energy Access Innovation Centres (EAICs)—one in Latin America, one in Asia, and three in Africa (South, East & West Africa). EAIC funding will support the establishment of a global fellowship program and its project/enterprise support infrastructure, the extension service, global summits, and a fund for research and implementation activities managed by the EAICs on a competitive and needs basis. The latter fund will be used to accelerate upstream research and downstream deployment of locally appropriate solutions that directly serve the five EAIC regions and accounts for approximately one third of total program budget.

Academic Investigator(s):

- Main PI: Prof. Jatin Nathwani (Management Sciences, UW)
- Co-PI: Prof. Srinivasan Keshav (Cheriton School of Computer Science, UW), Prof. Claudio Canizares (Electrical and Computer Eng., UW), Prof. Mehrdad Kazerani (Electrical and Computer Eng., UW), Prof. Catherine Rosenberg (Electrical and Computer Eng., UW), Prof. Ehab El-Saadany (Electrical and Computer Eng., UW), Prof. Magdy Salama (Electrical and Computer Eng., UW), Prof. Siva Sivoththaman (Electrical and Computer Eng., UW), Prof. Keith Hipel (Systems Design Eng., UW), Prof. Yuning Li (Chemical Eng., UW), Prof. Hany Aziz (Electrical and Computer Eng., UW), Prof. Roydon Fraser (Mechanical and Mechatronics Eng., UW), Prof. Linda Nazar (Chemistry), Prof. Maurice Dusseault (Earth and Environmental Sciences, UW), Prof. Neil Craik (School of Environment, Enterprise and Development), Prof. Paul Parker (School of Environment, Enterprise and Development), Prof. Ian Rowlands (School of Environment, Resources and Sustainability), Prof. Olaf Weber
(School of Environment, Enterprise and Development), Prof. Heather Douglas (Philosophy), Prof. Joachim Knebel (Karlsruhe Institute of Technology), Prof. Orestis Terzidis (Karlsruhe Institute of Technology), Prof. Armin Grunwald (Karlsruhe Institute of Technology), Prof. Veit Hagenmeyer (Karlsruhe Institute of Technology), Prof. Hartmut Schmeck (Karlsruhe Institute of Technology), Prof. Marc Hiller (Karlsruhe Institute of Technology), Prof. Thomas Leibfried (Karlsruhe Institute of Technology), Prof. Isabelle Suedmeyer (Karlsruhe Institute of Technology), Prof. Ioannis Lestas (University of Cambridge), Prof. Robert Doubleday (University of Cambridge), Prof. Hisham Zerriffi (University of British Columbia), Prof. Fred McBagonluri (Ashesi University), Prof. AbuBakr Bahaj (University of Southampton), Prof. Malcolm McColloch (University of Oxford), Prof. David Howey (University of Oxford), Prof. Charles Monroe (University of Oxford), Prof. Taha Selim Ustun (Carnegie Mellon University), Prof. Jouko Lampinen (Aalto University), Prof. Peter Lund (Aalto University), Prof. Martina Schäfer (Technical University of Berlin), Prof. Ortwin Renn (University of Stuttgart), Prof. Lucia Rodriguez (Columbia University), Prof. Pieter Van Der Zaag (Delft University of Technology & UNESCO-IHE), Prof. Ameena Al-Sumaiti (Masdar Institute of Science and Technology), Prof. Khanjan Mehta (Penn State University), Industry Partner(s) and Other Organization(s): Waterloo Global Science Initiative, Centre for Global Equality, Practical Action, Smart Villages Initiative, Mobisol, ME SOLshare Ltd., Boond, Trama TecnoAmbiental, ENVenture, Discourse Media, SunFarmer, Lumos Energy, Global Off-Grid Lighting Association (GOGLA), and Next Einstein Forum.

Other Academic Institution(s): Karlsruhe Institute of Technology, University of Cambridge, University of British Columbia, Ashesi University, University of Southampton, University of Oxford, Carnegie Mellon University, Aalto University, Technical University of Berlin, University of Stuttgart, Columbia University, Delft University of Technology & UNESCO-IHE, Masdar Institute of Science and Technology, and Penn State University.

Funding Agencies: MacArthur Foundation
Grant Name: 100&Change Grant
Status: Not Approved (2016)
Total Project Value: $100,000,000

2. A Compressed Air Energy Storage (CAES) - Demonstration Project

Abstract: NRStor Inc. has a proposed 1.75MW, no carbon CAES demonstration project in Goderich, funded in part by the ON IESO. This is an exceptional opportunity to develop applied engineering aspects of CAES (cavern and ground response, thermal issues, cyclic effects, etc.). Waterloo leads a government-funded CAES research project with industry partners (OPG, NRStor, Union Gas, Compass Minerals, HydroOne) developing CAES and grid management models integrating geomechanics, power and mechanical engineering. The model-oriented project ends in 2018. Field work with NRStor’s project allows testing models (calibration), emplacing monitoring arrays (cheap sensors we developed), addressing heat management issues, and advancing this potentially key ON technology.
3. Intermediate Grade Geothermal Energy (IGGE) for Decarbonization

Abstract: This project will provide ON access to deep geothermal energy to further decarbonize its energy usage and meet critical energy needs in the north. We will integrate Intermediate Grade Geothermal Energy (IGGE) and Thermal Energy Storage (TES) into a viable technology for communities and industry. In northern ON, IGGE may replace diesel, is of lower risk (no transport), has no Carbon(C) emissions, and is amenable to co-generation (power + heat) in a region where heat is valuable, infrastructure is lacking, and wind and solar are weak in the cold months. High-grade geothermal is absent in ON; below 3 km, IGGE is available (Grasby et al, 2012). The goal is C-free energy for large-volume, low-grade heating and small-scale power for communities and industry on an annual cycle. IGGE and TES can provide reliable, robust, and resilient energy.

Academic Investigator(s):
- Main PI: Prof. Roydon Fraser (Mechanical and Mechatronics Eng., UW)

Industry Partner(s): N/A
Other Academic Institution(s): N/A
Funding Agencies: Ontario Research Fund
Grant Name: Ontario Research Fund – Research Excellence (ORF-RE)
Status: Submitted – pending decision

Total Project Value: $12,000,000

4. Clean Technology Smart Grid R&D Consortia

Abstract: Smart grid in the energy sector is defined as newer sustainable energy generation technologies being incorporated into existing electrical grid systems, using advanced ICT communications systems to increase the efficiency, reliability and transmission of power through grid assets; electricity meeting ICT. Canada is one of the most advanced countries in the world in terms of its smart grid development and we have the market, energy policy drivers and regulatory frameworks in place to support economic growth in this sector. Waterloo, under the leadership of the Principal Investigator Dr. Jatin Nathwani, the Executive Director of WISE, will conduct research with companies, with high-growth potential, to develop next generation smart grid technologies that will become part of the IP portfolios of the companies as they move technology into the market. WISE and ArcTern Ventures will work together to develop
the research projects identified with matching funds to be provided by ArcTern. The companies will invest in the research at Waterloo, to be matched and leveraged by the investment from MBDA. Jatin, Nathwani, as the Principal Investigator will participate in the research projects working with each specific research group at Waterloo and the ArcTern counterparts. The core competencies of ArcTern lies in deep technology and emerging fields of science, from advanced materials to artificial intelligence, which apply broadly to sector of renewable energy with respect to smart grid applications, internet of things, electric vehicle technology networks, information and communication technology infrastructure, etc.

**Academic Investigator(s):**

- Main PI: Prof. Jatin Nathwani (Management Sciences, UW)
- Co-PIs: Prof. Claudio Canizares (Electrical and Computer Eng., UW), Prof. Mehrdad Kazerani (Electrical and Computer Eng., UW), Prof. Catherine Rosenberg (Electrical and Computer Eng., UW), Prof. Kankar Bhattacharya (Electrical and Computer Eng., UW), Prof. Ehab El-Saadany (Electrical and Computer Eng., UW), Prof. Magdy Salama (Electrical and Computer Eng., UW), Prof. Siva Sivoththaman (Electrical and Computer Eng., UW), Prof. Kumarswamy Ponnambalam (Systems Design Eng., UW), Prof. Yuning Li (Chemical Eng., UW), Prof. Hany Aziz (Electrical and Computer Eng., UW), Prof. Roydon Fraser (Mechanical and Mechatronics Eng., UW), Prof. Eric Croiset (Chemical Eng., UW), Prof. Armaghan Salehian (Mechanical and Mechatronics Eng., UW), Prof. Srinivasan Keshav (Cheriton School of Computer Science), Prof. Linda Nazar (Chemistry),

**Industry Partner(s):** MBDA France, Capital Hill Group, ArcTern Ventures, Morgan Solar, Polar Sapphire, Smarter Alloys, and Green Mantra

**Other Academic Institution(s):** N/A

**Funding Agencies:** Federal Government, NSERC, and OCE

**Grant Name:** N/A

**Status:** Submitted - pending decision

**Total Project Value:** Est. $6,720,000

5. Demonstration and Analysis of Net Zero Solar Powered Electric Vehicle Charging Stations

**Abstract:** The proposed demonstration project directly addresses the EIP Program’s objective which is to support energy technology innovation to produce and use energy more cleanly and efficiently. This project will first, in Ontario, demonstrate and characterize in detail the net zero concept of solar powered EV charging stations. It utilizes the renewable energy to reduce in principle 100% of the carbon footprint and other greenhouse gases for EV charging. Smart energy management tools will be implemented to achieve more efficient and secure energy conversion and transfer.

**Academic Investigator(s):**

- Main PI: Prof. John Wen (Mechanical and Mechatronics Eng., UW)

**Industry Partner(s):** Proponent, Canadian Solar Inc., Electrefy Inc., Sustainable Waterloo Region, CommunityCarSharing, Blackberry, Symanta, Canadian Standards Association (CSA) Group, Waterloo North Hydro (WNH),
6. Mag-Tech Motor

Abstract: The program’s objective is to support energy technology to produce and use energy more cleanly and efficiently. Specifically, the Mag-Tech Motor would support the strategic priority of renewable energy, smart grids and storage. The Mag-Tech Motor utilizes magnetic force generated from the positioning of permanent magnets to produce a constant stream of kinetic energy that is harnessed into electrical energy by the affiliated generator for immediate consumption, or, stored for use at a later date.

Academic Investigator(s):
- Main PI: Prof. Behrad Khamesee (Mechanical and Mechatronics Eng., UW)
- Co-PI: Prof. Jatin Nathwani (Management Sciences, UW)

Industry Partner(s): Mag-Tech Renewable Energies Inc. (Mag-Tech was the main applicant)

Other Academic Institution(s): N/A
Funding Agencies: Natural Resources Canada (NRCan)
Grant Name: Energy Innovation Program (EIP)
Status: Not Approved (2016)
Total Project Value: $4,960,800

7. Consultancy to Deploy Decentralized, Sustainable Power Systems in Health Facilities in Africa

Abstract: The goal of the project is to enable improved delivery of health services – primarily for maternal and child health – in primary health care facilities, through improved access to modern, affordable, and sustainable electricity services. Speaking on behalf of the UN Foundation, Pete Ogden, Vice President for Energy, Climate, and the Environment, said: “Sustainable and reliable electricity is critical to providing quality health services, but is often unavailable or insufficient at the primary health care level. With support from the UK government, the UN Foundation is working to demonstrate the importance of the energy-health nexus, through the implementation of this project and our broader work with partners and Sustainable Energy for All. With this project, we will continue to show how Sustainable Development Goal 7 – ensuring access to affordable, reliable, sustainable and modern energy for all – can facilitate progress on the other SDGs.”

Academic Investigator(s):
- Main PI: Prof. Jatin Nathwani (Mechanical and Mechatronics Eng., UW)
- UW Co-PIs: Prof. Srinivasan Keshav (computer Science), Prof. Claudio Canizares (ECE), Prof. Mehrdad Kazerani (ECE), Nigel Moore (WISE)
8. Energy Harvesting and Green Energy Technologies for Internet of Things

Abstract: The proposed research will be focused on training highly qualified personnel in the area of Natural resources and energy. The research will focus on several aspects of renewable and green energy technologies such as smart material-based harvesting technologies, low-power or zero-power energy monitoring systems, other forms of renewable energy generation such as solar, as well as energy storage.

Academic Investigator(s):
- Main PI: Prof. Armaghan Salehian (Mechanical and Mechatronics Eng., UW)
- Co-PIs: Prof. Raafat Mansour (Electrical and Computer Eng., UW), Prof. Catherine Rosenberg (Electrical and Computer Eng., UW), Prof. Kankar Bhattacharyya (Electrical and Computer Eng., UW), Prof. Srinivasan Keshav (Cheriton School of Computer Science), Prof. John Long (Electrical and Computer Eng., UW), Prof. Peter Levine (Electrical and Computer Eng., UW), Prof. Norman Zhou (Mechanical and Mechatronics Eng., UW), Prof. Farid Golnaraghi (Simon Fraser University), Prof. Behraad Bahreini (Simon Fraser University), and Prof. Ridha Ben Mrad (University of Toronto)

Industry Partner(s): Skyworks Solutions Inc., Kapik, Sensor Technology Ltd., Fibics, Burloak, Intel, Teledyne DALSA, Innovata Labs, Cisco Systems, Onion (IoT manufacturer), Greater Sudbury Utilities, Celestica, Canada Solar, SNC Lavalin Inc., Waterloo North Hydro, Alpha Technologies, and BC Hydro

Other Academic Institution(s): Simon Fraser University, and University of Toronto

Funding Agencies: NSERC

Grant Name: NSERC Collaborative Research and Training Experience (CREATE) Program

Status: Not Approved (2017)

Total Project Value: $1,650,000

9. Smart Graphene-Based Composites for High-Energy and Self-Healing Lithium-Ion Batteries

Abstract: Lithium based rechargeable battery technologies have become the focal point of research to fulfill the requirements of electric vehicles (EVs). The most commonly used LIBs utilize graphite and transition metal oxides as anode and cathode materials,
respectively. Such a battery can only provide an energy density of ~150 Wh kg\(^{-1}\) due to the low specific capacities of the electrode materials. To meet the requirements of both high energy and power density with cycle durability of modern EVs, the next generation of active material is necessary.

The proposed project will specifically address critical technical barriers to the improved performance including energy density, cycling stability and safety as well as power density of lithium ion batteries, while strategically lowering the cost of commercial production by designing and developing Smart graphene-based nanostructured composites for automotive applications. The novel graphene-based composite materials can overcome the existing challenges of energy density, cycling life, and safety as well as cost of current lithium-ion batteries. This work entails a unique approach in the development of highly porous graphene materials based Si nanoparticles to create a unique 3D architecture. Another approach is development of practical battery from self-healing functionalized smart electrode fabrication for safe operation of LiBs.

From the development of proposed research, it is expected that utilizing high quality modified graphene and silicon/graphene composite nanomaterials will efficiently overcome the current challenges of commercial electrodes, which will play the key role in improving the energy density, cycling stability, safety and power performance of LiBs. It can be predicted that the success of the proposed high-performance LiBs will reduce both toxic and greenhouse gas emissions by improving energy efficiency and integrating with transportation and green energy systems including solar and wind energy, and this will provide significant social and environmental benefits to all Canadians. The expertise developed and the training of HQP in this research project will contribute to expanding industrial and business activities and enterprises in Canada.

**Academic Investigator(s):**
- Main PI: Prof. Zhongwei Chen (Chemical Eng., UW)

**Industry Partner(s):** Canadian Standards Association (CSA)

**Other Academic Institution(s):**

**Funding Agencies:** NSERC

**Grant Name:** NSERC Collaborative Research and Training Experience (CREATE)

**Status:** Not Approved (2016)

**Total Project Value:** $1,650,000

---

10. **Developing Intermediate-Grade Geothermal Energy in Canada**

**Abstract:** There are only a few sites in Canada in British Columbia and the Yukon with reasonable access to high-grade geothermal energy. However, at depths of 4-8 km in the igneous rocks that underlie all of Canada there are huge quantities of intermediate-grade geothermal energy (IGGE). New rapid drilling technologies based on impact drilling using polycrystalline diamond bits promise to revolutionize our ability to economically drill boreholes to access this IGGE, and new concepts in hydraulic fracturing will allow linking of parallel horizontal wells at depth to achieve suitable rates of energy recovery. These developments will open the possibility of widespread use of zero-carbon IGGE, but its advantages will be most apparent in the Canadian Arctic, where the only reliable source of energy is currently fossil fuels, usually shipped in at great expense. The Arctic (indeed, most of Canada) needs massive amounts of low-
grade heat for homes and buildings. IGGE can provide this, and it appears that it can also provide electrical power.

The research project at Waterloo will explore three large themes: first, accessing the IGGE through drilling, controlled hydraulic fracturing and fluid circulation; second, understanding and simulating the rock mechanics behavior at depth as the rock mass is cooled; and third, developing better ways to extract some electrical power from the IGGE fluids so that power plus heat can be provided to these remote communities. If a complex but clear technology for IGGE development is established in the North, it will almost certainly become economic in the south of Canada as we seek to reduce greenhouse gas emissions from fossil fuels and expand our energy sources. IGGE is not invasive at the surface, in contrast to solar and wind power, and can provide the equivalent of electrical station base load in terms of steady heat and some power, but at a much more modest scale (e.g. total rate of 40-80 MW).

**Academic Investigator(s):**
- Main PI: Prof. Maurice Dusseault (Earth and Environmental Sciences, UW)
- Co-PI: Prof. Roydon Fraser (Mechanical and Mechatronics Eng., UW), and Prof. Dipanjan Basu (Civil and Environmental Eng., UW)

**Industry Partner(s):** Borealis Geopower, Egmond Associates Ltd., Dascan Groundheat Energy Services Ltd., and Centre for Excellence in Mining Innovation (CEMI)

**Other Academic Institution(s):** N/A

**Funding Agencies:** NSERC

**Grant Name:** NSERC Strategic Partnership Grants for Projects

**Status:** Not Approved (2016)

**Total Project Value:** $891,750

### 11. Decarbonization of Energy: Geothermal and Energy Storage

**Abstract:** Energy decarbonization and energy storage are key elements in the energy future of the world. In Canada, the cold climate, particularly in the north, means that a great need for reliable heat and electrical power exists, and right now, 100% of this is generated by diesel fuel, imported at great cost from Quebec City and Edmonton. Indigenous communities are dependent on this single, costly, carbon-rich energy source that is also a fire hazard and a potential pollutant. Deep geothermal energy and thermal energy storage in deep geothermal rock masses promises to provide heat and power to remote communities, enhancing their life quality and opening new possibilities for community activities.

**Academic Investigator(s):**
- Main PI: Prof. Maurice Dusseault (Earth and Environmental Sciences, UW)
- Co-PIs: Prof. Roydon Fraser (Mechanical and Mechatronics Eng., UW), Prof. Dipanjan Basu (Civil and Environmental Eng., UW), Prof. Andrew Swanson (Cape Breton University), Martin Mkandawire (Cape Breton University), and Annamarie Hatcher (Cape Breton University)

**Industry Partner(s):** NRStor, Egmond Associates Ltd., and Centre for Excellence in Mining Innovation
12. Cased Wellbore Integrity Assurance

**Abstract:** This Strategic Grant (SG) will develop better technology for mitigating fluid migration around Oil&Gas (O&G) wells - dominantly natural gas seepage from active and decommissioned wells. In addition to generating new knowledge and highly-qualified persons (HQPs), a novel down-hole logging tool is to be developed to more accurately determine the condition of the cement and rock behind steel casing, as well as evaluate the condition of the steel itself. Implementation of the logging tools and the models we will develop will reduce wellbore leakage and greenhouse gas emissions, identify zones for mitigation action, and provide a vastly improved quality assurance approach to wellbore integrity evaluation and maintenance. Given that there are 550,000 O&G wells in Canada (and five million more around the world), and that quality assurance for newly installed wells and wells being readied for decommissioning would readily benefit from these developments, the potential environmental and commercial impact could be substantial.

**Academic Investigator(s):**
- Main PI: Prof. Maurice Dusseault (Earth and Environmental Sciences, UW)
- Co-PIs: Prof. Giovanni Cascante (Civil and Environmental Eng., UW), Prof. Walter Illman (Earth and Environmental Sciences, UW)

**Industry Partner(s):** Scientific Drilling International Inc. (Canada)

**Other Academic Institution(s):** N/A

**Funding Agencies:** NSERC

**Grant Name:** NSERC Strategic Partnership Grants for Projects

**Status:** Not Approved (2017)

**Total Project Value:** $600,000


**Abstract:** Selecting the optimum time for infrastructure replacement and repair is an ongoing challenge for transportation authorities. The corrosion state of reinforcing steel (rebar) in roadways, bridge decks and structures (e.g. parking buildings) is a major factor in decisions to repair or replace, and a quantitative non-destructive assessment of the corrosion state of rebar remains challenging. Trials of a passive magnetic method on pipelines in Iran and China have proven successful in identifying corrosion locations using a simple transit method (Mahbaz et al. 2011). The method has great potential in non-destructive testing of rebar corrosion. Support of a research project with a student (SeyedBijan Mahbaz), one of the developers of this method in Iran, presents an
opportunity to benefit from several years of experience immediately, greatly increasing the chances of a successful project.

**Academic Investigator(s):**
- Main PI: Prof. Maurice Dusseault (Earth and Environmental Sciences, UW)

**Industry Partner(s) and Other Organization(s):** Ontario Ministry of Transportation
**Other Academic Institution(s):** N/A

**Funding Agencies:** Sustainable Development Technology Canada (SDTC)

**Grant Name:**
**Status:** Not Approved (2016)

**Total Project Value:** $500,000

---

14. **Strengthen the Engineering Capacity of Canada’s Energy Companies to Deliver Clean Energy Technology Innovations**

**Abstract:** A key purpose of the research focus is to develop a rigorous framework and the required quantitative metrics for understanding the linkages between innovation and environmental sustainability in the energy sector. A primary objective is to bring to bear the full capacity of engineering research methods that provide insight for decision-makers to shape business performance in alignment with corporate social responsibility and the necessary tools for global-scale applications.

**Academic Investigator(s):**
- Main PI: Prof. Jatin Nathwani (Management Sciences, UW)

**Industry Partner(s):** N/A

**Other Academic Institution(s):** N/A

**Funding Agencies:** NSERC

**Grant Name:** NSERC Discovery

**Status:** Not Approved (2016)

**Total Project Value:** $300,500

---

15. **EV Charging Infrastructure on UW Campus – Electric Vehicles and Additional EV Chargers**

**Abstract:** WISE initiative with the Advancement team of Faculty of Arts

**Academic Investigator(s):**
- Main PI: N/A

**Industry Partner(s):** Cox Automotive

**Other Academic Institution(s):** N/A

**Funding Agencies:** N/A

**Grant Name:** N/A [Donation]

**Status:** Not Approved (2017)

**Total Project Value:** $250,000

Abstract: WatTHERM is an engineering research and demonstration group at the University of Waterloo. Our R&D project for geothermal energy in Ontario focuses on analysis and field experiments to show heat storage energetics in geological media. Two wellbores will be drilled, cased and cemented at a depth of 100 m. Heat will be input to one well, and the adjacent well, offset by three metres, will serve as a monitor well. We will analyze how effectively heat is stored in the rock, and how we can extract it efficiently. Results will allow us to determine thermal characteristics of a rock mass in a real configuration, as well as testing the reliability of mathematical models we are developing. This knowledge and capability is an important part of designing heat storage systems in the future.

Academic Investigator(s):
- Main PI: Prof. Maurice Dusseault (Earth and Environmental Sciences, UW)
- Co-PIs: Prof. Yuri Leonenko (Earth and Environmental Sciences, UW), and Prof. Roydon Fraser (Mechanical and Mechatronics Eng., UW)

Industry Partner(s): GeoSmart Energy Inc., NRStor, and Scientific Drilling International (Canada) Inc.

Other Academic Institution(s): N/A

Funding Agencies: Ontario Centres of Excellence (OCE)

Grant Name: Ontario's Solutions 2030 Challenge

Status: Not Approved due to Disqualification on grounds of not securing matching funds (2017)

Total Project Value: $250,000

17. Thermal Energy Storage for Integration of Renewable Energy Sources in Microgrids

Abstract: Increasing concerns regarding greenhouse gas (GHG) emissions and continuous reduction in the cost of Renewable Energy Sources (RES) are encouraging the deployment of renewable-based Distributed Energy Resources (DERs) and Demand Side Management (DSM) options in power systems. The proposed research work will therefore be of direct benefit to the thermal energy storage (TES) and RES-based microgrid industry and operators, through the study and demonstration of thermal storage integration in microgrids to facilitate significant penetration of variable RES, based on balancing heating and cooling sources and loads with electrical demand and surplus supply.

Academic Investigator(s):
- Main PI: Prof. Claudio Canizares (Electrical and Computer Eng., UW)
- Co-PIs: Prof. Kankar Bhattacharya (Electrical and Computer Eng., UW)

Industry Partner(s): Canadian Solar Inc.

Other Academic Institution(s): Karlsruhe Institute of Technology

Funding Agencies: International Energy Agency (IEA)

Grant Name: Technology Collaboration Programme on District Heating and Cooling including Combined Heat and Power: Call for Proposals – Annex XII
Status: Not Approved (2016)

Total Project Value: $196,430

18. District Energy Data Collection, System Optimization and Readiness Toolkit

Abstract: The University of Waterloo has been engaged by a private firm to provide research related to the development of a sustainable, very low energy (or energy neutral), 13 acre mixed residential and commercial development. District heating implementations, utilizing a variety of energy sources and distribution schemes have been proposed as a means of achieving these goals. The client is a medium-sized municipality in southern Ontario.

Academic Investigator(s):
- Main PI: Prof. Maurice Dusseault (Earth and Environmental Sciences, UW)
- Co-PIs: Prof. Roydon Fraser (Mechanical and Mechatronics Eng., UW), Prof. Paul Parker (School of Environment, Enterprise, and Development, UW), Prof. Goretty Dias (School of Environment, Enterprise, and Development, UW), Prof. Amer Obeidi (Systems Design Eng., UW), Prof. John D. McLennan (University of Utah), and Prof. Sun Feng (China University of Petroleum)

Industry Partner(s): N/A

Other Academic Institution(s): University of Utah and China University of Petroleum

Funding Agencies: International Energy Agency (IEA)

Grant Name: Technology Collaboration Programme on District Heating and Cooling including Combined Heat and Power: Call for Proposals – Annex XII

Status: Not Approved (2016)

Total Project Value: $195,500


Abstract: The Level 3 charging station is the centrally necessary component of this RTI proposal. As explained in more detail in the proposal, without the Level 3 charger the interest of Local Distribution Companies (LDCs) in this research is greatly diminished. This is because, for example, the sizing of electricity grid transformers to date does NOT consider the charging of vehicles, certainly not Level 3 charging, or even extensive Level 2 charging. The Level 2 chargers are a necessary research component that complement the Level 3 charger as they will provide comparison data, and are very relevant for human behaviour and policy reasons as they are expected to be the most popular dedicated EV chargers for the next decade or more.

Academic Investigator(s):
- Main PI: Prof. Roydon Fraser (Mechanical and Mechatronics Eng., UW)
- Co-PI: Prof. Jatin Nathwani (Management Sciences, UW), Prof. Nasser Azad (Systems Design Eng., UW), Prof. Michael Fowler (Chemical Eng., UW), Prof.
20. Socio-Economic Implications of Energy Decarbonization Efforts on the Less Developed World - A System Dynamics Modelling Approach

Abstract: The study seeks to address the questions of effectiveness of existing decarbonisation policy instruments, the multi-faceted socio-economic implications and effects of energy decarbonisation on the less developed world, and which set of policy options and types can be recommended to achieve a relatively balanced and sustainable energy decarbonisation in the shortest time with minimum negative impact? The study is attempting to identify and address the system-based socio-economic factors that would require a mosaic integration approach to sustainability in order to make clean and affordable energy services available in the very near future to citizens of the energy-deficient world.

Academic Investigator(s):
- Main PI: Prof. Maurice Dusseault (Civil and Environmental Eng., UW)
- Co-PI: Prof. Jatin Nathwani (Management Sciences, UW)

Industry Partner(s): N/A
Other Academic Institution(s): Obafemi Awolowo University, Ile-Ife, Osun, Nigeria
Funding Agencies: NSERC, SSHRC, and CIHR IRSC
Grant Name: Banting Postdoctoral Fellowships
Status: Not Approved (2016)

Total Project Value: $140,000

21. Sustainable Management of Oil Sands (OS) Using System Dynamics: A Case Study of Three Continents

Abstract: The study seeks to address the question of whether OS development in three continents (North America, South America, and Africa) has a potential for sustainability,
and to what extent? It also considers the discourse on whether or not OS development will impact the global settings positively or negatively, in terms of sustainable management? Lastly, it also intends to answer the question of which policy options, and types can be recommended to achieve sustainable OS resource development?

**Academic Investigator(s):**
- Main PI: Prof. Maurice Dusseault (Civil and Environmental Eng., UW)
- Co-PI: Prof. Jatin Nathwani (Management Sciences, UW)

**Industry Partner(s):** N/A

**Other Academic Institution(s):** OP Jindal Global University, New Delhi, India

**Funding Agencies:** NSERC, SSHRC, and CIHR IRSC

**Grant Name:** Banting Postdoctoral Fellowships

**Status:** Not Approved (2015)

**Total Project Value:** $140,000

### 22. Geotechnical Design Optimization and Resiliency Analysis of Subway Infrastructure in Toronto

**Abstract:** Integrating sustainability into design and construction is becoming a priority for the geotechnical and civil engineering industries. Currently, geotechnical design practice is overly conservative, requiring excessive use of materials and resulting in excessive safety measures. The proposed research will provide RWH with a design tool (software) with which subway structure design will be optimized from geotechnical safety, serviceability, as well as, material use and resiliency points of view. RWH engineering will gain critical understanding of the implications of conservative geotechnical designs in terms of environmental and economic impacts. The company will be able to provide customers with optimized designs that balance sound engineering with economic, environmental, and resiliency aspects.

**Academic Investigator(s):**
- Main PI: Prof. Dipanjan Basu (Civil and Environmental Eng., UW)

**Industry Partner(s):** RWH Engineering Inc.

**Other Academic Institution(s):** N/A

**Funding Agencies:** Ontario Centres of Excellence (OCE), and NSERC

**Grant Name:** Voucher for Innovation and Productivity II (VIP II), and NSERC Engage Grant

**Status:** Submitted – pending decision

**Total Project Value:** $65,000

### 23. Developing Intermediate Grade Geothermal Energy for Arctic Canada

**Abstract:** Advances in drilling, hydraulic fracturing and power extraction in the last decade make deep intermediate grade geothermal energy viable in the north, where all power and heat are generated with diesel fuels. The ENGAGE grant will allow a quantitative assessment of systems and costs to develop this energy source for communities, and also for military sites and resource projects. Working with a company
specializing in geothermal systems will allow delineation of the research and development needs to bring this energy source to the people and projects in the Arctic that could benefit greatly.

**Academic Investigator(s):**
- Main PI: Prof. Maurice Dusseault (Earth and Environmental Sciences, UW)

**Industry Partner(s):** Egmond Associates Ltd.
**Other Academic Institution(s):** N/A
**Funding Agencies:** NSERC
**Grant Name:** NSERC Engage
**Status:** Not Approved (2016)

**Total Project Value:** $37,500


**Abstract:** This proposed research is conceived as part of new research collaboration between Dr. Roydon Fraser (Professor, University of Waterloo) and InspectTerra Inc. to conduct a research project entitled “Numerical Study of an Innovative Wind Tower Design for Natural Ventilation and Passive Cooling in Residential and Commercial Buildings”. The objective of this research project is to create a simulation model for a wind tower and use this model to optimize a window for a medium to large commercial or residential building in Ontario. In this project, Dr. Fraser and his research team will perform different tasks for investigation and analysis of the ventilation and thermal performance of an innovative design of wind tower to utilize in residential and commercial buildings.

**Academic Investigator(s):**
- Main PI: Prof. Roydon Fraser (Mechanical and Mechatronics Eng., UW)

**Industry Partner(s):** InspectTerra Inc.
**Other Academic Institution(s):** N/A
**Funding Agencies:** NSERC
**Grant Name:** NSERC Engage Grant
**Status:** Submitted – pending decision

**Total Project Value:** $37,000

### 25. Energy Engineering and Design Optimization of Thermal Energy Storage Systems for One of Three Specific Residential Dwellings in a Yukon Community

**Abstract:** In the proposed project, Dr. Claudio Canizares (Professor and Hydro One Endowed Chair) from the Department of Electrical and Computer Engineering at University of Waterloo will collaborate with RESTCo. to address the engineering research problem of clean, efficient, and reliable electrical and thermal supply, including
Electric Thermal Storage (ETS) systems, for clusters of new residential homes in the community of Burwash located in northern Ontario, south of Sudbury.

The main objective of the proposed research work is to study and develop techniques and tools for the optimal design of efficient, clean, and reliable electrical and thermal energy supply systems for clusters of new homes in northern communities in Canada, using the community of Burwash as the test site, and considering ETS systems to minimize the use of battery-based ESS to allow the proper management of RE sources.

**Academic Investigator(s):**
- Main PI: Prof. Claudio Canizares (Electrical and Computer Eng., UW)

**Industry Partner(s):** RestCo.

**Other Academic Institution(s):** N/A

**Funding Agencies:** NSERC

**Grant Name:** NSERC Engage Grant

**Status:** Not Approved (2017)

**Total Project Value:** $37,000

---

**Life Cycle Cost Modeling of VoltaAir’s Electric Auxiliary Power Units**

**Abstract:** This research proposal is built with partnership with VoltaAir Technology Inc. and primarily aims to develop a Life Cycle Cost modeling platform for VoltaAir’s battery powered A/C-R system. With an exclusive focus on advanced Lithium Ion Batteries, the scope of this project is to develop and employ Life Cycle Cost models for battery powered Auxiliary Power Units (APUs) in commercial vehicles. The objective is to optimize battery performance, environmental foot prints, and life cycle cost based on climate and load conditions and to analyze idle-free modes of new generation VoltaAir’s no-idle refrigeration systems. This R&D effort is further enabling the company to solve more sophisticated battery cost-performance optimization problems related to battery management system, taking into account the stochastic nature of certain exogenous factors (charging cost, fuel cost, customer demand, emission costs, and required performance characteristics).

**Academic Investigator(s):**
- Main PI: Prof. Jatin Nathwani (Management Sciences, UW)

**Industry Partner(s):** VoltaAir Technology Inc.

**Other Academic Institution(s):** N/A

**Funding Agencies:** NSERC

**Grant Name:** NSERC Engage

**Status:** Not Approved (2015)

**Total Project Value:** $33,000
3.3 Influence: Mobilizing Knowledge for a Sustainable Society
Influence:
Mobilizing Knowledge for a Sustainable Society

By publicizing our work, engaging with the media, and organizing a wide variety of events that bring our members together with external organizations and the public, we help to inform a broader and more constructive dialogue around sustainable energy.

WISE events create an environment in which leading energy experts can constructively share insights on key issues and collaboratively pursue impactful follow-up activities. By hosting these events, WISE provides our members with the networking opportunities to inspire innovative ideas that benefit their research. We take care of everything, from managing logistics to securing funds for promotion, and follow-up. This leaves our members free to focus on what they do best: advancing impactful research.

Our annual events provide consistent opportunities for interaction between our members and their stakeholders. These include the WISE Energy Day (held every spring and open to anyone from across the UW community) Technology Innovation and Policy Forum (every fall, held in partnership with the Canadian Council for Clean Reliable Electricity), and the Resource Recovery Partnership Workshop (a summertime gathering of researchers, industry players and governmental and non-governmental organizations engaged in the field of waste management and energy recovery). Through the AE4H initiative, WISE has also developed a unique event format – the innovation lab – which provides an interactive setting for members of this global consortium to develop joint projects in areas of shared interest. The first of these was held in Germany in 2017, resulting in a number of productive outputs including a Special Issue of the prestigious journal IEEE Proceedings. The second major innovation lab will take place in June 2019, bringing 50+ global leaders to Waterloo to advance the fight against global energy poverty.

As an outward face of the University, we also value the creation of opportunities for members of the public to learn about sustainable energy. To this end, over the past 5 years WISE has hosted 65 public lectures on campus, approximately one every month. Public lectures allow our members to share their research with a wider audience, allow us to bring in renowned experts to campus to interact with our faculty researchers and students, and give members of the general public opportunities to learn from and interact with sustainable energy researchers.
“Public lectures, major conferences, symposia and other outreach events organized by WISE provide a window to the world of energy, as well as strong motivation to our students and faculty members to engage in addressing complex societal problems”

Keith W. Hipel
University Professor, Systems Design Engineering
President, Academy of Science, Royal Society of Canada
Officer of the Order of Canada

I am clearly a strong supporter of WISE, it has the potential to continue to grow and become a strong body in Canada, informing the policy makers with science-based information to help them deliver good legislation to Federal and Provincial Legislatures.

Maurice B Dusseault
Professor of Earth Sciences, PhD, PEng
Department of Earth and Environmental Sciences

“WISE has a unique ability to both delve into the more complex questions related to Canadian energy while also making their findings accessible and more generally useful to the broader range of stakeholders we seek to engage.”

Colin Anderson
Chair
Energy Council of Canada
3.3.1 Conferences and Workshops

WISE Energy Day

Over the past 5 years, WISE has hosted an ‘Energy Day’ on the UW campus every year. The one-day event sees academics, industry, government and NGO experts come together to share insights and optimism for the future of the clean energy sector in Canada and the world. It is open and free to students, faculty-members and the public. Over 100 participants attend WISE Energy Day every year.

Energy Day provides an opportunity to highlight energy research at UW energy research through presentations, Q+A, posters, panel discussions and the opportunity to network with like-minded individuals.

Energy Day 2013-2018 have covered the following topics:

Energy Day 2013, October 4, 2013
- Panel 1: Shale Gas Development: The Use and Protection of Water
- Panel 2: The Need for Innovation in Energy Storage

Energy Day 2014, October 17, 2014
- Panel 1: Energy Entrepreneurship
- Panel 2: The Future of Energy Service Delivery

Energy Day 2016, March 30, 2016
- Panel 1: Geothermal Energy in Canada: How Can Research Shape Market Outcomes?
- Panel 2: Electric Mobility Infrastructure: Is it a Technology or a Business Model Challenge?
- Panel 3: Social & Policy Issues of De-Carbonizing the Canadian Energy Economy: Is there a Clear Path?

Energy Day 2017, March 30, 2017
- Panel 1: Energy Transitions for a Decarbonized Economy: How Fast and at What Cost?
- Panel 2: Low Energy Green Buildings: What can innovation do?
- Panel 3: Energy Access for Canada’s Remote First Nations Communities: If Not Now, When?
Energy Day 2018, March 27, 2018

- Panel 1: Access to Clean Energy for All: Is Innovation the Problem?
- Panel 2: Getting to a Low Carbon World: Capture or Utilize?
- Panel 3: Blockchain in the Energy Sector: Bust or Bonanza?

Technology Innovation and Policy Forum

Since 2016, WISE has partnered with the Council for Clean & Reliable Energy (CCRE) to organize the Technology Innovation and Policy Forum, an annual event with the goal of helping shape the next generation smart energy solutions and providing a direct link between cutting edge energy research at Waterloo and the Canadian energy policy community.

Each year, the forum brings together technology developers and innovators, leading researchers and entrepreneurs, industry thought leaders, and policy makers to share their insights on how to reach the convergence of policy development with technology advances via an innovation showcase including lab tours, networking sessions, poster and table presentations, panel discussions and presentations, and keynote talks.

The success of the first three Technology Innovation & Policy Forums has allowed WISE to secure sponsorship from relevant institutions that will allow the event to continue for future years.

Forum topics have included:

**Technology Innovation & Policy Forum 2016, November 24, 2016**

*Event title: Microgrids & Distributed Energy: Is there a revolution in the making?*

- Panel 1: Technology and Disruptive Innovation
- Panel 2: Policy Alignment - Financing, Business Models and Regulatory Construct

**Technology Innovation & Policy Forum 2017, November 9 2017**

*Event title: Disruptive Innovation over the Wires: Models for Success*

- Panel 1: Is Technology Disruption Driven by Economics?
- Panel 2: Financing Business Models: The Good, the Bad and the Ugly
Section III: Accomplishments and Impact

Technology Innovation & Policy Forum 2018, November 7 2018

Event title: Unlocking Energy Innovation for a ‘Low Cost-Low Carbon’ Economy
- Panel 1: The Promise and Perils of Technology Disruption
- Panel 2: Financing Energy Businesses: The Good, the Bad and the Ugly

Partners:

Resource Recovery Partnership Workshops

Starting in 2014, the Canadian Plastics Industry Association has partnered with WISE to host an annual workshop on the present and future of waste management and resource recovery research in Canada.

These invitation-only events have brought together key stakeholders from government, industry and academia and encouraged collaboration in solid waste research, the exploration of opportunities for partnership, and the integration of efforts across stakeholder groups.

The annual event has been gained support from multiple public and private institutions, growing to become a multi-day conference.

Workshop topics have included:

Solid Waste Management Partnership Workshop, June 24 2014
- Partnership opportunities by NSERC
- Overview of Solid Waste Management current trends in Europe
- Overview of Solid Waste Management current trends in U.S.A.
Resource Recovery Partnership Workshop 2015, June 24 2015
- What are the most critical research areas that would benefit municipalities and regulators and how can academia help local and national governments prepare for new and emerging challenges?
- How is industry investing in research and how would a dedicated program of research help meet the evolving needs on industry?

- Opportunities for Support and Fund Research in the Resource Recovery Sector
- Understanding and Managing Existing Data Valuable for the Resource Recovery Sector
- Identifying New Research and Innovation Within Reduction, Reuse and Recycling

Resource Recovery Partnership Workshop 2017, June 6 2017
- Circular Economy and Sustainable Materials Management
- Carbon Capture, Reduction and Preservation
- Moving Forward: How to Advance the Resource Recovery Agenda Towards Acceptance

Resource Recovery Partnership Workshop 2017, June 21-22 2018
- Circular economy: is there an integrated approach to sustainable energy and sustainable materials management?
- Competing philosophies of the sustainable economy: is there “one” right answer?
- Waste as feedstocks – technology – end markets: can we close the loop to maximize resource efficiency?
- Exploring the versatility of recovery technologies: we can discover the many hidden methods and sources to achieve sustainable energy.
- Charting the path to a sustainable economy by: identifying the financial, legislative and market challenges, impediments and opportunities for advancing the “4th R”.
Section III: Accomplishments and Impact

Partners:

Sustainable Development Technology Canada Workshops

SDTC Virtual Incubator Workshop (Sep 17, 2014) & SDTC Funding Workshop (March 9, 2015)

The first two workshops, hosted by WISE in partnership with SDTC, targeted entrepreneurs with early-stage clean technologies who plan on applying to SDTC for funding. They provided prospective applicants with key information and practical guidance to prepare quality funding submissions. The sessions enabled participants to assess the potential fit of their technology with SDTC funds, and to help gain an understanding of the application process and key evaluation criteria.

SDTC Workshop, October 28, 2016

For the third SDTC workshop, a selected group of academic researchers and start-up venture founders presented their ideas, proof of concepts, and technology development proposals with the goal to secure funding for their projects’ deployment while building tactics for market penetration strategies in the clean tech sector with like-minded partners.

Presentations included:

- Muaaz Masood: Energy Storage
- Abid Hussain: Energy-Efficient Wastewater Treatment: Partially Mixed Anaerobic Bioreactor
- Zac Young: Harnessing the Power of Nanotechnology in the Energy Sector
Section III: Accomplishments and Impact

- Bijan Mahbaz: Assessment of Concrete Structure
- Joseph Tam & Ahsan ul Alam: Electric Vehicle Charging Infrastructure
- Tom Siu & Jennifer Miller: Renewable Energy
- Hamed Mohammadifardi: Wind Energy
- Sanjeev Bedi: Solar Energy
- Mike Voll: Microgrids

Partners:

![AE4H Events](image)

**AE4H Events**

**AE4H Innovation Lab 2017**

AE4H hosted a 2.5-day workshop in June 2017, with support from WGSI, KIT, and the Institute for Advanced Sustainability Studies, focused on bringing together a collection of leading thinkers and innovators from the AE4H consortium to scope new research areas for the network to pursue.

This workshop was attended by an invited group of 53 experts from 31 institutions and 16 different countries, including academic researchers, entrepreneurs, energy policy-makers and civil society leaders.

The AE4H Innovation Lab featured working sessions on a diverse set of themes:

- Scaling micro-grid development
Section III: Accomplishments and Impact

- Capacity-building at the last mile
- Supporting energy access entrepreneurs
- Establishing effective research to impact labs
- Working with local partners: private vs. public
- Inclusive business models for the BOP
- Data, IoT and smart infrastructure deployment
- Global talent pool development and training
- End-uses and users of electricity

Key outcomes from the event included:

- The establishment of a core scientific advisory group for AE4H that will steer the development of future innovation lab events. The group is composed of leading experts from UW, KIT, the University of Oxford, UC Berkeley and Arizona State University.
- A special issue of IEEE Proceedings entitled ‘Electricity for All: Solutions for Energy Disadvantaged Communities’, with guest editors Prof. Jatin Nathwani (WISE), Prof. Claudio Canizares (WISE) and Prof. Dan Kammen (UC Berkeley).
- A follow-up innovation lab to be held as a side-event at the ‘International conference on solar technologies and hybrid mini-grids to improve energy access’ in Palma de Mallorca, Spain. The event a partnership between WISE, The Siemens Foundation, Trama TecnoAmbiental (a Spanish off-grid technology consultancy) GIZ (the German International Development Agency), SNV (the Dutch International Development Agency), EnDev (an energy access initiative financed by six donor countries: the Netherlands, Germany, Norway, United Kingdom, Switzerland and Sweden), and REPIC (An interdepartmental platform of the Swiss government for renewable energy promotion). The event will cover a range of topics from policy to finance, advanced technologies, and capacity-building related to energy access initiatives all over the world. Prof. Nathwani and AE4H Manager Nigel Moore are members of the scientific and organizing committees, respectively.
- A WISE report that outlines practical steps for planning, organizing and executing ‘innovation labs’, which is now available through the University of Waterloo’s Office of Research, and distributed to researchers engaged in international partnership building and workshop organization activities.
Section III: Accomplishments and Impact

Two follow-up side innovation lab side events were hosted by WISE at international conferences in 2018:

- Poverty Eradication Through Energy Innovation Workshop (Arizona State University, February 2018)
- International Conference on Solar Technologies and Hybif Mini-Grids to Improve Energy Access (University of the Balleric Islands, October 2018)

Owing to its success, WISE is pursuing the AE4H innovation lab as an annual event. The next AE4H innovation Lab is scheduled to take place in Waterloo in June 2019, and will involve core partners from the University of Oxford, Arizona State University, The University of California, Berkeley, the Massachusetts Institute of Technology, and the Karlsruhe Institute of Technology, along with a number of AE4H members from other collaborating institutions.

Partners:

OpenAccess Energy Summit

The Open Access Energy Summit’ was held in April 2016 at the Perimeter Institute for Theoretical Physics in Waterloo. Hosted by the Waterloo Global Science Initiative (WGSI), in collaboration with WISE Executive Director (WGSI Scientific Advisor, and WISE Manager Nigel Moore (WGSI Researcher and Writer), the summit brought together an interdisciplinary and multigenerational group of leading thinkers and practitioners on the topic of global energy access. Globally renowned experts and future leaders from 22 different countries and four of Canada’s First Nations participated. Extensive media coverage from TVO’s ‘The Agenda’, The Globe and Mail, and award-winning investigative journalism start-up Discourse Media followed the event.
The outputs of the summit include the ‘OpenAccess Energy Blueprint’ — an in-depth, solutions-focused summary of key recommendations from the summit. The Blueprint, co-authored by WISE Manager Nigel Moore, suggests four strategies to create a thriving energy access sector:

1. **Enable** – Establish national energy plans, and a policy and regulatory environment conducive to the creation of off-grid electricity services;

2. **Align** – Facilitate creative alliances between those seeking to provide electricity services and those who can finance the projects;

3. **Empower** – Build the human capacity to allow the sector to thrive – especially drawing on the strength of women and community members to deliver solutions at the ‘last mile’ through education, training and networking;

4. **Incubate** – Create financially sustainable platforms to help energy entrepreneurs succeed in creating sustainable energy businesses that can serve even the most difficult and impoverished markets.

Partners:
Other Events

Geothermal Symposium

This event, hosted by WISE on September 26, 2017, featured distinguished speakers from across the globe in the field of Geothermal Energy.

The Geothermal Symposium consisted of a keynote talk titled ‘Put the Planet in Your Portfolio’ by Murat Basarir, Manager, Business Development for CoPower, and four panel presentations led by authorities in different areas of the Geothermal Energy sector, including:

- Panel 1 (Academic) – Overcoming R&D challenges for Geothermal Energy: Navigating Convolutions of technical, social, and political Paradigm shifts of the 21st Century
- Panel 4 (Funding Agencies) – Science, Technology and Innovation Strategies: Management and Mobilization of Financial Resources for Geothermal Technology Development

Waterloo Regional Decarbonization Forum

On November 17th-18th, 2016 Professor Heather Douglas, Waterloo Chair in Science and Society and WISE Associate Director, launched the Decarbonization Forum: Charting Waterloo’s Energy Future, with the aim to envision a carbon free Waterloo Region by the year 2050.

This two-day forum brought together 50 academic, government, industry, and local NGO stakeholders from the Waterloo region to develop a holistic, long-term view of our energy system and identify decarbonization challenges.

The major challenges identified include:

1. Dramatically reducing energy needs of the build environment
2. Maximize local renewable power generation
3. Eliminating fossil fuels based transportation
4. Replacing natural gas as a source of energy for heating
Partners:

Green Growth, Sustainable Communities and the Circular Economy
International Workshop

This event hosted by WISE at the University of Waterloo on May 29, 2017 was the second in a series, following a meeting at Dalian University of Technology in 2015, as part of an international collaboration between Dalian University of Technology in China, the University of Waterloo in Canada, Imperial College London in the UK and the International Academy of Ecology and Life Protection Science in Russia.

The collaboration explores strategies for green growth through providing a platform for researchers from the four institutions to share case studies that illustrate widely applicable strategies to simultaneously achieve economic and environmental stewardship aims.

The event featured a keynote talk titled ‘Sustainability as a Source of Innovation for New Growth’ by Richard Blundell from the University of Toronto, and panel presentations and discussions on three topics:

- Business Strategies for green growth
- Cities, Infrastructure and Planning for Sustainability
- The Circular Economy

Partners:
Green House Gas Emissions Workshop

On October 12, 2016, WISE hosted a public event to share Waterloo’s research expertise on technologies that are revolutionizing the development of greenhouse gas reduction, including innovative solutions for a variety of industrial sectors. An overview of potential funding opportunities through Ontario Centres of Excellence and NSERC was also presented, to aid researchers in securing further funding for their work.

This event focused on the following domains of research exploration:

- Industrial Point Source emissions
- Emissions Throughout the Value Chain
- CO2 Capture, Storage and Utilization Innovations

Partners:
3.3.2 Public Lecture Series

Since 2013, WISE has hosted 65 lectures that have brought sustainable energy leaders from all over the world to the University of Waterloo. These lectures, which are open to the public, help bring the insights and latest developments in the field to the Waterloo community, allowing our professors, students, and other stakeholders to engage with leading researchers, industry experts, and government officials.

2013

PEM Fuel Cell Catalysis and Supercapacitors at National Research Council of Canada
Dr. Jiujun Zhang, Principle Research Officer, National Research Council Canada, Vancouver, BC
May 23, 2013

CO2 Storage at the Ketzin Pilot Site, Germany: 5th Year of Injection, Multidisciplinary Monitoring and Modelling
Dr. Sonja Martens, Project Manager Ketzin, Centre for Geological Storage, GFZ German Research Centre for Geosciences, Postdam
May 31, 2013

The Role of Hydro in Modern Sustainable Power Grids
Phil Helwig, M.Sc., P. Eng., Hydropower Consultant, Helwig Hydrotechnique Limited
July 12, 2013

Understanding Active Network Management in 40 Minutes
Prof. Damien Ernst, Associate Professor, University of Liège
August 9, 2013

Energy Perspectives for Germany and Europe: A Researcher’s View
Dr.-Ing. Joachim U. Knebel, Chief Science Officer, Karlsruhe Institute of Technology (KIT), Germany
October 2, 2013

Behaviour Change: An Untapped Resource in Coping with Climate Change
Dr. Ron Dembo, Founder and CEO of Zerofootprint, Founder and former CEO of Algorithmics
October 29, 2013

2014

Canadian Responsibility and the Energy Trilemma
Dr. Brenda Kenny, President & CEO, Canadian Energy Pipeline Association (CEPA)
February 12, 2014

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.
May 22, 2014
The Ecological Footprint: Meat, Energy, and Sustainability
Tony Weis, Associate Professor, Geography at the University of Western Ontario
October 15, 2014

Transformations across the Energy Sector: Past, Present and Future
Graham Campbell, President, Energy Council of Canada
November 5, 2014

2015

Demand and Response and Capacity Auctions for Ontario
Tom Chapman, Markets Group, Independent Electricity System Operator
February 10, 2015

Modeling Multi-Scale Processes in Hydraulic Fracture Propagation Using the Implicit Level Set Algorithm (ILSA)
Dr. Anthony Pierce, Professor, Department of Mathematics, The University of British Columbia
March 26, 2015

A Practical Framework for the Implementation of the Vehicle-to-Grid (V2G) Concept
Professor George Gross, Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign
April 17, 2015

Synthesis of Coal-Based Clean Fuels and Chemicals
Professor Zhong Li, Deputy Director, Key Lab of Coal Science & Technology, Taiyuan University of Technology
June 12, 2015

Microgrid Analysis, Optimization & Implementation
Dr. Bala Venkatesh, Lecturer, Dept. of Electrical and Computer Engineering and Academic Director, Center of Urban Energy, Ryerson University
September 30, 2015

Sustainability and Geothermal Energy Studies in Geotechnical Engineering
Dr. Anand Puppala, University of Texas at Arlington
October 9, 2015

The Impact of “Energiewende” on Renewable Energies in Germany
Dr. Alexandra Pehlken, Lecturer in Bioenergy for the International PPRE Program, Oldenburg University, Germany
October 22, 2015

Design of a Participatory-Model Microgrid/Smart-Farm System for the Mapuche Indigenous Communities
Dr. Doris Sáez Hueichapan, Associate Professor, Dept. of Electrical Engineering, Universidad de Chile
November 17, 2015
2016

*Electric Vehicle (EV) Charging*
Klaus Dohring, President, Green Sun Rising Inc.
February 4, 2016

*Insights and Considerations for PEX Energy and Plumbing Applications*
Teresa Jiang, Business Development Manager — Central Canada, Uponor Ltd.
April 12, 2016

*Forensic Energy Management*
B. Paul Mertes, President and CEO, CircuitMeter Inc.
May 3, 2016

*Forest Bioenergy in Ontario: Examining the Life Cycle Impacts and Costs of Using Harvest Residue as Feedstock for Small- and Large-Scale Bioenergy Systems*
Dr. Julian Cleary. Expert in Environmental Life Cycle Assessment
June 28, 2016

*Helical Piling Applications in Canada*
Jeff Lloyd, President, Almita Piling
July 22, 2016

*Natural Ventilation of Buildings Using a New Design of Wind-Catcher to Decrease Energy Consumption in Windy Regions*
Dr. Madjid Soltani, Director, HVAC & Energy Lab, K.N.Toosi University of Technology
August 4, 2016

*Wind Turbine Aerodynamics and Solar Car Cooling Systems*
Dr. Kobra Gharali, Assistant Professor, Mechanical Engineering, University of Tehran, Iran
August 16, 2016

*How Can We Help Electricity Access Scale-up Faster?*
Dr. Claudio Vergara, Postdoctoral Associate, MIT Tata Center for Technology and Design
September 26, 2016

*Demand-Side Management, Micro-Grids, Demand Response and Reducing the Need to Overbuild Capacity*
Paul M. Grod, President & CEO, Rodan Energy Solutions
November 22, 2016

*Natural Gas – an Important Transportation Fuel as Part of a Low Emission Logistics Strategy*
Tariq Qurashi, NGT Sales Consultant, Enbridge Gas Distribution Inc.
November 29, 2016

*Experimental and Computational Optimization of a Wind Turbine Blade De-Icing System*
Daniela Roeper, Founder, Borealis Wind
December 13, 2016
Energy Economics – Towards Sustainable Development & a ‘Green GDP’
Sankaran Ramalingam, President, Energy and Fuel Users Association of India (ENFUSE)
December 15, 2016

2017

Electricity, an Industry in Transition
Benjamin Grunfeld, Managing Director, Navigant
January 25, 2017

Solar + Storage + IOT + LED = $30 Trillion
Dr. Srinivasan Keshav, Professor, Cheriton School of Computer Science, UW
February 13, 2017

Piezoelectric Materials and Their Applications
S. Eswar Prasad, Chairman, Piemades, Inc. and Adjunct Professor, Dept. of Mechanical and Industrial Engineering, University of Toronto
April 18, 2017

Energy-Secure, Adaptable Housing and Infrastructure for Remote and Northern Communities
Peter Russell, President, RESTCo
April 19, 2017

Post-Net Metering for a Sustainable City
Dr. Matthew Peloso, CEO and Founder of Sun Electric Pte. Ltd., Singapore
May 19, 2017

Smarter Cities: New Services, New Applications for Control
Dr. Robert Shorten, Chair, Control Engineering & Decisions Science, University College, Dublin
June 26, 2017

Printed MEMS: sensors, actuators or energy harvesters processing with standard or modified screen-printing
Hélène Debéda, Associate Professor, University of Bordeaux, IMS Laboratory, PRIMS team
June 28, 2017

Hydraulic Fracture Field Experiments for Geothermal Energy
Dr. Mohammad Reza Jalali, Lecturer & Researcher, Swiss Federal Institute of Technology (ETH)
July 5, 2017

Directional Drilling and Magnetic Ranging Services for Geothermal Energy Development
Clinton Moss, President, Marksman Ranging Technologies, Scientific Drilling
July 5, 2017
Section III: Accomplishments and Impact

Self-Dependency in Remote Communities: Food, Energy, Future
Benjamin Canning, Co-Founder & Co-Project Manager, Growing North
As presented by Monica Khaper, Director, Sustainability, Growing North
July 11, 2017

Physics-based Control of Energy Systems Ranging from Smart Buildings and Power Grid to Smart Hybrid Electric Vehicles
Mahdi Shahbakhti, Associate Professor, Mechanical Engineering – Engineering Mechanics, Michigan Tech
August 2, 2017

Navigating Ontario’s Evolving Energy Landscape – A Utility’s Experience
Nirupa Balendran, Conservation Energy Manager, Newmarket-Tay Power Distribution Inc.
September 11, 2017

Ontario’s Emissions and Long-Term Energy Planning
Marc Brouillette, Principal Consultant, Strategic Policy Economics
October 24, 2017

Martin Vroegh, Senior Director, Greenhouse Gas Reduction Technologies, Ontario Centres of Excellence
October 26, 2017

Changing Perspectives in Ontario’s Electricity Industry
Erik Veneman, Vice President, Innovation and Growth, Guelph Hydro Electric Systems Inc.
November 21, 2017

2018

Energy: Ten BIG Ideas on Energy (What Everyone Needs to Know)
Adonis Yatchew, Professor, Economics, University of Toronto
January 25, 2018

The Future of New Zero Homes in Canada
Mehmet Ferdiner, Manager, energy Modelling Services, Building Knowledge Canada
February 13, 2018

Reducing Carbon Emissions Through Energy Efficiency: A Canadian Perspective
Chandra Ramadurai, CEO, Efficiency Capital
February 22, 2018

OTSG in Power Generation and Energy in Canada
Alex Berruti, Senior Product Engineer, Enhanced Oil Recovery for Innovative Steam Technologies (IST)
April 24, 2018
Actualizing Smart Infrastructure to Enable Data-Driven Asset Maintenance Decisions
Dr. Sriram Narasimhan, Canada Research Chair, Smart Infrastructure; Associate Professor, Civil and Environmental Engineering & Mechanical and Mechatronics Engineering (cross-appointed), University of Waterloo
June 15, 2018

Health Impacts of Climate Change and Climate Policy
Dr. Rebecca K Saari, Assistant Professor, Civil and Environmental Engineering, University of Waterloo
June 26, 2018

Decoding the Energy Access Puzzle: An Overview of an Experiment at the Grassroots Level
Sankaran Ramalingam, Founding Director, Fuel-Users Association of India
July 13, 2018

Biogas – Resource Recovery and Clean Tech
David Thompson, Project Manager, Technical Services, Walker Environmental
July 24, 2018

Csan Building Science Save the Day?
Jaan Timusk, Professor Emeritus, Civil Engineering, University of Toronto
August 14, 2018

The New Fast.Farm: Wind Farm Design and Analysis
Dr. Jason Jonkman, Senior Engineer, NREL
September 20, 2018

Blockchain: A New Foundation for Distributed Energy Resources?
Vikram Singh, Director of Advanced Planning, Alectra Utilities
September 28, 2018

Show Me Your Forecasts, I'll Show You Mine! Are we moving towards energy data markets?
Pierre Pinson, Professor, Centre for Electric Power and Energy, Electrical Engineering, Technical University of Denmark
October 10, 2018

The Aesthetics of Renewable Energy: Designing a Post Carbon Culture
Elizabeth Monoian and Robert Ferry, Co-founders, Land Art Generator Initiative
November 8, 2018
3.3.3 Media Exposure

Over the past five years, WISE, particularly through Executive Director Jatin Nathwani, has engaged with a variety of national and international media outlets — print, online and broadcast — to tell the story of the sustainable energy revolution and the cutting edge role of Waterloo research. This coverage reflects a growing recognition of WISE and its members as thought leaders and cornerstones of the Canadian sustainable energy research landscape. WISE members comprise an independent but authoritative source of commentary and analysis of energy issues, many of which are highlighted in the coverage below:

**Television**

CTV News Kitchener
Local News Interview
‘*Electric vehicle conference brings together researchers and owners*, Prof. Nathwani.
May 2, 2018

The Agenda with Steve Paikin
National TV Panel Discussion
‘*Our Nuclear Future*, Prof. Nathwani
October 20, 2016

The Agenda with Steve Paikin
Episodes of TV Ontario’s The Agenda program from the OpenAccess Energy Summit
‘*An Energy Revolution* Prof. Nathwani
April 26, 2016

The Agenda with Steve Paikin
Episodes of TV Ontario’s The Agenda program from the OpenAccess Energy Summit
‘*Ending Energy Poverty*, Prof. Nathwani
April 25, 2016

The Agenda with Steve Paikin
Ontario’s Overpriced Electricity
‘*Are Ontarians paying too much for electricity?*, Prof Nathwani’
November 26, 2013
Policy Options
‘Raise the GST as part of pragmatic plan for climate action’, Prof Nathwani
October 17 2018

‘Sustainable energy assessment under way in southern Inuit communities’, Prof Canizares
Jul 16, 2018

‘The good, the bad, and the ugly: A look back at 15 years of Liberal government’, Prof Nathwani
Jun 15, 2018

‘Hydro rates should be subsidized. Borrowing now ensures future capacity.’ Prof Nathwani
May 15, 2018

‘A Regional Energy Hub For A Global Transition To A Low-Carbon Economy’, Prof Nathwani
May 15, 2018

‘Ontario Auditor-General Bonnie Lysyk does disservice to public by getting it wrong on hydro costs’ Prof Nathwani
May 6, 2018

Why power-hungry Ontarians need to take a new approach to technology, Prof Nathwani
May 2 2018
Section III: Accomplishments and Impact

iPolitics
‘Putting Humpty Dumpty back together again: Ontario NDP’s hydro plan leaves experts cold,’ Prof Nathwani
Apr 27, 2018

The Record
‘UW charges ahead with electric vehicle research’, Prof Nathwani
Apr 26, 2018

Globe and Mail
‘Pipeline rhetoric and reality: It’s time for an adult conversation’, Prof Nathwani
February 9, 2018

The Conversation
‘Empowering the powerless: Let’s end energy poverty’, Prof Nathwani
Jan 29, 2018

Harrowsmith Magazine
‘Energy Poverty in Indigenous Communities – Confronting a national shame’, Nigel Moore
January 1, 2018

The Conversation (reprinted in the National Post)
‘Clean Energy Can Advance Indigenous Reconciliation,’ Prof. Nathwani
October 26, 2017

The Conversation (reprinted in the Energy Post)
‘Solar Alone won’t solve energy or climate needs,’ Prof Nathwani
Sept 25, 2017

TVO Current Affairs
‘What the Lake Erie Connector project could mean for your hydro bill,’ Prof. Nathwani
June 30, 2017
Globe and Mail
‘Climate Strategies – Tango Between Climate Change and Energy Policy’, Prof Nathwani
April 22, 2017

The Hill (US)
‘Renewables Are Not Equally Green’ D Lam and Prof Nathwani,
March 7, 2017

TVO Current Affairs
‘Outrage not justified on Ontario electricity prices,’ Prof Nathwani’
March 6, 2017

The Hill (US)
‘Trump unlikely to approve Keystone XL pipeline quickly’, D. Lam, Prof Nathwani
Jan 9, 2017

TVO Current Affairs
‘How Ontarians can take power back from big energy plants,’ Prof Nathwani
Sept. 22, 2016

CBC News
‘Wind, solar energy real options for Canada’s remote Arctic communities’ Prof Canizares
Sept 17, 2016

WWF Online
‘Renewable energy financially feasible in Nunavut, study shows’ Prof Canizares
May 31, 2016

Globe and Mail
‘Indigenous communities must be part of the global green energy revolution,’ Prof Nathwani
April 27, 2016

TVO Current Affairs
‘Could nuclear energy be Ontario’s trump card?’ Prof Nathwani
Dec. 16, 2015
Globe and Mail
‘Auditor General offers incomplete picture of Ontario’s power upgrade’, Prof Nathwani
Dec. 10, 2015

Maclean’s
‘The hard truths behind Ontario’s pricey electrical system’ Prof Nathwani
Dec 10, 2015.

TVO Current Affairs
‘Does Ontario’s Bruce nuclear deal make financial sense?’ Prof Nathwani
Dec. 7, 2015

Globe and Mail
‘Drafting a new architecture for energy’, Prof Nathwani, Report on Business Weekend
Nov 28, 2015

TVO Current Affairs
‘What Ontarians don’t know about rising hydro rates’, Prof Nathwani
Nov. 6, 2015

SmartGrid Today
‘Canadian Solar executive details buildup of microgrids’
Jan 15, 2015

Toronto Star Canada Day National Supplement
‘Canada Driving a global energy transition’ Prof Nathwani
June 30, 2014

Globe and Mail
‘Sustainable Energy Supplement’ Prof Nathwani
May 21, 2014

Bloomberg BNA, International Environment Reporter
‘Technical, Economic and Political Hurdles Hamper Renewable Energy Future’ Prof Nathwani
March 27, 2014
Toronto Star
‘Degrading condo windows expected to trigger major wave of replacements’ Prof. Straube
Feb 19, 2014

The Globe and Mail
‘Can wind power cut northern dependence on diesel?’ Prof Canizares
Dec 3 2013

The Globe and Mail
‘If nothing else, green power has to be green’ Prof. Nathwani
Dec 9, 2013

The Globe and Mail.
‘Major investments needed for Canada to achieve full electricity security’, Prof Nathwani
Nov 12, 2013

Toronto Star Media Planet
‘Ask the Experts: “The future of research and development in sustainable energy.”’ Prof Nathwani
Nov 28, 2013

Engineering Dimensions
‘Ontario’s Energy Policy: Looking Beyond Ontario’ Prof Nathwani
August 2013

Policy Options
‘Beyond Keystone: Canada’s Clean Electricity’ ‘Prof Nathwani
June 2013
3.3.4 Selected WISE Member Publications

2013


2014


2015


2016


2017


Leila Ahmadi, Steven B Young, Michael Fowler, Roydon A Fraser, Mohammad Ahmadi Achachlouei (2017). A cascaded life cycle: reuse of electric vehicle lithium-ion battery packs in energy storage systems. The International Journal of Life Cycle Assessment 22 (1), pp. 111-124


Adedamola Adepetu, Srinivasan Keshav (2017). The relative importance of price and driving range on electric vehicle adoption: Los Angeles case study. Transportation 44 (2), pp. 353-373

2018


4. FUTURE DIRECTIONS
4. Future Directions

4.1 CONTEXT

Since its founding in 2008, WISE has initiated projects across a wide range of knowledge domains encompassing sustainable energy development. From developing funding for new high-tech labs to support emerging disciplinary research clusters, to bringing together researchers, policy-makers and industry leaders in dialogues around the future of the clean energy sector in Ontario and beyond, WISE has pursued opportunities both opportunistically and with the long-term in mind.

As we look forward to our next five years, WISE has identified opportunities across four themes where our expertise, connections and resources align with a vision of global leadership. Not only are these areas of great interest to our members and partners, they also reflect increasingly vital elements of the sustainable energy transition at the local and global level. At WISE, we see this transition broadly following 5 macro-trends: decarbonization, decentralization, digitization, deregulation and democratization.

Rapid decarbonization of energy systems must be a central part of climate change action, as the energy sector represents a major source of greenhouse gas emissions globally. It has become increasingly clear however that the trend toward decarbonization of energy systems will continue irrespective of climate policy. The cost of renewable energy systems is falling fast, and they have other benefits including modularity and scalability. The past half decade has shown that stakeholders ranging from individual consumers to large industries have increasingly adopted clean technology.

The move towards renewable generation from sources available almost anywhere such as solar and wind makes decentralization of the power grid possible. This shift offers consumers more choice in the technologies and policies that govern energy generation and use, as well as the ability to participate more actively in the energy system as a ‘prosumer’ – a new kind of energy system stakeholder that is both a consumer and producer of energy. It also enhances grid resilience to external shocks such as natural disasters or cyber attacks.

In a future where many different sources and technologies are embedded within a highly complex decentralized energy system, digitization will become the cornerstone of a well-functioning, efficient grid. Through advanced information and communications technologies, as well as the extensive use of data to drive decision-making and enhance the intelligence of stakeholders and systems, the energy system of the future can become self-organizing: efficient markets, self-healing grids, and improved resilience.

As the energy system changes, deregulation has become a trend that allows the new paradigm to emerge organically and efficiently. Our regulatory structures were built for the old, centralized energy system. As the new system emerges, deregulation will allow new innovations to enter the market successfully, creating new economic value.

The confluence of these four trends should result in a fifth: democratization of the energy sector. This powerful force has the potential to create more transparency in energy systems, more consumer choice, and genuine opportunities for smaller stakeholder groups, including individuals, to participate meaningfully in the energy system and to extract and contribute value as a result of this participation.
4.2 PRIORITY AREAS

4.2.1 Smart Energy Infrastructure

The smart, sustainable energy systems of the future will require efficient integration of a variety of energy generation, transmission and end use technologies. From electric vehicles, to smart grids, energy storage and buildings that both produce and consume clean energy, this smart energy infrastructure must be efficiently networked to ensure the best use of variable sustainable energy resources.

Waterloo, as an established leader in cutting edge information and communications technologies (ICT), has an important role to play in developing new ideas and technologies that will enable a ‘whole-systems’ approach to smart energy infrastructure integration. WISE therefore aims to cement the leadership position of UW as a place for innovation on the convergence of sustainable energy technology and data-driven ICT-enabled solutions.

This approach is critical in any environment where clean technology will not only be deployed on a large scale but can become a basis for export-led economic growth in Canada. Increasingly, WISE realizes the vital role of efficient energy use in regions facing energy insecurity. As remote communities in Canada and abroad grapple with the opportunities and challenges of investing in cleantech, WISE will endeavor to work alongside them in developing smart energy solutions that allow them to maximise the benefits of limited resources. WISE believes that smart energy infrastructure is not a luxury but rather a critical component of any cost-effective clean energy system, irrespective of its location.

WISE Objectives:

1) **Collaborate** with UW faculty whose work is at the interface of ICT, data science and energy systems by providing assistance in identifying funds to support their work, and establish strong networks with industry so that UW innovations can find real-world applications.

2) **Reach Out** to communities, governments, and other stakeholders to develop innovative, end-user driven action research projects that test and deploy smart energy solutions in communities where they will improve energy service quality and reduce overall system costs, with particular focus on regions facing energy insecurity.

3) **Influence** and prioritize the emergence of data-driven solutions to energy sector challenges in the areas of electric mobility, energy market design, energy transactions and finance, energy system planning, and efficient buildings.
4.2.2 Inclusive Global Energy Transformation

The transformation of energy systems towards integration of sustainable energy infrastructure, new business models for energy delivery, and incentives around energy use, requires decisive policy action. Decisions made by powerful public and private sector actors should be inclusive of the desires, ability to pay, habits and priorities of consumers, as well as being resilient to future challenges posed by the need for climate adaptation.

UW-based experts from the social sciences, including economics, law, policy and environment can play an important role in guiding sustainable energy transitions with such complexities in mind. WISE aims to muster this expertise to help ensure that new technologies and socio-economic systems of energy delivery are fair, attuned to the needs of diverse stakeholders, and show a high degree of resilience against unpredictable threats.

Issues such as divestment from fossil fuels, stranded fossil fuel assets, conservation initiatives, and choices between sustainable energy generation, transmission and storage technology suites have far-ranging implications for Canada’s economy. These are areas with questions that cannot be answered solely by experts, requiring inclusive dialogue. WISE aims to use our position to help broker potential social conflicts around energy transformation and thereby support multi-level energy sector planning in Canada.

WISE Objectives:

1) **Collaborate** with faculty members from the social sciences, particularly within the Faculty of Environment and the School of Accounting, on issues such as divestment, stranded assets, conservation, and energy infrastructure investment, which are of acute interest to Canadian energy policy-makers and major industry players.

2) **Reach Out** to a range of stakeholders, including citizen-driven grassroots organizations to understand concerns about energy sector transformation and host events that cover key topics of interest and bring stakeholders together for constructive and inclusive dialogue.

3) **Influence** political and industry decision-making related to energy systems planning in Canada by leveraging our connections with the Canadian policy community and energy industry. Deliver insights that support decision-making that is aligned with pressing concerns of citizens.
### 4.2.3 Affordable Energy for Humanity

Over one billion people on the planet do not have access to electricity, and over a billion more have unreliable access. The challenge of providing energy that is both affordable and clean to a third of humanity is vital to meeting the climate change and sustainable development challenges of the 21st century. New cleantech solutions, including those developed at UW, must be brought to bear at a global level in accordance with the urgency of these issues.

WISE has therefore established a new flagship program, the Affordable Energy for Humanity Global Change Initiative (AE4H), which establishes UW as the central node of a globally networked research and action partnership comprised of over 140 global experts from 50+ institutions in 20+ countries. We have identified two core areas of impact: use-inspired design of cutting edge solutions that lower the cost of clean energy for those living at the economic margins, and building human capital for the emerging energy access sector. Through AE4H, WISE is currently advancing a number of initiatives that combine these areas of impact. This includes an active, externally funded global internship program for UW students and a proposal in development which would establish clean energy innovation incubation centres across the developing world.

Acknowledging UW’s position as an established global leader in STEM education, we also see an opportunity to broaden the innovation narrative at this institution. Through AE4H, WISE will provide pathways for technologically and entrepreneurially inclined UW community members to participate in the sustainable development revolution, both in the energy sector (UN Sustainable Development Goal 7) and in areas linked to energy (across the rest of the SDGs).

**WISE Objectives:**

1) **Collaborate** with AE4H partners to identify and pursue research funding opportunities across four domains: generation, devices and advanced materials; micro-grids for dispersed power; ICT for energy sector convergence; and environmental and human dimensions of energy sector transformation.

2) **Reach Out** to better understand the challenges and opportunities facing entrepreneurs, civil society organizations and policy-makers committed to clean energy for all. Establish an annual ‘Innovation Lab’ event in Waterloo that brings these stakeholders together, establishing UW at the centre of global-level dialogue.

3) **Influence** the emergence of future entrepreneurial leaders for global energy access by executing a new funded program that places UW students in international social enterprises in the energy sector. Offer excellent networking, leadership and social enterprise support activities on campus to create a vibrant community of UW-based international change-makers.
4.2.4 Geothermal Energy

Geothermal energy, sourced from warm, stable temperatures either near the land surface or from deep below, can be used to provide both emissions-free heat and power. While utilized in a variety of regions globally, geothermal energy research and deployment in Canada is sparse. WISE therefore sees a major opportunity to investigate this under-explored energy technology, and to position UW as a leader.

The utilization of geothermal energy to provide heat is particularly valuable in Canada where cold temperatures make alternatives to fossil fuels of great importance. Geothermal energy technologies, like other sustainable energy options, must also be analysed in the context of a wider suite of energy options, as one component of a smart and efficient energy system. Due to its under-explored nature and multiple uses, WISE sees a research gap in this area that is worth exploring.

WISE has recently undertaken a series of activities including joint funding proposals led by UW faculty experts and hosting a geothermal symposium that brought together the major Canadian stakeholders from the geothermal industry and research community. Moving forward, WISE will take advantage of our existing expertise, connections, and emerging leadership position to establish UW as a recognized hub of research on geothermal energy. This will include establishing pilot projects that advance understanding and de-risk the technology, particularly in the Canadian context.

WISE Objectives:

1) **Collaborate** with leading experts at UW, in Canada and abroad to place UW geothermal expertise at the epicentre of cutting edge research on the topic.
2) **Reach Out** to industry and other potential sources of funding to establish a geothermal energy laboratory in Waterloo that provides our experts with the tools necessary to advance knowledge in a meaningful way.
3) **Influence** policy-makers at all levels of government in Canada to take seriously the real-world potential of geothermal energy production. Clearly communicate uncertainties and gaps in knowledge so that long-term energy planning processes and energy infrastructure and research investments are made wisely.
4.2.5 Interdisciplinary Energy Research

In light of the five global mega trends in the energy sector – decarbonisation, digitalisation, decentralization, deregulation and democratization – the complexity implicit in the evolution of global and national energy systems puts an enormous premium on effective collaboration across disciplines. Beyond the technological dimensions of the energy system, there is strong need to integrate the perspectives of social sciences and the humanities that would include anthropology, psychology, economics and finance, political science, ethics, philosophy and historical perspectives on energy transitions. The goal is to shape the texture of societal decisions and how inclusive and effective we are in addressing the future challenges that meet the needs of every global citizen.

WISE acknowledges a gap in the University of Waterloo’s current approach to energy research, which is strongest in the natural sciences and engineering but lacks in the social sciences and humanities. In order to address this, WISE proposes to develop an Interdisciplinary Energy Research Visiting Fellows program. Through this program WISE will host 4-6 energy sector thought leaders from the social sciences and humanities, as well as the energy policy arena, for 3-4 month stays at Waterloo. Visiting fellows will collaborate with WISE faculty members and the WISE staff to advance a specific project that aims to create convergence in a critical area of energy policy debate that affects many stakeholders. The original content that this program generates will greatly expand the influence of WISE in national and global level energy policy debates.

To accomplish this objective, WISE is proposing an additional annual budget request of $80K for the Interdisciplinary Energy Research Visiting Fellows Program. A detailed breakdown and rationale is included in Section 5: Financial Summary.

**WISE Objectives:**

1) **Collaborate** with UW faculty members from the social sciences and humanities to advance thought-provoking ideas related to the five D’s of energy sector change: decarbonisation, digitalization, decentralization, deregulation and democratization.

2) **Reach out** to leading energy scholars and bring them to Waterloo to advance specific, timely projects that generate convergence and enhance interdisciplinarity both within the Waterloo energy innovation ecosystem and in wider energy policy debates.

3) **Influence** critical energy policy debates in Canada and globally (pipelines, stranded assets, subsidies, infrastructure investments, carbon pricing, etc.) through publication of an influential WISE working paper series and other avenues of dissemination of the outputs of the visiting fellows.
5. FINANCIAL SUMMARY
5.1 Financial Summary

Currently, WISE is supported by the Provost’s Office and in conformance with Policy 44 requirements, the WISE Executive Director reports to the Office of Research, VP Research. This is an operational budget that supports, primarily, the salaries of Institute Staff. The detailed breakdown of the Salary and the Operational expenses of the Institute for the period 2013-2018 are shown in Table 5.1.

In addition, WISE manages and administers funding from external organizations and partner organizations to support specific research programs and initiatives, Fellowships (for example the Energy Council of Canada) and internships for graduate and undergraduate students (i.e. the Queen Elizabeth Scholarship program). WISE Administrative activities include responses to calls for applications, selection and approval of research topics and proposals, financial and annual reporting, organizing and hosting visits and chairing meetings, and relationship management with partners. WISE and its members have been highly successful in leveraging industry funds through granting organizations, namely NSERC, NRC, OCE, MITACS and others.

Over the past 10 years, including Fiscal years 2013-2019, WISE has managed its activities and programs within budget – without deficits – for every year since its founding in 2008.

Please refer to the Table 5.2 for a summary of actual spending for the period 2013-2018 including data for the current Fiscal Year 2018-2019. As of January 30, 2019, WISE is projected to come within budget for Fiscal 2018-2019 with a likely carryover of approximately $8-10K.

Although WISE has played a prominent role in securing a significant level of funding for WISE members – in the order of $23 million over the past 5 years – the Institute has maintained a strong discipline in its internal management to focus on new research initiatives and enhance communication and outreach objectives. The level of administrative activity at WISE has increased over three-fold since its inception but we have maintained expenditures within the operating budget envelope provided by the Provost’s Office at a level of $350K per year.

The five-year financial plan for WISE for Fiscal 2020-2024 is summarized in Table 5.3.

- WISE is requesting funding support in the amount of $430K per annum. This is an additional request of $80K above the currently approved level of $350K per year. This level of financial support is necessary to achieve our aspirational goals and objectives set out in this Report and specifically to further enhance our capacity for Interdisciplinary Research at University of Waterloo. Please refer to Section 4.2.5 above and Table 5.2 for the ‘Rationale for an increase to our Operating Budget’.

- In addition, WISE will continue to seek to external funds to enhance the scope and scale of our activities to be recognized globally as an important source policy advice and research innovation in the energy sector.
Over the next five years, WISE will endeavor to incubate self-sustainable programs and initiatives consistent with our vision to deliver clean energy, affordable and accessible to all.
### 5.2 Use of Funds (Fiscal 2014 – Fiscal 2019)

**Table 5.2**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating (Provost Office)</td>
<td>200,000</td>
<td>250,000</td>
<td>250,000</td>
<td>300,000</td>
<td>350,000</td>
<td>350,000</td>
</tr>
<tr>
<td>Carry Forward</td>
<td>140,248</td>
<td>118,188</td>
<td>119,567</td>
<td>181,320</td>
<td>58,800</td>
<td>49,021</td>
</tr>
<tr>
<td>Salary Increase</td>
<td>2,288</td>
<td>2,173</td>
<td>2,761</td>
<td>1,584</td>
<td>4,086</td>
<td>10,030</td>
</tr>
<tr>
<td>External Support to WISE</td>
<td>-5,847</td>
<td>4,200</td>
<td>15,400</td>
<td>17,841</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Budget Total</strong></td>
<td>336,689</td>
<td>374,561</td>
<td>387,728</td>
<td>500,745</td>
<td>412,886</td>
<td>409,051</td>
</tr>
</tbody>
</table>

**Salary Expense**

| Staff Salaries                            | 163,942   | 134,081   | 161,645   | 205,012   | 264,392   | 214,001              |
| Co-op Students and Casuals (Part-Time)    | 24,362    | 42,360    | 45,992    | 27,199    | 48,858    | 22,129               |
| Associate Director - Stipends             | 10,000    | 10,000    | 8,250     | 6,667     | 0         | 0                    |
| **Base Funding - salaries**               | 188,304   | 176,441   | 207,637   | 232,212   | 313,250   | 236,130              |

**Operating Expense**

| Office (Supplies, Computers, Software, Telephones, Parking, Hospitality) | 9,202 | 8,386 | 8,504 | 21,224 | 23,224 | 11,087 |
| Travel (Accommodation, Car Rental, Mileage, Airfares)                    | 10,529 | 13,248 | 12,583 | 3,701 | 14,254 | 15,657 |
| Communication and Outreach (Public Lectures, Web, WISE Events, Publications) | 14,581 | 15,882 | 17,005 | 29,637 | 31,385 | 59,799 |
| Global Partnerships and Research Collaboration                            | 22,615 | 9,158 | 61,884 | 16,763 | 19,077 | 27,785 |
| **Base Funding - operating expense**                                       | 56,927 | 46,674 | 99,976 | 71,325 | 87,940 | 114,328 |

1 – This includes $50,000 for Hydro One projects and $11,000 for a Roxul project.
2 – This includes a WISE lecture/reception (approx. $1,100); SDTC workshop (approx. $1,600); CCRE 2017 forum (approx. $9,200); and decarbonisation forum (approx. $2,300).
3 – Promotion and advertising includes web cost (WISE & AE4H portal) approx. $13,000; professional editing approx. $1,500. In addition, hospitality includes approx. $5,000 for WISE Energy Day 2018.
4 – Promotion and advertising includes technical support (A/V equipment) for three events approx. $10,500; web cost approx. $7,900; professional editing approx.$1,600. In addition, hospitality includes RRPW 2018 approx. $11,500; building science symposium approx. $6,000; and CCRE forum 2018 approx. $7,000.
### 5.3 Budget Request (Fiscal 2020 – Fiscal 2024)

#### Table 5.3

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Budget (Request - Provost Office)</td>
<td>430,000</td>
<td>430,000</td>
<td>430,000</td>
<td>430,000</td>
<td>430,000</td>
</tr>
<tr>
<td><strong>Budget Total</strong></td>
<td>430,000</td>
<td>430,000</td>
<td>430,000</td>
<td>430,000</td>
<td>430,000</td>
</tr>
</tbody>
</table>

**Salary Expense**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Manager, Program Development, Partnerships and Finance</td>
<td>82,264</td>
<td>82,264</td>
<td>82,264</td>
<td>82,264</td>
<td>82,264</td>
</tr>
<tr>
<td>Manager, Global Programs and Initiatives</td>
<td>78,545</td>
<td>78,545</td>
<td>78,545</td>
<td>78,545</td>
<td>78,545</td>
</tr>
<tr>
<td><strong>WISE Interdisciplinary Research (IDR) Fellowship Program (Additional Funding Request)</strong></td>
<td>80,000</td>
<td>80,000</td>
<td>80,000</td>
<td>80,000</td>
<td>80,000</td>
</tr>
<tr>
<td>Communications Specialist</td>
<td>52,688</td>
<td>52,688</td>
<td>52,688</td>
<td>52,688</td>
<td>52,688</td>
</tr>
<tr>
<td>Administrative Assistant</td>
<td>54,164</td>
<td>54,164</td>
<td>54,164</td>
<td>54,164</td>
<td>54,164</td>
</tr>
<tr>
<td>Co-op Students and Casual Staff</td>
<td>20,000</td>
<td>20,000</td>
<td>20,000</td>
<td>20,000</td>
<td>20,000</td>
</tr>
<tr>
<td><strong>Base Funding - salaries</strong></td>
<td>367,661</td>
<td>367,661</td>
<td>367,661</td>
<td>367,661</td>
<td>367,661</td>
</tr>
<tr>
<td><strong>Operating Expense</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office (Supplies, Computers, Software, Telephones, Parking, Hospitality)</td>
<td>15,000</td>
<td>15,000</td>
<td>15,000</td>
<td>15,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Travel (Accommodation, Car Rental, Mileage, Airfares)</td>
<td>12,000</td>
<td>12,000</td>
<td>12,000</td>
<td>12,000</td>
<td>12,000</td>
</tr>
<tr>
<td>Communication and Outreach (Public Lectures, Web, WISE Events, Publications)</td>
<td>18,000</td>
<td>18,000</td>
<td>18,000</td>
<td>18,000</td>
<td>18,000</td>
</tr>
<tr>
<td>Global Partnerships and Research Collaboration</td>
<td>18,000</td>
<td>18,000</td>
<td>18,000</td>
<td>18,000</td>
<td>18,000</td>
</tr>
<tr>
<td><strong>Base Funding - operating expense</strong></td>
<td>63,000</td>
<td>63,000</td>
<td>63,000</td>
<td>63,000</td>
<td>63,000</td>
</tr>
<tr>
<td><strong>Base Funding Total</strong></td>
<td>430,661</td>
<td>430,661</td>
<td>430,661</td>
<td>430,661</td>
<td>430,661</td>
</tr>
</tbody>
</table>
Note to Table 5.3:
Rationale for additional funding for the Interdisciplinary Research (IDR) Fellows Program

- WISE acknowledges a gap in our ability to advance and strengthen Interdisciplinary Research (IDR) amongst colleagues in diverse departments and faculties at UW.

- Whereas we have been successful in bringing together external partners (businesses, industry, NGOs, government agencies) to establish large multidisciplinary projects for funding (in the $1-5 million range) on an opportunistic basis, we lack the academic strength to become the leading academic voice in the complex energy policy landscape, both in Canada and globally.

- In particular, our Advisory Council Members have made cogent observations on the need to engage colleagues in the social sciences and the humanities to help resolve and provide guidance to governments on the political and social challenges of energy infrastructure developments (ie. approvals of pipelines, transmission corridors, energy facilities etc...).

- There is a compelling need, from their perspective, for WISE to develop greater capacities outside of the natural science disciplines, in order to play a leadership role in enhancing constructive dialogue with stakeholder communities, including marginalized and indigenous peoples.

- With additional funding, we intend to set up a program that will bring in leading scholars for short stays at WISE where they will work with our members to develop interdisciplinary initiatives that address pressing energy sector challenges

- These initiatives will generate primary content. WISE will disseminate the outputs widely and provide a focal point for convening groups with strong divergent perspective to advance constructive dialogue and convergence. The products of the endeavor are ‘white papers’ fully researched and of high academic quality.

- The Visiting Fellows would collaborate closely with faculty members over selected time periods to create a marriage of social sciences, arts, philosophy, political science and the physical sciences and engineering.

- This will enable WISE to build a strong capacity to inform and guide decisions on the complex challenges at the interface of energy technology developments, society, philosophical and ethical issues and the broader political discourse.

- Fellows will be given desk space at WISE’s new location in EVOLV1. This space has already been secured.

- We propose to have visiting fellowships filled on a continuous basis. Fellowships will be 3-4 months in duration depending on the availability of fellows. We therefore estimate to host 4-6 visiting fellows per year (average of 5).

**BUDGET:** $80k/year is requested to run the program based on the breakdown of costs as follows:

<table>
<thead>
<tr>
<th>Budget Item</th>
<th>Cost/fellow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel to/from Waterloo</td>
<td>$2000</td>
</tr>
<tr>
<td>Fellowship budget (for research assistantship, meetings, etc.)</td>
<td>$2000</td>
</tr>
<tr>
<td>Fellowship stipend (average duration 3-4 months)</td>
<td>$7000</td>
</tr>
<tr>
<td>Accommodation in Waterloo</td>
<td>$5000</td>
</tr>
<tr>
<td><strong>TOTAL COST/FELLOW</strong></td>
<td><strong>$16,000</strong></td>
</tr>
<tr>
<td><strong>X5 FELLOWS/YEAR</strong></td>
<td><strong>$80,000</strong></td>
</tr>
</tbody>
</table>
Appendix I:
Letters of Support
April 15 2019

Dr. Charmaine Dean
Vice-President, Research and International
University of Waterloo

Dear Charmaine,

Subject: Renewal of Waterloo Institute for Sustainable Energy (WISE)

On Tuesday March 6th, the Chairs and Associate Deans (CAD) Committee of the Faculty of Engineering discussed a proposed 5-year renewal of the Waterloo Institute for Sustainable Energy (WISE). Such a decision must be made judiciously since it supports a request for a funding commitment of a minimum of $3.75M while the university is enduring government-mandated cutbacks. With this in mind, there was unanimous support by the leadership of the Faculty of Engineering for a renewal of WISE for a 5-year period assuming no increase in funding.

WISE has been an active and engaging centre that is the entry point for energy research at UW. There is wide support for WISE and the activities of this institute support and enhance UW research initiatives in the energy field. Notably, WISE launched the Affordable Energy for Humanity (AE4H), as part of the United Nations Sustainable Goal 7, taking the initiative for international development towards "affordable, reliable, sustainable, and modern" energy. WISE has directly supported students via Energy Council of Canada fellowships and Queen Elizabeth II Diamond Jubilee Scholarship Program. WISE activities include hosting numerous conferences and workshops including WISE Energy Day, Technology and Innovation and Policy Forum, and the Resource Recovery Partnership Workshops as well as an extensive public lecture series. Dr. Nathwani, in his leadership role as Director of WISE, has engaged widely as a media spokesperson in many different fora helping to promote the University of Waterloo.

The Engineering Research Office would be pleased to assist WISE in shaping and preparing proposals for large-scale funding opportunities that would benefit not only Engineering faculty members, but researchers from outside of Engineering to encourage and further foster interdisciplinary research.

We wish to address a concern by the Faculty leadership. This is related to the reporting of journals and graduate theses as "scholarly output" from WISE that are not representative of WISE activities. Such reporting detracts from the true initiatives, credibility, and impact of the Institute. We suggest that the renewal document only focus on the accomplishments of the Institute and not the successes of the members resulting from their efforts. A more focused approach would also reduce the administrative burden when creating the renewal document. Our recommendation is to remove these citations for the submission to Senate Graduate & Research Council and then Engineering would be pleased to provide an updated letter of support before review by SGRC.

Yours truly,

Pearl Sullivan
Dean, Faculty of Engineering
April 17, 2018

Dr. Jatin Nathwani, Executive Director
Waterloo Institute for Sustainable Energy (WISE)
University of Waterloo
200 University Avenue West
Building RAC 2119
Waterloo, ON N2L 3G1

RE: Support for WISE Renewal

Dear Professor Nathwani:

On behalf of Union Gas, I am pleased to provide this letter of support for the Waterloo Institute for Sustainable Energy (WISE).

The energy industry is continually evolving and we see dramatic changes in the way energy is generated, transmitted and delivered to customers. Our goal is to help Ontario and Canada meet its aspirational goals of a lower carbon energy economy while balancing the economy and energy affordability. WISE has contributed significantly to the public dialogue for a rational discourse and as an educational organization, plays a critical role. Union Gas promotes energy efficiency and is committed to a clean and affordable energy system that is easily accessed by all of our customers. Our objectives are very well aligned with those of WISE.

We continue to focus on innovative solutions that promote long term sustainability. We have been fortunate to be able to collaborate with the University of Waterloo and with WISE on many projects such as advancing the concepts of a ‘Smart Energy Network’ that extends the concepts beyond a smart electricity grid. Real world issues require thought leaders from diverse backgrounds and perspectives. WISE as a multi-disciplinary institute provides what we see as leading researchers from many areas, both local and international, coming together to help advance innovative solutions for the energy sector and the broader economy.

I have been fortunate to personally be involved in many forums and conferences in our industry. I notice that faculty and researchers from WISE are sought after speakers for many events. In particular, the views and research of Dr. Nathwani and his associates are always relevant and most helpful in shaping attitudes around energy policy to positively affect our lives and the impact on the global environment.

It is my hope that WISE continues its work, research and engagement within the energy sector. Union Gas looks forward to continued involvement with Dr. Nathwani and the well qualified associates at WISE to continue focusing on the research, knowledge and solutions that will benefit the energy sector and broader economy in Ontario.

Sincerely,

Steve Baker

Union Gas Limited, 50 Kell Drive North, Chatham, ON. N7M 5M1 tel. 519 436 5200 email sbaker@uniongas.com
Appendix I – Letters of Support

April 17, 2018

Dr. Jatin Nathwani
Executive Director, Waterloo Institute for Sustainable Energy (WISE)
University of Waterloo

RE: Letter of Support for WISE Renewal

I am pleased to support the renewal of the mandate for the Waterloo Institute for Sustainable Energy (WISE) for the next 5 years. In a short period of time, WISE has built critical mass in energy expertise and has demonstrated thought leadership in the Province by providing a clear, long-term vision for a sustainable energy future.

WISE’s mission of conducting original research and developing innovative solutions and policies continues to provide valuable support for the transformation and long-term sustainability of the energy sector. In that regard, I have had the pleasure of working with Dr. Nathwani and watching the evolution of WISE. Professor Nathwani has been a consistent long-term contributor to the Ontario Smart Grid Forum, a role that I trust he and WISE will continue as the Forum is recast as the Energy Transformation Network of Ontario.

WISE researchers have been valuable partners in many industry-led projects, with a good reputation for delivering insightful analysis and results in a timely fashion. The sector has also appreciated WISE’s ability to bring together teams of multi-disciplinary researchers - both from within WISE and from the wider research community - to address some of the major challenges faced by Ontario’s energy system.

I would also note the leadership exhibited by Professor Nathwani and WISE in addressing the global challenge of universal energy access - bringing together 150 researchers and thought leaders from 50 institutions in 30 countries to forge the “Global Change Initiative - Affordable Energy For Humanity”. Aiming to harness scientific and technological innovations to help reduce energy poverty globally, this work also has the potential to create new opportunities and markets for Ontario and Canadian entrepreneurs.

WISE is widely recognized as a leader by industry, as demonstrated by the selection of WISE as the home for the Hydro One Chair in Power Engineering and the Cisco Systems Research Chair in Smart Grid. Similarly, Union Gas has supported innovative work at WISE that has promoted a more integrated approach to energy systems, driving a vision for integrated smart energy networks to provide clean, accessible and affordable energy.

In short, WISE is to be congratulated on its many accomplishments over the last 5 years. I have no hesitation in recommending, and strongly supporting, the renewal of the mandate for the Waterloo Institute for Sustainable Energy. Please feel free to share this note in pursuit of that renewal.

Sincerely,

Bruce B. Campbell

Immediate Past President and CEO
Independent Electricity System Operator
April 18, 2018

Dr. Jatin Nathwani
Executive Director, Waterloo Institute for Sustainable Energy (WISE)
University of Waterloo

RE: Support for WISE Renewal

Dear Prof. Nathwani,

I am pleased to write this letter on behalf of the Independent Electricity System Operator (IESO) in support of the great work done by the Waterloo Institute for Sustainable Energy.

Ontario’s evolving electricity landscape is presenting new challenges to the way the IESO operates Ontario’s electricity system. In its endeavour to maintain reliability and develop solutions to these emerging challenges, the IESO has often consulted with external organizations that present innovative ideas to address some of the issues Ontario is facing.

In this respect, the Waterloo Institute for Sustainable Energy has been an instrumental partner of the IESO, providing valuable insights on the evolution of Ontario’s electricity sector and on emerging trends around the world. On multiple occasions, the IESO has specifically sought the expertise of Professor Ian Rowlands and from you, in your role as a contributing member to the newly formed Electricity Transformation Network for Ontario (ETNO and formerly the Smart Grid Forum).

WISE’s international, cross-discipline and collaborative approach to energy research promotes truly forward thinking that is shaping the future of the electricity sector in Ontario.

The IESO looks forward to continued collaborations with the Waterloo Institute for Sustainable Energy, as their leading research creates benefits for the operations of Ontario’s electricity system and ultimately, to Ontario consumers.

Regards,

Peter Gregg
President and CEO
To Whom It May Concern:

Re: Letter of Support – Jatin Nathwani – Executive Director of WISE

This letter of support recognizes the role and contribution of the Waterloo Institute of Sustainable Energy (WISE), and specifically of Jatin Nathwani, as its Executive Director.

As an industry participant in WISE’s Advisory Council, I’ve had the opportunity over the past few years to interact with both Jatin and other representatives of WISE. Over that period, I’ve been impressed by the caliber of the people involved and the meaningful efforts undertaken in support of broad energy policy development and energy technology research and innovation. I particularly commend WISE’s approach to bringing together a range of industry participants, energy policy makers and technology development proponents.

Jatin, specifically has done an admirable job in reaching out and engaging diverse energy sector participation, bringing together varied technical, economic and social policy considerations and expertise, and articulating in a very compelling manner energy policy options and development paths. Jatin effectively bridges the academic and real world policy/business perspectives.

As Executive Director – Investments of OPG Ventures (Ontario Power Generation’s corporate energy technology venture capital business) for the last 15+ years, I’m also impressed by the University of Waterloo’s commitment to practical technology development and innovation, including its leading edge Velocity entrepreneurship program.

I would be pleased to further share my experiences and perspectives as may be desired.

Regards,

Andrew (Andy) Teichman, M.Eng., MBA, P.Eng.
VP Corporate Strategy & Planning
Ontario Power Generation Inc.
a.teichman@symcatico.ca
416-828-3725
Energy Council of Canada
Conseil canadien de l’énergie

May 1, 2018

Dr. Jatin Nathwani
Executive Director, Waterloo Institute for Sustainable Energy (WISE)
University of Waterloo

RE: Support for WISE Renewal

Dear Prof. Nathwani,

I am writing in support of the Waterloo Institute for Sustainable Energy (WISE) and the renewal of its mandate by the Senate Graduate and Research Council (SGRC) at the University of Waterloo.

The mission of the Energy Council of Canada is to bring its members and energy stakeholders together to forge a better understanding of Canada’s energy opportunities and issues with the aim to optimally shape an affordable, stable and environmentally-sound energy system for the benefit of all Canadians.

WISE objectives closely reflect the goals of our organization and help us achieve them. It has been the Energy Council of Canada’s pleasure to support your organization’s efforts which have achieved advances in improving overall energy literacy while also fostering more specialized research. WISE has a unique ability to both delve into the more complex questions related to Canadian energy while also making their findings accessible and more generally useful to the broader range of stakeholders we seek to engage.

On behalf of the Energy Council of Canada, I am pleased to recognize WISE for its efforts in helping transform the energy sector and I encourage the SGRC to confirm and renew the institute’s mandate for an additional five-year term.

Sincerely,

Colin Andersen
Chair, Energy Council of Canada
April 23, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy (WISE)
University of Waterloo

RE: Support for WISE Renewal

Dear Dr. Nathwani,

I am pleased to write this letter in support of the excellent work done by the Waterloo Institute for Sustainable Energy (WISE). The Institute has grown in strength and reputation and is now well regarded as an important contributor to energy policy and energy research in Ontario and throughout Canada.

Ontario’s energy landscape is changing and new technologies present a significant opportunity to make our electricity systems better. As noted in the 2017 Long-Term Energy Plan, Ontario is taking the lead in Canada and abroad in the global fight against climate change. The energy sector will play a role in meeting this challenge.

The Ministry of Energy recognizes the ongoing transformation in the energy sector and the opportunities for innovation it presents. WISE brings together strong multidisciplinary expertise of a large number of faculty to develop and implement large-scale research projects in collaboration with business, industry, governments and civil society groups to address these opportunities. The scope and scale of energy research at WISE spans the full range of promising energy technologies, including energy storage, smart grid and smart energy networks, information and communications technology, and support for microgrids and off grid access.

We are modernizing the electricity system for the customer of tomorrow, who will directly participate in a more efficient, reliable and cost-effective system. Ontario customers will have choices to participate in clean, renewable energy while saving money on their electricity bills, supported by an enhanced net metering framework. Increased penetration of renewable distributed generation and other distributed energy resources will drive innovation and new opportunities. The future of electricity in Ontario will also incorporate innovative uses of the province’s natural gas distribution systems, electrification of transportation, and flexibility and choice for customers.
I am pleased to note that the Institute is working to ensure that Ontarians realize the full benefit of this ongoing transformation. For instance, your role with the Energy Transformation Network of Ontario, working closely with key stakeholders and policy makers of Ontario's electricity sector and providing valuable insights on emerging trends, regulation, and opportunities for partnership with Ontario’s post-secondary institutions.

I am also pleased to acknowledge the Institute’s leadership to help meet the global challenge of universal energy access. The ‘Global Change initiative – Affordable Energy for Humanity’ is an impressive effort to bring scientific and technological innovations to help reduce energy poverty globally. This will not only create positive change in the lives of Ontarians, but it also has the potential to create new enterprises and markets for Ontario and Canadian entrepreneurs.

I strongly support renewal of WISE and we look forward to future collaboration and WISE’s continued contribution to Ontario’s sustainable energy future.

Regards,

Serge Imbrogno
Deputy Minister of Energy
April 11, 2018

Dr. Jatin Nathwani
Executive Director, Waterloo Institute for Sustainable Energy (WISE)
University of Waterloo

RE: Support for WISE Renewal

Dear Prof. Nathwani,

I am writing in respect to Dr. Jatin Nathwani and the Research Chair in Public Policy for Sustainable Energy. I understand that the renewal for the mandate of the Waterloo Institute for Sustainable Energy (WISE) by the University’s Senate and Graduate Research Council (SGRC) is being considered for renewal for the next five years.

As the Chairman of the Council for Clean and Reliable Energy, I have had the pleasure of working with Professor Nathwani and WISE for the past several years. At this time I have significant appreciation for the contribution he and WISE have made to policy discussions. This is at a time when independent policy research and debate is needed in the areas of public policy and energy. There are very few organizations participating in this debate that do not exhibit a conflict of interest.

Their vision is simple: to look at ways to provide clean energy that is accessible and affordable to all. WISE accomplishes this by conducting original research and developing innovative solutions and policies to help transform the energy system for long-term sustainability. This is critical as they bring together leading researchers from dozens of disciplines while reaching out to many partners. Their partnerships include industry leaders, government and the non-profit sector that collectively work towards creating sustainable energy solutions. WISE is unique in its ability to do this and such efforts need to continue.

In conclusion, WISE’s research and participation contributes to fact based independent dialogue. This contribution has a very meaningful role in the development of effective policy here in Ontario, Canada and a broader global dialogue.

I strongly encourage the SGRC to approve WISE for the next five years. I speak to this as the Chairman for Clean and Reliable Energy and my former role as Chairman of the Joint Public Advisory Committee of the Commission for Environmental Cooperation. I am confident that their research is cutting edge and is needed as we go forward in the field of developing and sharing ways of creating sustainable, reliable energy for society’s needs.

Yours sincerely,

Glen Wright, Chairman
Council for Clean and Reliable Energy
March 20, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Prof. Nathwani,

I write to lend my support for the renewal of WISE for the role it has played in many aspects of research and networking in the domains of energy, power, blockchain, information and communication applications, environmental economics, climate control technologies, and addressing the importance of low-carbon emission solutions.

WISE has excelled in advancing the agenda of low carbon R&D projects through industry-academic partnerships. WISE management has provided strong support to my research initiatives through workshops, conferences, seminars, public lectures, research spotlights, and creating initial contacts with potential industry partners in the power and energy sector.

WISE has been a key contributor in raising Waterloo’s profile both at the Canadian and global context in terms of getting recognition for excellence and innovation in research, scholarship and education, and building greater awareness of our research productivity and impact.

I would also like to acknowledge WISE’s role in enhancing student opportunities to participate in entrepreneurial activities, and advancing commercialization and other forms of utilization of leading-edge entrepreneurial research and intellectual property.

I strongly support WISE and look forward to additional collaboration with the Institute in the near future.

Yours truly,

[Signature]

Dr. Ranjini Jha
Associate Professor – School of Accounting and Finance
HH – 383H
200 University Ave West
Waterloo, ON N2L 3G1
519-888-4567, ext. 35703
rjha@uwaterloo.ca
April 18, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Prof. Nathwani,

I would like to express my strong support for the renewal of WISE so that it can continue and expand on the work it does in support of research and networking. I have been a member of WISE for many years, and have participated in a number of activities including workshops and conferences, seminars, and industry networking and introduction opportunities. The WISE management has provided strong support to these and other activities, and also to several of my research initiatives.

In recent years, WISE has provided logistical and networking support for an initiative that I started in 2014, namely a workshop on solid waste management opportunities and research needs, including energy from waste challenges. This proved to be highly successful and led to a collaboration with the Canadian Plastics Industry Association and other industry, government and NGO partners. We are now approaching our 5th annual event in June 2018, which has expanded this year to a two-day conference (Resource Recovery Partnership Conference) with speakers and participants from across North America and even Europe. Attendees over the past four years have emphasized the value they see in this activity, and how they appreciate learning about the complex and integrative role that energy plays in materials recovery, recycling, and various energy from waste alternatives. These successful events would not have been possible without the leadership and support from WISE and their network.

On a more personal level, these events have led to several research grant and contract awards for my group, and the raising of awareness of Waterloo’s capabilities in a wide variety of research areas related to climate change, waste reduction, materials transformation and policy development.

Overall, I can readily confirm that WISE has been a key contributor in raising Waterloo’s profile both at the Canadian and global context in terms of getting recognition for excellence and innovation in research, scholarship and education, and building greater awareness of our research productivity and impact.

I would also like to acknowledge and support WISE’s role in enhancing graduate and undergraduate student opportunities to participate in entrepreneurial activities, and advancing commercialization and other forms of utilization of leading-edge entrepreneurial research and intellectual property.

I strongly support WISE and look forward to additional collaboration with the institute in the near future.

Yours truly,

[Signature]

Dr. William A. Anderson, P.Eng.
Professor, Chemical Engineering
E6 – 3018
519-888-4567, ext. 35011
wanderson@uwaterloo.ca

200 UNIVERSITY AVENUE WEST, WATERLOO, ON, CANADA N2L 3G1
Letter of Support – Waterloo Institute for Sustainable Energy

I strongly support renewal of the WISE mandate a central contact point at Waterloo for the promotion of energy related research at our institution. Energy is key feature of Canada’s economic future, and Waterloo has a strong profile in energy related research largely due of the efforts of WISE. I strongly feel that energy related research funding will be growing in the future and that ‘Energy Research’ can be a key and unique strategic thrust for Waterloo that distinguishes Waterloo from other institutions.

WISE has played in supporting my research efforts through the coordination of workshops, promotion of Waterloo research activities, and coordinating initial contact with potential industrial sponsors. I have participated in numerous WISE activities such Energy Days and the annual public workshops where I have been able to network with industrial partners.

WISE has been fundamental in raising Waterloo’s profile with key organizations in Ontario and at the federal level, specifically Ontario Centre of Excellence and other key organization within the Provincial Government. With the implementation of the Ontario’s ‘Cap and Trade’ program WISE has the potential to key role in ensuring that the University of Waterloo plays a role associated projects in the future.

Michael Fowler  
Professor  
Chemical Engineering  
University of Waterloo  
519-888-4567 ext 33415  
mfowler@uwaterloo.ca
Dr. Jatin Nathwani
Professor and Ontario Research Chair in Public Policy for Sustainable Energy
Executive Director, Waterloo Institute for Sustainable Energy (WISE)
Faculty of Engineering and Faculty of Environment
University of Waterloo
Waterloo, ON, N2L 3G1

March 20, 2018

Dear Dr. Nathwani:

I am writing to strongly support the renewal of the WISE mandate. My research is in the area of catalysis and green engineering for the production of sustainable and clean fuels. Since 2008 I started to work on the production of biodiesel from waste oils, fats or non-food grade oils. I also worked on and have patents on the production of green high octane gasoline and jet fuel. I have a number of Ph.D. students, postdoctoral fellows and undergraduate research students and co-op students working on novel processes to produce sustainable and clean fuels from bio-resources. My students working on these projects are now successful researchers working on various aspects of clean and sustainable energy in industry and Government. One Ph.D. student has recently started a successful commercial biodiesel plant in China. The plant is producing biodiesel which is sold in China and European Union.

WISE has provided an opportunity for colleagues to work collaboratively across the University. WISE has organized workshops, seminars and meetings with various industry and Government organizations; such activities provide us an opportunity to showcase our research or get introduced to potential users and funding agencies for our research. The spotlight of our research on the WISE website also help to increase the visibility of our research to the outside community. In summary, WISE has played an important role to foster research collaboration and increase our visibility to potential research partners both in industry and Government. I strongly support the renewal of the WISE mandate.

Yours sincerely,

[Signature]

Flora T.T. Ng, FCIC, FRSC
University Professor
February 7, 2018

Dear Jatin,

I write to **strongly support** renewal of the WISE mandate. WISE has played an incredibly supportive role in my research in the last eight years. Indeed, I think that I could not do the work I am doing now if it were not for WISE. Let me elaborate.

My background is in computer networking, an area I have been working in since 1988. About ten years ago, I got interested in energy systems and in early 2010 I decided to work full-time in the area of intelligent energy systems, at the intersection of information technology and energy systems. One of my first steps was to approach WISE, which was, as it turned out, a very fortuitous move. WISE provided me with the ideal environment to become familiar with the underlying technical issues and to make contact with like-minded researchers. WISE also introduced me to numerous industry partners that resulted not only in my being able to ground my work in real-world constraints but also in my being awarded the Cisco Chair in the Smart Grid in 2012.

As I look back, I can identify numerous specific instances where WISE has played a key role in my research work, including:

- **Introducing me to technical leads at Hydro One that gave me insights into Ontario’s Smart Grid initiatives and challenges**
- **Arranging for my student to do an internship at Hydro One in 2010: this student subsequently has played a key role in educating my other students**
- **Helping me to obtain matching funds from Hydro One for an NSERC strategic grant as well as a CRD**
- **Introducing me to several innovative startups that resulted in my becoming aware of cutting-edge technologies and significant levels of collaboration including access to real-world data and paper co-authorship**
- **Through the AE4H initiative, opening a new area of research for me in energy access for developing regions, and more specifically, putting me in touch with end-users and researchers in this area**
- **Bringing me together with faculty in Management Sciences (Łukasz Golab), ECE (Prof.s Canizares, Kazerani, and Bhattacharyya), Geography (Prof.s Rowlands and Parker), School of Planning (Prof. Jennifer Dean and Dr. Sara Edge), Civil Engineering (Prof.s Narasimhan and Tolson) to form productive partnerships that have led to significant funding from entities such as NSERC, Hydro One, IBM, City of Guelph, and CIHR, to name but a few.**
- **Introducing me to executives from Cisco Systems that eventually led to my**
selection as a Cisco Chair

- Promoting my work with industry leaders, including a presentation at the Ontario Smart Grid Forum
- Giving me and my group access to presentations and tutorials from the latest industry conferences
- Doing the spadework necessary for my group to obtain data from EV dealers in KW as well as smart water-meter data from the City of Abbotsford, BC
- Highlighting my work on the WISE website

It should be evident from this long list that WISE has been instrumental in advancing my research work, as it has for numerous other researcher at Waterloo. Thus, I am very much in favour of its renewal, so that it can continue to play an essential supportive role.

Whenever I travel out of Waterloo, I mention to other researchers about all that WISE has to offer, and how much it has helped me. They are uniformly impressed and wish that their universities could give them this level of support. We are very fortunate to have this entity at Waterloo. I would therefore like to offer my strongest possible recommendation that WISE’s mandate be renewed.

Sincerely,

\[ \underline{\text{Srinivasan Keshav}} \]

Professor, ACM Fellow, IEEE Senior Member  
David R. Cheriton School of Computer Science  
University of Waterloo

**Brief Biography**

I received a Ph.D. in Computer Science from the University of California, Berkeley in 1991. I subsequently was a researcher at AT&T Bell Laboratories and an Associate Professor at Cornell University, holding an Alfred Sloan Fellowship. I left academia in 1999 to co-found Ensim Corporation and GreenBorder Technologies Inc. in Silicon Valley, returning as an Associate Professor at the University of Waterloo in 2003. I have been a Professor since 2008, holding first a Canada Research Chair and subsequently the Cisco Chair in Smart Grid.
March 20, 2018

Dr. Jatin Nathwani  
Executive Director  
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Prof. Nathwani,

This is to convey my support for the renewal of WISE for the role it has played in my career by helping me connect to proper industries in the domains of energy, power, geotechnical engineering, and energy geomechanics, and addressing the importance of sustainability and energy resilience in my research. WISE has helped me secure multiple funding with different industry partners through NSERC and I look forward to such bridging with industry partners in the future.

I am aware that WISE has excelled in advancing the agenda of low carbon R&D projects through industry-academic partnerships. I am extremely pleased with WISE management that has provided a strong support to my research initiatives through workshops, conferences, seminars, public lectures, and creating initial contacts with potential industry partners in the geotechnical and energy sectors.

WISE has been a key contributor in raising Waterloo’s profile both at the Canadian and global context in terms of getting recognition for excellence and innovation in research, scholarship and education, and building greater awareness of our research productivity and impact. I myself have promoted WISE in places like India because I believe that WISE has a global reach in capacity and stature.

I am happy to note WISE’s role in enhancing student opportunities to participate in entrepreneurial activities, and in advancing commercialization and other forms of utilization of leading-edge entrepreneurial research and intellectual property.

I strongly believe that WISE is an indispensable part of UW and support its existence and future activities. I would like to have greater collaborations with WISE in the future.

Yours truly,

Dipanjan Basu
Dr. Dipanjan Basu  
Associate Professor – Civil and Environmental Engineering  
E2 – 2308  
200 University Ave West  
Waterloo, ON N2L 3G1  
519-888-4567, ext. 31284  
dipanjan.basu@uwaterloo.ca
April 6, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Prof. Nathwani,

I would like to express my strongest support for the renewal of WISE for its contributions to many research and networking activities encompassing energy, power, geologic engineering, smart infrastructure, climate control technologies, and green applications.

WISE provides great visibility to UW’s leadership position in the area of green technologies and has excelled in advancing the agenda of low carbon R&D projects through industry-academic partnerships. WISE management has provided strong support to my research initiatives through workshops, conferences, seminars, public lectures, research spotlights, and creating initial contacts with potential industry partners in the power and energy sectors.

WISE has been a key player in raising Waterloo’s profile in both Canadian and global contexts in terms of getting recognition for excellence and innovation in research, scholarship and education, and building greater awareness of our research productivity and impact.

I would also like to acknowledge WISE’s role in enhancing student opportunities to participate in entrepreneurial activities, and advancing commercialization and other forms of utilization of leading-edge entrepreneurial research and intellectual property.

I strongly support WISE and look forward to additional collaboration with the institute in the near future.

Yours truly,

Dr. Sriram Narasimhan
Associate Professor, Canada Research Chair – Civil and Environmental Engineering
E2 – 2325
200 University Ave West
Waterloo, ON N2L 3G1
519-888-4567, ext. 38081
snarasim@uwwaterloo.ca
April 5, 2018

Dr. Jatin Nathwani
Executive Director, WISE
University of Waterloo

RE: Support for WISE Renewal

Dear Dr. Nathwani,

I am writing to you to express my strong support for the renewal of WISE. The institute has grown in strength and reputation and is now well regarded as an important contributor to energy policy and energy research in Canada.

I wish to acknowledge my personal gratitude and also highlight the critical role you have played in helping me set up the NSERC-UNENE IRC here at Waterloo. Your insights in shaping the technical direction of the IRC was crucial to success. The subsequent guidance that you have provided through your leadership as Chair and Board member of UNENE for over a decade has raised the reputation of UW within industry circles including the Canadian Nuclear Safety Commission.

My NSERC-UNENE IRC has brought financial benefit to University of Waterloo in the order of $6 million and renewal of the IRC will add to further creation of HQP’s. Apart from your continued support to my IRC program, I wish to underscore the fact that WISE has provided valuable infrastructure to my IRC program and new contacts with the energy industry world-wide. I must say that WISE staff continue to provide tangible support for organizing several meetings, workshops and disseminating our work, in addition to day to day administrative support.

WISE has become the most recognized name in the industry and successfully serves as a platform to bring together a diverse community of researchers and create new ideas and projects. The most notable example is my collaboration with Professor Giovanni Cascante that has resulted in a sizable grant from Hydro One, OCE, Waterloo North Hydro, and NSERC. One signature development is a distribution asset management model to enhance resilience of critical electricity infrastructure.

I remain truly indebted to your help and contributions. Looking ahead, I think the best years in energy research are still ahead of us. I remain confident that WISE will play a crucial role in advancing solutions for a global energy system with a low-carbon energy footprint.

With best regards,

[Signature]

Professor M. Pandey, PhD, P.Eng
NSERC/UNENE Industrial Research Chair in Risk and Life Cycle Management
Department of Civil and Environmental Engineering
(519) 888-4567-35858
mdpandey@uwaterloo.ca
www.watrisk.ca
March 15, 2018

Dr. Jatin Nathwani  
Executive Director  
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Prof. Nathwani,

I am writing to express my strong support for the Waterloo Institute for Sustainable Energy (WISE).

WISE brings together a wide variety of platforms focused on sustainable energy technologies, systems and policies. As a University institute, WISE has continued to assist many faculty members of the Department of Chemical Engineering (21 faculty members in CHE are active WISE members) in stewarding multiple R&D initiatives since its inception. Sustainable energy is of strategic importance to the Department of Chemical Engineering. Of particular importance to our Department, WISE has lent its support to multi-disciplinary research initiatives in the areas of low carbon energy technologies, such as CO2 utilization, which directly benefited a newly hired faculty member. WISE management has played a significant role in establishing and maintaining effective working relationships with the industry partners, government officials, academic researchers, and young entrepreneurs.

WISE has always provided substantial strategic leadership and administrate support to advance research projects, conferences, workshops (e.g. WISE helped organizing an NSERC Partnership Workshop on Smart Energy Network), and other academic activities (such as initial coordination with potential industry partners) to create a strong value for the Waterloo ecosystem. WISE has been a key contributor to the university’s broad advocacy and engagement strategy and ongoing awareness campaign for the internal & external community emphasizing the importance of research and commercialization.

Through this letter, I acknowledge WISE’s role in nurturing industry-academic relationship and bringing a unique technical capacity to integrate and develop diverse elements of major multi-disciplinary research initiatives and proposals for funding.

I continue to support WISE and look forward to our Department’s collaboration with the institute in the future.

Yours truly,

Dr. Eric Croiset  
Professor & Department Chair – Chemical Engineering  
E6 – 3020  
200 University Ave West  
Waterloo, ON N2L 3G1  
519-888-4567, ext. 36472  
ecroiset@uwaterloo.ca
Dear UW Reviewers,

I am writing as Chair of the Department of Systems Design Engineering, regarding the review and renewal of the Waterloo Institute for Sustainable Energy (WISE).

WISE was launched as an Institute in 2008 to provide a mechanism for facilitating and supporting energy research within the university. Since its inception, WISE has made admirable efforts to draw in members from various academic units across the university and has become the external face of energy research for the university. I do believe it is meaningful to have a single point of contact for industry and government to engage with energy researchers from different faculties.

From the perspective of Systems Design Engineering, we have five faculty associated with WISE. Of those five, only one is particularly active or connected to WISE, however that individual has benefitted strongly from WISE seminars, interactions, and industry research connections, which indeed have led to a number of new research grants coming into the department.

I see a centre which has a successful research agenda and which provides important links bringing together a wide variety of researchers on campus. I also feel that the sustainable energy domain is an essential one for Waterloo to be involved, and where further visibility and presence is badly needed. I very much support the renewal of Waterloo Institute for Sustainable Energy.

Sincerely,

Paul Fieguth
Professor and Chair
Systems Design Engineering
University of Waterloo
Waterloo, Ontario, Canada

https://uwaterloo.ca/systems-design-engineering/
April 9, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Prof. Nathwani,

I am writing to express my strong support for the Waterloo Institute for Sustainable Energy (WISE).

WISE brings together a wide variety of platforms focused on sustainable energy technologies, systems and policies. As a University Institute, WISE has continued to provide assistance to the faculty members of the Department of Electrical and Computer Engineering in stewarding multiple R&D initiatives since its inception. WISE management has played a significant role in establishing and maintaining effective working relationships with industry partners, government officials, academic researchers, and young entrepreneurs.

WISE has always provided substantial strategic leadership and administrated support to advance research projects, conferences, workshops, and other academic activities to create a strong value for the Waterloo ecosystem. WISE has been a key contributor to the university’s broad advocacy and engagement strategy and ongoing awareness campaign for the internal & external community emphasizing the importance of research and commercialization.

Through this letter, I acknowledge WISE’s role in nurturing industry-academic relationship and bringing a unique technical capacity to integrate and develop diverse elements of major multi-disciplinary research initiatives and proposals for funding.

I continue to support WISE and look forward to our Department’s collaboration with the Institute in the future.

Sincerely,

Vincent Gaudet, PhD, P.Eng.
Professor and Chair
Department of Electrical and Computer Engineering, Faculty of Engineering
519-888-4567, ext. 84016
vgaudet@uwaterloo.ca
March 5, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Prof. Nathwani,

I am writing to express my support for the Waterloo Institute for Sustainable Energy (WISE) in the strongest possible terms.

WISE brings together a wide variety of platforms focused on sustainable energy technologies, systems and policies. As a University institute, WISE has continued to provide assistance to the faculty members of the Department of Civil and Environmental Engineering in stewarding multiple R&D initiatives since its inception. WISE management has played a significant role in establishing and maintaining effective working relationships with the industry partners, government officials, academic researchers, and young entrepreneurs.

WISE has always provided substantial strategic leadership and administrate support to advance research projects, conferences, workshops, and other academic activities to create a strong value for the Waterloo ecosystem. WISE has been a key contributor to the university’s broad advocacy and engagement strategy and ongoing awareness campaign for the internal & external community emphasizing the importance of research and commercialization.

Through this letter, I acknowledge WISE’s role in nurturing industry-academic relationship and bringing a unique technical capacity to integrate and develop diverse elements of major multi-disciplinary research initiatives and proposals for funding.

I continue to support WISE and look forward to our Department’s collaboration with the institute in the future.

Sincerely,

Dr. Carl T. Haas
Professor & Department Chair – Civil and Environmental Engineering
E2 – 2346C
200 University Ave West
Waterloo, ON N2L 3G1
519-888-4567, ext. 35492
chaas@uwaterloo.ca
March 13, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Prof. Nathwani,

I am writing to express my support for the Waterloo Institute for Sustainable Energy (WISE) in the strongest possible terms.

WISE brings together a wide variety of platforms focused on sustainable energy technologies, systems and policies. As a University institute, WISE has continued to provide assistance to the faculty members of the Department of Earth and Environmental Sciences in stewarding multiple R&D initiatives since its inception. WISE management has played a significant role in establishing and maintaining effective working relationships with the industry partners, government officials, academic researchers, and young entrepreneurs.

WISE has always provided substantial strategic leadership and administrate support to advance research projects, conferences, workshops, and other academic activities to create a strong value for the Waterloo ecosystem. WISE has been a key contributor to the university’s broad advocacy and engagement strategy and ongoing awareness campaign for the internal & external community emphasizing the importance of research and commercialization.

Through this letter, I acknowledge WISE’s role in nurturing industry-academic relationship and bringing a unique technical capacity to integrate and develop diverse elements of major multi-disciplinary research initiatives and proposals for funding.

I continue to support WISE and look forward to our Department’s collaboration with the institute in the future.

Sincerely,

Dr. David L. Rudolph
Professor & Department Chair – Earth and Environmental Sciences
EIT – 2033
200 University Ave West
Waterloo, ON N2L 3G1
519-888-4567, ext. 36778
drudolph@uwaterloo.ca
March 21, 2018

Dr. Jatin Nathwani
Executive Director, WISE

RE: Support for WISE Renewal

Dear Prof. Nathwani,

It is my pleasure to write this letter of support for the renewal of the Waterloo Institute for Sustainable Energy (WISE). Since its establishment, the Institute has played a significant role in many aspects of research and networking in the domains of energy, power, geologic engineering, climate control technologies, promoting low-carbon emission ideas and applications meeting current global demand of energy production with environmental constraints.

WISE has had great success in connecting researchers from the University of Waterloo with industry partners resulting in several fruitful industry-academic collaborations. The WISE management team has effectively connected researchers with potential industry partners and a variety of funding agencies through workshops, conferences, seminars, public lectures and research spotlights.

Additionally, after the initial connection is established, WISE provides substantial support in grant application processes for both large-scale multidisciplinary projects and individual applications. Recently, with a great amount of support from WISE, I was successful in securing an NSERC Engage Grant. I would also like to acknowledge WISE’s role in enhancing student opportunities to participate in research and entrepreneurial activities.

The support from WISE staff to help out on various R&D projects is really appreciated. I would like to emphasize one of the core competencies of WISE and that is to develop projects for the faculty members, manage those projects, and keep them alive with additional support by securing further funding from the private sector companies.

The positive attitude of the WISE management helps to run the projects smoothly. I truly appreciate WISE efforts and strongly support the WISE renewal.

Sincerely,

[signature]

Dr. Yuri Leonenko
Associate Professor – Earth and Environmental Sciences,
Geography and Environmental Management
EIT – 2048
200 University Ave West
Waterloo, ON N2L 3G1
519-888-4567, ext. 32160
leonenko@uwaterloo.ca
Dr. Jatin Nathwani  
WISE - Waterloo Institute for Sustainable Energy

Dear Jatin:

I would like to re-iterate my appreciation of your leadership of WISE, and thank you for the valuable discussions and advice you have given us in our pursuit of leading-edge research and innovation in the area of subsurface energy. I am clearly a strong supporter of WISE, and WISE has the potential to continue to grow and become a strong body in Canada, informing the policy makers with science-based information to help them deliver good legislation to Federal and Provincial Legislatures. I know that our industrial partners have and will continue to benefit from various WISE initiatives (the Geothermal Symposium, Energy Day, etc.). I have made several new links in my activities with WISE, and appreciate this. Finally, I must mention the AE4H initiative is a most appealing and important initiative, and I wish you and your colleagues the greatest success in this valuable endeavour to bring energy to the energy-impoveryished.

The broad scope of WISE is one of its great strengths, with member skill sets varying from risk analysis to geomechanics, from grid management to energy efficient buildings, from policy studies to economic analysis.

Personally, I have one active Research Associate in Earth Sciences, five active PhD students in Civil Engineering, Mechanical Engineering and Earth Sciences, a MSc student in Civil Engineering, and a number of undergraduates working on energy related projects for their Capstone projects. This amounts to over 250K per year in personal funding, and my students are working on issues such as compressed air storage, salt cavern behavior, pipeline integrity, hydraulic fracturing and geothermal energy – all highly relevant to the mandate of WISE. I am the PI in a large CRD, and hold other grants, always mentioning my WISE affiliation.

I look forward to the future and working with WISE: it has been important to me, and WISE has been a great supporter of my initiatives.

Sincerely yours,

Maurice B Dusseault, PhD, PEng  
Professor of Earth Sciences, Department of Earth and Env. Sci., University of Waterloo
Appendix I – Letters of Support

Dr. Kankan Bhattacharya, P.Eng., FIEEE
Professor
Waterloo, Ontario
2nd February 2018

To:
Dr. Jatin Nathwani
Professor and Ontario Research Chair in Public Policy
Executive Director, Waterloo Institute for Sustainable Energy (WISE)
University of Waterloo, Waterloo, Ontario.

Dear Professor Nathwani,

It is with great pleasure that I write this letter of appreciation and support to the outstanding initiatives undertaken by the Waterloo Institute of Sustainable Energy (WISE) to fulfill the mandates set out by the University in the strategic area of energy research. Since its inception, WISE has successfully brought together scores of academics and researchers from different departments, and faculties, and from Universities across the globe to collaborate under the umbrella of sustainable energy, and address diverse and critical issues.

Through your outstanding leadership, WISE has now become well-known for the work and activities it pursues in the field of sustainable energy. You have also led the AE4IH initiative, which has attained a very significant role in providing affordable energy to the humanity.

In particular, the support of WISE has helped foster some of the major research projects and grants, that I have been involved in, as the Principal Investigator (PI) or co-PI, such as:


b) Advanced Information and Communication System for Smart Grid, NSERC Strategic Research Grant, 2013-2017, Led by Prof. X. Shen.


d) Operation, Communications and Information Management of Smart Electricity Grids, NSERC Strategic Research Grant, 2010 – 3013, Led by Prof. Kankan Bhattacharya.


f) EHMS- Enabling and Empowering Energy Managers Through Increased Information and Control, 2008-2011; Ontario Centres of Excellence, Hydro One, Emergent, OPA, Led by Prof. Ian Rowlands.

One of the most significant indicators of the important role played by WISE is the number of graduate students I have supervised / co-supervised in the past six years. In the past six years, I have supervised/co-supervised 11 PhD and 13 MASc students to graduation, and currently 12 PhD and 1 MASc students are working with me. Several of these research students’ funding has come from research projects which were/ and are being supported or initiated by WISE. In the NSERC Strategic Grants, WISE has played a vital role in securing the industry support required for the projects and helped establish useful contact with various industries.

Apart from the above contributions, WISE has played a very significant role in supporting several of the academic programs and initiatives in the field of sustainable energy and electric power engineering. In particular, the MEng (Electric Power Engineering) program, one of the unique online graduate programs in power engineering, worldwide, was established with the support of Hydro One Inc., and is continuously being supported by WISE. This Program has been highly successful in creating HQP for the Canadian power industry.

In view of such outstanding, and central role played by WISE in fostering a leading role in facilitating research in the critical area of sustainable energy, it is utmost important for the University of Waterloo to support WISE in its further growth and success, so that the Canadian society as a whole can benefit from its contributions.

I very strongly support WISE in its future endeavours and look forward to my continued participation in its activities.

Yours sincerely,

[Signature]

Professor Kankan Bhattacharya
June 5, 2018
Prof. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy (WISE)
University of Waterloo

Re: Support for WISE renewal

Dear Jatin,

It is a great pleasure as well as an obligation for me to write this letter supporting the continuation and enhancement of WISE, given all what the Institute and you as its leader have done for the University of Waterloo, the Institute members, and me personally since the institute inception.

I will briefly summarize next my research activities and some career highlights directly linked to WISE, so that people reading this get a good idea of how the Institute has been a fundamental part of various and significant research partnerships that have very positively impacted many researchers associated with WISE, particularly me. Thus, as you know, besides being a Professor at the Electrical and Computer Engineering (ECE) Department, holding various academic and administrative positions since 1993, including Associate Director (2008-2015) and Acting Executive Director (2015) of WISE, I currently serve as the Hydro One Endowed Chair. The latter position is associated with a $1.5 million endowment from Hydro One, as part of a 5-year, $2.5 million MOU with the company that directly and wholly resulted from your and the Institute’s efforts to establish strong research and institutional links with Hydro One, one of the largest electric utilities in Canada, North America and the world. This endowment and the associated MOU’s research funding enabled several WISE members, and especially the ECE Power Group including me, to significantly enhance our research capability and funding, allowing us to increase our funding pool through matching funds provided by institutions like NSERC, OCE and NRCAN, as well as attracting the interest and participation of other industrial partners in these projects. In fact, of the 28 research grants and contracts I have been involved with since the creation of WISE back in 2006, 14 of these projects, which are listed below, have been directly enabled and/or facilitated by WISE, amounting to a total of close to $46 million in cash and in-kind contributions, with a personal cash share of close to $3 million, and involving over 25 different companies and government agencies, including NSERC, NRCAN, OCE, Hydro One, OPG, IESO, OPA, Emergent, Hatch, Milton Hydro, and many others.

As you are aware, my research activities focus on the study of stability, modeling, simulation, control, optimization, operation, planning, and computational issues in power and energy systems within the context of competitive energy markets, smart grids and microgrids. In these areas, particularly energy systems, smart grids and microgrids, WISE has allowed me to establish strong contacts and interactions with colleagues from various departments and faculties, particularly in environmental and computer sciences, as well as
with colleagues in international academic institutions, especially at the Karlsruhe Institute of Technology (KIT) in Germany, with whom we have formed various partnerships that have driven many of my research projects. I believe that facilitating and enabling research by government, industry, and academic multidisciplinary teams from national and international institutions has been one of main characteristics and advantages of the Institute. In fact, this was one of the main reasons for its creation, as I clearly recall from my direct participation in its design in 2006-2007 and its deployment and growth from 2008 to 2015.

In closure, and based on the facts just stated, I would like to clearly express my strongest support for the Institute and you personally as its very successful leader, as I undoubtedly believe that WISE has more than met and continues to meet its original objectives, exceeding expectations since its creation back in 2008. I’m eager to continue supporting and actively participating in WISE!

Sincerely,

Claudio A. Cañizares
Professor and Hydro One Endowed Chair
Director, ASE Division, RSC Academy of Science
March 13, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Prof. Nathwani,

It is my pleasure to support the renewal of WISE, considering the multidisciplinary activities that are being carried out by the members of WISE. These activities bring many researchers to work together and accomplish, which is possible to the role WISE has been playing. The role WISE has played encompass many areas like energy, climate control, power management, and sustainability of energy and power sectors.

One of the key goals WISE has set is the agenda of low carbon R&D projects through industry-academic partnerships. In this regard, WISE has been supporting research projects related to this aspects through introducing faculty researchers to industry partners. Furthermore, WISE management has striving to help establishing networks by organising workshops, conferences, seminars, and public lectures.

I would also like to acknowledge WISE’s role in supporting the students by encouraging them to participate in WISE organized conferences, entrepreneurial activities, and innovation days where the students have the opportunities to interact with their potential employers. Such forums also help them to show case their research outputs. I would like to continue to work together with WISE members, including the management team for all the benefits said above.

Yours truly,

[Signature]

Shesha Jayaram
Professor and University Research Chair
Electrical and Computer Engineering
200 University Ave West
Waterloo, ON N2L 3G1
519-888-4567, ext. 35337
jayaram@uwaterloo.ca
April 12, 2018

Dr. Jatin Nathwani
Executive Director, Waterloo Institute of Sustainable Energy (WISE)
University of Waterloo

Dear Professor Nathwani,

Over the years, WISE has played a vital role in bringing University of Waterloo researchers from across disciplines together, facilitating their communication and collaboration, and helping them to identify and make contact with related industry partners. I greatly appreciate the honest efforts made by WISE staff under your directions in fostering opportunities for me to get in touch with colleagues from all over the world as well as industry representatives, and present my work and experience to them in numerous meetings.

My most recent major experiences with WISE have been participation in the Affordable Energy for Humanity (AE4H) workshop in Potsdam (Germany) in June 2017, pioneered by WISE, and facilitating a successful connection with a wind energy giant that led to obtaining very useful wind farm data for my research. I really appreciate the possibilities that were created by WISE towards my success in research career.

I am a proud member of WISE and very strongly support its renewal.

Sincerely,

Mehrdad Kazerani, Ph.D., P.Eng.
Professor
Department of Electrical & Computer Engineering
University of Waterloo
200 University Ave. W.
Waterloo, Ontario N2L 3G1 CANADA
Phone: (519)888-4567, ext. 33737
Fax: (519)746-3077
Email: mkazerani@uwwaterloo.ca
URL: http://www.power.uwaterloo.ca
Catherine Rosenberg
Professor and Canada Research Chair
Department of Electrical and Computer Engineering

March 15, 2018

Jatin Nathwani, PhD, P.Eng
Professor and Ontario Research Chair in Public Policy for Sustainable Energy
Executive Director, Waterloo Institute for Sustainable Energy (WISE)

Re: Letter of Support for WISE

Dear Jatin,

I strongly support the renewal of the WISE mandate. WISE has been pivotal in the success of the ISS4E (Information Systems and Sciences for Energy) laboratory cofounded by Prof. Keshav from Computer Science and I. WISE has allowed us to meet colleagues interested in energy systems working in different faculties at the University of Waterloo. It has also given us numerous opportunities to meet with industry and that has yielded several contracts and collaborative projects. It has also added to our credibility when we talk to colleagues all over the world.

In the past 4 years, I have given seminars on the activities of ISS4E at Columbia, Erasmus Energy Forum, Berkeley, Caltech and, everywhere, everyone was very impressed by the critical mass and level of expertise that WISE has.

Altogether, I consider that what WISE brought to me under your leadership is invaluable.

Sincerely yours,

Dr. Catherine Rosenberg, FCAE, FIEEE
Appendix I – Letters of Support

April 5, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Prof. Nathwani,

I am delighted to write this letter in support of the renewal of the Waterloo Institute for Sustainable Energy. A few words about myself: I am an Assistant Professor in Electrical and Computer Engineering, where I have been since April 2015, and I have been a member of WISE since that time. My research is in the area of control engineering, with a focus on applications to power systems and microgrids. The goals of my research are two-fold: to develop theoretically rigorous control and optimization techniques, and to apply and tailor those techniques to problems in power systems analysis and design.

WISE has provided strong support to my research initiatives through the organization of workshops, seminars, and public lectures, where they have consistently secured exceptional speakers. The organization of these events with high-profile speakers from both academia and industry raises University of Waterloo’s profile both nationally and internationally, and I have greatly enjoyed attending them and conversing with representatives from industry. When I joined WISE, my research in microgrid control was featured as a WISE spotlight, which was quite helpful as a way to announce my arrival to other members in the area of power and energy control. Moreover, I was graciously awarded a small grant via WISE’s partnership with Cisco Systems, and have used these funds to support my basic research into microgrid control systems.

I believe that WISE is an essential institute for organizing large collaborations between University of Waterloo researchers and industry partners in the energy sector. I strongly support WISE’s renewal and look forward to substantial collaboration with the institute in the near future.

Yours truly,

[Signature]

Dr. John W. Simpson-Porco
Assistant Professor – Electrical and Computer Engineering
EIT – 3112
200 University Ave West
Waterloo, ON N2L 3G1
519-888-4567, ext. 31216
jsimpson@uwaterloo.ca
April 17, 2018

Dr. Jatin Nathwani  
Professor, Civil and Environmental Engineering  
Executive Director, Waterloo Institute for Sustainable Energy (WISE)

LETTER OF SUPPORT

Dear Jatin,

I am writing to express my strong support for the continuation of the Waterloo Institute of Sustainable Energy (WISE) at the University of Waterloo.

With Energy & Environment being one of the eight Research Theme Areas in the University’s Strategic Research Plan, an institute in the caliber of WISE is a strong necessity to get us where we want to be in the rapidly changing energy landscape. I am glad to see what started off as the Green Energy Research Institute (GERI) more than fifteen years ago has evolved into WISE with broader reach and international recognition.

WISE gives a great degree of visibility worldwide to the sustainable energy research being carried out at Waterloo. This is important for our researchers to gain more exposure, interact with international researchers, and get into potential external research collaborations. Since the energy-related research at Waterloo spans many departments and faculties (Engineering, Science, Environment, Math), the researchers can continue to benefit from WISE, as a platform to interact internally and to make new research initiatives. Our Centre for Advanced Photovoltaic and Display Systems (CAPDS) itself has benefitted from the numerous visits and tours organized by WISE, that also helped establish broader networking. In the recent past WISE has played important roles in the global initiative of Affordable Energy for Humanity (AE4H), annual Energy Day events, WISE public lecture series, Technology Innovation and Policy Forum etc., making strong contributions to policy-making and providing great visibility to UW’s role in sustainable energy research. WISE has also made Energy Council of Canada Energy Policy Research Fellowships available for our graduate students.

Overall, I strongly support the renewal of the WISE mandate and its continued service to the University community.

Sincerely,

Siva Sivoththaman  
Professor, Electrical and Computer Engineering  
Director, Centre for Advanced Photovoltaic and Display Systems (CAPDS)  
Tel: (159) 888-4567 ext.35319, Email: sivoththaman@uwaterloo.ca
Dr. Jatin Nathwani
Professor and Ontario Research Chair in Public Policy for Sustainable Energy
Executive Director, Waterloo Institute for Sustainable Energy (WISE)
University of Waterloo, Waterloo, ON N2L 3G1

Dear Professor Nathwani,

I strongly support the renewal of the Waterloo Institute for Sustainable Energy (WISE). WISE provides University of Waterloo researchers with a great opportunity to develop interdisciplinary projects with broader groups of colleagues than we could achieve on our own. It raises the profile of research and outreach activities at the University of Waterloo and offers strategic connections with partners on and off campus.

Strategically, WISE has played a key role in developing the Affordable Energy for Humanity Global Change Initiative, a global consortium of researchers and practitioners committed to ending energy poverty through the sustainable deployment of clean technology. This initiative aligns perfectly with the United Nations Sustainable Development Goal #7 (Clean Energy) and enables action to taken to address Sustainable Development Goal #13 (Climate Action). These SDGs are expected to be a high priority for our work with the United Nations Sustainable Development Solutions Network which will announce the University of Waterloo as its Canadian node in May.

WISE has complimentary links with the Interdisciplinary Centre for Climate Change (IC3) which we expect to grow with the planned relocation of WISE and IC3 to evol1 – the net positive energy building under construction on the north campus. Using the building as a demonstration platform for the future where buildings contribute energy to neighbours rather than only being consumers, WISE is expected to increase its influence in public dialogue and the identification of solutions to address critical energy issues in Canada or around the world.

I have benefited as a researcher in projects with WISE colleagues (smart grid technologies; renewables in remote indigenous communities). My students have benefitted from Energy Council of Canada scholarships administered through WISE. Interactions with external partners are enhanced by the reputation established by WISE. A strong foundation has been established and I expect WISE to continue to gain national and international recognition for the University of Waterloo in the future.

WISE demonstrates the collaborative and experiential success of Waterloo. I strongly support its renewal for even greater impact in the future.

Sincerely,

Paul Parker
Professor and Associate Dean Strategic Initiatives, Faculty of Environment
parkerj@uwaterloo.ca, 519-888-4567 x32791
To whom it may concern

Waterloo, January 22, 2018

Letter of support for WISE

Dear Committee, dear Feridun

It is my pleasure to write a letter of recommendation for an extension of the mandate for the Waterloo Institute for Sustainable Energy (WISE).

I write to lend my support to WISE for the role it has played in supporting my research efforts on sustainable energy and given me an excellent opportunity to work collaboratively with colleagues across the university. What makes WISE unique is its interdisciplinary approach and its industry outreach and collaboration. As a social scientist it is extremely helpful to have institutions that bring together colleagues from various disciplines and around the globe for research on energy, a topic that is highly relevant for our society.

WISE has continuously provided helpful assistance and enabled me to gain contacts with industry and government agencies in the government and private sector in order to conduct research on topics such as green bonds and corporate environmental reporting.

From my point of view WISE is an institute that has a significant impact on sustainable energy technologies and policies in Canada and increasingly on a global scale. WISE is an asset for the University of Waterloo that increases the reputation of the university as an innovative institution with regard to sustainable energy globally.

Sincerely

Olaf Weber
29 January 2018

Dr. Jatin Nathwani
Professor and Ontario Research Chair in Public Policy for Sustainable Energy
Executive Director, Waterloo Institute for Sustainable Energy (WISE)
University of Waterloo, Waterloo, ON

Dear Prof. Nathwani,

I write to offer strong support for the renewal of the Waterloo Institute for Sustainable Energy (WISE) for another term. WISE does critical work on the University of Waterloo campus, and I have seen how impactful that work can be. Indeed, I have viewed this from two perspectives – that of a researcher on campus and that of a senior administrator on campus. Please allow me to elaborate upon each.

As a researcher on campus – based in the Faculty of Environment – I have come to rely upon WISE in multiple ways. First, it has been ‘the place’ to go on campus for information about sustainable energy issues – be that contemporary debates (political, scientific, etc.) or be that research opportunities. With respect to the former, WISE regularly hosts important speakers (external and internal) to share their knowledge and wisdom on different aspects of energy systems. Securing this kind of input into my own work as a researcher is critical. Indeed, it is also extremely beneficial to my graduate students. And with respect to the latter, WISE invites me to meetings to explore research possibilities, often playing the role of ‘honest broker’, offering information, introductions and invitations to pursue further. WISE is generous with its many connections, and I have had the opportunity to benefit from some of them. (I should say that these connections that WISE facilitates are not only external, but ‘cross-campus, internal’ as well.)

And as a senior administrator on campus – serving as Associate Vice-President, International – I have come to value WISE as a constructive ‘team player’ as many of us work collaboratively across campus to achieve common goals. Whether it be in terms of ‘general agreements’ or ‘joint academic programmes’, WISE has been open to advice as it works with international partners to advance the University of Waterloo’s interests on energy issues. I have been struck by the constructive ambition of WISE, as it works effectively with many international peers in order to achieve global impact. Its work in ‘AE4H’ is one such example with which I am familiar.

In conclusion, then, I am very pleased to provide WISE with my strong support, and I look forward to my future engagement with it.

Of course, please let me know if you require any clarification or elaboration.

Sincerely,

Ian H. Rowlands, PhD
Associate Vice-President, International
Professor, School of Environment, Resources and Sustainability
March 21, 2018

Dr. Jatin Nathwani
Professor and Ontario Research Chair in Public Policy for Sustainable Energy
Executive Director, Waterloo Institute for Sustainable Energy (WISE)
University of Waterloo, Waterloo, ON

Dear Professor Nathwani,

I strongly support the renewal of the Waterloo Institute for Sustainable Energy (WISE). The Faculty of Environment has been a key player in WISE since its inception, and we are committed to working even more closely with WISE in the coming years – as WISE relocates into the Evolv1 Building on the north campus, where it will be proximate to the Interdisciplinary Centre on Climate Change (IC3) and the Faculty of Environment’s leaders and activities related to entrepreneurship, economic development and climate change.

Professors and students from the Faculty of Environment regularly participate in and benefit from the events and programs of WISE. Professor Ian Rowlands was Acting Executive Director of WISE in 2014; and three additional faculty members from Environment have been Associate Directors. Since 2013, 21 Environment students have received Energy Council of Canada Fellowship Awards.

WISE offers exceptional opportunities for researchers from the University to engage with external partners on important energy issues, leading to impactful collaborations. The Affordable Energy for Humanity Global Change Initiative, which is a global consortium of researchers and practitioners committed to ending energy poverty through the sustainable deployment of clean technology, aligns directly with the United Nations Sustainable Development Goal #7 (Clean Energy). As such, it also aligns directly with one of four themes that the soon-to-be-launched Sustainable Development Solutions Network (Canada) is addressing and which the Faculty of Environment is hosting, in partnership with the Waterloo Global Science Initiative.

WISE is delivering on its mandate to shape public attitudes, inform energy policy, tackle current problems and create transformative change for the future. I look forward to our Faculty’s continued interaction with WISE in the future.

Sincerely,

Jean Andrey
Dean
Faculty of Environment
March 7, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Prof. Nathwani,

I am writing to express my support for the Waterloo Institute for Sustainable Energy (WISE) in the strongest possible terms.

WISE brings together a wide variety of platforms focused on sustainable energy technologies, systems and policies. As a University institute, WISE has continued to provide assistance to the Science faculty members in the departments of Biology, Chemistry and Earth & Environmental Science in stewarding multiple R&D initiatives since its inception. WISE management has played a significant role in establishing and maintaining effective working relationships with industry partners, government officials, academic researchers, and young entrepreneurs.

WISE has always provided substantial strategic leadership and administrate support to advance research projects, conferences, workshops, and other academic activities to create a strong value for the Waterloo ecosystem. WISE has been a key contributor to the university’s broad advocacy and engagement strategy and ongoing awareness campaign for the internal & external community emphasizing the importance of research and commercialization.

Through this letter, I acknowledge WISE’s role in nurturing industry-academic relationship and bringing a unique technical capacity to integrate and develop diverse elements of major multi-disciplinary research initiatives and proposals for funding.

I continue to support WISE and look forward to our Faculty’s collaboration with the institute in the future.

Sincerely,

Robert P. Lemieux, PhD
Dean of Science and Professor of Chemistry
April 5, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Prof. Nathwani,

I write to lend my support for the renewal of WISE for the role it has played in many aspects of research and networking in the domains of renewable energy, electricity generation, and addressing the importance of low-carbon emission solutions.

WISE has excelled in advancing the agenda of low carbon R&D projects through industry-academic partnerships. WISE management has provided strong support to multiple research initiatives through workshops, conferences, seminars, public lectures, research spotlights, and creating initial contacts with potential industry partners in the power and energy sector.

WISE has been a key contributor in raising Waterloo’s profile both at the Canadian and global context in terms of getting recognition for excellence and innovation in research, scholarship and education, and building greater awareness of our research productivity and impact. WISE management has been extremely helpful for consultation for raising research funds. With colleagues, I have recently been a beneficiary of matching seed funds from WISE that were successfully leveraged for a SSHRC Connection Grant for the project, “Climate Change and Energy Futures Workshop: Challenges and Opportunities for Global and Interdisciplinary Research”.

I would also like to acknowledge WISE’s role in enhancing student opportunities to participate in entrepreneurial activities, and advancing commercialization and other forms of utilization of leading-edge entrepreneurial research and intellectual property. One of my PhD students, Mr. Jude Kurniawan, was a WISE Energy Fellow.

I strongly support WISE and look forward to additional collaboration with the institute in the near future.

Yours truly,

Dr. Vanessa Schweizer
Assistant Professor, Knowledge Integration, Faculty of Environment
EV1 – 211
200 University Ave West
Waterloo, ON N2L 3G1
519-888-4567, ext. 35106
vanessa.schweizer@uwaterloo.ca
April 30, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Prof. Nathwani,

Since its establishment, the Waterloo Institute for Sustainable Energy (WISE) has helped a number of faculty from the Department of Management Sciences on multiple R&D initiatives. The most recent ones being:

1. Optimization and Machine Learning for Smart Grid Applications (Prof. Bissan Ghaddar)
2. Smart Meter Data Mining (Prof. Lukasz Golab)

I take this opportunity to congratulate you on the leadership role that WISE continues to play in fostering collaboration with industrial partners, enabling multi-disciplinary research projects, and providing research leadership in the area of Sustainability.

I look forward to seeing more of our faculty members involved with the Institute. You have our full support.

Sincerely,

[Signature]

Samir Elhedhli, PhD, PEng
Professor and Chair
Department of Management Sciences
University of Waterloo
200 University Ave. West
Waterloo, ON
Canada N2L 3G1
Phone: +1 519 888-4667 ext 35683
Fax: +1 519 746-7252
elhedhli@uwaterloo.ca
Appendix I – Letters of Support

To Whom It May Concern:

I am writing to express my support for the Waterloo Institute for Sustainable Energy (WISE). I am currently an Associate Professor in the department of Management Sciences and a Tier-II Canada Research Chair in Data Analytics for Sustainability. When I joined the University of Waterloo in the fall of 2011, I engaged in a new research area of energy data analytics. Thanks to the support of WISE, I was able to obtain data and funding for my research as well as connect with industry partners.

I believe WISE serves an important role within the university and has been successful in identifying funding opportunities, connecting with industry partners and organizing workshops and conferences. I enthusiastically support the mission of WISE and look forward to participating in its initiatives for years to come.

Sincerely,

Lukasz Golab
Associate Professor and Canada Research Chair
Department of Management Sciences
Faculty of Engineering
University of Waterloo
519-888-4567 x31383
golab@uwaterloo.ca
April 15 2019

Dr. Charmaine Dean  
Vice-President, Research and international  
University of Waterloo

Dear Charmaine,

Subject: Renewal of Waterloo Institute for Sustainable Energy (WISE)

On Tuesday March 6th, the Chairs and Associate Deans (CAD) Committee of the Faculty of Engineering discussed a proposed 5-year renewal of the Waterloo Institute for Sustainable Energy (WISE). Such a decision must made judiciously since it supports a request for a funding commitment of a minimum of $1.75M while the university is enduring government-mandated cutbacks. With this in mind, there was unanimous support by the leadership of the Faculty of Engineering for a renewal of WISE for a 5-year period assuming no increase in funding.

WISE has been an active and engaging centre that is the entry point for energy research at UW. There is wide support for WISE and the activities of this institute support and enhance UW research initiatives in the energy field. Notably, WISE launched the Affordable Energy for Humanity (AE4H), as part of the United Nations Sustainable Goal 7, taking the initiative for international development towards "affordable, reliable, sustainable, and modern" energy. WISE has directly supported students via Energy Council of Canada fellowships and Queen Elizabeth II Diamond Jubilee Scholarship Program. WISE activities include hosting numerous conferences and workshops including WISE Energy Day, Technology and Innovation and Policy Forum, and the Resource Recovery Partnership Workshops as well as an extensive public lecture series. Dr. Nathwan, in his leadership role as Director of WISE, has engaged widely as a media spokesperson in many different fora helping to promote the University of Waterloo.

The Engineering Research Office would be pleased to assist WISE in shaping and preparing proposals for large-scale funding opportunities that would benefit not only Engineering faculty members, but researchers from outside of Engineering to encourage and further foster interdisciplinary research.

We wish to address a concern by the Faculty leadership. This is related to the reporting of journals and graduate theses as "scholarly output" from WISE that are not representative of WISE activities. Such reporting detracts from the true initiatives, credibility, and impact of the institute. We suggest that the renewal document only focus on the accomplishments of the institute and not the successes of the members resulting from their efforts. A more focused approach would also reduce the administrative burden when creating the renewal document. Our recommendation is to remove these citations for the submission to Senate Graduate & Research Council and then Engineering would be pleased to provide an updated letter of support before review by SGRC.

Yours truly,

[Signature]

Pearl Sullivan  
Dean, Faculty of Engineering
Appendix I – Letters of Support

Jatin Nathwani  
Executive Director, Waterloo Institute for Sustainable Energy (WISE)  
Faculty of Engineering and Faculty of Environment  
Carl Pollack Hall  
University of Waterloo, Waterloo, ON

Dear Dr. Nathwani:

Re: Support for Waterloo Institute for Sustainable Energy (WISE)

I strongly support the past work done by, and the renewal of, the Waterloo Institute for Sustainable Energy (WISE).

WISE has made available opportunities to explore research possibilities and collaborations that I would not have otherwise been exposed to, and for this I am very grateful. Although many opportunities do not lead to specific collaborations with myself, some have and in important ways. For example, connecting with those companies and individuals interested in WISE’s Drive4Data program which is directly related to my research. And more recently, for example, the multi-disciplinary compressed air energy storage (CAES) project with colleagues in Earth Science and Civil Engineering would not have happened without WISE support. Currently, I am also now very excited about deep geothermal opportunities that may develop because of strong support from WISE.

I have always been very impressed with the inclusive nature of WISE which often does not exist when busy professors on their own are initiating industry and community research relationships. When someone from outside the university comes to UW in pursuit of research and development opportunities it is critical in my opinion to have an institute like WISE, WatCAR, etc., that enables those coming to campus in search of research collaborations to be connected with a wide swath of faculty. If anything, it would be nice to see WISE expand its scope of activities to assist more faculty in writing multi-disciplinary sustainable energy proposals though this would likely require more staff. I do realize though that a lot depends on what industries are actually interested in research collaborations at any given time, but without WISE there would certainly be fewer sustainable energy collaborations.

In closing, I am a strong supporter of multi-disciplinary research and WISE clearly supports and encourages such. With this I am very pleased. I have connected with faculty across campus (e.g., Environmental Science, Electrical Engineering, Civil Engineering, Environmental Studies) that I would otherwise not have connected with on projects related to my research interests. I look forward to the continuation of WISE and am hopeful that it will grow in the opportunities it provides UW faculty.

Thank you.

Sincerely,

Roydon A. Fraser  
Professor, Mechanical & Mechatronics Engineering  
519-888-4764, rafreaser@uwaterloo.ca

200 UNIVERSITY AVENUE WEST, WATERLOO, ON, CANADA, N2L 3G1
March 22, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy

Support for WISE Renewal

Dear Prof. Jatin Nathwani,

I strongly support the renewal of WISE for significant contribution in supporting research activities and networking in the several disciplines particularly sustainable energy.

Currently, I have a CRD project with an industry partner that all was arranged through WISE. WISE has identified the industry partner, arranged several meetings for us, and guided the industry partner to apply for the CRD research grant with me. I had an NSERC Engage with the same industry partner which that also arranged by WISE.

WISE has been a key contributor in raising Waterloo’s profile both at the Canadian and global context in terms of getting recognition for excellence and innovation in research, scholarship and education, and building greater awareness of our research productivity and impact.

I would also like to acknowledge WISE’s role in enhancing HQP training through providing collaboration opportunity with industry partnership, and advancing commercialization and other forms of utilization of leading-edge entrepreneurial research and intellectual property.

I strongly support WISE and look forward to additional collaboration with the institute in the near future.

Yours truly,

Dr. Behrad Khamesee, P.Eng
Professor – Mechanical and Mechatronics Engineering
E3 – 3148
200 University Ave West
Waterloo, ON N2L 3G1
S19-888-4587, ext. 35095
khamesee@uwaterloo.ca
February 15, 2018

Dr. Jatin Nathwani
Executive Director, WISE
University of Waterloo

Dear Jatin,

I am writing this letter in strong support of the renewal of the Waterloo Institute for Sustainable Energy.

WISE has played an important role for me in facilitating communication and collaboration among researchers across disciplines. I highly appreciate the efforts made by WISE to promote my profile in order to bring my research to the attention of potential industry partners. I have benefited from the information on research funding programs and new connections with potential industrial partners. WISE has directly created opportunities for me to meet and communicate with representatives from industry for potential collaboration, e.g., Auresa - Wind Energy. Additionally, WISE has identified specific funding opportunities (such as NRCan - The Energy Innovation Program: Green Infrastructure Phase II). The Director has actively assisted me with such funding applications.

Prof. Nathwani and Mr. Armughan Al-Haq have been instrumental in creating links between researchers and providing a forum for discussion and planning. In addition, WISE also helped me host a group of people from Shandong Jianzhu University in China in 2017, who were particularly interested in R&D activities at UW to develop innovative solutions and policies related to renewable energy. My graduate students also benefited greatly from attending the annual WISE Energy Day, in which they were able to present their research work and interact with people from local industry.

In my opinion, WISE has been extremely successful in identifying funding opportunities for WISE researchers and connecting them with industry partners.

I look forward to continuing my relationship with WISE.

Sincerely,

Fue-Sang Lien
Professor, PEng
Department of Mechanical & Mechatronics Engineering
200 University Avenue West
University of Waterloo
Waterloo, Ontario
N2L 3G1
CANADA
Tel: (519) 888-4567 Ext: 36528
Fax: (519) 885-5862
E-mail: fslien@uwaterloo.ca
http://mme.uwaterloo.ca/~fslien/
April 25, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Prof. Nathwani,

I write to lend my support for the renewal of WISE for the role it has played in many aspects of research and networking in the domains of energy harvesting, power, smart grid sensors, and piezoelectric materials.

WISE management has provided strong support to my research initiatives through workshops, conferences, seminars, public lectures, research spotlights, and creating initial contacts with potential industry partners in the power and energy, smart materials, electronics and industrial sector. In addition, WISE has supported my research by contributing $72,000 through “WISE-CISCO Systems Smart Grid Research Fund” and other funding sources. This has led to the training of several highly qualified personnel (MQP), technical publications, and advancement in the fundamental and applied research for and in partnership with a broad range of stakeholders both at the national and global level.

WISE has been a key contributor in raising Waterloo’s profile both at the Canadian and global context in terms of getting recognition for excellence and innovation in research, scholarship and education, and building greater awareness of our research productivity and impact.

I would also like to acknowledge WISE’s role in enhancing student opportunities to participate in entrepreneurial activities, and advancing commercialization and other forms of utilization of leading-edge entrepreneurial research and intellectual property.

I strongly support WISE and look forward to additional collaboration with the institute in the near future.

Yours truly,

Armaghan Salehian

Dr. Armaghan Salehian
Associate Professor – Mechanical and Mechatronics Engineering
ES – 3046
200 University Ave West
Waterloo, ON N2L 3G1
519-888-4567, ext. 38531
salehian@uwaterloo.ca
April 02, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Prof. Nathwani,

I write to acknowledge my ongoing support for the renewal of WISE.

I have had the pleasure of working with the WISE management team over many years to assist their efforts in internationalization through multiple initiatives including, in particular, applications to major international granting agencies (Grand Challenges, MacArthur Foundation), managing major funded programs (Queen Elizabeth Scholars), negotiating international partnership agreements, hosting visiting delegations and participating in WISE workshops and seminars.

WISE has been a key contributor in raising Waterloo’s profile in a global context in terms of getting recognition for research excellence and innovation in the broad sustainable energy sector and building greater awareness of our research productivity and impact in both developed and developing countries.

I strongly support WISE and look forward to continued collaboration with the Institute.

Yours truly,

Drew Knight
Director, Global Research and Strategic Alliances
Office of Research
519-888-4567, ext. 32288
dknight@uwaterloo.ca
March 21, 2018

Dr. Jatin Nathwani
Executive Director
Waterloo Institute for Sustainable Energy

RE: Support for WISE Renewal

Dear Jatin,

I write to lend my support for the renewal of WISE, in recognition of its impact on research at UW, particularly its role in facilitating engagement with industry.

WISE has broad reach across UW Faculties, and plays a critical role in facilitating research interdisciplinarity in a research area of growing prominence and international importance. WISE management has provided strong support to multiple research initiatives through workshops, conferences, seminars, public lectures, research spotlights, and creating initial contacts with potential industry partners in the power and energy sector.

WISE provides greatly enhanced visibility and integration of the broad expertise at UW in sustainable energy. These factors are very attractive to industry and make promotion of Waterloo research far more effective than merely a collection of investigators.

I strongly support WISE and look forward to continued collaboration with the institute.

Yours truly,

Dr. Mike Szarka
Director, Research Partnerships – Office of Research, University of Waterloo
ECS – 3141
200 University Ave West
Waterloo, ON N2L 3G1
519-888-4567, ext. 33948
mszarka@uwaterloo.ca
Dear Colleagues,

Please accept this letter of support for the renewal of the Waterloo Institute for Sustainable Energy.

In my six years at the University of Waterloo, WISE has proven to be an invaluable asset and partner. It is one of the university’s central locations for developing interdisciplinary projects and exchanges. Even more admirably, it does this with an aim both towards practical/implementable ends and towards concerns for social justice and the good of society. As such, it serves as effective hub for pursuing the goals of not just innovation, but responsible innovation.

It does this through the hosting of events (like the annual Energy Day, which regularly provides the right mix of academics, practitioners, policy-makers, and entrepreneurs), through partnering with other science and technology focused groups (like the Waterloo Global Science Initiative), and through supporting faculty in their own energy-related initiatives. It provided invaluable support for my major effort in this area, the Decarbonization Forum, which brought together local expertise from government, business, NGOs, and academia to see if we could produce a technologically plausible vision of a decarbonized energy system for the Waterloo Region (held in November 2016). I had hoped to follow up from this effort with smaller events in 2017, but my health issues impeded me. For what I could do, WISE has been an excellent partner.

Given the nature of the University of Waterloo and the need for well-supported structures that encourage work across the silos of our faculties, the centrality of energy policy for sustainable societies, and the responsibilities of universities to foster innovative approaches for pressing societal problems, continued support for WISE is imperative.

Sincerely,

Heather Douglas
Waterloo Chair of Science and Society
Department of Philosophy
March 26, 2018

Dr. Jatin Nathwani
Executive Director, WISE
University of Waterloo

Dear Dr. Nathwani,

Working with WISE is very beneficial to our research group in terms of opening new horizons and focusing our efforts. We have the pleasure to connect with New Market Utility with an NSERC Engage project thanks to the help from WISE. It is now an active project and we hope many new activities will continue from this ice breaking project.

I look forward to strengthening such activities and I highly appreciate the role of WISE in this matter. The experience we had with MIOVISION due to a WISE initiative has opened a link between our research group and an important section of the industry and I would like to see more contributions from WISE. I believe that having an institute like WISE that manages and steers collaborative research work between both different fields of engineering at the University of Waterloo and researchers and the industry is a key to establishing sustainable practices in engineering.

I have had two Ph.D. students in the WISE area, one has just graduated and other is a current student working in Smart grid research. I have had research support in OCE and NSERC discovery grants (approximately 50,000/year in total for the last two years).

The various lecture series organized by WISE from time to time are really a very good way for enabling joint research between the University of Waterloo community and other institutes.

I strongly support renewal of the WISE mandate in order to realize various goals in the concerned research area. Best wishes!

Sincerely,

K. Pornambalam, PhD
Department of Systems Design Engineering
Phone: (519) 888-4567 ext. 33282
Fax: (519) 746-4791
Email: pornu@uwaterloo.ca
Website: http://epoch.uwaterloo.ca/~pornu/
February 8, 2018

To Whom It May Concern,

I understand that the Waterloo Institute for Sustainable Energy (WISE) is undergoing a five-year review and associated consideration for renewal of its mandate. Over the years, WISE has proven to be a valuable source of information and proactive activities related to energy and sustainable development, which has been highly beneficial to my research team and me. Accordingly, I am glad to strongly support a renewal of its mandate because of a range of reasons, some of which are outlined below.

I have been privileged to be a Member of the Internal Board of Management of WISE, since 2016. In fact, my association with WISE dates back for at least two decades prior to the formal founding of WISE. Specifically, over the years much of my research with my students and colleagues has dealt either directly or indirectly with issues related to risk assessment. Therefore, we were quite heavily involved with activities connected to the Institute for Risk Research (IRR), which was led by highly respected researchers such as Prof. Niels Lind and Prof. John Shortreed. While still at Ontario Hydro, the current Director of WISE, Dr. Jatin Nathwani, worked directly with IRR members who jointly developed the highly referenced Life Quality Index. My research team published a number of papers related to risk such as the article entitled, “Risk and Systems Theory”, by A.J. Hatfield and K.W. Hipel, which appeared in Risk Analysis: An International Journal, in 2002. For our research in risk, in 2016 I received the Disaster Prevention Research Institute (DPRI) Award from Kyoto University. From an academic point of view, IRR was certainly successful.

I am pleased that research in risk at the University of Waterloo has been subsumed by WISE. This is very important since energy is so closely interrelated with environmental issues and climate change. Hence, WISE greatly broadened the scope of IRR by heading into other areas of research that are of great concern to society. Likewise, members of my Conflict Analysis Group based in the Department of Systems Design Engineering are now not only investigating water and environmental problems but also interrelated energy problems within a system of systems engineering perspective. In fact, I was Co-Chair of the Expert Panel on Energy Use and Climate Change which produced the report entitled “Technology and Policy Options for a Low-Emission Energy System in Canada”, published by the Council of Canadian Academies (CCA), and released on October 27, 2015, by the CCA in Ottawa. Therefore, my research group is glad to be able to participate in activities orchestrated by WISE.
An attractive feature of WISE is its network of connections both nationally and internationally that greatly benefit WISE members. For instance, its Director, Dr. Jatin Nathwani, was an author of the important “Equinox Summit Energy 2030” report and has written insightful newspaper articles that bring favourable attention to Waterloo. Dr. Nathwani is a leader in many important external committees such as being Chair of the Board of Directors of the University Network of Excellence in Nuclear Engineering, and Member of the Ontario Energy Board Chair’s Roundtable for Industry. These kinds of valuable connections bring opportunities for funding and for tackling interesting research problems.

Currently, WISE is involved in a range of highly worthwhile academic and professional projects. I am particularly pleased that WISE has launched a major “Global Change Initiative — Affordable Energy for Humanity (AE4H)” program, ably headed by Professor Jatin Nathwani, has now reached an impressive level of collaboration among more than 150 researchers and practitioners at 50 institutions in 25 countries who are working towards the laudable goal of eradicating energy poverty. The leadership displayed by WISE to advance and promote such an important objective via a multi-disciplinary focus on use-inspired research puts the University of Waterloo’s reputation in the forefront as an innovative global university. As former President of the Academy of Science, Royal Society of Canada, I appreciate and fully endorse this direction and look forward to seeing positive outcomes from this undertaking.

WISE continues to seed, sponsor and actively develop research projects that span across collective expertise located in many departments at Waterloo, which is a testament to the true interdisciplinary nature of research at WISE. Moreover, the compressed air energy storage project and recent initiatives to strengthen geothermal energy research undertaken at the University of Waterloo are good examples of relevance towards achieving a low-carbon energy economy. Added to this, public lectures, major conferences and symposia, and other outreach activities organized by WISE provide a window to the world of energy, as well as strong motivation to our students and faculty members to engage with external organizations to address complex societal problems.

At the meeting of the Internal Board of Management of WISE held on January 29th, 2018, I was very impressed with the rich range of WISE projects described by Dr. Jatin Nathwani (Executive Director), Mr. Armughan Al-Haq (Manager, Program Development and Partnerships), Mr. Nigel Moore (Manager, Global Programs and Initiatives), Dr. Maurice Dusseau (spearheaded a number of WISE projects which were funded) and others. This meeting was chaired by Professor Charmaine Dean (Vice President University Research) with minutes transcribed by Ms. Iris Strickler (WISE Administrative Assistant).
In conclusion, due to the foregoing and other reasons, it is my pleasure and desire to highly recommend that WISE be granted a further five-year mandate under the able leadership of Dr. Jatin Nathwani.

Most respectfully yours,

Keith W. Hipel

University Professor, O.C.
PhD, DrHC, HDSc, P.Eng, NAE, Hon.D.WRE, FRSC, FCAE, FIEEE, FAWRA, FASCE, FNIIOSE, FEIC
Department of Systems Design Engineering
University of Waterloo, Waterloo, Ontario, Canada N2L 3G1
Past President, Academy of Science, Royal Society of Canada
Senior Fellow, Centre for International Governance Innovation
Fellow, Balsillie School of International Affairs
Coordinator, Conflict Analysis Group, University of Waterloo

kwhipel@uwaterloo.ca; Tel: 1 519 888 4567 ext. 32830
Homepage: http://www.systems.uwaterloo.ca/Faculty/Hipel/
Conflict Analysis Group: http://iwaterloo.ca/conflict-analysis-group/
Appendix II:
Research Spotlights
PUTTING FLYWHEELS TO WORK IN SOLAR ENERGY SYSTEMS

Magdy Salama
Professor, Electrical and Computer Engineering, University of Waterloo

From steam engines to spaceships, humans have been using flywheels for centuries. These simple wheels serve as batteries by stockpiling excess energy as mechanical motion, spinning faster the more energy they store.

Now, WISE researchers suggest this tried-and-true technology could give photovoltaic systems a boost, addressing two of the key challenges involved in tapping the sun’s energy.

Challenge number one is that the sun doesn’t always shine when we need energy, creating a mismatch in supply and demand. Problem number two is that passing clouds create rapid voltage fluctuations that can wreak havoc on everything from light bulbs to laptops. Automatic voltage regulators can be used to curb those fluctuations, but they reduce the amount of electricity reaching the grid.

Magdy Salama, Ayman Eltantawy and their colleagues at Natural Resources Canada and PowerStream Inc. have proposed a different approach, using a flywheel to store excess electricity during off-peak periods and also reduce voltage fluctuations.

The system consists of a flywheel, a permanent magnet synchronous machine and three-phase back-to-back converters. The researchers put it to the test in a simulation of a residential distribution network that includes photovoltaic panels.

The model worked. Their simulation revealed that incorporating a flywheel energy storage system can compensate for the fluctuations in output power, thus reducing the need for an automatic voltage regulator. As a result, more electricity produced by solar panels is actually used, extracting maximum benefit from each ray of sunshine.

Researchers: Ayman Eltantawy, Magdy Salama, Tarek El-Fouly and Glenn Allen

Partners: Natural Resources Canada (CanmetENERGY), PowerStream Inc.
Canadians burn a lot of fuel to keep our buildings warm in winter. WISE researcher Pooneh Maghoul believes a key way to cut heating bills and reduce our carbon emissions lies beneath our feet.

The geotechnical engineer set out to better understand the heating, cooling, freezing and thawing that occurs in the soil surrounding building foundations. These are processes that depend not only on air temperature and heat loss from the building but also on the level of moisture in the soil.

Maghoul created a numerical model of coupled heat and mass transfer and validated it by comparing her results with experimental data published by other researchers. She then applied her model to a case study of soil around an insulated basement, creating a detailed picture of how soil temperature and ice distribution vary during the year.

This research provides valuable information for improving the energy efficiency of Canadian basements: the next logical target now that most buildings are well-insulated above-ground. In today’s homes, as much as 30 to 50 per cent of heat loss occurs below ground.

Maghoul’s findings can also be applied to the design of geothermal pile foundations. This zero-carbon technology incorporates geothermal pipework into the foundation piles that support buildings. In the winter, the pipework transfers heat from the surrounding soil to the building via a heat exchanger, providing warmth. In the summer, the system can run in reverse, keeping the building cool.

For all these reasons, this is research that should be warmly embraced by Canada’s building sector.

**Researcher(s):** Pooneh Maghoul

**Partners:** IREQ

A GREENER WAY TO STORE MORE ENERGY

David Simakov
Assistant Professor, Department of Chemical Engineering, University of Waterloo

Microgrids are transforming the way we produce and distribute electricity, enabling communities to generate their own power independently of the main grid. These small-scale systems are well suited for renewables, but daily fluctuations in wind and solar energy make it difficult to guarantee a reliable supply. And although storing excess electricity in batteries can buffer supply and demand, this approach requires high capital cost investment. Professor David Simakov believes chemistry may offer a better and cheaper solution. In his lab at the University of Waterloo’s Sustainable Reaction Engineering Group, Prof. Simakov and his team are developing a highly efficient thermocatalytic converter for microgrids.

The ultimate goal is to develop a power-to-fuel system that will use renewable energy (produced by wind turbines, solar panels etc.) to drive an electrolyzer that will convert water into oxygen and hydrogen. The generated hydrogen will then be fed into the thermocatalytic converter being developed by Prof. Simakov’s team. This highly efficient catalytic unit combines the hydrogen with carbon dioxide from sources such as raw biogas, landfill gas, and flue gas from a power plant, producing synthetic methane. This renewable natural gas can be injected into the existing natural gas infrastructure.

Thermo-catalytic conversion isn’t a new process, but until now, it has been limited primarily due to large scale industrial applications, such as natural gas reforming. To scale down the technology for microgrids, Prof. Simakov’s team is using emerging materials, nano-structuring and state-of-the-art reactor design to develop a compact and low-cost reactor for conversion of CO₂ into a synthetic renewable fuel.

According to Prof. Simakov, this green, highly-efficient energy storage technology will make microgrids more viable, paving the way for greater use of renewable energy and reduction of our reliance on fossil fuels.

Researchers: Assistant Professor David Simakov
DETECTING FAULTS IN POWER SUPERHIGHWAYS

Sahar Pirooz Azad
Assistant Professor, Electrical and Computer Engineering, University of Waterloo

Electricity is often generated hundreds of kilometres from where it’s consumed. (Think offshore wind farms and remote hydroelectric dams.) The most efficient and economical way to move electricity over those kinds of distances is through high-voltage direct current (HVDC) transmission lines — so-called “power superhighways.”

However, addressing faults like voltage or current spikes and short circuits is far more difficult in an HVDC grid than in a standard AC grid, because they travel so much faster.

WISE researcher Sahar Pirooz Azad is tackling that issue. Together with Belgian collaborator Dirk Van Hertem, Azad has developed a relaying algorithm that can detect an HVDC fault and identify its location in a fraction of a millisecond, making it possible to contain the problem quickly.

Unlike conventional fault detection systems that require communication between the local relay and a centralized decision-making unit, Azad and Van Hertem’s algorithm handles everything locally, saving crucial time.

The two researchers have proved their algorithm successfully detects both transmission line faults and faults on the DC buses that form connection points in the grid — and it can discriminate between the two. It can also distinguish between actual faults and other disturbances, so it doesn’t trigger unnecessary circuit breaks.

The two researchers conclude their algorithm satisfies the main requirements for any relaying algorithm: selectivity, sensitivity, reliability and speed. And because it uses current sensors rather than costly voltage sensors, the price tag is attractive.

Put it all together, and you’ve got a powerful way to avoid bumps on the power superhighway.

**Researchers:** Sahar Pirooz Azad and Dirk Van Hertem

**Partners:** The Seventh Framework Programme of the European Union


[READ FULL ARTICLE]
The better you can optimize the flow of electricity in a power grid, the more energy you save and the fewer planet-warming greenhouse gases you generate. But that’s easier said than done.

Supply and demand fluctuate month by month, day by day and hour by hour. On top of that, there are a host of constraints to take into account. To date, no one has come up with an algorithm that can consistently find the optimal answer in every situation — at least, not in a reasonable length of time. Instead, grid managers use approximations. And each year, the difference between “approximate” and “accurate” adds up to billions of dollars of wasted money around the world.

Waterloo operations research expert Dr. Bissan Ghaddar recently teamed up with colleagues at IBM Research to come up with a closer answer, thanks to some sophisticated mathematics.

They focused on two of the main factors that make optimal flow so difficult to calculate: so-called non-convexities due to the non-linear physical constraints and the sparse structure of the power network. Ghaddar and her team treated the issue as a sparse polynomial optimization problem and used strong and efficient convexifications to find the optimal solution while making the calculations more manageable.

When Ghaddar and her colleagues applied their approaches on different test cases, they came up with accurate answers every time in smaller-scale grids. For bigger grids, they produced significantly better results than current methods. And when we’re talking about a billion-dollar problem, those improvements mean very significant savings.

**Researcher:** Bissan Ghaddar

**Partner:** IBM Research
HEAT PUMPS GIVE SOLAR HOT WATER A BOOST

Michael R. Collins

Associate Professor, Mechanical and Mechatronics Engineering, University of Waterloo

Some things go better together: peanut butter and jam, patios and beer, movies and popcorn. According to University of Waterloo mechanical and mechatronics engineering professor Michael Collins, you can add solar hot water systems and heat pumps to that list.

More and more rooftops across Canada are sporting solar thermal collectors that use heat from the sun to warm the water destined for showers, dishwashers, washing machines and even radiators. Because they use significantly less energy than their electric counterparts, these domestic solar water-heating systems are great for the environment and for your bank balance.

Want to slash your energy use even further? Add a heat pump to the mix, says Collins. These devices work like an A/C unit in reverse, transferring heat from a cold space to a warmer one.

By incorporating a heat pump and a second tank to a standard solar water-heating setup, Collins has created a highly flexible system that adapts to changing household demands and weather conditions. If the sun isn’t shining strongly, for example, the heat pump kicks in. Running a bath in the evening? The system can draw on hot water from the additional storage tank. A custom-built controller decides which of 12 configurations is the most energy-efficient option at any given moment.

A normal 7.5-square-metre solar water-heating system uses 40 per cent of the electricity needed to run an electric water-heater. Collin’s dual-tank system reduces that to just 31 per cent, offering businesses and homeowners significant electricity and cost savings.

Researchers: Carsen J. Banister, Michael R. Collins

Partners: Smart Net-Zero Energy Buildings Strategic Research Network, and Natural Sciences and Engineering Research Council of Canada
CONVERTING PEAT INTO POWER


*Professor, Department of Chemical Engineering, University of Waterloo
**Researcher/Student, Department of Chemical Engineering, University of Waterloo

Each year, a noxious haze blankets much of Indonesia. It’s the result of burning peatlands — the boggy land that covers more than ten per cent of the country. Farmers here have traditionally used slash-and-burn techniques to prepare land for planting, but the level of burning has increased dramatically as large areas are converted to industrial-scale palm oil plantations.

WISE researchers hate to see a valuable resource go up in smoke. So they’ve proposed a better idea: gasification. Chemical engineers Ali Elkamel and Bill Anderson and their team have developed a conceptual design to convert peat into electricity and methanol, creating valuable commodities while cutting pollution.

They started by exploring different combinations of gasifiers and methanol synthesizing reactors. Next, they judged the designs based on levels of methanol and electricity production, emissions, upfront costs and payback periods.

One stood out: a combination of fluidized-bed gasification and liquid-phase methanol synthesis. Elkamel and Anderson and their colleagues then refined this design, adding more details and tweaking different components.

Their simulations reveal a process that could transform 1,000 tonnes of peat a day into 214 tonnes of methanol and 56 MW of electricity — figures that are competitive with other types of biomass-to-methanol plants and integrated gasification plants.

Their design virtually eliminates haze-producing particles and keeps sulphur dioxide and nitrogen dioxide emissions below emission limits. Meanwhile, greenhouse gas emissions are 22 per cent less than the emissions from uncontrolled burning. And with a projected payback period of just four years, this approach to tackling peaty pollution is clearly worth exploring.

Researchers: Ali Elkamel, William Anderson, Mohamed Elsholkami, Matthew Warren, Chu Huang, Sheryl Peters, Zhengkai Tu


READ FULL ARTICLE
Even rechargeable batteries eventually die. Month after month of using a battery, topping it up and repeating the cycle gradually reduces its ability to hold a charge and the amount power it can supply. That’s why electric vehicle (EV) manufacturers suggest replacing the battery pack when its storage capacity drops below 80 per cent of maximum, and have 8 year warranties.

WISE researchers envisioned a different approach. A battery is only as strong as its weakest cells, proposed by researchers in Chemical Engineering. That means if a single cell fails or degrades below the 80 per cent threshold it impacts the battery pack as a whole. But rather than throwing away the entire pack, why not replace just the low-performing cells?

Dr. Fowler and his team set about testing the feasibility of this idea. First, they collected data on how cells degrade over time, subjecting two different types of lithium ion batteries to a variety of accelerated test conditions. Next, they developed a computer simulation of a reconfigurable battery pack and fed in the experimental data.

Their results reveal that checking the battery on a seasonal basis and replacing faulty cells makes it possible to keep the battery’s state of health safely above 80 per cent. That’s far better for the environment than replacing the entire pack. Moreover, since batteries account for a big part of EV costs, this approach promises to make electric vehicles more affordable, and could extend their life.

With this concept demonstrated electric vehicle manufacturers, and other applications with large battery packs, can start to consider the feasibility designing battery packs with replaceable cells, effectively creating battery packs with vastly extended life based on basic maintenance schedules.

Researchers: Michael Fowler, Manoj Mathew, Q.H. Kong, Jake McGrory

Partners: Natural Sciences and Engineering Research Council of Canada

POWER-TO-GAS SYSTEMS: THE ECONOMICS OF GREEN ENERGY STORAGE

Michael Fowler*, Ushnik Mukherjee**, Sean Walker**, Azadeh Maroufmashat** & Abdullah Alsubaie

*Professor, Department of Chemical Engineering, University of Waterloo  
**Researcher/Student, Department of Chemical Engineering, University of Waterloo

Power-to-gas systems may offer the energy storage solution the green energy sector has been searching for, allowing grid managers to match supply and demand. The process uses surplus electricity produced by wind and solar power to split water into oxygen and hydrogen.

That hydrogen then can be injected into existing natural gas distribution lines — providing customers with cleaner, hydrogen-enriched natural gas — or converted back to electricity when the grid needs it hours, weeks or months. The hydrogen can also be used to supply refuelling stations for fuel cell vehicles.

Chemical engineering professor Michael Fowler and his research team have been conducting studies into the potential application pathway for Power-to-gas in Ontario. The team modeled a two-megawatt power-to-gas energy hub that links the electricity and natural gas grids. From there, they developed scenarios that factored in hourly operating costs, daily hydrogen demand for vehicles and other key factors. They also examined the impact of different prices for hydrogen fuel, hydrogen-enriched natural gas and electricity on demand.

The current study provides pricing structures that policymakers could use to make such an energy hub economically viable such including the provision of auxiliary services and carbon pricing. Most importantly the research has shown on Power-to-Gas has a number of application pathways, and could immediately make use of the surplus power in Ontario, thus reducing the Global Adjustment charges the province’s consumers are paying, or increasing the renewable energy content of our current fuels.

Adopting green energy on a significant scale requires effective energy storage technology. Power-to-gas systems can help us transition to a renewable energy future.


READ FULL ARTICLE
HELPING HOUSEHOLDS SAVE ELECTRICITY

Ian Rowlands
Professor, School of Environment, Resources, and Sustainability, University of Waterloo

Around the world, governments, utility companies and environmental organizations alike are encouraging consumers to use electricity more wisely. And with good reason. Reducing electricity consumption or shifting it to off-peak hours can cut greenhouse gas emissions, postpone the need for new generating stations and reduce the pressure on electricity grids.

What exactly does that look like at the household level? Three WISE researchers decided to find out.

Ian Rowlands, Paul Parker and Ivan Kantor examined electricity consumption and conservation in 18 Ontario homes — right down to the level of individual appliances. The first-of-its kind study tracked electricity use circuit by circuit. And not only did the investigators see the data, so did the consumers.

Instead of waiting for their monthly bill to arrive, residents could get detailed information in near-real time. Thanks to an online portal, they could see precisely how many kilowatts they used when they turned on the TV, tossed a load of clothes in the dryer, cranked up the space heater and so on.

As a result, 28 per cent of households shifted their time of use, waiting until off-peak hours to switch on media centres, laundry machines and dishwashers. Meanwhile, 11 per cent of households cut their overall use. For these conservers, the biggest savings came from reducing air conditioning.

Although the study was too small to draw broad conclusions, the real-world snapshot of consumer behaviour offers insights for policy makers and energy planners, as well as new approaches to analyzing household energy consumption.

Researchers: Ian Rowlands, Paul Parker and Ivan Kantor

Partners: Ontario Centres of Excellence, Hydro One Networks Incorporated, Milton Hydro Distribution Incorporated, Energent Incorporated
A MODEL FOR SMART EV CHARGING

Mehrdad Kazerani* & Claudio Cañizares*,
*Professor, Electrical and Computer Engineering,
University of Waterloo

Although plug-in electric vehicles (EVs) currently make up less than one per cent of vehicles on the world’s roads, that figure is poised to increase significantly as more and more drivers recognize the advantages of going electric.

Mass adoption of EVs would put a big dent in global carbon emissions. However, it also poses challenges for electrical distribution systems. When thousands of commuters within a city arrive at work and plug in their vehicle, the surge in demand could overload local feeders and transformers and create undervoltages in system nodes.

Where some people see problems, others see opportunities. Since most drivers only operate their cars a few hours a day, the idle power in those parked vehicles could serve as important buffers between electricity supply and demand.

The key is bidirectional smart chargers that give drivers the option of charging when power is plentiful (and rates are cheaper) and earning discounts or rebates by supplying electricity from their vehicles back to the grid when they don’t need it.

WISE researchers are helping make that vision a reality. Electrical engineers Mehrdad Kazerani, Claudio Cañizares, Mauricio Restrepo and Jordan Morris have developed and validated a model of a single-phase, two-stage bidirectional charger. The model can be easily integrated into simulations, allowing researchers to analyze the impacts in distribution networks, examining voltage interactions with other chargers and loads in the distribution systems.

Ultimately, this work is paving the way to greater use of electric vehicles — and fewer greenhouse gases in the atmosphere.

Researchers: Mehrdad Kazerani, Claudio Cañizares, Mauricio Restrepo, Jordan Morris

Partners: Natural Sciences and Engineering Research Council, Hydro One
Today, hundreds of millions of riders are hopping on electric bicycles, making this the fastest growing mode of low-carbon urban transport worldwide. And with good reason. E-bikes are environmentally friendly, they’re easy to use and maintain, yet they cost much less than electric cars.

As alternative vehicles such as e-bikes grow in popularity, what impact will they have on Canada’s roads and cities? To find out, WISE’s Dr. Srinivasan Keshav and Dr. Łukasz Golab launched WeBike: a three-year study that probes what Canadians think about electric bicycles and how we use them, in 2014.

To start, the team distributed a survey to University of Waterloo faculty, staff and students to gauge their attitudes toward electric bicycles. Now, in phase two, they have deployed 31 e-bikes equipped with sensors and a smartphone to study riders’ behaviours. Voltage and current sensors on the bikes gather data about the electric charge. Meanwhile, the smartphone uses GPS and accelerometers to track distances, terrain, speed, the number of trips each day and other pertinent details. Since the project launched in the summer of 2014, those sensors have collected more than 100 GB of data.

Analyzing that information offers insights on how electric bicycle use will affect Canada’s transportation infrastructure and how electric vehicles more broadly may impact the grid. Whether it’s determining where to install charging stations or how temperatures affect battery life, the WeBike team are helping electrify transportation in Canada.


 Partners:

- eProdigy Bikes, Vancouver, British Columbia
- Cycle Electric, Waterloo, Ontario
- Professor Tobias Schröder, Potsdam University of Applied Sciences
- Professor Angele Reinders, Universiteit Twente
- The ISS4E team
AN ELECTRIFYING PLAN: ENVISIONING A VEHICLE CHARGING NETWORK

Yassir Alhazmi* & Magdy Salama**

*Assistant Professor/ **Professor, Electrical and Computer Engineering, University of Waterloo

There’s no question: electric vehicles are a greener choice than their gas-powered counterparts, producing less air pollution and greenhouse gases. But a major barrier to their adoption is limited battery range. If drivers want to use electric vehicles for anything more than short commutes or errands around town, they need a network of fast-charging stations.

So how do we go about building an effective one? Over the past few years, WISE researchers Yassir Alhazmi and Magdy Salama examined that question from many angles.

They started by estimating future sales of plug-in electric vehicles (PEVs) in order to predict how demand for charging stations will grow. The duo developed a forecasting model based on variables including gas prices, electricity rates, and government incentives to buy electric vehicles, current charging infrastructure and more.

Step two was developing formulas to determine the optimal locations for charging stations, ensuring drivers are always within battery range of one.

Next, they evaluated the combined impact of fast-charging stations and home charging stations on the grid, making sure the extra load wouldn’t create voltage violations, power losses or line loading.

Finally, they turned their attention to economics, developing a phase-in plan to ensure each new station will attract enough drivers to make it economically viable.

The result is a comprehensive model for creating PEV charging infrastructure: one that best serves drivers, creates returns for investors and doesn’t overwhelm the electric grid. In other words, a road map to greener transportation.

Researchers: Yassir Alhazmi and Magdy Salama

READ FULL PAPER
More than half of Canada’s 280 remote communities are cut off from centralized electricity grids, relying instead on high-polluting diesel generators. But as the need to reduce greenhouse gas emissions grows, more and more of these isolated communities are searching for greener microgrid options that add renewable energy to the mix.

Waterloo engineering professors Kankar Bhattacharya and Claudio Cañizares are helping guide that search. Along with PhD student Bharatkumar Solanki, the WISE researchers developed a mathematical model that can zero in on the optimal microgrid system that is affordable, sustainable and reliably meets electricity demands.

They started by creating a formula to calculate the fuel consumed and CO₂ emissions produced by fossil-fuel-based generators. They then integrated data from wind and solar systems in one Ontario First Nation microgrid to forecast the variable amounts of electricity that renewables produce over the course of a day.

Meanwhile, the trio also considered the potential impact of demand response programs that encourage customers to curtail their electricity consumption or shift their use to off-peak hours.

Using a five-generator microgrid as a case study, the researchers applied their comprehensive algorithm to a variety of microgrid operating strategies. The results show that the right approach can reduce CO₂ emissions by up to 52 per cent without dramatically increasing operating costs.

The model offers engineers an important tool for developing greener microgrids. At the same time, the research highlights the demand side of the equation — illustrating the important role consumers play in creating a sustainable energy future.

Researchers: Bharatkumar V. Solanki, Kankar Bhattacharya, Claudio A. Cañizares

Partners: Natural Sciences and Engineering Research Council (NSERC) of Canada


READ FULL ARTICLE
NO BATTERIES REQUIRED:
SELF-POWERED SENSOR USES AMBIENT ENERGY

Hassan Askari**, Ehsan Asadi**, Amir Khajepour* & Mir Behrad Khamesee*

*Professor, Department of Mechanical and Mechatronics Engineering
**Researcher/Student, Department of Electrical and Computer Engineering, University of Waterloo

The world is filled with ambient energy: stray heat, vibrations, electromagnetic fields and more that pulse all around us. Instead of letting those resources go to waste, WISE researchers are taking full advantage of them. In the case of a team led by Waterloo mechanical and mechatronics engineering professors Amir Khajepour and Behrad Khamesee, that means designing a self-powered sensor that taps into two different forms of freely available energy.

One is movement. Hassan Askari a PhD student of Khajepour and Khamesee’s team used a coil and magnet to generate electricity from mechanical energy. When anything from vibrating machinery to a jogger’s heel hitting the pavement compresses the coil, the magnetic field generates electrical current.

On top of that, the device taps into the triboelectricity created when specific types of material rub against one another — what we commonly think of as static electricity. The investigators created a triboelectric nano-generator (TNG) made from polyurethane and a polymer film called Kapton. When mechanical force brings the two together, electricity flows. Packaged together, these mini-generators create a flexible, lightweight prototype that measures just a few centimetres long. And as the experimental results revealed, it can transform even low-frequency, small-amplitude energy into high power density.

After optimizing the device, the team successfully tested it in various settings: as a wearable sensor that harvests energy from human motion, as a sidewall-mounted sensor for monitoring tire condition, and as a general pressure sensor. And that’s just scraping the surface. With absolutely no batteries required, this self-powered technology has all kinds of potential applications.

Researchers: Hassan Askari, Ehsan Asadi, Amir Khajepour, Mir Behrad Khamesee

Partners: Zia Saadatnia, Jean Zu, University of Toronto


READ FULL ARTICLE
PRODUCING ENERGY OUT OF THIN AIR: HARVESTING ELECTROMAGNETIC ENERGY

Omar M. Ramahi*, Faruk Erkmen** & Thamer S. Aloneef**

* Professor, Department of Electrical and Computer Engineering
** Researcher/Student, Department of Electrical and Computer Engineering, University of Waterloo

All around us, energy currently goes to waste. At any given moment, billions of Wi-Fi antennas and TV and radio stations are filling the atmosphere with electromagnetic waves. By harvesting these waves and converting them into electricity, we could tap into a vast source of “free” energy.

The question is how.

WISE member Omar Ramahi, a professor in Waterloo’s Department of Electrical and Computer Engineering, is exploring the potential of frequency-selective surfaces (FSSs). Essentially, these are surfaces deliberately contoured to absorb and channel electromagnetic waves of a specific frequency, extracting as much usable energy as possible.

Ramahi and his students started by optimizing FSS cells to harvest radio-frequency waves, producing a surface that could capture 97 per cent of available energy. Next, they combined a series of these cells with a rectifier to convert that energy to DC electricity.

By pairing a single rectifier with multiple cells, rather than one per cell, they created a far more efficient prototype than any previously reported FSS system. In lab settings, it converted an impressive 61 per cent of electromagnetic radiation into DC energy. According to researchers’ subsequent simulations, the optimal design would consist of one rectifier for every 16 cells.

Although the amount of energy harvested isn’t enough to fuel a car or heat a home, it could power a low-power device: an industrial sensor, for example, or a wireless computer mouse. As a result, we could say goodbye to our reliance on batteries and all the environmental headaches that creates.

**Researchers:** Omar M. Ramahi, Faruk Erkmen and Thamer S. Aloneef
In April, Waterloo became the first Canadian university to install smart charging infrastructure for electric vehicles (EVs). That’s good news for anyone on campus who wants to charge up for free. It’s even better news for the 21 WISE faculty whose research focuses on EVs.

Unlike regular chargers, these units optimize charging patterns based on demand levels and time-of-use electricity costs. They also collect a wealth of detailed data to help investigators shed light on critical issues of grid management and next generation EV design.

For example, how do different charging behaviours affect battery performance? Will the growing popularity of EVs stress the electrical grid? Could EV batteries sell power back to the grid during peak demand periods?

What is the difference between a level II and a level III charger? Time required for charging is the key differentiator. This is important for consumers. Typically, a level II charger (max 7.2 KW capacity) can be used for overnight charging at home. The level III charger can deliver up to 50 kW for full charge between 20 minutes to an hour.

The units come with PowerLimiting option, making it possible to remotely control how much power they deliver. At UW, researchers will also have access to 20 kW Tesla Wall Connector that can be enabled as a smart charger with additional metering.

The capability to collect a large amount of data through telematic devices provides a significant boost to UW researchers in support of an ongoing Drive4Data program at WISE. The existing program involves 10 EVs and the data collected reflect “real-life” usage: length of trip, drive cycles and status of battery charge under hot and cold conditions.

The installation of the smart chargers will allow a large number of vehicles to be included in the D4D program. Data mining and analytics will support the next generation of modelling tools and algorithms.

**Lead Researcher:** Prof. Roydon Fraser + WISE Team of 21 Faculty
SELF-POWERED SENSORS COULD HELP AVOID BLACKOUTS

Armaghan Salehian*, David Nairn**, Lan Wei***, Hélène Debéda****, Egon Fernandes****, Blake Martin****, Isabel Rua**** & Sid Zarabi****

*Associate Professor, Department of Mechanical and Mechatronics Engineering, University of Waterloo
** Associate Professor/*** Assistant Professor, Department of Electrical and Computer Engineering, University of Waterloo
****Researcher, Department of Electrical and Computer Engineering, University of Waterloo

As the electricity grid ages, blackouts become more likely. Placing sensors at strategic locations along transmission lines would allow grid managers to detect faults or fluctuations before they cause major headaches. However, powering those sensors with batteries would require replacing the batteries every couple of years — an expensive proposition when you consider the labour involved. That makes the idea of self-powered sensors very attractive. Once installed, they would keep working, year after year, without human intervention.

Now, WISE researchers have developed the technology to make that possible. A team led by Prof. Armaghan Salehian (Director of Waterloo’s Energy Harvesting and Vibrations Lab), Prof. David Nairn and Prof. Lan Wei (Electrical & Computer Engineering), have designed a system that takes advantage of the alternating magnetic fields created by the A/C electricity that flows through power lines. As the magnetic field alternates, a magnet within the device moves accordingly. In the process, it presses on the surrounding piezoelectric material, which generates current when it is compressed. Bingo: electricity. The researchers fabricated the energy harvester using screen-printing technology, laying down a layer of piezoelectric lead zirconate titanate in a symmetrical “meandering” design to minimize twisting and bending and therefore maximize power output. The resulting microelectromechanical system (MEMS) measures just 12.7 mm by 14.7 mm. But as the investigators proved, it boasts more power density than any similar MEMS device.

Now, Profs. Salehian, Nairn, Wei and their team are working to integrate this technology with power conditioning and wireless communications circuitry, all on a single chip. If they succeed, self-powered sensors could soon be monitoring the health of our power grid.

Researchers: Armaghan Salehian, David Nairn, Lan Wei, Hélène Debéda, Egon Fernandes, Blake Martin, Isabel Rua, and Sid Zarabi.

Partners: Cisco Systems, University of Bordeaux

When it comes to forecasting the weather, Waterloo’s Dr. Fue-Sang Lien believes that two crystal balls (or three or four or five) are better than one. By linking a number of systems, Dr. Lien and his team of researchers have pioneered a new way to more accurately anticipate wind speeds and power.

It’s a welcome improvement for the energy sector. While hydroelectric and nuclear power offer a predictable source of electricity, wind speeds vary from hour to hour. That makes it difficult for utilities to know how much electricity wind turbines will add to the grid on any given day — and therefore how to manage their power supply efficiently. It also complicates energy trading between jurisdictions.

So what’s the solution? Historical data and physics-based modelling systems can provide rough wind speed predictions. Feeding that information into artificial neural networks that learn and adapt makes those forecasts more reliable. Still, Dr. Lien knew there was room for improvement.

On a wind farm in Northern China, he and his colleagues developed a better model, feeding the best statistical and meteorological data into an interconnected framework of artificial neural networks to forecast wind speed and turbine power.

The result is more accurate 72-hour forecasts (plus a clearer sense of how much confidence utilities can place in those predictions). In Ontario, where wind power supplies a growing percentage of the province’s energy mix, the new approach is sure to be a breath of fresh air.

**Partners:** Natural Sciences and Engineering Research Council of Canada (NSERC), Waterloo CFD Engineering Consulting Inc., Defence Research and Development Canada, Taiwan Power Research Institute, North China Electric Power University, York University, Shared Hierarchical Academic Research Computing Network (SHARCNET)
In an ideal electrical grid, the frequency and voltage stay constant. However, when you have several sources of power, the variations in the amount of power generated create shifts in voltage and frequency.

In a traditional grid where the electricity flows in a single direction from generator to consumer, that’s relatively simple to achieve with a centralized control system of primary and secondary controls.

So-called “droop control” stabilizes voltage and frequency, which is good. However, it also tends to shift the frequency away from the North American standard of 60 Hz — and that can damage the appliances you plug into the grid. That’s why conventional grids add secondary control to shift the frequency back to 60 Hz.

It gets a bit more complicated in a microgrid powered by many small-scale and unpredictable energy inputs, such as wind turbines and photovoltaic panels, hooked together in a complex network. Adding droop control to the individual energy sources does stabilize the frequency, synchronizing the system involves brief power losses.

University of Waterloo professor John Simpson-Porco and his colleagues in Sweden believe they have the answer: adding a distributed averaging proportional-integral (DAPI) controller as a second measure of control. Their results show that a DAPI controller can significantly reduce transient power losses, and they have identified the optimal tuning to achieve that reduction.

By offering a simple, “plug-and-play” form of decentralized control, DAPI technology makes micro-grids more stable — and, in the process, makes renewable energy more practical.

Researchers: John Simpson-Porco, Emma Tegling, Martin Andreasson, Henrik Sandberg

Partners: Swedish Research Council, Swedish Foundation for Strategic Research
When you cut greenhouse gas emissions, slowing climate change isn’t the only benefit. According to Waterloo environmental engineer Rebecca Saari, you also save on healthcare costs. In many scenarios, those savings could actually outweigh the costs of reducing emissions.

That’s because when you curb the amount of carbon being pumped into the atmosphere, you also reduce co-emissions of pollutants that form smog, which is comprised of ground-level ozone and fine particulates. These air pollutants are linked to a range of respiratory and cardiovascular diseases.

Saari and her collaborators at the Massachusetts Institute of Technology set out to determine just how much of an effect carbon policies could have on those diseases — and hence healthcare costs.

They created highly sophisticated models that looked at the impact of three potential approaches to reducing U.S. carbon emissions: an economy-wide cap-and-trade program, policies that focus on the electricity sector and policies that focus on the transportation sector. The researchers included a range of projections for economic growth, the cost of renewable energy and improvements to fuel efficiency.

The numbers that emerged were compelling. Cutting carbon emissions produces healthcare savings that offset anywhere from 26 per cent to 1,050 per cent of the program costs, depending on the particular scenario.

The biggest net savings came from cap and trade, thanks mainly to its lower price tag. Although the incremental benefits were smaller with a stricter emissions standard, every scenario produced healthcare savings.

These insights can help decision-makers craft carbon policies that are good for the environment, good for health, and good for the economy.

**Researchers:**
Rebecca K. Saari, Tammy M. Thompson, Sebastian Rausch, Noelle E. Selin

**Partners:**
- The U.S. Environmental Protection Agency
- The Massachusetts Institute of Technology, including the Joint Program for the Science and Policy of Global Change and its consortium of sponsors
- The U.S. Department of Energy
Mention hydro bills at any Tim Hortons in Ontario and you’re sure to set off a chorus of grumbling. Electricity rates in the province have skyrocketed in recent years. Today, they’re among the highest in Canada.

According to WISE researcher Anindya Sen, that’s due in part to the province’s High-5 program. Introduced in 2011, it provides incentives for large industries to reduce electricity consumption during the highest demand hours of the year.

Trimming peak consumption avoids the need to build more generating stations — and Sen’s analysis shows the program has been effective. However, it comes at a hefty cost.

The Waterloo Economics professor calculates that Ontario’s major industrial users collectively reduced their use by 195 MW during High-5 days in 2011 and 2012. As a result, industry paid $422 million less in 2012 than they would have under the previous formula.

While that’s great for big users, Sen found much of the savings came from the pockets of smaller businesses and individuals. According to his analysis, the High-5 program has added an average of $34 to the annual electricity bill of Ontario households. Meanwhile, the program fails to help sectors such as manufacturing that can’t easily shift their production to non-peak hours.

That’s why Sen recommends the Ontario government phase out High-5 and instead rely on the capacity system currently being developed to reduce peak demand. This competitive, market-based system would help lower electricity costs for everyone, he says, while giving industry real-time data to help them cut their consumption.

*Researcher: Anindya Sen*
GOING GREEN PAYS DIVIDENDS

Olaf Weber

Professor, School of Environment, Enterprise, and Sustainability, University of Waterloo

Sure, green business practices are good for the planet. But are they good for the bottom line? That’s the question that WISE’s Olaf Weber has been probing for more than a decade. And according to his research, the answer is (mostly) yes.

In 2008, Weber analyzed the most recent sustainability, environmental, social and financial reports of 100 companies around the world. He discovered that the higher firms scored on an internationally recognized set of sustainability measures, the better they tended to perform financially.

In another study published that same year, he showed that small- and medium-sized companies with a strong environmental track record were less likely to default on loans. Weber and his colleagues concluded that financial institutions could reduce their risks by incorporating environmental criteria into their lending decisions.

Most recently, Weber turned his attention to the performance of more than 400 equity funds. His analysis revealed that every 100 tonne drop in carbon dioxide emissions per million dollars in sales correlates to a 10 per cent increase in the fund’s three-year compound return. Adding more green companies to a fund’s portfolio also yielded a small bump in returns.

It all adds up to a compelling business case for sustainability. However, Weber does sound one note of caution. According to his results, Canadian equity funds that invest in a greater percentage of green companies underperform those with less eco-exposure, perhaps due to the small pool of green firms in Canada.

Researchers:
Olaf Weber, Thomas Koellner, Dominique Habegger, Henrik Steffensen, Peter Ohnemus, Roland W. Scholz, Georg Michalik

Partners:
- Institute for Environmental Decisions
- Swiss Federal Institute of Technology
- Asset4
- Gesellschaft für Organization und Entscheidung
BUILDING THE CASE FOR FLEXIBLE CARBON CAPTURE

Ali Elkamel*, Colin Alie**, Peter L. Douglas* & Eric Croiset*

*Professor, Department of Chemical Engineering, University of Waterloo
**Researcher/Student, Department of Chemical Engineering, University of Waterloo

Carbon capture and storage (CCS) is an important tool for reducing greenhouse gas emissions from coal-fired generating stations. CO₂-scrubbing systems, for example, use solvents to pull carbon dioxide from the flue gas before it’s released into the atmosphere. However, because it takes energy to regenerate the solvents used in the process, capturing carbon this way either reduces the power plant’s generating capacity or its efficiency, or both.

That’s why WISE faculty members Ali Elkamel, Peter Douglas, Eric Croiset and their colleague in Waterloo’s Chemical Engineering department are fans of flexible CCS. This approach lets managers adjust the rate of CO₂ recovery based on factors like electricity demand and carbon pricing.

To better assess the costs and benefits of CCS, the UW team ran scenarios comparing three generating stations: one with no CCS system, one with a fixed CCS unit constantly operating at full capacity, and one with the ability to adjust the amount of CO₂ recovery.

Using a method called short-term resource scheduling, the researchers modeled not only the technical factors such as electricity loads and operating capacity but also changing electricity prices, carbon prices, and more.

Their results showed that flexible CCS reduced greenhouse gas emissions. And although it did not reduce those emissions quite as much as fixed CCS, it maximized the generating station’s net revenue.

The other important takeaway is the impact of greenhouse gas mitigation strategies depends on exactly how the electrical system in question operates. Short-term resource scheduling makes it possible to accurately assess that impact.


READ FULL ARTICLE
MAKING THE MOST OF HYBRID ELECTRIC VEHICLES

Nasser L. Azad*, John McPhee**, Reza Sharif Razavian*** & Amir Taghavipour***

*Associate Professor/**Professor, Department of Systems Design Engineering, University of Waterloo
**Professor, Department of Systems Design Engineering, University of Waterloo
***Researcher/Student, Department of Systems Design Engineering, University of Waterloo

In a world where petroleum supplies are shrinking and global temperatures keep inching higher, hybrid electric vehicles (HEVs) are a smart choice.

With both gas and electric motors under the hood, these cars enjoy the best of both worlds.

At low speeds, HEVs can take advantage of the energy-efficient electric motor. Not only are these motors inherently more efficient than their gas-powered counterparts, they can also draw on the energy captured during braking.

When serious power is required, however — for high-speed driving or sudden acceleration, for example — the conventional engine kicks in.

That creates a key design question: when to switch from one engine to the other for greatest fuel efficiency.

Systems design researchers at WISE recently developed a mathematically optimal feedback controller designed to address that challenge. By using prior knowledge of the upcoming driving conditions, the controller can select the best engine for the job at any given moment.

On top of that, the investigators were able to narrow down the amount of data about the future driving conditions the controller needs. They settled on three key pieces of information: the time when power is needed for acceleration, the time when power is needed for cruising, and the amount of energy that can be captured during braking until the next stop. The result is real-time optimization that doesn't demand hefty number crunching.

By choosing the most efficient engine, the controller can cut fuel consumption along with planet-warming carbon emissions. Thanks to a little optimal control theory, a smart transportation choice just got smarter.

Partners: The Natural Sciences and Engineering Research Council of Canada, Toyota, Maplesoft, the Ontario Centres of Excellence
USING REAL EV DATA TO DESIGN SMART CHARGING STRATEGIES

Mauricio Restrepo
PhD Student, Department of Electrical and Computer Engineering

Plug-in electric and plug-in hybrid electric vehicles (EVs) are clean transportation technologies that are slowly gaining a share of the Canadian transportation market. The number of EVs is expected to increase significantly in the coming years, creating a challenge for electricity delivery systems by raising the power demand and stressing distribution system assets. These negative impacts can be mitigated using smart charging strategies, which consist of controlling EV chargers to operate in periods of low demand and thus reduce their impact on distribution grids.

To design strategies to minimize EV impact, a key element is learning to understand EV owner behavior related to battery charging. Drive4Data, an initiative from the Waterloo Institute of Sustainable Energy, provides the actual performance measurements to researchers in the Power and Energy Systems and the Information Systems and Science for Energy groups to use for their work on grid EV control. The research groups are analyzing this database to identify patterns regarding the minimum battery state-of-charge, charging levels, charging times, and frequency of charging in different EV types, to use the information as input data in EV impact studies and smart charging strategy design.

Access to actual EV charging data is important in order to confirm or discard many assumptions found in the literature regarding behavior of EV users and to thus propose more realistic charging algorithms. For example, the researchers have identified that Plug-in hybrid EV users tend to discharge their batteries up to the minimum acceptable level, possibly because they can rely on the gas engine to support the vehicle operation. In contrast, researchers observed that Plug-in EV users act more conservatively since they tend to connect and charge their batteries more often, even several times per day, to keep the state-of-charge of their batteries at high levels.

Researchers: Mauricio Restrepo, Claudio Cañizares, Mehrdad Kazerani.
Partners: NSERC, Hydro One Inc., IBM.
Few of us think twice before we flip on a light switch. Yet lighting eats up 20 per cent of the world’s electricity production and accounts for more than 1,900 megatonnes of carbon dioxide emissions each year.

Energy-efficient lighting like fluorescent bulbs and LEDs have made a big difference, but they’re complex to design and expensive to manufacture. That’s why Pavle Radovanovic, Canada Research Chair in Spectroscopy of Nanoscale Materials, turned to nanotechnology for alternatives.

The Waterloo chemistry professor and his team started with gallium oxide nanocrystals. Because gallium oxide is photoluminescent, it gives off light when it absorbs photons. However, it produces blue-green light rather than the white light that consumers and businesses want. To address that problem, the researchers added organic dye molecules to the mix.

By selecting dyes that emit red-orange light and by controlling the size of the gallium oxide nanocrystals, which controls the precise colour of light the crystals emit, the team was able to create pure white light.

The result is a new class of hybrid light-emitting nanostructures with a whole range of potential applications — including energy-efficient light bulbs that might give fluorescent lighting and LEDs a run for their money.

**Partners:** Natural Sciences and Engineering Council of Canada (I2I and Discovery grants), C4 Consortium (PoP fund), Ontario Ministry of Research and Innovation (Early Researcher Award), Ontario Centers of Excellence (Market Readiness).
THINKING SMALL: ASSESSING THE VIABILITY OF MICROGRIDS

Magdy Salama* & Rajiv Varma**
*Professor, Electrical and Computer Engineering, University of Waterloo
**Professor, Electrical and Computer Engineering, University of Western

For decades, North America's electricity systems have relied on just a handful of mega-generating stations to provide electricity for millions of homes and businesses. Today, however, more and more renewable energy projects are coming on board. This makes the grid more decentralized and, as a result, far more complex to manage.

The solution, according to UW power expert Magdy Salama? Thinking small. Dividing the grid into self-sufficient units called microgrids makes it easier to handle the challenges of integrating renewable energy. Microgrids are also more efficient: because the electricity travels shorter distances, less energy is lost in transmission.

Salama is part of a team of researchers studying the feasibility of such a system in London, Ontario. The proposed 5-7 MW microgrid will include a mix of renewable energy sources such as solar, biogas and geothermal.

The researchers will develop control systems that will let power grid operators quickly ramp up and down different energy sources to meet fluctuating levels of demand. These new devices will also help power grid operators regulate voltage, stabilize frequencies and smooth out harmonics - damaging distortions in the voltage waveform that can be created by small-scale generating systems.

Ultimately, the team will create a detailed implementation plan for designing, building and operating a microgrid in the northeast corner of London. Once it's up and running, this system will showcase an efficient and dynamic approach to managing power systems and making optimal use of renewable energy.

Partners: London Hydro, Bluewater Power Distribution Corporation, Hydro One, the Independent Electricity System Operator, Omniwatt Inc., Schweitzer Engineering Laboratories, Ontario Centres of Excellence
Electricity grids are getting smarter. Today, electricity distributors are taking advantage of sophisticated meters and two-way communication systems to match power production to demand in real time. Thanks to this technology, utilities can base their prices on usage patterns or even remotely dial down home air conditioners when the grid faces peak loads.

But there are big privacy concerns around transmitting consumer data over the Internet: data such as the amount of electricity each house uses, when it was used and what it was used for.

Grid managers need some way of encrypting it so, for example, thieves cannot figure out when someone is away from home by monitoring their electricity patterns. At the same time, the encryption process cannot require too much computing power or slow down the speed of data transfer — a problem with many encryption techniques.

To solve that issue, WISE researcher Xuemin (Sherman) Shen and his colleagues have developed an approach they call EPPA: Efficient and Privacy-Preserving Aggregation. EPPA uses a technique called Pallier’s homomorphic cryptosystem to encrypt the multidimensional consumer data and then send it to local data gateways.

The beauty of homomorphic encryption is that it allows the local gateways to merge data from different consumers without decrypting it, keeping the process highly efficient. Each gateway can then compact the aggregated data and forward it to grid managers. When Shen and his colleagues tested their system against a range of security threats, the EPPA-encrypted data stayed safe and secure.

As a result, EPPA allows the kind of real-time communications that the smart grid requires yet still protects all-important consumer privacy.

**Partners:** Natural Science and Engineering Research Council of Canada
WHERE TO PUT WIND TURBINES?

Geoffrey McD. Lewis
Assistant Professor, School of Planning, University of Waterloo

Wind power offers a clean, infinitely renewable source of energy that could play a valuable part in meeting the world’s energy needs. But where should we put turbines for maximum value?

Traditionally, developers have looked at topography, wind patterns, land values, and the attitudes of local residents. Now, WISE researcher Geoffrey Lewis is proposing an additional factor: locational marginal price.

Locational marginal price (LMP) is the constantly updated wholesale price of electricity at a specific location. The harder it is for a system to meet local electricity demand, the higher the LMP. So adding turbines in areas where LMP is high takes stress off the system and lowers electricity costs.

Lewis mapped LMP data in Michigan over a two-year period, looking at how it varied across the state and over time. While he found that LMP was low at most sites, several locations had strikingly high values.

By combining this information with wind speed data, Lewis pinpointed the sites where installing wind turbines could generate the most electricity and create the greatest benefits for the electricity system.

As more and more electricity system operators incorporate renewable energy into their mix, this research can help them get the biggest bang for their buck.

Partners: the Alcoa Foundation Conservation and Sustainability Fellowship Program (University of Michigan)
BULL’S EYE!
HOW FRAMING ENVIRONMENTAL MESSAGES HELPS THEM HIT THEIR TARGET

Jennifer Lynes
Associate Professor, School of Environment, Enterprise, and Sustainability, University of Waterloo

We all know that we should drive less, recycle more and turn down the thermostat for the sake of the planet. However, it takes more than knowledge to spur most people to action. That’s where the right kind of messaging comes in. And just how those messages are framed can have a big impact, according to the School of Environment’s Jennifer Lynes.

By reviewing a number of cognitive psychology and social psychology studies, Lynes and two of her fourth-year students concluded that negative messages tend to be more effective than positive ones. For example, most people pay more attention to messages that describe how much money they’re losing by not insulating their house, rather than how much money they could save with a high-efficiency furnace.

Messages work better when they emphasize benefits for the current generation, rather than benefits for future generations.

Finally, messages that focus on social outcomes resonate more with women than men. For example, teenaged girls are more likely to drive less if you emphasize how cool it is to use greener forms of transportation, rather than how ditching the car benefits the planet.

Lynes cautions that because research in this area is few and far between, there isn’t a lot of data to draw on. One thing is clear, however: the better you know your audience, the more effectively you can frame your message.

Researchers: Jennifer Lynes, Tania Cheng, Danielle Kathryn Woon

Acknowledgements: Erin Harvey of UW Statistics Consulting Service, Dr. Clara M. Cheng of American University, Glen Taylor, Chris Cressman, Debra Campbell, and John Barclay
SETTING GOALS FOR ENERGY CONSERVATION

Ian Rowlands*, Claudio Cañizares**, Kankar Bhattacharya** & Paul Parker*

*Professor, School of Environment, Resources, and Sustainability, University of Waterloo
**Professor, Electrical and Computer Engineering, University of Waterloo

Setting a target and striving towards it is something we all do, whether it’s getting fitter, losing weight and or saving more money. So why not take advantage of that goal-setting instinct to encourage energy conservation? That’s part of the thinking behind the Energy Hub Management System (EHMS), the brainchild of a group of environment and engineering researchers at the University of Waterloo.

Once homeowners have set specific energy goals, they can log on to the EHMS to monitor their conservation progress in terms of money saved, energy consumption reduced and emissions avoided. They can also compare their results with their past performance and measure progress towards their goal.

But that’s only half of the EHMS. The other half is an electronic “brain.” The hub collects data from all of the devices connected to it - dishwashers, fridges and even natural gas furnaces - as well as local electricity demand, time-of-day pricing and even weather forecasts. Not only can homeowners set limits on their overall energy budget, they can also put different priorities on different energy uses throughout the day. Presto! The system will optimize home energy use based on all those factors.

The result is a household smart grid that can be customized from a smart phone. Seeing their results makes homeowners smarter too. EHMS feedback helps everyone understand how their behaviour affects their hydro bill.

With a residential model established, a pilot project to test EHMS on real households in Ontario is now fully underway. Next up? Industrial and commercial models aimed at large-scale energy consumers and producers.

Partners: Energent Incorporated, Hydro One Networks Incorporated, Milton Hydro Distribution Incorporated, Ontario Centres of Excellence, Ontario Power Authority
Lightweight, powerful, rechargeable batteries are the Holy Grail for many energy researchers: batteries that can propel electric cars hundreds of kilometres on a single charge or store large quantities of electricity for local power grids.

The answer could lie in zinc-air batteries. Instead of packaging all the essential chemicals inside the battery casing, zinc-air batteries use oxygen in the surrounding air to drive a key chemical reaction. As a result, they’re much lighter than conventional batteries. And at least in theory, they have the potential to deliver much more specific energy than any other kind of battery technology.

But rechargeable zinc-air batteries also suffer from several key drawbacks. They require expensive metals or alloys, they don’t charge and discharge quickly, and they’re not durable.

A new, nanoengineered solution could change all that. University of Waterloo chemical engineering professor Zhongwei Chen and his colleagues recently developed something they call a core corona bifunctional catalyst (CCBC).

The outer layer of the CCBC consists of carbon nanotubes studded with nitrogen. When zinc in the battery meets oxygen from the air, these nanotubes catalyze a reaction that generates electricity. Meanwhile, the core of CCBC is made of lanthanum nickelate, which catalyzes the opposite reaction. By regenerating oxygen and zinc, it recharges the battery.

Thanks to these low-cost ingredients, CCBC batteries won’t break the bank. And unlike current state-of-the-art metal-air batteries, they continue to hold charge even after a thousand recharging cycles. Thanks to funding from NSERC Idea to Innovation and the C4 Network, the WISE researchers are now developing prototypes that can be used to market this highly promising technology to investors and partners.

To ensure nuclear power plants are running safely, operators closely scrutinize a slew of different measurements, monitoring for any signs of wear-out. Take the example of the electro-hydraulic system controlling the plant’s turbines. Operators collect weekly samples of the control fluid, looking for an uptick in acids that indicate the fluid is starting to break down.

The problem is deciphering what are the important, underlying trends and what is simply noise in the data — short-term fluctuations caused by variations in the chemical processes and environment.

Standard statistical analysis methods like least-squares regression and stationary time series analysis don’t work because that noise component can vary in complex, time-dependent ways. That’s why WISE investigator Mahesh Pandey and research associate Bo Li are proposing a different approach: empirical mode decomposition.

Borrowed from climate and geophysical sciences, this method starts with the graph of data points plotted over time and breaks it down into a number of component waves, along with an underlying trend line. A simple statistical significance test reveals which oscillating waves represent noise that can be ignored. Once you’ve eliminated the noise data, you can recombine the “real” waves with the trend line to produce a clean graph.

Pandey and Li used simulations to test this approach and then applied it to real data taken from control fluids at a nuclear plant. The results gave plant operators a clear picture of acid levels in the fluid — and hence how well the plant’s maintenance methods are working.

Researchers: Mahesh D. Pandey, Bo Li

Partners: The Natural Sciences and Engineering Research Council of Canada, The University Network of Excellence in Nuclear Engineering
PRODUCING PROPA NOL: A MICROSCOPIC SOLUTION

Kajan Srirangan***, Lamees Akawi***, Xuejia Liu***, Murray Moo-Young* & C. Perry Chou**

*Emeritus Professor/**Professor, Department of Chemical Engineering, University of Waterloo
***Student/Researcher, Department of Chemical Engineering, University of Waterloo

In the quest to find planet-friendly substitutes for fossil fuels, more and more researchers are turning their attention to propanol. This alcohol boasts a higher energy content than its cousin ethanol, widely touted as a green substitute for gasoline. And unlike ethanol, propanol can be transported in existing gas pipelines. The problem is how to produce it.

Perry Chou and fellow researchers in Waterloo’s department of Chemical Engineering believe the answer could be bacteria. By tinkering with the metabolic pathways of E. coli — a harmless and easily grown microorganism — the investigators succeeded in producing a microscopic propanol factory.

By genetically manipulating a novel pathway in the bacteria, they were able to churn out propanol in concentrations up to 7 g/L. It’s an intriguing glimpse of how this environmentally responsible biofuel might be produced in the future.

While the new technology might have a potential for commercialization, Chou, Moo-Young, and their colleagues have identified several issues that first need to be addressed. On the to-do list is eliminating bottlenecks at key points in the pathway, knocking other metabolic pathways that generate unwanted byproducts, and determining the optimal conditions for cultivating these bacterial workhouses.

**Partners:** Natural Sciences and Engineering Research Council of Canada, Strategic Program
Welcome to the Canadian oil sands. While this is one of the largest oil reserves on the planet, extracting the increasingly hard-to-reach resource requires substantial amounts of energy and water. Not only does that drive up the cost of production, it makes the oil sands Canada’s single largest emitter of greenhouse gases (GHG).

So how can producers minimize costs, maximize profits, and stay within federal GHG emission and fresh water withdrawals targets? That’s where WISE researcher Luis Ricardez-Sandoval and his colleagues come in. Ricardez-Sandoval is working on the development of a comprehensive integrated energy optimization model to improve efficiency in Canadian oil sands operations. Currently, his model incorporates a range of variables such as carbon emissions, natural gas prices, and the amount of steam required to extract oil trapped well below the surface.

Producers can use this model to select the most appropriate production levels and schemes to maintain carbon emissions and water withdrawals within the specifications outlined by government of Alberta. In addition, this model helps producers to plan infrastructure by identifying the optimal configuration of commodities like power plants, boilers, and extraction approaches.

Ricardez-Sandoval’s research also includes the use of alternative energy sources for the oil sands. A study conducted by his research group suggests that better water management, carbon storage and capture, and carbon-free energy sources such as nuclear power could play bigger roles in the oil sands industry. Future integrated modeling systems will add those variables into the equation.

With the province of Alberta expected to churn out three million barrels of oil a day by 2020, Ricardez-Sandoval’s modelling activities gives oil producers a practical tool to optimize, plan and schedule their operations in profitable and sustainable ways.
Named one of Maclean’s future leaders under 25, Dominic Toselli from the University of Waterloo is set to graduate with a mechanical engineering degree and has jumpstarted his career with his start-up company PetroPredict. Toselli was inspired by his previous work term experiences within petroleum companies like Shell and Suncor that helped him gain skills and apply them to bigger problems in the industry.

Alongside his co-founder Andrew Andrade, their company PetroPredict brings advanced data mining and machine learning techniques to solve some of the toughest problems in the oil and gas industry. These issues include detecting well and pipeline integrity issues that cause great damage to the environment if not detected early on. Toselli believes that to be able to enter into this industry, there needs to be the technology that can improve processes and extraction by a substantial amount to get noticed. Thus, new technology must be thoroughly tested with the appropriate measures to mitigate risk.

“What the future holds for PetroPredict is exciting,” Toselli says. “We are surfing a major technological wave and shift in the oil and gas industry. Equipment is becoming more intelligent. The digital oil field is no longer just a concept. Companies in oil and gas have to reinvent themselves like never before. For example, GE is converting its oil and gas field equipment to allow greater remote monitoring and data collection, lessening the time required from field operators. Extrapolating insights from this data is, in a sense, is like searching for sunken treasure, though with a much higher probability of success – have the patience, develop the right tools, be persistent in looking, and the outcome of your efforts can save or earn a company millions.”
TRANSFORMING SOLID WASTE INTO USABLE ENERGY

Bill Anderson
Associate Professor, Department of Civil and Environmental Engineering, University of Waterloo

Waste disposal and its environmental impacts have become an increasingly growing concern within Canada. Canada generates more municipal waste per capita than any of its peer countries—at 777kg per capita in 2008, twice as much as Japan—across the Organization for Economic Co-operation and Development (OECD). Solid and semi-solid waste is major waste category, with the oil sands industry being the largest solid waste producer in Canada.

In Ontario, most of the municipal solid waste is landfilled or incinerated. Given the increasing difficulty in finding acceptable sites for landfilling, there is enormous pressure to find a viable, sustainable, and economic alternative.

Bill Anderson, Director of Admissions and Professor in the Faculty of Engineering at the University of Waterloo, and his colleagues believe the answer lies within converting waste into useful energy.

Using methods such as agricultural waste processing and resource recovery, solid waste can be burnt into ash, reducing the volume of landfilled waste up to 90% and recovering useful nutrients for organic fertilizer components. Modern energy recovery facilities equipped with air pollution control devices can also remove hazardous gases and particulates during the incineration process, leaving useful steam for electricity generation.

Anderson and his team look forward to informing and scaling the research through the upcoming Solid Waste Management Partnerships Workshop on June 24 that will bring together a group of leading academics and industry personnel to identify the solution pathways for addressing solid waste issues in Canada. The goal is to foster research collaboration with a focus on R&D capacity of integrated waste management systems.
If Mir Behrad Khamesee has his way, the snowblower you’re hauling out yet again this winter could do more than just clear a path to your front door. The mechanical engineering researcher foresees a day when a small gizmo attached to that snowblower could capture vibrational energy from the motor and convert it into useful electricity.

Khamesee and his graduate student Pratik Patel recently developed a micro-energy harvesting system. The device is elegantly simple. At either end are stationary magnets. Sandwiched between them is a stack of moving magnets, arranged to repel one another. As external vibrations from the snowblower move the hovering stack of magnets up and down, a set of cylindrical coils surrounding the device generates an electromagnetic force.

While clearing your driveway won’t create enough electricity to light up Las Vegas, it could be enough to power wireless sensors that currently rely on batteries, for example.

Nor do the benefits end when the snow melts. By adjusting the gap between the stationary magnets and the moving magnets, the researchers were able tune the vibrational frequency to different power equipment like lawnmowers.

Now, Khamesee and Patel have taken things one step further, developing the world’s first patent-pending energy harvester with converting multi-directional motion into linear motion. Unlike existing harvesting devices, which must be aligned with the direction of the vibrations in order to generate electricity, their 3D harvester can be mounted in any orientation and still capture energy.

Any way you look at it, these are electrifying breakthroughs.

**Partner:** Natural Sciences and Engineering Research Council of Canada
WISE researcher Jeff Gostick can envision a day when clean, efficient fuel cells replace today’s internal combustion engines. These eco-friendly energy generators run on hydrogen and air. Best of all, they produce no greenhouse gases — only water.

Fuel cells are ideal for consumer vehicle applications, due to their long range and quick refueling times, but lack of a hydrogen refueling infrastructure has delayed their deployment in favor of battery powered vehicles. This has not been a problem for commercial fleets though, and hydrogen fuel cells are being widely deployed in materials handling equipment like fork-lifts and delivery trucks which can fuel up at central, but private depots. Right now, one of the hurdles facing PEM fuel cells is water management. When hydrogen ions reach the cathode, they combine with electrons and oxygen to form water. If that water is in gas form, the moisture helps keep the membranes hydrated. However, if it turns to liquid, it can flood the electrode — and that’s bad news.

Gostick and his McGill collaborator, Mahmoudreza Aghighi, set out to better understand how and when liquid water forms at the cathode. They developed a pore network simulation and incorporated a sophisticated algorithm that takes into account heat, mass and electrical transfer. The pair demonstrated their model successfully predicts the change from gas to liquid under different operating conditions. On top of that, it predicts where liquid water clusters will form within the cathode.

That’s a significant improvement over existing models, creating important insights into condensation and evaporation in the electrodes. As a result, it paves the way to better water management in PEM fuel cells — and brings us closer to the day when we can ditch internal combustion engines.

**Researchers:** Jeff Gostick and Mahmoudreza Aghighi

**Partners:** Natural Sciences and Engineering Research Council of Canada through the Collaborative Research and Development Program in partnership with the Automotive Fuel Cell Cooperation.

POWERFUL TOOLS FOR ANALYZING POWER FLOW OF MODERN MICROGRIDS

Mehrdad Kazerani*, Mahmoud A. Allam** & Amr A. Hamad**

*Professor, Department of Electrical and Computer Engineering, University of Waterloo
**Researcher/Student, Department of Electrical and Computer Engineering, University of Waterloo

Microgrids integrate small-scale electrical energy sources and energy storage systems into local electrical distribution grids. This modern concept facilitates the integration of renewable energy sources, such as solar and wind energy, for greener energy generation. Also, microgrids are potentially more reliable than conventional electrical distribution networks, because they can operate independently if disconnected from the main utility grid under any circumstance. As a result of their new and unique operational philosophy, the tools used to analyze power flow in traditional electricity grids simply cannot do the job for microgrids.

That is why WISE researcher, Mehrdad Kazerani, and his PhD student, Mahmoud Allam, set out to develop a robust algorithm capable of analyzing power flow in complex microgrids operating under a variety of conditions. Their goal was to develop an approach that would work with the two possible methods for controlling frequency and voltage within a microgrid: droop control and isochronous control.

Kazerani and Allam began by breaking down their system model into smaller sub-problems, enabling them to develop relatively simpler equations that could be solved quickly. They also incorporated a broad range of factors that affect microgrids’ operation and analysis, including unbalanced loads, transformer connections and different load configurations.

The researchers then put their algorithm through its paces on a microgrid with 13 nodes, as well as a more complex system with 123 nodes. They tested it under various conditions, changing from light to heavy loading and switching between droop and isochronous modes of operation.

Their approach proved both fast and accurate, outperforming other existing analysis methods. With this novel algorithm, microgrid system operators now have a robust analysis tool that works with a variety of complex distributed generation networks with different types of controls.

Researchers: Mehrdad Kazerani, Mahmoud A. Allam and Amr A. Hamad


READ FULL ARTICLE
Metamaterials seem to come straight out of science fiction. By controlling the precise shape and configuration of microscopic materials such as plastic or metals, investigators can bend light or sound in unnatural ways. The result could be invisibility cloaks, earthquake shields, or—according to Waterloo’s Dr. Omar Ramahi—energy harvesting devices.

To test their theory, Ramahi and members of his research group assembled a split-ring resonator (SRR), made up of tiny C-shaped loops. When zapped with microwaves at a specific frequency, these carefully arranged metamaterials generate a strong magnetic field within the SRR array and a relatively high voltage across the gap in each ring.

To harvest that energy, the team inserted a resistor into the gap to absorb the power. They measured a voltage of 611 mV across the resistor, proving the feasibility of using SRRs to collect power from electromagnetic fields.

The researchers then took a step back, looking at how efficiently their split-ring resonator converted microwaves into energy. By experimenting with the angles at which the microwaves hit the SRR, the team could determine the ideal configuration for energy collection at different frequencies.

This work creates the potential of harvesting energy from the abundant electromagnetic fields in the world around us. Even more interestingly, Dr. Ramahi’s group is developing the same technology to harvest energy from the solar infrared and visible spectra. Future experiments will focus on feeding the collected current into a power grid, opening up new frontiers in the world of sustainable energy.

**Partners:** Natural Sciences and Engineering Research Council of Canada, Saudi Arabian Ministry of Higher Education
Demand for wireless sensing units has increased in recent years, particularly for large networks of power transmission lines. Dr. Armaghan Salehian and her Energy Harvesting Laboratory team seek to design and fabricate sensing devices to measure electric current for smart grid applications. These technologies are self-contained and require minimal energy for their operation. This is done through the use of various smart materials to convert ambient vibrations and the magnetic flux of transmission lines into usable power. These sensing and harvesting units are miniature-sized and are thus much smaller than the available technologies used by hydro industries.

Although energy harvesting plays a large role for Dr. Salehian's research team, the Energy Harvesting Laboratory is not limited to this one aspect. Other areas of research include the use of smart materials in bioengineering applications, flatness control of Kapton membranes for space antenna membranes, dynamics modelling of complex cable-harnessed systems, as well as using GNSS reflectometry through micro-satellites for climate change monitoring.

The Energy Harvesting Laboratory is currently investigating the development of a pressure sensing and actuation system to apply compression to lower extremities that will improve venous blood flow. This type of bioengineering requires sensor characterization, experimental and physiological testing, and algorithm development. The ability to produce a unit that is both mobile and lightweight is a key priority for this work. Smart materials satisfy both of these criteria and the Energy Harvesting Laboratory has invested significant hours into the applicability of various types of smart materials for use in the sensing and actuation system. Ultra-light space structures, known as Gossamer or inflatable structures, commonly use Kapton membranes. As an example, a synthetic-aperture radar (SAR) antenna makes the use of Kapton membranes for the antenna surface. Despite their lightweight a common problem for these membranes is the material being susceptible to wrinkles. The Energy Harvesting Laboratory has successfully modelled the wrinkle pattern of these Kapton antenna membranes when patched by macro fiber composite actuaries (MFCs) for flatness control.

The Energy Harvesting Laboratory is also equipped with vibrations testing facility that allows the determination of the frequencies of vibration. Currently, these types of tests are being performed to validate a proposed model for cable-harnessed space structures. As space structures become increasingly lightweight the addition of power and signal cables greatly affects the dynamics of these structures. The ability to predict their vibrations behavior will have significant impacts for design considerations of these structures.

Researchers: Dr. Armaghan Salehian

Partners: Riley’s 321 Sleep, Silicone Pro, Canadian Space Agency, Lockheed Martin, U.S. Air Force
From crashing waves to a brisk breeze, energy is constantly flowing around us. But how do we convert that energy into usable electricity?

For mechanical engineer Sean Peterson, the answer might lie in ionic polymer metal composites (IPMC)—synthetic, electro-active materials that produce a voltage when you apply mechanical force.

In recent experiments, he has immersed an ultra-thin strip of IPMC material at one end of a container of water and generated a vortex of swirling liquid at the other end. The vortex ring shoots across the container where it hits the IPMC strip, generating an electric charge.

Peterson and his colleagues have used a variety of tools, including time-resolved particle image velocimetry, to analyze exactly how energy is transferred from the vortex to the IPMC strip. It all adds up to a clearer picture of the mechanics—and potential—of fluid energy harvesting. Furthermore, Peterson demonstrates the feasibility of using IPMCs as a practical alternative to other electro-active materials that perform poorly in wet environments.

Peterson’s work feeds a growing interest in small-scale energy harvesting systems. With real-world applications ranging from powering miniature electronic devices to enhancing underwater propulsion systems, the ability to extract power from our surroundings is making big waves in the world of sustainable energy.

**Partners:** Natural Sciences and Engineering Research Council; National Science Foundation
CATALYZING A LOWER-CARBON WORLD

David S. A. Simakov*, Duo Sun** & Faisal M. Khan**

*Assistant Professor, Department of Chemical Engineering, University of Waterloo
**Researcher/Student, Department of Chemical Engineering, University of Waterloo

The more carbon dioxide (CO₂) we pump into the atmosphere, the hotter the planet will get. That’s why researchers around the world are looking for ways to transform those emissions into useful resources. One promising approach is to convert them into methane fuel, using a hydrogenation process called the Sabatier reaction.

In theory, it’s simple: just add hydrogen gas to CO₂ in the presence of a catalyst. However, there are technical challenges. Because the process generates a lot of heat, the reactor must be constantly cooled. It’s also crucial to limit the creation of carbon deposits that can deactivate the catalyst.

WISE researcher David Simakov is addressing those issues. He and his chemical engineering team have developed a mathematical model of an actively cooled Sabatier reactor.

The researchers tested the reactor performance using transient numerical simulations varying operating conditions such as pressure, cooling rate and feed rate, assessing their impact on methane production and catalyst deactivation. As well as looking at pure CO₂ as a feedstock, the researchers also examined biogas: a mixture of CO₂ and methane produced by landfills and the anaerobic digesters often used on farms.

Dr. Simakov and his team found that, although high pressure accelerates methane production, it also speeds up catalyst deactivation. According to their results, the key to optimizing methane production is achieving the right level of cooling.

By carefully managing operating conditions, they predict that it is possible to keep the reactor operating for up to 10,000 hours and still achieve conversion rates of 80 per cent or more — results that take CO₂ hydrogenation one step closer to commercial realization.

Researchers: David S. A. Simakov, Duo Sun, Faisal M. Khan

Partners: WISE-Cisco Systems Smart Grid Research Fund


READ FULL ARTICLE
PUTTING THE PRESSURE ON SOLAR ROAD PANELS

Andrew B. Northmore** & Susan L. Tighe*

*Professor, Department of Civil and Environmental Engineering, University of Waterloo
**Researcher/Student, Department of Civil and Environmental Engineering, University of Waterloo

Energy-generating highways are far from science fiction. Waterloo’s Centre for Pavement and Transportation Technology (CPATT) and other groups have already developed prototypes of modular road panels that can produce electricity thanks to embedded solar cells.

But can panels made of sensitive photovoltaic material and tempered glass withstand the impact of 18-wheelers or Toronto’s rush hour traffic?

To find out, WISE researchers Susan Tighe and Andrew Northmore conducted a finite element analysis to predict how CPATT’s prototype would perform in real-world conditions.

Using modelling software, the duo tested the panel’s durability on four structural bases typically used in Ontario pavement: concrete, asphalt, granular and subgrade. For each, they applied the maximum wheel and axle loads allowed under Canadian regulations to different areas on the panels, checking whether they would crack or fail under the pressure. They didn’t.

In all cases, the strain put on the transparent and base layers of the panels fell well below their endurance limits, demonstrating that the prototype is road-worthy. In fact, the additional reinforcement provided by the solar panels helped distribute tire loads, actually maintaining or improving the structural performance of the base they’re installed on.

With a better understanding of how much strain panels can take, engineers can now refine their designs to reduce costs. The results also suggest that researchers can move their trials out of the lab and into the field — paving the way for a network of solar highways.

Researchers: Andrew B. Northmore and Susan L. Tighe

Partners: Natural Sciences and Engineering Research Council of Canada, Ontario Graduate Scholarship Program, University of Waterloo, Transportation Association of Canada, Norman W. McLeod Chair in Sustainable Pavement Engineering

Appendix III: Research Labs
1. **Advanced Glazing System Laboratory (AGSL)**

Researchers are creating a library of tools to model window glazing and shading for green building design. Our cutting-edge equipment includes a rooftop test facility, an exceptionally high-resolution spectrophotometer and the unique Broad Area Illuminated Integrating Sphere, which allows researchers to measure directional and spectral transmittance and reflectance of spatially non-uniform samples.

**Location:** Energy Research Centre (ERC), Room: ERC-3009

**Principal Investigator:** Michael Collins (Associate Chair, Undergraduate Studies and Associate Professor, Mechanical and Mechatronics Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/advanced_glazing_system_laboratory
https://uwaterloo.ca/advanced-glazing-system-laboratory/

2. **Applied Nanomaterials & Clean Energy Lab**

Looks at how nanomaterials can advance clean energy and environmental technology. We’re reducing the cost and improving the efficiency of fuel cells through electrocatalysts and proton exchange membranes. We’re developing metal-air batteries, which can store more than three times as much energy, by weight, as lithium-ion batteries. Finally, we’re investigating the use of polymer-zeolite composite membranes for water purification.

**Location:** Engineering 6 (E6), Room: E6-2107

**Principal Investigator:** Zhongwei Chen (Canada Research Chair in Advanced Materials for Clean Energy and Professor, Chemical Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/applied_nanomaterials__clean_energy_lab
http://chemeng.uwaterloo.ca/zchen/
3. Carbon Nanomaterials Laboratory

Nanotubes and graphene offer many intriguing applications for renewable energy and manufacturing. Our lab is developing improved nanocomposites energy-dense supercapacitors that can extend battery run time; and lightweight, flexible photovoltaic cells made from organic materials.

**Location:** Engineering 6 (E6), Room: E6-2113

**Principal Investigator:** Aiping Yu (Associate Professor, Chemical Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/carbon_nanomaterials_lab
http://chemeng.uwaterloo.ca/ayu/

4. Centre for Advanced Materials Joining (CAMJ)

Aims to develop new and innovative technologies to join materials together, which is fundamental to manufacturing industrial products, from microelectronics and medical devices to automobiles. We focus on microjoining, nanojoining, welding, and brazing, collaborating closely with leading companies in their R&D efforts.

**Location:** Engineering 3 (E3), Room: 2135A

**Principal Investigator:** Norman Zhou (Professor, Mechanical and Mechatronics Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/centre_for_advanced_materials_joining
https://uwaterloo.ca/centre-advanced-materials-joining/
5. Centre for Advanced Photovoltaic Devices and Systems (CAPDS)

Promotes cutting-edge research and development that spans the spectrum of photovoltaic (PV) technology. Our 14,000-square-foot facility includes infrastructure for synthesizing semiconductor base materials; developing nanotechnologies for PV; designing and fabricating advanced PV devices and modules; and testing and characterizing PV materials, devices and systems.

**Location:** Energy Research Centre (ERC), 1st Floor

**Principal Investigator:** Siva Sivoththaman (Director, CAPDS and Professor, Electrical and Computer Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/centre_for_advanced_photovoltaic_devices_and_systems
http://www.capds.uwaterloo.ca/index.htm

6. Electricity Market Simulation and Optimization Laboratory (EMSOL)

Provides a state-of-the art facility for power systems studies geared toward the operation of restructured electricity markets. Our work includes modeling, simulation, analysis and optimization of power systems and smart grids; stability and security analysis and improvements of power systems in a deregulated environment; studies of energy systems with multiple energy carriers; and optimal power management and forecasting in competitive electricity markets.

**Location:** Centre for Environmental & Information Technology (EIT), Room: 4151

**Principal Investigator:** Claudio Canizares (Hydro One Chair and Professor, Electrical and Computer Engineering); Kankan Bhattacharya (Associate Chair, Graduate Studies and Professor, Electrical and Computer Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/electricity_market_simulation_and_optimization_lab
https://uwaterloo.ca/power-energy-systems-group/electricity-market-simulation-and-optimization-lab
7. Energy Harvesting Laboratory

Seeks to design and fabricate sensing devices to measure electric current for smart grid applications. Other areas of research include the use of smart materials in bioengineering applications, and flatness control of Kapton membranes for space antenna membranes. Our $1.5 million collection of lab equipment includes an LMS data acquisition system is the most up to date vibrations measurement unit that used by many cutting edge industries such as Mercedes and aerospace companies.

**Location:** Davis Centre (DC), Room: DC-1702

**Principal Investigator:** Armaghan Salehian (Associate Professor, Mechanical and Mechatronics Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/energy_harvesting_lab
http://www.eng.uwaterloo.ca/~salehian/research/index.html

8. Giga-to-Nano Centre

A $17 million lab that offers a wide range of capabilities for processing electronic materials and devices, from nano-materials to large-area electronics and electronics on unconventional substrates. Unique in Canada, we provide users with training and access to conduct their own cutting-edge research, as well as rapid system prototyping for commercial applications. Our facilities include equipment for characterization, deposition, etching, lithography and packaging and bonding.

**Location:** Engineering 3 (E3), Room: E3-1157

**Principal Investigator:** William Wong (Professor, Electrical and Computer Engineering); Hany Aziz (Professor, Electrical and Computer Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/gigatonano_centre
https://uwaterloo.ca/giga-to-nanoelectronics-centre/
9. High Voltage Engineering Laboratory (HVEL)

A leading research and teaching lab in the field of insulation, applied electrostatics, nanodielectrics, pulse power applications, and power electronics. Our extensive experimental and test facilities - available to industry - allow the design, prototyping, and testing of high-voltage components and advanced dielectric materials, while our research experts are recognized around the world.

**Location:** Carl A. Pollock Hall (CPH), CPH-1332/1333

**Principal Investigator:** Sheshokamal Jayaram (Director, HVEL and Professor, Electrical and Computer Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/high_voltage_energy_lab
https://uwaterloo.ca/high-voltage-engineering-laboratory/

10. Information Systems and Science for Energy (ISS4E) Laboratory

At the (ISS4E) Laboratory, we're applying the concepts and techniques pioneered by the Internet to energy problems, from monitoring individual buildings to developing an efficient, decentralized "smart" grid that draws energy from millions of small-scale sources and uses communications technology to match supply and demand.

**Location:** Davis Centre (DC), Room: DC-2554

**Principal Investigator:** Srinivasan Keshav (Professor, Cheriton School of Computer Science); Catherine Rosenberg (Canada Research Chair in the Future Internet & Cisco Research Chair in 5G Systems and Professor, Electrical and Computer Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/information_systems_and_science_for_energy_lab
http://blizzard.cs.uwaterloo.ca/iss4e/
11. Kleinke Research Centre

A strong focus on areas such as Inorganic Solid State Chemistry and Thermoelectric materials. The research projects include (High temperature) synthesis, structure determination, transport properties, magnetic and thermochemical properties (equipment), band structures (EH, LMTO), correlations between crystal structure, electronic structure, and physical properties, Unusual Sb-Sb and Te-Te bonding, square net distortions, and structure maps.

**Location:** Chemistry 2 (C2), Room: C2-067

**Principal Investigator:** Holger Kleinke (Program Director, Collaborative Graduate Nanotechnology Program and Professor, Chemistry)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/kleinke_research_centre
http://kleinke.uwaterloo.ca/research.html

12. Lab for Biomanufacturing

Merges engineering and biology, converting cells into miniature factories to generate useful products. Our lab concentrates on three main areas: the production of industrial enzymes and therapeutic proteins; the production of biofuels such as biohydrogen, biobutanol and biodiesel; and techniques to purify biomanufactured products.

**Location:** Davis Centre (DC), Room: 2554

**Principal Investigator:** Chih Hsiung (Perry) Chou (Canada Research Chair in Biomanufacturing, Editor of Biotechnology Advances and Professor, Chemical Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/lab_for_biomanufacturing
https://sites.google.com/site/choulabgroup/
13. Laboratory for Emerging Energy Research Lab (LEER)

Exploring potential solutions to energy security and global warming. We focus on not only revisiting the existing technologies for energy conversion and utilization but developing novel methods by means of nanotechnology and multi-disciplinary approaches. The lab is equipped with a 'big' drop tube reactor which is 3 meters tall, for developing and evaluating the catalytic combustion technology in the industrial scale.

**Location:** Engineering 3 (E3), Room: E3-2036

**Principal Investigator:** John Wen (Associate Professor, Mechanical and Mechatronics Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/leer
http://www.leer.uwaterloo.ca/

14. The Fuel Cell and Green Energy Lab

Investigating green energy topics through modeling, system analysis, experimental research and scale-up design. Among our current projects, we are developing reliable, cost-effective polymer electrolyte membrane fuel cells and clean biodiesel engines for automotive purposes. Our lab capabilities include materials characterization, process development, circuit design and fabrication, and prototyping.

**Location:** Energy Research Centre (ERC), Room: ERC-3023/3003

**Principal Investigator:** Xianguo Li (Professor, Mechanical and Mechatronics Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/laboratory_for_fuel_cell_and_green_energy
https://uwaterloo.ca/fuel-cell-green-energy-lab/
15. Maglev Microrobotics Laboratory

Maglev Microrobotics Laboratory studies the design and development of magnetically levitated (Maglev) robots. To accomplish this, a magnetic levitation setup enabling high precision 3D remote positioning was built. Our Maglev systems find applications in areas spanning various disciplines such as: contactless micromanipulation and microrobotics, manipulation in hazardous environment, clean rooms applications, wind tunnel testing, and wafer growth and wafer transportation. We are also working on the development and industrialization of various applications of magnetism such as electromagnetic energy harvesters and non-destructive testing for detecting cracks and defects in live pipelines.

Location: E5-3044

Principal Investigator: Behrad Khamesee (Professor, Mechanical and Mechatronics Engineering)

Additional information can be found below:
https://uwaterloo.ca/maglev-microrobotics-laboratory/

16. The Mechatronics Vehicle Lab

Developing novel technologies such as green power-trains, advanced suspension, and vehicle stability and control. These technologies are critical to the improvement of performance, safety and environmental sustainability of a new generation of electric and hybrid automobiles that hold great potentials to reduce vehicle emissions and improve the fuel economy. We are also involved in vehicle modelling, using real-time simulation and hardware-in-the-loop.

Location: Davis Centre (DC), Room: DC-1704

Principal Investigator: Amir Khajepour (Professor, Mechanical and Mechatronics Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/mechatronics_vehicle_lab
https://uwaterloo.ca/mechatronic-vehicle-systems-lab/
17. Nazar Research Group

Encompassing complex material synthesis, physical and structural characterization, electrochemical testing and electrode design for various energy storage devices. Promising new directions particularly lie in nanomaterials. They offer the possibility of moving into the realm of high-capacity systems that operate on the basis of intimate contact of the redox active components. The research employs a range of physical chemistry techniques, including ex-situ and in-situ studies involving X-ray/neutron diffraction, Raman microprobe and NMR spectroscopies, combined with fundamental electrochemical studies used to examine the underlying processes in solids. We are a multidisciplinary group consisting of students enrolled in the Departments of Chemistry and Electrical and Computer Engineering.

**Location:** Earth Sciences & Chemistry (ESC), Room: ESC-135

**Principal Investigator:** *Linda Nazar* (Canada Research Chair in Solid State Energy Materials and Professor, Chemistry)

Additional information can be found below:

- [https://wise.uwaterloo.ca/research/our_labs/nazar_research_group](https://wise.uwaterloo.ca/research/our_labs/nazar_research_group)
- [http://www.science.uwaterloo.ca/~lfnazar/research.html](http://www.science.uwaterloo.ca/~lfnazar/research.html)

18. Printable Electronic Materials Lab

Our lab conducts cutting edge research on advanced materials, which are suitable for electronics and electrical devices. Currently we are focusing on the development of printable electronic materials including polymer semiconductors, polymer conductors, polymer binders, and various nanomaterials for thin film transistors (flexible displays, RFID tags, smart labels, sensors, and wearable electronics), photovoltaics (solar cells and photodetectors), and batteries (lithium batteries).

**Location:** Quantum Nano Centre, Room: QNC-B506

**Principal Investigator:** *Yuning Li* (Professor, Chemical Engineering)

Additional information can be found below:

- [https://wise.uwaterloo.ca/research/our_labs/printable電子ic_materials_laboratory](https://wise.uwaterloo.ca/research/our_labs/printable電子ic_materials_laboratory)
Appendix III – Research Labs

19. Non-destructive Testing Laboratory

Evaluating the quality of concrete infrastructure (including bridges, roads, buildings, oil & gas pipelines), and distribution wood poles. A few of our recent research projects include study of the effect of lateral in-homogeneities on the propagation of Rayleigh waves in an elastic medium and condition assessment of construction joints in asphalt pavements and for the void detection in grout. Our research domains consist of dynamic characterization of soil for in-situ measurement of damping using surface waves, a novel non-destructive method, based on ultrasonic waves, for condition assessment of utility wood poles, the effect of frequency loading on Dynamic property of geo materials, NDT applications in condition assessment of concrete elements using ultrasonic surface waves, NDT for condition assessment of joints, steel thickness evaluation, and void detection in grouts, applications of NDT in Civil Engineering, and NDT evaluation of asphalt pavement joint using light weight deflectometer (LWD) and multi-channel analysis of surface waves (MASW) tests.

**Location:** Engineering 3 (E3), E3-2140

**Principal Investigator:** Giovanni Cascante (Associate Chair, Graduate Studies and Professor, Civil and Environmental Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/nondestructive_testing_laboratory

20. Qing-Bin Lu's Laboratory

Our focus is on femtomedicine and cancer therapy, as well as the sciences of atmospheric ozone depletion (the ozone hole) and global climate change (“global warming”). A lot of our work is in the ozone-depleting reactions and developing a prediction model for the ozone hole based on effective dissociative electron transfer reactions of CFCs and other halogen-containing molecules absorbed on ice surfaces. We study the impacts of man-made chlorofluorocarbons (CFCs) on the atmospheric ozone depletion and global climate change.

**Location:** Physics (PHY), Room: PHY-136/137

**Principal Investigator:** Qing-Bin Lu (University Research Chair and Professor, Physics and Astronomy)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/quingbin_lus_laboratory
21. Research Laboratory for Green Energy & Pollution Control

Investigates the thermochemical conversion of biomass to biofuels, such as the hydrothermal conversion of cellulose to HMF (a solid biofuel) and bio-oil. In addition, we examine air pollution control, indoor air quality, and the use of filtration and absorption to purify syngas and biofuels.

Location: ERC-2006

Principal Investigator: Zhongchao Tan (Executive Director, Tsinghua-Waterloo Joint Research Center for Micro/Nano Energy and Environment and Professor, Mechanical and Mechatronics Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/april_air_pollution_research_and_innovation_labor
http://tan.uwaterloo.ca/

22. Smart Distribution Research Lab (SDRL)

A modeling and simulation research laboratory, and it is the only one in the City of Waterloo. The areas of interest are: distribution systems operation and control, power quality issues, distributed generation; operation, control and interfacing, fuel Cell interfacing and load management, MEMS Micro-power generators, and mechatronics.

Location: Engineering 5 (E5), Room: 5008

Principal Investigator: Ehab El-Saadany (Professor, Electrical and Computer Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/sdrl
http://sds.uwaterloo.ca/research-topics
23. Solar Thermal Research Laboratory (STRL)

We develop next-generation solar thermal technologies, including side-by-side PV/solar thermal systems and heat-pump-assisted solar systems. Our facilities include first-class optical measurement equipment and a rooftop test platform. In addition to performing original research, STRL is frequently contracted to do solar reflective index measurements for companies around the world.

Location: Energy Research Centre (ERC), Room: ERC-3009

Principal Investigator: Michael Collins (Associate Chair, Undergraduate Studies and Associate Professor, Mechanical and Mechatronics Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/solar_thermal_research_centre
https://uwaterloo.ca/solar-thermal-research-laboratory/

24. Sustainable Reaction Engineering Laboratory

In the Sustainable Reaction Engineering laboratory, research focuses on heterogeneous catalysis and reactor design, with the goal of developing highly efficient processes that use renewable energy to convert greenhouse gases into sustainable synthetic fuels. This includes converting carbon dioxide that would otherwise pollute the environment into a sustainable and affordable fuel would minimize greenhouse gas emissions and reduce our dependence on fossil fuels.

Location: E6-2009

Principal Investigator: David Simakov (Assistant Professor, Chemical Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/sustainable_reaction_engineering
25. Wind Energy Lab

Investigates a broad range of wind energy topics, from turbine blade aerodynamics to wind resource assessment. Our advanced experimental measurement tools include laser Doppler velocimetry and particle image velocimetry, while our wind flow facility was designed to permit large-scale airflow studies under controlled flow conditions.

**Location:** Engineering 3 (E3), Room: E3-2134

**Principal Investigator:** David Johnson (Professor, Mechanical and Mechatronics Engineering)

Additional information can be found here:
https://wise.uwaterloo.ca/research/our_labs/wind_energy_lab
http://windenergy.uwaterloo.ca/proj_Waterloowindturbine.php

26. The University of Waterloo Fire Research Group

Collaborates with a wide range of industrial and government partners on fire safety. Among other things, we examine the behaviour of full-scale fires, the flammability and performance of materials and products, fire initiation and spread, and methods of fire detection. Our world-class, $5.6 million fire research infrastructure includes a large cross-flow test area used for a variety of wind-driven experiments, including wind turbine performance.

**Faculty Member(s):**

1. David Johnson (Professor, Mechanical and Mechatronics Engineering)
2. Michael Collins (Associate Chair, Undergraduate Studies and Associate Professor, Mechanical and Mechatronics Engineering)
3. Roydon Fraser (Teaching Chair and Professor, Mechanical and Mechatronics Engineering)
4. Cecile Devaud (Professor, Mechanical and Mechatronics Engineering)
5. John Straube (Associate Professor, Civil and Environmental Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/uw_live_fire_research_facility
https://uwaterloo.ca/fire-research-and-safety/
27. Power and Energy Systems Group

The Power and Energy Systems Group at the University of Waterloo is one of the largest research groups in power engineering in North America, with a very reputed faculty base and available research support and a broad expertise covering practically all aspects in power engineering research. The group is engaged in the latest state-of-the-art research activities in several areas of power engineering such as power electronics, high voltage engineering, power quality and distributions systems, power systems operation and control, smart grids, electric vehicles and electricity market deregulation. The group is also very active in providing power engineering courses at the under-graduate, graduate and doctoral level, and also external courses.

Faculty Member(s):

1. **Claudio Canizares** (Hydro One Chair and Professor, Electrical and Computer Engineering)
2. **Ehab El-Saadany** (Professor, Electrical and Computer Engineering)
3. **Kankar Bhattacharya** (Associate Chair, Graduate Studies and Professor, Electrical and Computer Engineering)
4. **Magdy Salama** (University Research Chair, Fellow of the Institute of Electrical and Electronics Engineers (FIEEE) and Professor, Electrical and Computer Engineering)
5. **Mehrdad Kazerani** (Senior Member of the Institute of Electrical and Electronics Engineers (SMIEEE) and Professor, Electrical and Computer Engineering)
6. **Ramadan El-Shatat** (Lecturer, Regular Administrative Appoint, Electrical and Computer Engineering)
7. **Shesha Jayaram** (Director, HVEL and Professor, Electrical and Computer Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/powerandenergysystemsgroup
https://uwaterloo.ca/power-energy-systems-group/
28. Sustainable Energy Policy Group

Brings together a number of researchers in the University of Waterloo’s Faculty of Environment. More specifically, our members are investigating a range of policy, management and behavioural issues related to advanced energy efficiency, conservation, demand management and increased use of renewable energy in our energy systems. We have numerous links with international, national and local partners (including intergovernmental agencies, governments, utilities, businesses, civil society and other researchers). We have funding from a range of agencies, including national funding bodies (NSERC, SSHRC), provincial associations and the private sector. Our research aims to explain current situations, to explore technology-society interactions and to advance future opportunities for sustainability.

Faculty Member(s):

1. Ian Rowlands (Associate Vice-President, International and Professor, School of Environment, Resources and Sustainability)
2. Paul Parker (Associate Dean, Strategic Initiatives and Professor, School of Environment, Enterprise and Development)
3. Jennifer Lynes (Associate Professor, School of Environment, Enterprise and Development)
4. Olaf Weber (Associate Professor, School of Environment, Enterprise and Development)
5. Steven B. Young (Associate Professor, School of Environment, Enterprise and Development)
6. Stephanie Whitney (PhD Candidate, School of Environment, Enterprise and Development)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/sustainable_energy_policy_group
https://uwaterloo.ca/sustainable-energy-policy/about

29. Student Design Centre (SDC)

Consisting of over 20,000 square feet of space dedicated to design teams and student projects. There are more than two dozen design teams, all of which are student-led, and many of which represent Waterloo internationally. It is the largest facility of our type in North America.

Location: Engineering 5 (E5), 1ST Floor

Principal Investigator: Peter Teertstra (Director, SDC and Continuing Lecturer, Mechanical and Mechatronics Engineering)

Additional information can be found below:
https://wise.uwaterloo.ca/research/our_labs/student_design_centre
https://uwaterloo.ca/sedra-student-design-centre/
Appendix III – Research Labs

30. Geomechanics Group

Geomechanics studies deal mainly with coupled problems requiring simultaneous consideration of changes in temperature, pressure, stress, and chemical potential (THMC). Major current challenges in this domain include: accurate delineation of in situ physical properties and conditions \((T, [\sigma], p)\), especially for naturally fractured reservoirs; wellbore wall stability predictions in swelling and fractured shale strata; modeling and monitoring of multiple-stage hydraulic fracturing used for development of resources in low-permeability rocks; controlling or exploiting sand ingress into producing wellbores; predicting subsidence accurately enough so that rational design decisions can be made; mitigating or reducing the incidence of casing shear arising from subsidence or thermal reservoir stimulation; understanding and analyzing thermal production processes in viscous oil reservoirs; monitoring of deformations in and around reservoirs being subjected to complex processes; and, a newer development, using the deep sedimentary basin environment for the permanent and secure heat recovery, and disposal of fluid and granular wastes.

Faculty Member(s):

1. Maurice Dusseault (Professor, Earth and Environmental Sciences)

Other Team Member(s):

1. Seyedbijan Mahbaz (Research Associate, Civil and Environmental Engineering)
2. Alireza Dehghanisani (Postdoctoral Fellow, Earth and Environmental Sciences)
3. Ruiqiang Li (PhD Candidate, Earth and Environmental Sciences)
4. Milad Mosharafi (PhD Candidate, Mechanical and Mechatronics Engineering)
5. Ali Ghavidel (PhD Candidate, Civil and Environmental Engineering)

Additional information can be found below:
https://uwaterloo.ca/geomechanics-group/
Appendix IV:
Public Lecture Series Posters
Appendix IV – Public Lecture Series Posters

**PRESENTED BY THE WATERLOO INSTITUTE FOR SUSTAINABLE ENERGY**

**Friday June 15, 2018**

2:00 pm – 3:00 pm
DC 1002

**ACTUALIZING SMART INFRASTRUCTURE TO ENABLE DATA-DRIVEN ASSET MAINTENANCE DECISIONS**

Shravan Narasimhan, Canada Research Chair, Smart Infrastructure -Akateam Project, Civil and Environmental Engineering -University of Waterloo

The use of sensors and sensor information has now become a reality in infrastructure applications. This has led to a proliferation of what is being called “smart infrastructure”. However, the volume of such activity has not been paralleled by a comparable increase in our understanding of the condition of structures. This talk will focus on bridging the gap, mainly related to civil and mechanical infrastructure and will present highlights of the work being carried out by prof. Narasimhan and his students at the University of Waterloo. He will focus on practical data collection challenges and the theoretical background related to diagnostics and prognostics, while motivating the link to enable asset management and maintenance planning. Finally, the speaker will introduce how the use of robotics is likely to shape the future of Smart Infrastructure.

**PRESENTED BY THE WATERLOO INSTITUTE FOR SUSTAINABLE ENERGY**

**Tuesday April 24, 2018**

10:00 – 11:00 am
DC 1002

**OTSG IN POWER GENERATION AND ENERGY IN CANADA**

Alex Bernt, Senior Project Engineer, Enhanced Oil Recovery (EOR) Technology -Saskatchewan Institute for Scientific Innovations (SIT)

Use of Once-Through Steam Generators (OTSGs) in power plants offers several advantages over traditional drum boilers, which include smaller footprint, high turndown, fast start and simplified operation. Commonly OTSGs are equipped with dust burners for additional steam capacity and emissions control equipment. When OTSGs are designed to operate in dry mode, the plant has maximum flexibility to match steam demand to process requirements. OTSGs are also used in Enhanced Oil Recovery applications and in Organic Rankine Cycle low temperature vapor heat recovery. This presentation will look at the OTSG technology and peripheral equipment such as burners and emissions equipment.

**PRESENTED BY THE WATERLOO INSTITUTE FOR SUSTAINABLE ENERGY**

**Thursday February 22, 2018**

10:30 – 11:30 am
CRH 4330

**REDUCING CARBON EMISSIONS THROUGH ENERGY EFFICIENCY: A CANADIAN PERSPECTIVE**

Chandra Ramadurai, CEO, Efficiency Capital

Renovating a building to reduce carbon emissions in the current Canadian market can offer returns of up to 15-20%. So why has the response been so seemingly low? Chandra Ramadurai, CEO of Efficiency Capital explores the rapidly evolving energy efficiency landscape with an overview of current and historical market value, and his professional insight into the future of energy performance based investment strategies at this WISE Public Lecture. All are welcome at this free event and questions from the audience are encouraged.

A full abstract of this lecture is available online.

**PRESENTED BY THE WATERLOO INSTITUTE FOR SUSTAINABLE ENERGY**

**Tuesday February 13, 2018**

10:00 – 11:00 am
DC 1002

**THE FUTURE OF NET ZERO HOMES IN CANADA**

Mohsen Ferdowsi, Manager, Energy Modeling Services, Building Knowledge Canada

This presentation will identify the Net Zero home in Canada today and provide insight into the future. Areas discussed will include findings and lessons learned pertaining to both the building envelope and mechanical design. The presenter will discuss the requirements of the Canadian Home Builder Associations Net Zero program and give an overview of specific Net Zero projects the Building Knowledge team has assisted and designed.
Appendix IV – Public Lecture Series Posters

**ENERGY: TEN BIG IDEAS ON ENERGY (WHAT EVERYONE NEEDS TO KNOW)**

Adina Yatchew, Professor, Economics, University of Toronto

If one had to survey a handful of ideas that are foundational to understanding energy, its past, present and future, where would one begin? And how would one communicate them to those who do not specialize in one or another aspect of energy? Drawing on the sciences, humanities and the liberal sciences, this talk will focus on ten big ideas, illustrating their essentiality, and how they reach across the disciplines.

**GREENHOUSE GAS REDUCTION TECHNOLOGIES IN ENERGY INTENSIVE SECTORS OF ONTARIO**

Martin Vrablek, Senior Director, Greenhouse Gas Reduction Technologies, Ontario Centres of Excellence

On January 1, 2017 the Province of Ontario implemented a Greenhouse Gas Cap and Trade program compatible with California and Quebec. Revenue generated by the program is required to be invested into greenhouse gas and climate change mitigation projects in Ontario. The TargetGHG program of the Ontario Centres of Excellence works with Ontario’s industrial sectors to reduce GHG emissions by providing matched funding for large-scale GHG reduction projects.
Appendix IV – Public Lecture Series Posters

**Navigating Ontario’s Evolving Energy Landscape – A Utility’s Experience**

**Presenter:** Nazgul Batool, Con Edison Energy Manager, Newmarket Ray Power Distribution Inc.

Canada’s changing technological innovation, shift in electricity demand and expanding customer expectations are leading to an accelerated transition in what was once a monopolistic monopoly utility business. Local distribution companies (LDCs) need to ensure these changes continue to deliver safe and reliable electricity to their customers.

Newmarket – Ray Power Distribution is at the forefront in developing potential solutions being driven by these changes. Today’s lecture will present some of the innovative projects happening in Newmarket that, upon implementation, will provide direction for the future of Ontario’s electricity sector.

**Physics-Based Control of Energy Systems Ranging From Smart Buildings and Power Grid to Smart Hybrid Electric Vehicles**

**Presenter:** Mahdi Shabashvili, Assistant Professor, Mechanical Engineering – Engineering Mechanics, University of Michigan

Control of complex energy systems requires knowledge of complex energy system dynamics and integration of this knowledge into control design. In this talk, innovative model-based control techniques are illustrated for various complex energy systems including building heating, ventilation, and air conditioning (HVAC) systems, leading to power grid operating systems, and hybrid electric vehicles.

A novel energy-aware control framework will be introduced. The benefit of the proposed framework will be demonstrated for energy systems in the transportation and building sectors, which combined consume 54% of the total energy use in the world.

**Self Dependency in Remote Communities: Food, Energy, Future**

**Presenter:** Benjamin Canning, Co-Founder, Growing North

Remote communities in Canada, and for that matter around the world, live in increasingly remote and unsustainable methods of energy. Growing North challenges this existing mentality, through the construction of off grid food production facilities in Canada’s Arctic. This allows remote communities to produce massive amounts of food on location, reduce the overall cost, reduce dependency on supply chains, and with incorporated educational programming help increase local production rates. Join us to discuss incorporating Green Technology, and the future of expansion!

**Hydraulic Fracture Field Experiments for Geothermal Energy**

**Presenter:** Mohammad Reza Jalali, Lecturer, Assistant Professor, Smith Faculty of Technology, UTSC

The Libyan government has decided to phase out nuclear power by 2020 and transition electricity production by alternatives such as hydro power plants and enhanced geothermal systems (EGS). In this context, the newly formed Queens University Center for Energy Research – Supply of Electricity (QUER-E) is conducting various types of research and development. As a part of the ongoing research, hydraulic stimulation experiments, called hydraulic fracturing or hydraulic stimulation (HCS), have been initiated at the Green Test Site (GTS). This lecture will explore the phases and objectives of this experiment.
Appendix IV – Public Lecture Series Posters

**DIRECTIONAL DRILLING AND MAGNETIC RANGING SERVICES FOR GEOTHERMAL ENERGY DEVELOPMENT**

Clinton Main, President, Markitum Ranging Technologies, Freehold, New Jersey

Process-oriented drilling and workflow placement techniques have yielded significant improvements in oil and gas extraction but in Canada they have not yet been utilized to improve the technical and economic feasibility of deep geothermal energy systems. This talk will review the state of the art in precision directional drilling and discuss how those techniques may decrease the capital cost and increase the operating efficiency of deep geothermal systems in Canada.

**PUBLIC LECTURE SERIES POSTERS**

**Biography**

**PRINTED MEMS: SENSORS, ACTUATORS OR ENERGY HARVESTERS PROCESSING WITH STANDARD OR MODIFIED SCREEN-PRINTING TECHNOLOGY**

Hélène Déabé, Associate Professor, University of Warwick, Warwick, WRFOS, England

This presentation will discuss the research being done by the RISOE-Cardiff team on wireless microsensor technology in the context of the European project SCREENPRINT. The team is using screen-printing for the production of MEMS and NEMS devices for wireless gas detection. Recent advances in screen-printing are presented and future applications are discussed.

**SUSTAINABLE COMMUNITY ENERGY PLANNING**

Paul Parker, Professor & Associate Dean, Strategic Initiatives, Geography & Environmental Management, University of Waterloo

Canadians have a high lifestyle, yet we have been increasing climate change impacts. The need to transform our energy system is urgent. Conventional approaches to the distributed energy system of the future require a community energy planning mindset that balances the demand and supply of energy systems. As we plan to transition to sustainable energy options, energy systems are redefined to suit the context for planning decisions and tools such as the Partners for Climate Protection framework, Passive House design, Enhanced project evaluation, LEDD and EcoGuide for Houses are introduced. At the individual level, Ontario’s reduced emissions by closing its coal-fired power plants. Electricity consumption was promoted with smart grid technology and various initiatives. Remote communities have seen an increase in smaller, high cost solar systems, so renewable and alternative energy technologies and mechanisms are being explored at a variety of scales. Energy efficiency is no longer considered a choice, and economic considerations are a necessity as well as technical considerations.

**Biography**

**SMARTER CITIES: NEW SERVICES, NEW APPLICATIONS FOR CONTROL**

Robert Dushkin, Professor & Chair, Control Engineering & Decision Sciences, University of Waterloo

The potential is already being realized. Discrete event systems (DES) are the standard technology for computer networked control, increasingly larger systems, and increasingly complex problems. The DES framework offers the ability to model, control, and optimize these systems. The talk will provide an overview of the DES framework, its applications, and its potential for future research.

**Biography**

**SUSTAINABLE ENERGY PLANNING**

Paul Parker, Professor & Associate Dean, Strategic Initiatives, Geography & Environmental Management, University of Waterloo

Canadians have a high lifestyle, yet we have been increasing climate change impacts. The need to transform our energy system is urgent. Conventional approaches to the distributed energy system of the future require a community energy planning mindset that balances the demand and supply of energy systems. As we plan to transition to sustainable energy options, energy systems are redefined to suit the context for planning decisions and tools such as the Partners for Climate Protection framework, Passive House design, Enhanced project evaluation, LEDD and EcoGuide for Houses are introduced. At the individual level, Ontario’s reduced emissions by closing its coal-fired power plants. Electricity consumption was promoted with smart grid technology and various initiatives. Remote communities have seen an increase in smaller, high cost solar systems, so renewable and alternative energy technologies and mechanisms are being explored at a variety of scales. Energy efficiency is no longer considered a choice, and economic considerations are a necessity as well as technical considerations.

**Biography**
Appendix IV – Public Lecture Series Posters

**POST-NET METERING FOR A SUSTAINABLE CITY**

**Dr. Matthew Peloso, CEO, Sun Electric Pte Ltd., Singapore**

Blockchain technologies have revolutionized the way we think of transacting, offering a decentralized platform to enable secure transactions. This talk will focus on how the impact of information technologies on transactions is here to stay. Meanwhile, the renewable energy is shifting our world from a utility model with centralized generation of power to a distributed model where energy is generated and consumed near the point of origin. The integration of renewable energy with electric grids will create a new era of electric grids that can accommodate the variability of renewable resources.

**ENERGY-SECURE, ADAPTABLE HOUSING & INFRASTRUCTURE FOR REMOTE & NORTHERN COMMUNITIES**

**Paul Reimer, President, RESCo**

Housing in too many of Canada’s remote communities is in deplorable condition. This presentation will address approaches to boosting production of low-energy housing through innovations in structure, fabrication, delivery, and associated infrastructure, taking into account that future conditions are highly unpredictable.

All are Welcome!

Please Register Via Eventbrite!

---

**PIEZOELECTRIC MATERIALS AND THEIR APPLICATIONS**

**S. Eliezer Presser, Chairman, Permatex Inc & Adjunct Professor, Department of Mechanical & Industrial Engineering, University of Toronto**

This public lecture will include a discussion of piezoelectric materials and their applications. They will be presented with particular reference to energy harvesting and sensors. The presentation will review existing technologies, their benefits and disadvantages to show the potential of piezoelectric materials for use in power harvesting applications.

All are Welcome!

Please Register Via Eventbrite!

---

**SOLAR + STORAGE + IOT + LED = $30 TRILLION**

**Bishr Saaid, Assistant Professor of Computer Science, University of Waterloo**

Recent technological advances in the areas of solar panels, light emitting diodes, and the Internet of Things will continue to change the energy, electrical grid, building and transportation sectors. These technologies will further change the way we live, work, and travel. The expanding energy market creates new opportunities for the future.

Please join us afterwards for refreshments and a reception in DC 1301.
Appendix IV – Public Lecture Series Posters

**ELECTRICITY, AN INDUSTRY IN TRANSITION**

Benjamin Courtfield, Managing Director in the Energy Sector, Navigant

Benjamin will present Navigant’s view of the electricity industry transformation taking place across North America and Europe. He will discuss the disruptive triggers, potential future state, and pace of change globally and locally in Ontario. The discussion will also highlight Navigant’s work with utilities, governments, and suppliers as they grapple with the challenges and opportunities associated with the transformation.

**ENERGY ECONOMICS - TOWARDS SUSTAINABLE DEVELOPMENT & A ‘GREEN GDP’**

Sathakan Ramakrishnan, President, Energy & Fuel User Advocacy Alliance (EUFVA)

Carbon penalties on calculating economic growth fail to account for micro-scale disruptions, degradation and loss of biodiversity. In time, sustainable development and economic growth are insufficient. The objective of natural wealth leads to a concern for environmental and social goods. The growing discourse on sustainability has sparked interest in recent transitional issues of calculating GDP which account for the environmental factor. This new approach, commonly referred to as the ‘Green GDP’, seeks to broaden the scope of this measurement through the addition of social and environmental dimensions to the GDP scorecard. The primary difference in this approach is that future growth will be defined by sustainable development, resource conservation, environmental degradation, and climate change, instead of any other factor. This alternate metric advances a paradigm shift towards the strong market drivers to support corporate actions for creating a ‘Green GDP’ Singapore Model. Demands such as public, regulations, and corporate efforts will all be addressed in an integrated part of developing a ‘Green GDP’ and inclusion growth model.

**EXPERIMENTAL AND COMPUTATIONAL OPTIMIZATION OF A WIND TURBINE BLADE DE-ICING SYSTEM**

Damianus Remigio B. A. Jr., Founder, Bonzea Wind

Before biodiesel is formulated in biodiesel soybean oil and biodiesel must undergo a solid to liquid changes. The process of the system is to locate the state of the biodiesel, one it is in the liquid state, it is then circulated to the biodiesel. This process allows to the adipose given that has been completed and the result. The biodiesel contain the oil adipose biodiesel that contains diesel (C14), which needs to be within the range of 180 to 210 degrees. The biodiesel collected from the oil seed is then transferred and is filtered. This process is known as the biodiesel oil and the biodiesel is then filtered. The process is the same to do the biodiesel oil is filtered and this is done to the biodiesel oil is filtered. The biodiesel oil is then transferred to be mixed with the biodiesel oil. The biodiesel oil is then transferred to the biodiesel oil. The biodiesel oil is then transferred to the biodiesel oil.
Appendix IV – Public Lecture Series Posters

**PRESENTED BY THE WATERLOO INSTITUTE FOR SUSTAINABLE ENERGY**

**Demand-Side Management, Micro-Grids, Demand Response and Reducing the Need to Overbuild Capacity**

*Tuesday November 22, 2016*

10:30 – 11:30 am

CPH 4333

Paul M. Grale, President & CEO, Rock Energy Solutions

Ontario has been a global leader in smart grid implementation. Having transformed the power system in record time with manageable political fallout, we are looking at the next phase of power system evolution. This lecture will present ideas on new energy technologies, power market evolution and new approaches to how power consumers and utilities interact in a dynamic and arguably decentralised manner. A must attend session for anyone interested in the future of North American energy systems.

**WIND TURBINE AERODYNAMICS & SOLAR CAR COOLING SYSTEMS**

*Tuesday August 16, 2016*

10:30 – 11:30 am

CPH 4333

Dr. Khabir Ghalimi, Assistant Professor of Mechanical Engineering, University of Tehran, Iran

Dynamic stall is a phenomenon which occurs in wind turbines causing significant energy waste. In more extreme instances it has also been known to lead to wind turbine failure. The first part of this lecture will discuss how to deal with various environmental factors that can cause vortices and irregular wake structures leading to dynamic stall aerodynamic forces.

The second part of the lecture will move on to focus on an introduction to solar automobile applications. I will also touch upon the subject of solar cooling systems and their applications in my work with the Fraunhofer Group in India and other solar competitions such as Green IT.

**PRESENTED BY THE WATERLOO INSTITUTE FOR SUSTAINABLE ENERGY**

**How Can We Help Electricity Access Scale-Up Faster?**

*Monday September 26, 2016*

4:00PM – 5:00PM

Earl, Pollock Hall 4333

During his lecture, Dr. Claudio Vergés will present his work being carried out at AE4H to support the expansion of access to electricity in the developing world.

In collaboration with the University of São Paulo researchers from AE4H’s Solar Centre for Technology and Design are partnering with organisations such as the Enda Foundation, ProBono, the World Bank and the German and Italian International Cooperation Agencies to create impactful solutions to energy access needs.

Dr. Vergés will discuss the following activities and how they relate to each other and their potential impact.

- The following distribution model is being defined: microgrids, solar parks, and solar home systems.
- Remote sensing and inference
- Energy and monitoring and appliance at a business level
- Power electronics and decentralized energy management for low-power DC microgrids
- Modeling of energylarınınmentstrategies for local systems and electricity access
- Population analysis for electrification processes and computer simulations

**PRESENTED BY THE WATERLOO INSTITUTE FOR SUSTAINABLE ENERGY**

**Introduction to Helical Piling Applications in Canada**

*Friday July 22, 2016*

10:30 – 11:30 am

CPH 4333

Jeff Lydon, President, Aedas Piling

Significant advancements in pile design and engineering have allowed Aedas’s technical foundation studies to be utilized for an array of innovative projects. Jeff Lydon, President of Aedas Piling, will present the technologies behind the explosive growth in the use of concrete piles in Canada, and the many benefits they offer in a variety of environments.

Aedas has led the industry in the research and development of concrete piles and has proven that they are the preferred means of foundation support for buildings, whether new or existing. Aedas has expanded its capability to provide solutions across the energy and renewable energy sectors.

This presentation will cover:

1. **Introduction**
   - Brief description of Aedas
2. **Concrete Pile Alternatives**
   - Cut-off systems
   - Precast foundations
3. **Design Considerations**
   - Load and environmental
   - Foundation type
4. **Conclusion**

289
Appendix IV – Public Lecture Series Posters

**Lecture Series**

**Natural Ventilation of Buildings Using a New Design of Wind Catcher to Decrease Energy Consumption in Windy Regions**

*Presented by the Waterloo Institute for Sustainable Energy*

**Dr. Masoud Falaki**

**Biography**

In this study, a new design of wind catcher is presented. The wind catcher has a flow column, a conical base, an air opening with the curtain, and two windows at the end of the flow column. The modern wind catcher can be installed on roof tops to take in ambient air. The wind catcher’s height can be controlled exactly or adjusted in the minimum wind velocity direction. In addition, when wind velocity is less, it can enhance the operation of the wind catcher, which can be used for natural ventilation systems that do not require electricity as a significant benefit of wind catchers, as it can decrease financial and environmental costs.

**FORENSIC ENERGY MANAGEMENT**

*Presented by the Waterloo Institute for Sustainable Energy*

**B. Paul Vermeers, MBA, P.Eng, President & CEO**

**Biography**

Advanced forensic technology is poised to play a major role in ensuring energy systems help management of technical and innovative buildings will energy more efficiently. This will ultimately lead to significant reductions in energy costs and lower carbon footprint.

Sustainable electricity has grown over the past ten years as it has significantly increased beyond traditional applications into the entire green building envelope. Now a complete new generation of forensic technology is coming out on the market that has significantly lower cost, and so much which can be economically deployed on the circuit level. Combining data-sharing communication with cloud-based big data analytics, this new technology has the ability to look back energy usage data and identify where and when it is wasted. The status quo in terms of energy management and technology cannot economically identify the energy waste, whether it is the result of equipment operating inefficiently or independently.

DataMan technology has broken through the barriers of cost, with existing technology at a fraction of current market, and is designed for integration at the circuit level. It features a one-time determination of all electrical data (3961 data samples in 6 second communication), and Perfects real-time data software designed to scale and address the needs of various partners. With its ability to identify and broadcast electrical use into global data, for any specific time, circuit by circuit. EnerData is introducing the concept of Forensic Energy Management™.

**Forest Bioenergy in Ontario: Examining the Life Cycle Impacts and Costs of Using Harvest Residue as Feedstock for Small- and Large-Scale Bioenergy Systems**

*Presented by the Waterloo Institute for Sustainable Energy*

**Dr. Julian Clancy**

**Biography**

Forest bioenergy has been touted as an important option for reducing GHG emissions from the energy sector. With its abundant supply of potential feedstock, Ontario has recently entered into this technology option by retrofitting coal-fired power plants to use wood pellets. However, bioenergy can also be produced using smaller scale, combined heat and power systems using local feedstock supplies. This presentation addresses the life cycle impacts and costs of large- and small-scale forest bioenergy systems via an Ontario case study.

**Electric Vehicle (EV) Charging**

*Presented by the Waterloo Institute for Sustainable Energy*

**Klaus Dohring**

**Biography**

In this EV charging presentation you will learn about:

- Why drive an EV (e.g. clean air legislation)
- EVs available in Canada
- Level 1, level 2 and level 3 charging examples
- Charging experience within the WEEMA membership and by our own associates (e.g. winter charging)
- Solar carports for EV charging
Dr. Jiaqin Zhang, Principle Research Officer, National Research Council Canada, Vancouver, BC

South-eastern Ontario is the largest contributor to Ontario’s electricity generation from coal. The current debate on fossil fuel energy and renewable energy will be reviewed in terms of their reserves, extraction rates, and future supply scenarios. Among sustainable energy storage and conversion technologies, electrochemical technologies are believed to be the most promising ones. In PEM fuel cells, supercapacitors, and their coupling, are believed to be the key future sustainable option for electric vehicles. Regarding PEM fuel cells, both high cost and insufficient durability are the two major barriers leading their commercialization. Developing micro-electrode and twinned catalysts has been identified as the critical cost priority of PEM fuel cell research and development. For supercapacitors, the insufficient energy density is the critical barrier for their application. In this presentation, the challenges and perspectives of fuel cell catalysts, the catalyst synthesis and characterization, and supercapacitor electrodes are reviewed and some research directions is explored are suggested in terms of ensuring breakthroughs towards PEM commercialization.

Presented by the Waterloo Institute for Nanotechnology
Appendix V: Member Publications
William Anderson


Zhou, Qiong; Wen, John Z; Zhao, Pei; (2017). Anderson, William A. Synthesis of Vertically-Aligned Zinc Oxide Nanowires and Their Application as a Photocatalyst, Nanomaterials 7 (1), pp. 9

Dipanjan Basu


Dusseault, M. B; Gracie, R; Basu, D; Rothenburg, L; & Yin, S; (2016). Petroleum Geomechanics: A Computational Perspective. In New Frontiers in Oil and Gas Exploration (pp. 285-333)


Haldar, Sumanta; Sharma, Jitendra; Basu, Dipanjan; (2018). Probabilistic analysis of monopile-supported offshore wind turbine in clay, Soil Dynamics and Earthquake Engineering 105, pp. 171-183

Philip Beesley


Kankar Bhattacharya


Alarfaj, O; and Bhattacharya, K; (In Press) *A Controlled Load Estimator Based Energy Management System for Water Pumping Systems*, IEEE Transactions on Smart Grid.


Alharbi, W; & Bhattacharya, K; Electric Vehicle Charging Facility as a Smart Energy Microhub. *IEEE Transactions on Sustainable Energy*.


Bozchalui, M. C; Cañizares, C. A; & Bhattacharya, K; (2015). Optimal operation of climate control systems of produce storage facilities in smart grids. *IEEE Transactions on Smart Grid, 6*(1), 351-359.


Farrokhabadi, Mostafa; Canizares, Claudio; and Bhattacharya, Kankar; (2016). Unit Commitment for Isolated Microgrids Considering Frequency Control. *IEEE Transactions on Smart Grid.*


Farrokhabadi, M; Cañizares, C. A; & Bhattacharya, K; (2015). Evaluation of droop-based controls in an islanded microgrid with electronically interfaced distributed energy resources. In *PowerTech, 2015 IEEE Eindhoven* (pp. 1-6)


Farrokhabadi, M; Cañizares, C; and Bhattacharya, K. Unit Commitment for Isolated Microgrids Considering Frequency Control, *IEEE Transactions on Smart Grid.*

Farrokhabadi, Mostafa; Cañizares, Claudio A; (2017). Bhattacharya, Kankar; Frequency control in isolated/islanded microgrids through voltage regulation. IEEE Transactions on Smart Grid 8 (3), pp. 1185-1194

Farrokhabadi, Mostafa; Solanki, Bharatkumar V; Canizares, Claudio A; Bhattacharya, Kankar; Koenig, Sebastian; Sauter, Patrick S; Leibfried, Thomas; Hohmann, Sören; (2017). Energy Storage in Microgrids: Compensating for Generation and Demand Fluctuations While Providing Ancillary Services. *IEEE Power and Energy Magazine 15* (5), pp. 81-91

Farrokhabadi, Mostafa; Koenig, Sebastian; Canizares, Claudio A; Bhattacharya, Kankar; Leibfried, Thomas; (2017). Battery energy storage system models for microgrid stability analysis and dynamic simulation. *IEEE Transactions on Power Systems.*


Hafez, Omar; and Bhattacharya, Kankar; (2016). Integrating EV charging stations as smart loads for demand response provisions in distribution systems. *IEEE Transactions on Smart Grid.*

Hafez, Omar; and Bhattacharya, Kankar; (2016). Queuing analysis based siting of PEV charging stations considering on distribution system impact. *Power and Energy Society General Meeting (PESGM), 2016.*

Hafez, O; and Bhattacharya, K; (In Press). Integrating EV Charging Stations as Smart Loads for Demand Response Provisions in Distribution Systems, *IEEE Transactions on Smart Grid.*

Hafez, Omar; Bhattacharya, Kankar; (2016). Queuing Analysis Based PEV Load Modeling Considering Battery Charging Behavior and Their Impact on Distribution System Operation. *IEEE Transactions on Smart Grid*.


Humayd, Abdullah S. Bin; Lami, Badr; and Bhattacharya, Kankar; (2016). The effect of PEV uncontrolled and smart charging on distribution system planning. *Electrical Power and Energy Conference (EPEC)*, 2016 IEEE.

Humayd, A. S. B; & Bhattacharya, K; (2015). Assessment of distribution system margins to accommodate the penetration of plug-in electric vehicles. In *Transportation Electrification Conference and Expo (ITEC)*, 2015 IEEE (pp. 1-6). IEEE.


Mosaddegh, Abolfazl; Canizares, Claudio A; and Bhattacharya, Kankar; (2017). Optimal Demand Response for Distribution Feeders with Existing Smart Loads. *IEEE Transactions on Smart Grid*.


Mosaddegh, A; Cañizares, C. A; & Bhattacharya, K; (2015). Distributed computing approach to solve unbalanced three-phase DOPFs. In *Electrical Power and Energy Conference (EPEC)*, 2015 IEEE (pp. 408-413).


Sauter, Patrick S; Solanki, Bharatkumar V; Cañizares, Claudio A; Bhattacharya, Kankar; Hohmann, Sören; (2017). Electric Thermal Storage System Impact on Northern Communities’ Microgrids. *IEEE Transactions on Smart Grid*.


Solanki, B; Sauter, P; Cañizares, C; Bhattacharya, K; Hohmann, S; (In Press). Electric Thermal Storage System Impact on Northern Communities’ Microgrids, *IEEE Transactions on Smart Grid*.

**Philip Bigelow**


Jalali, Leila; Bigelow, Philip; McColl, Stephen; Majowicz, Shannon; Gohari, Mahmood; Waterhouse, Ryan; (2016). Changes in quality of life and perceptions of general health before and after operation of wind turbines. *Environmental Pollution* 216, pp. 608-615

Jalali, L; Bigelow, P; McColl, S; Majowicz, S; Gohari, M; & Waterhouse, R; (2016). Changes in quality of life and perceptions of general health before and after operation of wind turbines. *Environmental Pollution*, 216, 608-615.

Jalali, L; Bigelow, P; Nezhad-Ahmadi, M. R; Gohari, M; Williams, D; & McColl, S; (2016). Before–after field study of effects of wind turbine noise on polysomnographic sleep parameters. *Noise and Health*, 18(83), 194.

Jalali, L; Gohari, M; Bigelow, P; McColl, S; & Nezhad-Ahmadi, M. R; (2017). Author response: Letter to the editor: A critical analysis: Why “firm conclusions are not possible”. *Environmental Research*.


**Terri Meyer Boake**


Claudio Cañizares


Ávila, F; Cañizares, C; Sáez, D; & Valencia, F; (2015, October). Load modelling using affine arithmetic for demand side management. In *Innovative Smart Grid Technologies Latin America (ISGT LATAM), 2015 IEEE PES* (pp. 456-460). IEEE.


Farrokhabadi, Mostafa; Canizares, Claudio; Bhattacharya, Kankar; (2016). Unit commitment for isolated microgrids considering frequency control. *IEEE Transactions on Smart Grid*.


Farrokhabadi, M (Student); König, S (Visitor); Cañizares, C.A; Bhattacharya, K; and Leibfried, T; Energy Storage System Models for Microgrid Stability Analysis and Dynamic Simulation, *IEEE Transactions on Power Systems*, submitted April 2017, revised and resubmitted July 2017, accepted July 2017.


Mosaddegh, A; Canizares, C. A; & Bhattacharya, K; (2017). Optimal Demand Response for Distribution Feeders with Existing Smart Loads. *IEEE Transactions on Smart Grid*.

Mosaddegh, A; Cañizares, C. A; & Bhattacharya, K; (2015, October). Distributed computing approach to solve unbalanced three-phase DOPFs. In *Electrical Power and Energy Conference (EPEC), 2015 IEEE* (pp. 408-413). IEEE.

Muñoz, Juan C; Ordoñez, Jefferson F; Gutierrez, Victor; Cañizares, Claudio A; Bhattacharya, Kankar; Paudyal, Sumit; (2017). Applications of optimal industrial load management modeling in smart grids, PowerTech, IEEE Manchester, pp. 1-6

Remon, Daniel; Cañizares, Claudio A; Rodriguez, Pedro; (2017). Impact of 100-MW-scale PV plants with synchronous power controllers on power system stability in northern Chile. IET Generation, Transmission & Distribution.


Restrepo, Mauricio; Canizares, Claudio; Kazerani, Mehrdad; (2016). Three-stage distribution feeder control considering four-quadrant EV chargers. IEEE Transactions on Smart Grid.

Romero-Quete, D; and Cañizares, C.A; Affine Arithmetic Formulation of the Unit Commitment Problem under Uncertainty, Proc. Bulk Power Systems Dynamics and Control X Symposium, IREP, Espinho, Portugal, August 2017.

Sauter, P; Solanki, B.V; Cañizares, C.A; Bhattacharya, K; and Hohmann, S; (2017). Electric Thermal Storage System Impact on Northern Communities' Microgrids, IEEE Transactions on Smart Grid.


Solanki, B.V (Student); Bhattacharya, K; and Cañizares, C. A; Integrated Energy Management System for Isolated Microgrids, Proc. Power Systems Computation Conference (PSCC), Genoa, Italy, June 2016, 7 pages.


Tamimi, B; & Cãñizares, C; (2016). Practical application of the Hybrid Power Flow Controller. In Power and Energy Society General Meeting (PESGM), 2016 (pp. 1-5). IEEE.


Giovanni Cascante


Appendix V – Member Publications


**Trevor Charles**


Cheng, Jiujun; Romantsov, Tatyana; Engel, Katja; Doxey, Andrew C; Rose, David R; Neufeld, Josh D; Charles, Trevor C; (2017). Functional metagenomics reveals novel β-galactosidases not predictable from gene sequences. *PloS one* 12(3)

Cheng, Jiujun; Nordeste, Ricardo; Trainer, Maria A; Charles, Trevor C; (2017). Methods for the Isolation of Genes Encoding Novel PHA Metabolism Enzymes from Complex Microbial Communities, Metagenomics: Methods and Protocols, pp.237-248

Cheng, Jiujun; Charles, Trevor C; Novel polyhydroxyalkanoate copolymers produced in Pseudomonas putida by metagenomic polyhydroxyalkanoate synthases, *Applied microbiology and biotechnology*, 100,17,7611-7627,2016,Springer Berlin Heidelberg


Nett, Ryan S; Montaneares, Mariana; Marcassa, Ariana; Lu, Xuan; Nagel, Raimund; Charles, Trevor C; Hedden, Peter; Rojas, Maria Cecilia; Peters, Reuben J; (2017). Elucidation of gibberellin biosynthesis in bacteria reveals convergent evolution, *Nature Chemical Biology* 13(1) 69-74


**Pu Chen**

Eftekhari, A; Liu, Y; & Chen, P; (2016). Different roles of ionic liquids in lithium batteries. *Journal of Power Sources*, 334, 221-239.
Han, Z; Askhatova, D; Tuan, K. A; Chen, P; (2015). Experimental and mathematical studies on cycle life of rechargeable hybrid aqueous batteries. *Journal of Power Sources*, 279, 238-245.

Hoang, T. K; Doan, T. N. L; Lu, C; Ghaznavi, M; Zhao, H; & Chen, P; (2016). Performance of Thixotropic Gel Electrolytes in the Rechargeable Aqueous Zn/LiMn2O4 Battery. *ACS Sustainable Chemistry & Engineering*.

Hoang, T.K.A; Acton, M; Chen, H.T.H; Huang, Y; Doan, T.N.L; Chen, P; (2017). Sustainable gel electrolyte containing Pb2+ as corrosion inhibitor and dendrite suppressor for the zinc anode in the rechargeable hybrid aqueous battery, Materials Today Energy 4, pp. 34-40

Hoang, Tuan K. A.; Doan, The Nam Long; Lu, Changyu; Ghaznavi, Mahmoudreza; Zhao, Hongbin; and Chen, P; (2017). Performance of thixotropic gel electrolytes in the rechargeable aqueous Zn/LiMn2O4 battery, ACS Sustainable Chemistry and Engineering 5 (2), pp. 1804-1811

Hoang, Tuan K. A; Doan, The Nam Long; Cho, Julie Hyeonjoo; Su, Jane Ying Jun; Lee, Christine; Lu, Changyu; Chen, P; Sustainable Gel Electrolyte Containing Pyrazole as Corrosion Inhibitor and Dendrite Suppressor for Aqueous Zn/LiMn2O4 Battery ChemSusChem 10 (13), pp. 2816-2822


Li, M; Yu, Y; Li, J; Chen, B; Konarov, A; & Chen, P; (2015). Fabrication of graphene nanoplatelets-supported SiOx-disordered carbon composite and its application in lithium-ion batteries, *Journal of Power Sources*, 293, 976-982.

Sheydaeian, E; Sarikhani, K; Chen, P; Toyserkani, E; (2017). Novel carbon materials in the cathode formulation for high rate rechargeable hybrid aqueous batteries, Materials and Design 135, pp. 142-150

Sun, K.E.K; Hoang, T.K.A; Doan, T.N.L; Yu, Y; Zhu, X; Tian, Y; Chen, P; (2017). Suppression of Dendrite Formation and Corrosion on Zinc Anode of Secondary Aqueous Batteries, ACS Applied Materials and Interfaces 9 (11), pp. 9681-9687

Sun, Kyung E. K; Hoang, Tuan K. A; Doan, The Nam Long; Yu, Yan; Chen, Pu; (2017). Highly Sustainable Zinc Anodes for a Rechargeable Hybrid Aqueous Battery, Chemistry - A European Journal.

Wu, X; Li, Y; Li, C; He, Z; Xiang, Yanhong; Xiong, L; Chen, D; Yu, Y; Sun, K; He, Z; & Chen, P; (2015). The electrochemical performance improvement of LiMn2O4/Zn based on zinc foil as the current collector and thiourea as an electrolyte additive, *Journal of Power Sources*, 300, 453-459.

Zhongwei Chen


Deng, Ya-Ping; Yi Jiang, Dan Luo, Jing Fu, Ruilin Liang, Shaobo Cheng, Zhengyu Bai, Yangshuai Liu, Wen Lei, Lin Yang, Jing Zhu, Zhongwei Chen. (2017). Hierarchical Porous

Deng, Y; Dong, Y; Wang, G; Sun, K; Shi, X; Zheng, L; ... & Liao, S; (2017). Well-Defined ZIF-Derived Fe–N Codoped Carbon Nanoframes as Efficient Oxygen Reduction Catalysts. ACS Applied Materials & Interfaces.


Lee, D. U; Li, J; Park, M. G; Seo, M. H; Ahn, W; Stadelmann, I; Ricardez-Sandoval, L; and Chen, Z; (2017). Self-assembly of Spinel Nano-crystals into Mesoporous Spheres as Bifunctionally Active Oxygen Reduction and Evolution Electrocatalysts. ChemSusChem. Accepted Author Manuscript. doi:10.1002/cssc.201700369


Liu, Y; Li, G; Fu, J; Chen, Z; and Peng, X; (2017), Strings of Porous Carbon Polyhedrons as Self-Standing Cathode Host for High-Energy-Density Lithium–Sulfur Batteries. *Angewandte Chemie*.


Luo, Dan; Ya-Ping Deng, Xiaolei Wang, Gaoran Li, Juan Wu, Jing Fu, Wen Lei, RuiLin Liang, Yangshuai Liu, Yuanli Ding, Aiping Yu, Zhongwei Chen. (2017). Tuning Shell Numbers of Transition Metal Oxide Hollow Microspheres toward Durable and Superior Lithium Storage, *ACS nano 11*(11), pp. 11521-11530


Wang, Yang; Jing Fu, Yining Zhang, Matthew Li, Fathy Mohamed Hassan, Guang Li, Zhongwei Chen. (2017). Continuous fabrication of a MnS/Co nanofibrous air electrode for wide integration of rechargeable zinc–air batteries. *Nanoscale* 9 (41), pp. 15865-15872


Yang, Jie; Gaoran Li, Meidan Cai, Pengju Pan, Zhoupeng Li, Yongzhong Bao, Zhongwei Chen. (2017). A facile self-templating synthesis of carbon frameworks with tailored hierarchical porosity for enhanced energy storage performance, *Chemical Communications 53* (36), pp. 5028-5031

Yang, Y; Wang, Z; Yan, G; Guo, H; Wang, J; Li, X; ... & Zhou, R; (2017). Pitch carbon and LiF co-modified Si-based anode material for lithium ion batteries. *Ceramics International*.


Chih Hsiung (Perry) Chou


Michael Collins


James Craig


Appendix V – Member Publications

Neil Craik


Eric Croiset


Toor, Sannan Yousaf; Eric Croiset. (2017). Fabrication of Metal Supported Solid Oxide Fuel Cells (MS-SOFC) with Ceria and Zirconia Based Electrolytes, *ECS Transactions* 78 (1), pp. 2051-2058


**Cecile Devaud**


**Paul Doherty**

Reilly, C., Rugero, S., & Doherty, P. The geotechnical properties of the pulverised coal ash produced at Moneypoint Power Station.


Heather Douglas


Peter Douglas


Maurice Dusseault


Appendix V – Member Publications


**Ali Elkamel**


Mukherjee, Ushnik; Sean Walker, Azadeh Maroufmashat, Michael Fowler, Ali Elkamel. (2017). Development of a pricing mechanism for valuing ancillary, transportation and environmental services offered by a power to gas energy system, Energy 128, pp. 447-462


Appendix V – Member Publications

Ehab El-Saadany


**Ramadan El-Shatshat**


Xianshe Feng


Michael Fowler

Ahmadi, Leila; Steven B Young, Michael Fowler, Roydon A Fraser, Mohammad Ahmadi Achachlouei. (2017). A cascaded life cycle: reuse of electric vehicle lithium-ion battery packs in energy storage systems, The International Journal of Life Cycle Assessment 22 (1), pp. 111-124


Mathew, M; QH Kong, J McGroary, M Fowler. (2017). Simulation of lithium ion battery replacement in a battery pack for application in electric vehicles, Journal of Power Sources 349, pp. 94-104


Panchal, S; R Khasow, I Dincer, M Agelin-Chaab, R Fraser, M Fowler. (2017). Thermal design and simulation of mini-channel cold plate for water cooled large sized prismatic lithium-ion battery, Applied Thermal Engineering 122, pp. 80-90

Panchal, S; I Dincer, M Agelin-Chaab, M Fowler, R Fraser. (2017). Uneven temperature and voltage distributions due to rapid discharge rates and different boundary conditions for series-connected LiFePO 4 batteries, International Communications in Heat and Mass Transfer 81, pp. 210-217


Walker, Sean B; Daniel van Lanen, Ushnik Mukherjee, Michael Fowler. (2017). Greenhouse gas emissions reductions from applications of Power-to-Gas in power generation, Sustainable Energy Technologies and Assessments 20, pp. 25-32
Appendix V – Member Publications


Roydon Fraser


Panchal, S; I Dincer, M Agelin-Chaab, R Fraser, M Fowler. Transient electrochemical heat transfer modeling and experimental validation of a large sized LiFePO4/graphite battery, International Journal of Heat and Mass Transfer 109, pp. 1239-1251 (2017/6/30)


Vincent Gaudet


Bissan Ghaddar


Appendix V – Member Publications

**Lukasz Golab**


**Wojciech Golab**


**Irene Goldthorpe**


**Jeff Gostick**


**Robert Gracie**


**Komal Habib**


Appendix V – Member Publications


**Feridun Hamdullahpur**


**Keith Hipel**


Robert Hudgins


Ihab Ilyas


Shesha Jayaram


Khanali, Mahdi; Shesha Jayaram. A study on PD activities of oil-impregnated paper under pulse voltages using gas analysis, IEEE Transactions on Dielectrics and Electrical Insulation 24 (4), pp. 2503-2510 (2017)


Appendix V – Member Publications

**David Johnson**


**Mehrdad Kazerani**


Appendix V – Member Publications


**Srinivasan Keshav**


**Behrad Khamesee**


**Holger Kleinke**


**Nasser Lashgarian Azad**


Hyung-Sool Lee


Yuri Leonenko


Yuning Li


Huang, Sheng; Meng, Chao; Xiao, Min; Ren, Shan; Wang, ShuanJin; Han, Dongmei; Li, Yuning; Meng, Yuezhong. (2017). Multi-shell Tin Phosphide Nanospheres as High Performance Anode Material of Sodium Ion Battery. *Sustainable Energy Fuels*, 1, 1944-1949


**Xianguo Li**


**Fue-Sang Lien**


**Jennifer Lynes**


**John McPhee**


**Sriram Narasimhan**


**Jatin Nathwani**


Malek, K., Nathwani, J (2016), ‘Cost Modeling and Valuation of Grid-Scale Electrochemical


Linda Nazar

Bonnick, Patrick; Xiaqi Sun, Lauren Blanc, Linda F Nazar. (2017). A Comparison of Thiospinel Mg Battery Cathode Materials: MgxTi2S4 and MgxZr2S4, Meeting Abstracts 5, pp. 432-432

De la Llave, Ezequiel; Prasant Kumar Nayak, Elena Levi, Tirupathi Rao Penki, Shaul Bubil, Pascal Hartmann, Frederick-Francois Chesneau, Miri Greenstein, Linda F Nazar, Doron Aurbach. (2017). Electrochemical performance of Na 0.6 [Li 0.2 Ni 0.2 Mn 0.6] O 2 cathodes with high-working average voltage for Na-ion batteries, Journal of Materials Chemistry A 5 (12), pp. 5858-5864


Appendix V – Member Publications


**Flora Ng**


**Amer Obeidi**


**Chijioke Oji**

Mahesh Pandey


Li, Bo; Mahesh D Pandey. (2017). An advanced statistical method to analyze condition monitoring data collected from nuclear plant systems, *Nuclear Engineering and Design* 323, pp. 133-141

Paul Parker


Rowlands, I. H., Reid, T., Parker, P. (2015). Research with disaggregated electricity end-use data in households: review and recommendations. *WIREs Energy and Environment*

Wayne Parker


Appendix V – Member Publications


**Mehrdad Pirnia**


**Kumaraswamy Ponnambalam**


**Mark Pritzker**


Appendix V – Member Publications


**Pavle Radovanovic**


**Omar Ramahi**


**Garry Rempel**


**Luis Ricardez-Sandoval**


Appendix V – Member Publications


Catherine Rosenberg


Song, Chunhe; Wei Jing, Peng Zeng, Catherine Rosenberg; (2017). An analysis on the energy consumption of circulating pumps of residential swimming pools for peak load management, Applied Energy 195, pp. 1-12

Ian Rowlands


Rebecca Saari


Magdy Salama


Appendix V – Member Publications


**Armaghan Salehian**


**Andrei Sazonov**


**Gerry Schneider**


**Anindya Sen**

Xuemin (Sherman) Shen


Ren, Ju; Junying Hu, Ruilong Deng, Deyu Zhang, Yaoxue Zhang, Xuemin Sherman Shen. Joint Load Scheduling and Voltage Regulation in Distribution System with Renewable Generators, *IEEE Transactions on Industrial Informatics (2017/12/12)*


**David Simakov**


**John Simpson-Porco**


**Siva Sivoththaman**


**Zhongchao Tan**

Appendix V – Member Publications

Susan Tighe


Robert Varin


Olaf Weber


Lan Wei

John Wen
Appendix V – Member Publications


**John Wright**


**Steven Young**


**Aiping Yu**


**Weihua Zhuang**


Appendix VI: Student Posters
Appendix VI – Student Posters

Critiquing Time-Of-Use Pricing in Ontario
Adedamola Adepetu, Elnaz Rezaei, Daniel Lizotte, Srinivasan Keshav
Cheriton School of Computer Science, University of Waterloo

1. What is Time-Of-Use (TOU) Pricing?
- Less than 10.0 kWh
- 10.0-11.4 kWh
- 11.4-13.0 kWh

Midnight 7 AM 11 AM 5 PM 7 PM Midnight
SUMMER

Midnight 7 AM 11 AM 5 PM 7 PM Midnight
WINTER

Midnight 7 AM 11 AM 5 PM 7 PM Midnight
WEEKENDS & HOLIDAYS

2. Is it effective?
- TOU is aimed at reducing the daily peak-to-average (PTA) load ratio.
- Let \( P = P_1, P_2, \ldots, P_N \) & \( Q = Q_1, Q_2, \ldots, Q_N \)
represent the daily PTA values in 2003 and 2012 respectively.
- \( D = D_1, D_2, \ldots, D_N \) is obtained such that
\( (P_i - Q_i) \)

3. Making TOU Effective: Optimal Number of Seasons
a. Feature Representation
\[ \phi_k^e = \begin{cases} 1 & \text{if } L(h) \geq P_3 \\ 0.5 & \text{if } P_2 < L(h) < P_3 \\ 0 & \text{if } L(h) < P_2 \end{cases} \]
\( \phi \) is Peak, \( \phi \) is Mid-Peak, \( \phi \) is Off-Peak

b. Brute-Force Clustering:


5. Recommendations
- The TOU scheme should have 4 seasons, with appropriate daily time divisions, OR
- The daily time divisions in the 2-season TOU scheme should be adjusted accordingly.

Cascaded Use and Repurposing of Li-ion Batteries From PHEVs
Leila A. B. Walker, Michael Fowlie, Roydon A. Fraser, Steven B. Young
Department of Mechanical Engineering, University of Waterloo, Ontario, Canada

Motivations
- Major increase in electric vehicles (EV) and plug-in hybrid electric vehicles (PHEV) adoption
- Reduced environmental effects of producing electric vehicles
- Renewable energy systems are a major source of energy
- Repurposing the batteries used in vehicles and applying them in stationary energy storage systems can reduce the number of new batteries needed

Concentration of Capacity
- 80% reduction in the life cycle (LCA) of batteries
- 90% reduction in the life cycle (LCA) of batteries

Capacity Trade-Off Model of Li-ion Battery During First/Second Use
- Power and energy trade-off between the first and second use

Models
1. Environmental Feasibility
- Improvement in the performance of Li-ion batteries
- Improvement in the performance of Li-ion batteries
- Improvement in the performance of Li-ion batteries

2. Predicted model of battery degradation effect on SOC degradation
- Improvement of the performance of Li-ion batteries
- Improvement of the performance of Li-ion batteries

3. Energy Use of Li-ion Battery Over Its Expected Life
- Improvement of the performance of Li-ion batteries
- Improvement of the performance of Li-ion batteries

Conclusion
- Battery degradation is an important consideration in the long-term use of Li-ion batteries
- This project aims to improve the performance of Li-ion batteries by reducing the degradation and increasing the cycle life of batteries

Acknowledgements
Appendix VI – Student Posters

Is The Grass Greener? Mining Electric Vehicle Opinions
Tommy Carpenter, Lukasz Golab, Schahil Syed

Questions of interest:
- Why are EV sales low?
- What do owners think of their cars?
- What are manufacturers doing wrong (and right)?

Challenges to Answer:
- Fast trials are expensive
- Drivers to survey are hard to find
- No easily-consumable review database (e.g., Amazon)
- Reading test is time consuming/indust (compared to Amazon)

Mine Solution:
Automatically mine & summarize EV ownership forums based on the features the user cares about:
- Get input features from user; e.g., range, battery life, etc.
- Crawlers to build a review corpus
- Mine features-opinion pairs, (f, v), using a
- Produce data visualizations

Handling Context Dependent Opinions:
1. For some opinion features, more of it is always better, e.g., "performance" and "price"
2. Intensity modifiers change sentiment of word features:
   - \( R \) for the "low" intensity
   - \( S \) for the "high" intensity

Experimental Performance:
Lead Time Metrics

References:
1. http://meka.org/
2. Thessaloniki, Greece Mining Undergraduate 2010
3.营造良好

POWER TO GAS FOR ENERGY STORAGE IN ONTARIO
Usman Mullerjee, Dan Feng, Michael Fowler
Department of Chemical Engineering, University of Waterloo, Waterloo, ON, Canada

Current Energy Scenario in Ontario

<table>
<thead>
<tr>
<th>Supply</th>
<th>Conversion</th>
<th>Conditioning</th>
<th>Storage</th>
<th>Conversion</th>
<th>End Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>Liquid</td>
<td>Compressed</td>
<td>Battery</td>
<td>Liquid</td>
<td>Electricity</td>
</tr>
</tbody>
</table>

Benefits:
- Reduces greenhouse gas emissions
- Store energy for later use
-偶数回 Getty Images

Comparison of Energy Storage Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Charging Time</th>
<th>Discharging Time</th>
<th>Energy Density</th>
<th>Power Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery</td>
<td>30 min</td>
<td>30 min</td>
<td>50 kWh</td>
<td>100 kW</td>
</tr>
<tr>
<td>Compressed Gas</td>
<td>1 hr</td>
<td>1 hr</td>
<td>1000 kWh</td>
<td>1 MW</td>
</tr>
<tr>
<td>Liquid Hydrogen</td>
<td>10 min</td>
<td>10 min</td>
<td>2000 kWh</td>
<td>2 MW</td>
</tr>
</tbody>
</table>

End Users
- On-site Energy Hub at Underground Natural Gas Storage Site
  - End-users not considered as additional components
  - Base Case Scenario - Underground Gas Storage Site
  - Baseline Scenario - Underground Gas Storage Site

Renewable Natural Gas Integration

- Natural Gas from renewable sources

Storage Reservoir Node
There are 11 underground natural gas storage facilities in Ontario.

Electrolyzer Node
Electrolysis of water can split water into hydrogen and oxygen.  

Storage Reservoir Node
Renewable Natural Gas Integration

Solar Power

Net-Medium-Small wind farms (100 MW to 10 MW)

A CIGS based on a solar cell with a high concentration ratio of up to 1:10,000
Appendix VI – Student Posters
Appendix VI – Student Posters

[Image of a poster discussing Student Posters]

[Image of another poster titled "Electricity grid issues in Canada's Remote Communities"]

- **OVERVIEW**
  - In Canada, approximately 200,000 people live in 280 communities across the country that are not connected to the North American electric grid.
  - The objective of this research was to create an updated and detailed database of energy-related information for Northern and Remote Communities (NRCs), including detailed solar irradiation and wind speed data.

- **SUMMARY**
  - The total NRCs' installed capacity is estimated at 612MW, including 190MW of hydro power, 315MW of diesel generators, and 77MW of natural gas turbines, with the remaining capacity being relatively small wind and solar systems.
  - **Main Issues**
    - Most remote communities (RCs) currently satisfy their electricity needs mainly by using diesel-based generators, making their energy-related costs significantly higher than those for the rest of the country.
    - Energy-related information for NRCs is scattered and outdated, making it difficult to create a solid baseline.
    - Several initiatives are required to improve the expected energy output from RE technologies.
Appendix VI – Student Posters
Appendix VI – Student Posters

H-SPOT: A Personal Thermal Comfort System for Offices
A. Robbani, R. Kabaisani, G. Rosenberg, and S. Keshav
University of Waterloo

What does it do?
- Provides personal thermal comfort in offices
- Interacts with the HVAC system to minimize energy use

A Building with H-SPOT

Outside Temperature

HVAC System

Central Control

Temperature and Occupancy Data

Office 1

H-SPOT (Local Control)

Office N

H-SPOT (Local Control)

H-SPOT has two components:
- Central HVAC system
- Local desktop fan/heater

The web interface shows historical data and gets feedback from users.

The actuation box has a Raspberry Pi optionally connected to WiFi, and controls the fan/heater.

This H-SPOT user is comfortable in his office. The variable speed fan turns on when he feels hot, and the heater kicks in when he feels cold.

How Does H-SPOT Work?
- Uses HVAC control as a baseline, and uses Model Predictive Control.
- Local reactive control in each office.
- Controls comfort as a function of temperature, humidity, air velocity, clothing, and metabolic rate for each individual.
- Uses a web interface to learn comfort parameters and office areas.

Benefits
- H-SPOT can address diverse comfort requirements, which conventional HVAC systems cannot provide.
- H-SPOT can achieve the desired comfort level in around 30 seconds. That enables the system to respond quickly to load variations.
- H-SPOT potentially reduces the overall energy consumption during partial loads. We are planning to verify this with a field trial in the future.
- H-SPOT requires minimal user involvement.

Local Control Evaluation for 58,000 Hours of Operation

The local component of H-SPOT improves comfort significantly.

A Self-contained Integrated System for Electricity Grid Monitoring
Sid Zarabi, Egon Fernandes

Department of Electrical and Computer Engineering, University of Waterloo

Department of Electrical and Computer Engineering, University of Waterloo

Laboratoire de l’Intégration du Matériau aux Systèmes, Université de Bordeaux

Objective
America and Europe’s plan for a clean energy future is the development of smart grid, a modern electricity system using advanced monitoring, communication and control technologies to build a flexible, reliable and efficient smart grid electricity system. Hence, we are working to develop a non-invasive, low-cost and self-contained electricity grid monitoring solution to enable real-time grid monitoring and data communication.

Methodology

Results

The system needs to be electromechanically coupled to the 15kV AC current in the power transmission line.

Components
- Energy harvester
- Power conditioning circuitry
- Current sensor
- Microcontroller and the wireless communication circuitry

Piezoelectric Output

Optimal Power Transfer

Processing of piezoelectric MEMS

Piezoelectric Microsystems

Conclusion
Low-cost real-time monitoring is essential for the smart grid infrastructure. Consequently, there has been significant research effort to drive progress in this area. The expected outcome from this project is to provide an innovative and economically practical solution to smart grid monitoring. This will be the first single chip self-powered current sensor device for industry application, which can be foreseen to be widely adopted by Canadian and European electrical power utilities.

Funding Source:

CISCO

364
Appendix VI – Student Posters

Compressed Air Energy Storage in Ontario: 
A Solution to Providing Energy Grid Flexibility

Fraser Lord (fraser.d.lord@gmail.com) and Jai Duhan (jkdahun@uwindsor.ca)

Implementing CAES in Ontario

Grid integration

Ontario has a significant share of wind energy generation, primarily from high-quality energy sources and demand centers.

Geology

Salt domes are found in the Salzgitter formation of the Michigan basin that extends from Illinois to Ohio. These domes are a natural resource for storing geothermal energy and power.

Capital Costs

The cost of building a 1000 MW CAES plant is estimated to be approximately $2.5 billion. This is a conservative estimate considering the current capital costs for large-scale power plants.

Recent progress and challenges in the development of a multiscale modeling framework for wind farm planning and power predictions

Ping Mei, Hang Meng, Chris Men, Deyong Wen, Fae-sang Lien, William Melek, Eugene Xue, Yongsheng Chen

Introduction & Objectives

Wind energy is expected to play a significantly increasing role in the generation of electric power worldwide owing to the fast fact that it is the most developed and cost-effective of all the renewable energy sources. However, achieving the current level of power production from wind farms (clusters of wind turbines) requires predictive tools based on proper physics and theory.

The aim of this project is to develop a high-resolution multiscale computational fluid dynamics model that simulates the flow patterns around wind turbines. The model will be validated and improved through a series of experiments conducted in the laboratory and field.

Proposed Methodology

1. Fluidic actuator line (FAL) model
2. Hydraulic wind model
3. Microscale model
4. Artificial neural networks (ANN)
5. A new model for blade dynamics
6. Lid-driven cavity

Elastic actuator line modeling for wake-induced fatigue analysis of horizontal wind turbine
Appendix VI – Student Posters

Re-Use of Electric Vehicle Batteries for Smart Grid Energy Storage Systems

Fourth Year Design Project Group: Andreas Adamikis, Alex Daniel, Ali Komei, Manon Poti, Wouter Syd

Advise Professors: Michael Fowler, Raymond Fraser, William Metz, Oscar Nepoli

University of Waterloo: Mechanical, Systems Design, Mechanical and Chemical Engineering

1. System Need

2. Solution: Re-purposed Electric Vehicle Batteries for Energy Storage

3. History Modeling

4. Electrical Design

5. Mechanical Design

6. Results

Modeling and Testing of a Bidirectional Smart Charger for Distribution System EV Integration

Mauricio Restrepo, Jordan Morris, Claudio A. Caltabiano, and Mehrdad Korani

1Department of Electrical and Computer Engineering, University of Waterloo

2Tesla Motors Inc.

OBJECTIVES

- Describe a new average model of a single-phase, two-stage bidirectional charger, that is able to operate in all four quadrants of the PQ plane, and validate it with an actual bidirectional EV charger
- Demonstrate three operation strategies of bidirectional EV chargers in LV distribution systems, illustrating their application through time-domain simulations based on the proposed average model.

VALIDATION OF AVERAGE MODEL

CASE STUDY

CONCLUSIONS

- The results obtained from the average model were shown to be generally in close agreement with those of the prototype.
- The model proved to be appropriate for representing the steady-state response and cycle-to-cycle dynamics of the chargers when interacting with a distribution system.
Appendix VI – Student Posters
Appendix VI – Student Posters

Compressed Air Energy Storage in Ontario: A Solution to Providing Energy Grid Flexibility
Fraser Lord (fraserrd.lord@gmail.com) and Jia Duhan (jdahun@uwaterloo.ca)

Design and Optimization of a Locomotive Powertrain using Hydrogen Fuel Cells
Group 28: Saliham Adnan, Khan P good Version, Marvin Bacher
Advisor: Dr. Michael Hollecker

370
Appendix VII:
Highly Qualified Personnel
<table>
<thead>
<tr>
<th>#</th>
<th>WISE Faculty Member(s)</th>
<th>Graduate Students</th>
<th>Program Status</th>
<th>Theses Titles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anderson, William A.</td>
<td>Sycz, Mateusz</td>
<td>Completed Program</td>
<td>Photochemical Degradation of Monochlorobenzene</td>
</tr>
<tr>
<td>2</td>
<td>Anderson, William A.</td>
<td>Choi, Eureka</td>
<td>Completed Program</td>
<td>The Role of Germicidal Ultraviolet Light in the Formation of Secondary Organic Aerosols</td>
</tr>
<tr>
<td>3</td>
<td>Anderson, William A.</td>
<td>Bustami, Yazmin</td>
<td>Completed Program</td>
<td>Development of a Nanocatalytic-Based Assay for the Detection of an Endocrine Disrupting Compound in Aqueous Solution</td>
</tr>
<tr>
<td>4</td>
<td>Anderson, William A.</td>
<td>Mehrata, Mina</td>
<td>Completed Program</td>
<td>Hospital Air Emission Capture and Recovery</td>
</tr>
<tr>
<td>5</td>
<td>Anderson, William A.</td>
<td>An, Ran</td>
<td>Completed Program</td>
<td>Antibacterial and Mercury Detection Abilities of Triangular Silver Nanoparticles</td>
</tr>
<tr>
<td>7</td>
<td>Basu, Dipanjan</td>
<td>Duhan, Jai Kant</td>
<td>Completed Program</td>
<td>Compressed Air Energy Storage in Salt Caverns: Geomechanical Design Workflow, CAES Siting Study from a Geomechanics Perspective, and Deep Brine Disposal</td>
</tr>
<tr>
<td>8</td>
<td>Basu, Dipanjan</td>
<td>Fartosy, Sabah Hassan Lafta</td>
<td>Completed Program</td>
<td>Non-Destructive Evaluation of Damage in Concrete with Applications in Shallow Foundations</td>
</tr>
<tr>
<td>9</td>
<td>Basu, Dipanjan</td>
<td>Fazaeli, Mohammad Mahdi</td>
<td>Completed Program</td>
<td>Stability Assessment of Salt Cavern Roof Beam for Compressed Air Energy Storage in South-Western Ontario</td>
</tr>
<tr>
<td>10</td>
<td>Basu, Dipanjan</td>
<td>Gupta, Bipin Kumar</td>
<td>Completed Program</td>
<td>Soil-Structure Interaction Analysis of Monopile Foundations Supporting Offshore Wind Turbines</td>
</tr>
<tr>
<td>12</td>
<td>Bhattacharya, Kankar</td>
<td>Han, Qinghui</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Bhattacharya, Kankar</td>
<td>Lui, Edmond</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Advisor</td>
<td>Student</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>------------------</td>
<td>---------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Bhattacharya</td>
<td>Kant,I-Ling Xenia</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Bhattacharya</td>
<td>Le,Brian</td>
<td>Completed Program <strong>Incentive Design of Conservation Voltage Reduction Planning for Industrial Loads in Ontario</strong></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Bhattacharya</td>
<td>Bhatt,BHAVDEEP</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Bhattacharya</td>
<td>Bin Humayd,Abdullah</td>
<td>Completed Program <strong>Distribution System Planning in Smart Grids to Accommodate Distributed Energy Resources and Electric Vehicles</strong></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Bhattacharya</td>
<td>Pirnia,Mehrdad</td>
<td>Completed Program <strong>Stochastic Modeling and Analysis of Power Systems With Intermittent Energy Sources</strong></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Bhattacharya</td>
<td>Lami,Badr</td>
<td>Completed Program <strong>New Approaches to Composite Reliability Assessment of Smart Power Systems</strong></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Bhattacharya</td>
<td>Hangilipola,ATHULA</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Bhattacharya</td>
<td>Dash,Santosh Kumar</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Bhattacharya</td>
<td>Hafez,Omar</td>
<td>Completed Program <strong>Smart PEV Charging Station Operation and Design Considering Distribution System Impact</strong></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Bhattacharya</td>
<td>Munoz Guerrero,juan Carlos</td>
<td>Completed Program <strong>Affine Arithmetic Based Methods for Transient and Voltage Stability Assessment of Power Systems With Intermittent Sources of Power</strong></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Bhattacharya</td>
<td>Hliusser,Phillip</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Bhattacharya</td>
<td>Sharma,Isha</td>
<td>Completed Program <strong>Operation of Distribution Systems With PEVs and Smart Loads</strong></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Bhattacharya</td>
<td>Das,Indrajit</td>
<td>Completed Program <strong>Investment Planning Models and Optimal Incentive Design for System Planners and Investors to Integrate Renewables</strong></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Bhattacharya</td>
<td>Torkaman,Reza</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Bhattacharya</td>
<td>Sailer,Karl-Eugen</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Name 1</td>
<td>Name 2</td>
<td>Program Completion</td>
<td>Project Title</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>----------------</td>
<td>--------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>29</td>
<td>Bhattacharya,Kankar</td>
<td>Jain,Rupali</td>
<td>Completed Program</td>
<td>Optimal Operation of Climate Control Systems of Indoor Ice Rinks</td>
</tr>
<tr>
<td>30</td>
<td>Bhattacharya,Kankar</td>
<td>Farrokhabadi,Mostafa</td>
<td>Completed Program</td>
<td>Primary and Secondary Frequency Control Techniques for Isolated Microgrids</td>
</tr>
<tr>
<td>31</td>
<td>Bhattacharya,Kankar</td>
<td>Kundu,Rajib</td>
<td>Completed Program</td>
<td>Smart Operation of Centralized Temperature Control Systems in Multi-Unit Residential Buildings</td>
</tr>
<tr>
<td>32</td>
<td>Bhattacharya,Kankar</td>
<td>Madhavan,Adarsh</td>
<td>Completed Program</td>
<td>An Integrated Voltage Optimization Approach for Industrial Loads</td>
</tr>
<tr>
<td>33</td>
<td>Bhattacharya,Kankar</td>
<td>Mosaddegh,Abolfazl</td>
<td>Completed Program</td>
<td>Optimal Operation of Power Distribution Feeders with Smart Loads</td>
</tr>
<tr>
<td>34</td>
<td>Bhattacharya,Kankar</td>
<td>Ramos-Gaete,Felipe</td>
<td>Completed Program</td>
<td>Modeling and Analysis of Price-Responsive Loads in the Operation of Smart Grids</td>
</tr>
<tr>
<td>35</td>
<td>Bhattacharya,Kankar</td>
<td>Lara,Jose Daniel</td>
<td>Completed Program</td>
<td>Robust Energy Management Systems for Isolated Microgrids Under Uncertainty</td>
</tr>
<tr>
<td>36</td>
<td>Bhattacharya,Kankar</td>
<td>Raghurajan,Akash</td>
<td>Completed Program</td>
<td>Optimal Demand Response of Controllable Loads in Isolated Microgrids</td>
</tr>
<tr>
<td>37</td>
<td>Bhattacharya,Kankar</td>
<td>Shetty,Subhalakshmi</td>
<td>Completed Program</td>
<td>Impact of PEV Charging Loads on Distribution System Operations and Optimal Siting and Sizing of PEV Charging Stations</td>
</tr>
<tr>
<td>38</td>
<td>Bhattacharya,Kankar</td>
<td>Solanki,Bharatkumar</td>
<td>Completed Program</td>
<td>Improved and Practical Energy Management Systems for Isolated Microgrids</td>
</tr>
<tr>
<td>39</td>
<td>Bhattacharya,Kankar</td>
<td>Kandenkavil,Sreedevi Valsan</td>
<td>Completed Program</td>
<td>Some Aspects of Static and Dynamic Distribution System State Estimation with Optimal Meter Placement Studies</td>
</tr>
<tr>
<td>40</td>
<td>Bigelow,Philip Lloyd</td>
<td>Zummach,Dana Marie</td>
<td>Completed Program</td>
<td>Examining the Impact of a Restrictive Retail Food Environment Intervention on Pharmacy Sales Over Time in Baddeck, Nova Scotia</td>
</tr>
<tr>
<td>41</td>
<td>Bigelow,Philip Lloyd</td>
<td>Christidis,Tanya</td>
<td>Completed Program</td>
<td>Wind Turbines in Ontario: An Examination of Perceptions and Potential Health Effects, and how they Relate to Policy and Decision-Making Processes</td>
</tr>
<tr>
<td>42</td>
<td>Bigelow,Philip Lloyd</td>
<td>Campbell,Graham Robert</td>
<td>Completed Program</td>
<td>Mapping Community with African-Canadian Youth Newcomers: Settlement Narratives and Welcoming Communities</td>
</tr>
<tr>
<td>No.</td>
<td>First Name</td>
<td>Last Name</td>
<td>Title</td>
<td>Supervisor</td>
</tr>
<tr>
<td>-----</td>
<td>-------------</td>
<td>----------------------------------</td>
<td>---------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>43</td>
<td>Bigelow</td>
<td>Philip Lloyd</td>
<td>Completed Program</td>
<td>Paller</td>
</tr>
<tr>
<td>44</td>
<td>Bigelow</td>
<td>Philip Lloyd</td>
<td>Completed Program</td>
<td>Wawzonek</td>
</tr>
<tr>
<td>45</td>
<td>Bigelow</td>
<td>Philip Lloyd</td>
<td>Completed Program</td>
<td>Du</td>
</tr>
<tr>
<td>46</td>
<td>Bigelow</td>
<td>Philip Lloyd</td>
<td>Completed Program</td>
<td>Laberge</td>
</tr>
<tr>
<td>47</td>
<td>Bigelow</td>
<td>Philip Lloyd</td>
<td>Completed Program</td>
<td>Lane</td>
</tr>
<tr>
<td>48</td>
<td>Bigelow</td>
<td>Philip Lloyd</td>
<td>Completed Program</td>
<td>Jalali</td>
</tr>
<tr>
<td>49</td>
<td>Bigelow</td>
<td>Philip Lloyd</td>
<td>Completed Program</td>
<td>Versteeg</td>
</tr>
<tr>
<td>50</td>
<td>Bigelow</td>
<td>Philip Lloyd</td>
<td>Completed Program</td>
<td>Van Eerd</td>
</tr>
<tr>
<td>51</td>
<td>Boake</td>
<td>Terri</td>
<td>Completed Program</td>
<td>Jackson</td>
</tr>
<tr>
<td>52</td>
<td>Boake</td>
<td>Terri</td>
<td>Completed Program</td>
<td>Black</td>
</tr>
<tr>
<td>53</td>
<td>Boake</td>
<td>Terri</td>
<td>Completed Program</td>
<td>Young</td>
</tr>
<tr>
<td>54</td>
<td>Boake</td>
<td>Terri</td>
<td>Completed Program</td>
<td>Ma</td>
</tr>
<tr>
<td>55</td>
<td>Boake</td>
<td>Terri</td>
<td>Completed Program</td>
<td>Lui</td>
</tr>
<tr>
<td>56</td>
<td>Boake</td>
<td>Terri</td>
<td>Completed Program</td>
<td>Rutherford</td>
</tr>
<tr>
<td>No.</td>
<td>Name1</td>
<td>Name2</td>
<td>Program Status</td>
<td>Title</td>
</tr>
<tr>
<td>-----</td>
<td>-------</td>
<td>-------</td>
<td>----------------</td>
<td>-------</td>
</tr>
<tr>
<td>57</td>
<td>Cascante,Giovanni</td>
<td>El Menoufy,Adham</td>
<td>Completed Program</td>
<td>Flexural Fatigue Behaviour of Corroded Pretensioned Beams and Their Repair Using Carbon Fibre Reinforced Polymer Sheets</td>
</tr>
<tr>
<td>58</td>
<td>Cascante,Giovanni</td>
<td>Kirlangic,Ahmet Serhan</td>
<td>Completed Program</td>
<td>Condition Assessment of Cemented Materials Using Ultrasonic Surface Waves</td>
</tr>
<tr>
<td>59</td>
<td>Cascante,Giovanni</td>
<td>Ali,Hassan</td>
<td>Completed Program</td>
<td>Study of Laboratory and Field Techniques to Measure Shear Wave Parameters - Frequency Effects</td>
</tr>
<tr>
<td>60</td>
<td>Cascante,Giovanni</td>
<td>Mollahasani Madjadbadi,Behrad</td>
<td>Completed Program</td>
<td>Experimental Evaluation of a Distributed Fiber Optic Sensor for Mining Application</td>
</tr>
<tr>
<td>61</td>
<td>Cascante,Giovanni</td>
<td>Mahbaz,Seyedbijn</td>
<td>Completed Program</td>
<td>Non-Destructive Passive Magnetic and Ultrasonic Inspection Methods for Condition Assessment of Reinforced Concrete</td>
</tr>
<tr>
<td>62</td>
<td>Cascante,Giovanni</td>
<td>Rodriguez Roblero, Maria Jose</td>
<td>Completed Program</td>
<td>Condition Assessment of Concrete Elements Through two Nondestructive Ultrasonic Techniques</td>
</tr>
<tr>
<td>63</td>
<td>Charles,Trevor C</td>
<td>Lam,Kathy Nguyen</td>
<td>Completed Program</td>
<td>Development and Analysis of Molecular Methods for Functional Metagenomics of the Human gut Microbiome</td>
</tr>
<tr>
<td>64</td>
<td>Charles,Trevor C</td>
<td>Heil,John</td>
<td>Completed Program</td>
<td>Bacterial Chromosome Engineering for Applications in Metabolic Engineering</td>
</tr>
<tr>
<td>65</td>
<td>Charles,Trevor C</td>
<td>Vey,Gregory Detlev Alexander</td>
<td>Completed Program</td>
<td>The Proximon: Representation, Evaluation, and Applications of Metagenomic Functional Interactions</td>
</tr>
<tr>
<td>66</td>
<td>Charles,Trevor C</td>
<td>Marcassa,Ariana Gail</td>
<td>Completed Program</td>
<td>Gibberellin Biosynthesis in Bradyrhizobium japonicum USDA110</td>
</tr>
<tr>
<td>67</td>
<td>Charles,Trevor C</td>
<td>Ali,Shimaila</td>
<td>Completed Program</td>
<td>Plant Growth-Promoting Bacterial Endophytes That Contain ACC Deaminase: Isolation, Characterization, and Use</td>
</tr>
<tr>
<td>68</td>
<td>Charles,Trevor C</td>
<td>Tran,Tam</td>
<td>Completed Program</td>
<td>Metabolic Engineering Siorhizobium Meliloti and Pseudomonas Putida for Novel Polymer Production</td>
</tr>
<tr>
<td>69</td>
<td>Chen,Pu</td>
<td>Naahidi,Sheva</td>
<td>Completed Program</td>
<td>Biocompatibility Evaluation of Engineered Amino Acid Pairing Peptides for Drug Delivery</td>
</tr>
<tr>
<td>70</td>
<td>Chen,Pu</td>
<td>Ghaznavi,Mahmoudreza</td>
<td>Completed Program</td>
<td>Continuum Modeling of two Battery Systems: Lithium-Sulfur and Rechargeable Hybrid Aqueous Cells</td>
</tr>
<tr>
<td>71</td>
<td>Chen,Pu</td>
<td>Soltani,Madjid</td>
<td>Completed Program</td>
<td>Numerical Modeling of Drug Delivery to Solid Tumor Microvasculature</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Advisor</td>
<td>Program Completion</td>
<td>Project Description</td>
</tr>
<tr>
<td>-----</td>
<td>---------------</td>
<td>--------------------------</td>
<td>--------------------</td>
<td>-------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>72</td>
<td>Chen, Pu</td>
<td>Jafari, Mousa</td>
<td>Completed Program</td>
<td>Design, Characterization, and Application of Amphipathic Peptides for siRNA Delivery</td>
</tr>
<tr>
<td>73</td>
<td>Chen, Pu</td>
<td>Zargar, Bahram</td>
<td>Completed Program</td>
<td>A Synthetic Biology Approach to Bacteria Mediated Tumor Targeting</td>
</tr>
<tr>
<td>74</td>
<td>Chen, Pu</td>
<td>Sadatmousavi, Parisa</td>
<td>Completed Program</td>
<td>Self/Co-Assembling Peptide-based Nanocarriers for Anticancer Drug Delivery</td>
</tr>
<tr>
<td>75</td>
<td>Chen, Pu</td>
<td>Sun, Kyung Eun Kate</td>
<td>Completed Program</td>
<td>Synthesis of Novel Zinc Anode via Electroplating for Rechargeable Hybrid Aqueous Batteries</td>
</tr>
<tr>
<td>76</td>
<td>Chen, Pu</td>
<td>Lu, Sheng</td>
<td>Completed Program</td>
<td>Cationic Lytic Peptides as Drugs or Drug Carriers for Targeted Cancer Therapy</td>
</tr>
<tr>
<td>77</td>
<td>Chen, Pu</td>
<td>Xu, Wen</td>
<td>Completed Program</td>
<td>Endosomolytic Arginine-Rich Peptides for Therapeutic siRNA Delivery</td>
</tr>
<tr>
<td>78</td>
<td>Chen, Pu</td>
<td>Sheikholeslam, Mohammadali</td>
<td>Completed Program</td>
<td>Self-Assembling Peptide-Carbon Nanotube Dispersions and Hydrogels for Tissue Engineering and Biosensor Applications</td>
</tr>
<tr>
<td>79</td>
<td>Chen, Pu</td>
<td>Zhang, Yongguang</td>
<td>Completed Program</td>
<td>Sulfur Based Composite Cathode Materials for Rechargeable Lithium Batteries</td>
</tr>
<tr>
<td>80</td>
<td>Chen, Pu</td>
<td>Ding, Yong</td>
<td>Completed Program</td>
<td>Self-Assembling Peptide as HIV-1 Vaccine Design</td>
</tr>
<tr>
<td>81</td>
<td>Chen, Pu</td>
<td>Chen, Baoling</td>
<td>Completed Program</td>
<td>Characterization and Evaluation of HIV-1 Vaccine Design</td>
</tr>
<tr>
<td>82</td>
<td>Chen, Pu</td>
<td>Mitha, Aly</td>
<td>Completed Program</td>
<td>Polyethylene Glycol as an Electrolyte Additive for Rechargeable Hybrid Aqueous Batteries</td>
</tr>
<tr>
<td>83</td>
<td>Chen, Pu</td>
<td>Jeddi, Kazem</td>
<td>Completed Program</td>
<td>Polymer Electrolytes for Rechargeable Lithium/Sulfur Batteries</td>
</tr>
<tr>
<td>84</td>
<td>Chen, Pu</td>
<td>Pan, Ran</td>
<td>Completed Program</td>
<td>Stearylated Peptides for Therapeutic siRNA Delivery and Their Cellular Uptake Mechanisms</td>
</tr>
<tr>
<td>85</td>
<td>Chen, Pu</td>
<td>Li, Kai</td>
<td>Completed Program</td>
<td>A Study on Nano-Si/Polyaniline/Reduced Graphene Oxide Composite as Anode Material for Lithium-Ion Batteries</td>
</tr>
<tr>
<td>86</td>
<td>Chen, Pu</td>
<td>Sarikhani, Kaveh</td>
<td>Completed Program</td>
<td>Effect of Silica Nanoparticles on Interfacial Tension and Crystallization of Poly(lactic Acid) in Supercritical Carbon Dioxide</td>
</tr>
<tr>
<td>No.</td>
<td>Name1</td>
<td>Name2</td>
<td>Program Status</td>
<td>Project Title</td>
</tr>
<tr>
<td>-----</td>
<td>---------</td>
<td>---------------------</td>
<td>----------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>87</td>
<td>Chen,Pu</td>
<td>Li,Jing</td>
<td>Completed</td>
<td>Development of Sulfur-Polyacrylonitrile/Graphene Composites Cathode for Lithium Batteries</td>
</tr>
<tr>
<td>88</td>
<td>Chen,Pu</td>
<td>Wan,Zizhen</td>
<td>Completed</td>
<td>Arginine-Rich Ionic Complementary Peptides and Their Drug Delivery Potential</td>
</tr>
<tr>
<td>89</td>
<td>Chen,Pu</td>
<td>Ahmed,Moin</td>
<td>Completed</td>
<td>Reduced Graphene Oxide as Artificial Solid Electrolyte Interphase for Anodes of Aqueous Lithium Energy Storage Systems</td>
</tr>
<tr>
<td>90</td>
<td>Chen,Pu</td>
<td>Mohammadi,Mohammad</td>
<td>Completed</td>
<td>Dynamic Modeling of Drug Transport in Solid Tumors and Optimal Chemotherapy Regimen</td>
</tr>
<tr>
<td>91</td>
<td>Chen,Pu</td>
<td>Han,Zhixu</td>
<td>Completed</td>
<td>Mathematical Modeling of Rechargeable Hybrid Aqueous Batteries</td>
</tr>
<tr>
<td>92</td>
<td>Chen,Pu</td>
<td>Zhao,Yan</td>
<td>Completed</td>
<td>Polymer Electrolytes for Rechargeable Lithium/Sulfur Batteries</td>
</tr>
<tr>
<td>93</td>
<td>Chen,Pu</td>
<td>Hwangbo,Jeyeol</td>
<td>Completed</td>
<td>Fabrication of Nanostructured Manganese Oxide Electrode With M13 Phage Template</td>
</tr>
<tr>
<td>94</td>
<td>Chen,Pu</td>
<td>Konarov,Aishuak</td>
<td>Completed</td>
<td>Self-Discharge of Rechargeable Hybrid Aqueous Battery</td>
</tr>
<tr>
<td>95</td>
<td>Chen,Pu</td>
<td>Yu,Yan</td>
<td>Completed</td>
<td>Electrowinning of Zinc for the Anode of Rechargeable Hybrid Aqueous Batteries (ReHABs)</td>
</tr>
<tr>
<td>96</td>
<td>Chen,Pu</td>
<td>Zhu,Xiao</td>
<td>Completed</td>
<td>Nanocarbon-Containing High Power Cathode for Rechargeable Hybrid Aqueous Battery</td>
</tr>
<tr>
<td>97</td>
<td>Chen,Pu</td>
<td>Wang,Caixia</td>
<td>Completed</td>
<td>Extended Range Electric Vehicle Powertrain Simulation and Comparison with Consideration of Fuel Cell and Metal-Air Battery</td>
</tr>
<tr>
<td>98</td>
<td>Chen,Pu</td>
<td>Alhusaini,Khalsa</td>
<td>Completed</td>
<td>Therapeutic Potential of CPP (NP1) Mediated siRNA Delivery: Evidence in 3D Spheroids of Colon Cancer Cells (HCT 116)</td>
</tr>
<tr>
<td>99</td>
<td>Chen,Zhongwei</td>
<td>Higgins,Drew Christopher</td>
<td>Completed</td>
<td>Nanostructured Oxygen Reduction Catalyst Designs to Reduce the Platinum Dependency of Polymer Electrolyte Fuel Cells</td>
</tr>
<tr>
<td>100</td>
<td>Chen,Zhongwei</td>
<td>Wu,Jason Wen Tse</td>
<td>Completed</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Student Name</td>
<td>Advisor Name</td>
<td>Program Status</td>
<td>Project Title</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------</td>
<td>-------------------</td>
<td>----------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>101</td>
<td>Chen, Zhongwei</td>
<td>Lee, Dong Un</td>
<td>Completed</td>
<td>Nanostructured Spinel Oxides as Bi-Functional Electrocatalysts for Rechargeable Metal-Air Batteries</td>
</tr>
<tr>
<td>102</td>
<td>Chen, Zhongwei</td>
<td>Choi, Ja-Yeon</td>
<td>Completed</td>
<td>Nanostructured Non-Precious Metal Catalyst and its Behavior in the Catalyst Layer in PEM Fuel Cells</td>
</tr>
<tr>
<td>103</td>
<td>Chen, Zhongwei</td>
<td>Elsayed, Abdel Rahman</td>
<td>Completed Program</td>
<td>Nickel-Seeded Silicon Nanowires Grown on Graphene as Anode Material for Lithium Ion Batteries</td>
</tr>
<tr>
<td>104</td>
<td>Chen, Zhongwei</td>
<td>Kim, Baejung</td>
<td>Completed</td>
<td>Non-Precious Cathode Electrocatalytic Material for Zinc-Air Battery</td>
</tr>
<tr>
<td>105</td>
<td>Chen, Zhongwei</td>
<td>Song, Hoon Sub</td>
<td>Completed</td>
<td>Desulfurization by Metal Oxide/Graphene Composites</td>
</tr>
<tr>
<td>106</td>
<td>Chen, Zhongwei</td>
<td>Ahmed, Raihan</td>
<td>Completed</td>
<td>Durable High Surface Area Electrodes for Rechargeable Zinc Air Batteries</td>
</tr>
<tr>
<td>107</td>
<td>Chen, Zhongwei</td>
<td>Park, Hey Woong</td>
<td>Completed</td>
<td>Nanostructured Composites as Electrochemical Catalysts for Li-air Batteries</td>
</tr>
<tr>
<td>108</td>
<td>Chen, Zhongwei</td>
<td>Zarrin, Hadis</td>
<td>Completed</td>
<td>Novel Polymer Electrolyte Nano-Composite Membranes for Fuel Cell Applications</td>
</tr>
<tr>
<td>109</td>
<td>Chen, Zhongwei</td>
<td>Raimbault, Justin Nathaniel</td>
<td>Completed Program</td>
<td>Na0.66(Ni0.13Mn0.54Co0.13)O2 Cathode Coated with Alucone by Molecular Layer Deposition for Sodium Ion Batteries</td>
</tr>
<tr>
<td>110</td>
<td>Chen, Zhongwei</td>
<td>Xu, Calvin</td>
<td>Completed</td>
<td>Enhanced Durability of Pt Alloy Nanoparticles Using Sulfur-Doped Graphene via Metal-Support Interactions for PEMFC Cathode Catalysis of ORR</td>
</tr>
<tr>
<td>111</td>
<td>Chen, Zhongwei</td>
<td>Lenos, Jared</td>
<td>Completed</td>
<td>Improved Environmental Operation of Alcohol Breathalizers with Functionalized Graphene Nanocomposite Membranes</td>
</tr>
<tr>
<td>112</td>
<td>Chen, Zhongwei</td>
<td>Abureden, Salah</td>
<td>Completed</td>
<td>Advanced Nanostructure Materials for Hybrid Supercapacitors</td>
</tr>
<tr>
<td>113</td>
<td>Chen, Zhongwei</td>
<td>Hassan, Fathy Mohamed</td>
<td>Completed Program</td>
<td>Engineered Nano-Architectures as Advanced Anode Materials for Next Generation Lithium ion Batteries</td>
</tr>
<tr>
<td>114</td>
<td>Chen, Zhongwei</td>
<td>Batmaz, Rasim</td>
<td>Completed</td>
<td>Advanced Silicon Anode Architectures for High Energy Density Lithium-Ion Batteries</td>
</tr>
<tr>
<td>115</td>
<td>Chen, Zhongwei</td>
<td>Liu, Yulong</td>
<td>Completed</td>
<td>Carbon-based Bifunctional Electrocatalysts for Metal-air Battery Applications</td>
</tr>
<tr>
<td>No.</td>
<td>Name 1</td>
<td>Name 2</td>
<td>Status</td>
<td>Project Description</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------</td>
<td>---------------------------------</td>
<td>-----------------</td>
<td>-------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>116</td>
<td>Chen, Zhongwei</td>
<td>Hoque, Md Ariful</td>
<td>Completed Program</td>
<td>Advanced Heteroatom Doped Nanocarbon Materials as Platinum Catalyst Supports for Fuel Cells</td>
</tr>
<tr>
<td>117</td>
<td>Chen, Zhongwei</td>
<td>Zamani, Pouyan</td>
<td>Completed Program</td>
<td>Advanced Carbon Nanomaterials as Non-Precious Metal Catalysts for Fuel Cells</td>
</tr>
<tr>
<td>118</td>
<td>Chen, Zhongwei</td>
<td>Ismayilov, Vugar</td>
<td>Completed Program</td>
<td>Perovskite Oxide Combined With Nitrogen-Doped Carbon Nanotubes as Bifunctional Catalyst for Rechargeable Zinc-Air Batteries</td>
</tr>
<tr>
<td>119</td>
<td>Chen, Zhongwei</td>
<td>Feng, Kun</td>
<td>Completed Program</td>
<td>Advanced Silicon-Based Electrodes for Rechargeable Lithium-ion Batteries</td>
</tr>
<tr>
<td>120</td>
<td>Chen, Zhongwei</td>
<td>Jiang, Gaopeng</td>
<td>Completed Program</td>
<td>Advanced Non-Precious Metal Catalyst for Oxygen Reduction Reaction in Polymer Electrolyte Membrane Fuel Cells</td>
</tr>
<tr>
<td>121</td>
<td>Chen, Zhongwei</td>
<td>Mao, Zhiyu</td>
<td>Completed Program</td>
<td>Mathematical Model and Calendar Aging Study of Commercial Blended-Cathode Li-ion Batteries</td>
</tr>
<tr>
<td>122</td>
<td>Chen, Zhongwei</td>
<td>Ghorbani Kashkooli, Ali</td>
<td>Completed Program</td>
<td>Nanoscale X-ray Computed Tomography Based Modeling of Lithium-ion Battery Electrodes</td>
</tr>
<tr>
<td>123</td>
<td>Chen, Zhongwei</td>
<td>Fan, Xingye</td>
<td>Completed Program</td>
<td>Rational Design of Nanostructured Electrode Materials for High-Performance Supercapacitors</td>
</tr>
<tr>
<td>124</td>
<td>Chen, Zhongwei</td>
<td>Hu, Qianqian</td>
<td>Completed Program</td>
<td>Hybrid Tin Based Nanostructures Wrapped with Graphene as Efficient Anode Material for Lithium Ion Batteries</td>
</tr>
<tr>
<td>125</td>
<td>Chen, Zhongwei</td>
<td>Fu, Jing</td>
<td>Completed Program</td>
<td>Materials Design and Engineering for Polymer Electrolyte Membrane Zinc-Air Batteries</td>
</tr>
<tr>
<td>126</td>
<td>Chen, Zhongwei</td>
<td>Pei, Yu</td>
<td>Completed Program</td>
<td>Design and Synthesis of Three-Dimensional Interconnected Porous Carbon Nanostructure and its Nanocomposite as Anodes for Li-ion Batteries</td>
</tr>
<tr>
<td>127</td>
<td>Chen, Zhongwei</td>
<td>Patel, Pathik Daxeshkumar</td>
<td>Completed Program</td>
<td>SO2 Gas Abatement Using Ionic Liquids for Marine Applications</td>
</tr>
<tr>
<td>128</td>
<td>Chen, Zhongwei</td>
<td>Ray, Archisman</td>
<td>Completed Program</td>
<td>Novel SiCNW-Si/SiOx-Graphite Based Composite Anode Materials for Li-ion Battery</td>
</tr>
<tr>
<td>129</td>
<td>Chou, C.H. Perry</td>
<td>Pyne, Michael</td>
<td>Completed Program</td>
<td>Development of Genetic Tools for Metabolic Engineering of Clostridium Pasteurianum</td>
</tr>
</tbody>
</table>

Appendix VII – Highly Qualified Personnel (HQP)
<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Completed Program</th>
<th>Project Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>Chou,C.H. Perry</td>
<td>Completed Program</td>
<td>Manipulating the Sleeping Beauty Mutase Operon in Engineered Escherichia Coli for Controlled Biosynthesis of 1-Propanol and Other Value-Added Chemicals</td>
</tr>
<tr>
<td>131</td>
<td>Chou,C.H. Perry</td>
<td>Completed Program</td>
<td>A Comprehensive CRISPR-Cas9 Toolkit for B. subtilis: Development for Biomanufacturing Applications</td>
</tr>
<tr>
<td>132</td>
<td>Chou,C.H. Perry</td>
<td>Completed Program</td>
<td>High-Level Microbial Production of Propionate in Engineered Escherichia Coli</td>
</tr>
<tr>
<td>133</td>
<td>Chou,C.H. Perry</td>
<td>Completed Program</td>
<td>Fermentation Study of Metabolically Engineered Escherichia Coli Strains for High-Level 1-Propanol Production</td>
</tr>
<tr>
<td>134</td>
<td>Chou,C.H. Perry</td>
<td>Completed Program</td>
<td>Exploration of Acetate as a Feedstock for Propionate Production in Engineered Escherichia Coli</td>
</tr>
<tr>
<td>135</td>
<td>Chou,C.H. Perry</td>
<td>Completed Program</td>
<td>Application of Hydrocarbon and Perfluorocarbon Oxygen Vectors to Enhance Heterologous Production of Hyaluronic Acid in Engineered Bacillus subtilis</td>
</tr>
<tr>
<td>136</td>
<td>Collins,Michael</td>
<td>Completed Program</td>
<td>Characterization of Space Conditioning Loads for Energy Efficient Houses in Canada</td>
</tr>
<tr>
<td>137</td>
<td>Collins,Michael</td>
<td>Completed Program</td>
<td>Design, Analysis, and Optimization of a Dual Tank Solar-Assisted Heat Pump System</td>
</tr>
<tr>
<td>138</td>
<td>Collins,Michael</td>
<td>Completed Program</td>
<td>A Study of Mechanical Systems in Canadian High-Rise Multi-Unit Residential Buildings</td>
</tr>
<tr>
<td>140</td>
<td>Collins,Michael</td>
<td>Completed Program</td>
<td>Simulation and Validation of a Single Tank Heat Pump Assisted Solar Domestic Water Heating System</td>
</tr>
<tr>
<td>141</td>
<td>Collins,Michael</td>
<td>Completed Program</td>
<td>A New Technique for Characterizing Multi-Temperature Convection with Application in Building Energy Simulation</td>
</tr>
<tr>
<td>143</td>
<td>Craig,James R.</td>
<td>Completed Program</td>
<td>The Effects of Soil Heterogeneity on the Performance of Horizontal Ground Loop Heat Exchangers</td>
</tr>
<tr>
<td></td>
<td>Name</td>
<td>Mentor</td>
<td>Program Completion</td>
</tr>
<tr>
<td>---</td>
<td>-----------------------------</td>
<td>-------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>144</td>
<td>Craig, James R.</td>
<td>Princz, Daniel</td>
<td>Completed Program</td>
</tr>
<tr>
<td>145</td>
<td>Craig, James R.</td>
<td>Haslam, Simon Robert</td>
<td>Completed Program</td>
</tr>
<tr>
<td>146</td>
<td>Craig, James R.</td>
<td>Sheffield, Philip</td>
<td>Completed Program</td>
</tr>
<tr>
<td>147</td>
<td>Craig, James R.</td>
<td>Snowdon, Andrew Paul</td>
<td>Completed Program</td>
</tr>
<tr>
<td>148</td>
<td>Craig, James R.</td>
<td>Ramadhan, Muhammad</td>
<td>Completed Program</td>
</tr>
<tr>
<td>149</td>
<td>Craig, James R.</td>
<td>Chowdhury, Mashrur Anam</td>
<td>Completed Program</td>
</tr>
<tr>
<td>150</td>
<td>Craig, James R.</td>
<td>Sgro, Nicholas Andrew</td>
<td>Completed Program</td>
</tr>
<tr>
<td>151</td>
<td>Craig, James R.</td>
<td>Chlumsky, Robert</td>
<td>Completed Program</td>
</tr>
<tr>
<td>152</td>
<td>Craig, James R.</td>
<td>Ameli, Aliasghar</td>
<td>Completed Program</td>
</tr>
<tr>
<td>153</td>
<td>Craik, Alastair Neil</td>
<td>Thomson, Jeffrey August Thomas</td>
<td>Completed Program</td>
</tr>
<tr>
<td>154</td>
<td>Craik, Alastair Neil</td>
<td>DeWolf, Julie</td>
<td>Completed Program</td>
</tr>
<tr>
<td>156</td>
<td>Craik, Alastair Neil</td>
<td>Aboutorabifard, Haniehalsadat</td>
<td>Completed Program</td>
</tr>
<tr>
<td>157</td>
<td>Croiset, Eric</td>
<td>Shafeen, Ahmed</td>
<td>Completed Program</td>
</tr>
<tr>
<td>No.</td>
<td>Graduate Advisor</td>
<td>Student</td>
<td>Program Status</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------</td>
<td>---------</td>
<td>----------------</td>
</tr>
<tr>
<td>158</td>
<td>Croiset, Eric</td>
<td>Yao, Weifang</td>
<td>Completed Program</td>
</tr>
<tr>
<td>159</td>
<td>Croiset, Eric</td>
<td>Ismail, Mazni</td>
<td>Completed Program</td>
</tr>
<tr>
<td>160</td>
<td>Croiset, Eric</td>
<td>Ideris, Asmida</td>
<td>Completed Program</td>
</tr>
<tr>
<td>161</td>
<td>Croiset, Eric</td>
<td>Chung, Kyung Sil</td>
<td>Completed Program</td>
</tr>
<tr>
<td>162</td>
<td>Croiset, Eric</td>
<td>Chansomwong, Atchariya</td>
<td>Completed Program</td>
</tr>
<tr>
<td>163</td>
<td>Croiset, Eric</td>
<td>Ahmadi, Lena</td>
<td>Completed Program</td>
</tr>
<tr>
<td>164</td>
<td>Croiset, Eric</td>
<td>Li, Jingde</td>
<td>Completed Program</td>
</tr>
<tr>
<td>165</td>
<td>Croiset, Eric</td>
<td>Alarifi, Abdulaziz</td>
<td>Completed Program</td>
</tr>
<tr>
<td>166</td>
<td>Croiset, Eric</td>
<td>Hamadeh, Hachem</td>
<td>Completed Program</td>
</tr>
<tr>
<td>167</td>
<td>Croiset, Eric</td>
<td>Nittaya, Thanita</td>
<td>Completed Program</td>
</tr>
<tr>
<td>168</td>
<td>Croiset, Eric</td>
<td>Raj, Abhishek</td>
<td>Completed Program</td>
</tr>
<tr>
<td>169</td>
<td>Croiset, Eric</td>
<td>Cheng, Kuang</td>
<td>Completed Program</td>
</tr>
<tr>
<td>170</td>
<td>Croiset, Eric</td>
<td>Alie, Colin Francis</td>
<td>Completed Program</td>
</tr>
<tr>
<td>ID</td>
<td>Name</td>
<td>Title</td>
<td>Completion</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------</td>
<td>----------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>172</td>
<td>Devaud,Cecile B</td>
<td>Labahn,Jeffrey William Leslie</td>
<td>Completed Program</td>
</tr>
<tr>
<td>173</td>
<td>Devaud,Cecile B</td>
<td>Le,Duy Quang</td>
<td>Completed Program</td>
</tr>
<tr>
<td>174</td>
<td>Devaud,Cecile B</td>
<td>Lee,Seung Hi</td>
<td>Completed Program</td>
</tr>
<tr>
<td>175</td>
<td>Devaud,Cecile B</td>
<td>Dovizio,Daniele</td>
<td>Completed Program</td>
</tr>
<tr>
<td>176</td>
<td>Devaud,Cecile B</td>
<td>Wilson,Daniel Pegg</td>
<td>Completed Program</td>
</tr>
<tr>
<td>177</td>
<td>Devaud,Cecile B</td>
<td>Ashrafizadeh,Amirali</td>
<td>Completed Program</td>
</tr>
<tr>
<td>178</td>
<td>Devaud,Cecile B</td>
<td>Li,Yangtao</td>
<td>Completed Program</td>
</tr>
<tr>
<td>179</td>
<td>Douglas,Heather</td>
<td>Isaac,David Thompson</td>
<td>Completed Program</td>
</tr>
<tr>
<td>180</td>
<td>Douglas,Peter</td>
<td>Shafeen,Ahmed</td>
<td>Completed Program</td>
</tr>
<tr>
<td>181</td>
<td>Douglas,Peter</td>
<td>Alnifro,Mohamed</td>
<td>Completed Program</td>
</tr>
<tr>
<td>182</td>
<td>Douglas,Peter</td>
<td>Khan,Omar</td>
<td>Completed Program</td>
</tr>
<tr>
<td>183</td>
<td>Duever,Thomas A</td>
<td>Masoumi,Samira</td>
<td>Completed Program</td>
</tr>
<tr>
<td>184</td>
<td>Duever,Thomas A</td>
<td>Guo,Chang</td>
<td>Completed Program</td>
</tr>
<tr>
<td>185</td>
<td>Duever,Thomas A</td>
<td>Du,Yuncheng</td>
<td>Completed Program</td>
</tr>
<tr>
<td>No.</td>
<td>Name 1</td>
<td>Name 2</td>
<td>Status</td>
</tr>
<tr>
<td>-----</td>
<td>--------</td>
<td>----------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>186</td>
<td>Dusseault, Maurice B</td>
<td>Shafiei, Ali</td>
<td>Completed Program</td>
</tr>
<tr>
<td>187</td>
<td>Dusseault, Maurice B</td>
<td>Jalali, Mohammadreza</td>
<td>Completed Program</td>
</tr>
<tr>
<td>188</td>
<td>Dusseault, Maurice B</td>
<td>Skomorowski, Natalia</td>
<td>Completed Program</td>
</tr>
<tr>
<td>189</td>
<td>Dusseault, Maurice B</td>
<td>Arfaei Malekzadeh, Farshad</td>
<td>Completed Program</td>
</tr>
<tr>
<td>190</td>
<td>Dusseault, Maurice B</td>
<td>Lord, Fraser Duncan</td>
<td>Completed Program</td>
</tr>
<tr>
<td>191</td>
<td>Dusseault, Maurice B</td>
<td>Gomez Rodriguez, Diana Magaly</td>
<td>Completed Program</td>
</tr>
<tr>
<td>192</td>
<td>Dusseault, Maurice B</td>
<td>Yetisir, Michael Mitat</td>
<td>Completed Program</td>
</tr>
<tr>
<td>193</td>
<td>Dusseault, Maurice B</td>
<td>Pirayehgar, Atena</td>
<td>Completed Program</td>
</tr>
<tr>
<td>194</td>
<td>Dusseault, Maurice B</td>
<td>MacDonald, Daniel</td>
<td>Completed Program</td>
</tr>
<tr>
<td>195</td>
<td>Elkamel, Ali</td>
<td>Al-Shawarghi, Hamzah</td>
<td>Completed Program</td>
</tr>
<tr>
<td>196</td>
<td>Elkamel, Ali</td>
<td>Khorami, Hassan</td>
<td>Completed Program</td>
</tr>
<tr>
<td>197</td>
<td>Elkamel, Ali</td>
<td>Liu, Hui</td>
<td>Completed Program</td>
</tr>
<tr>
<td>198</td>
<td>Elkamel, Ali</td>
<td>Obaid, Juwairia</td>
<td>Completed Program</td>
</tr>
<tr>
<td>No.</td>
<td>Advisor</td>
<td>Student Name</td>
<td>Program Completion</td>
</tr>
<tr>
<td>-----</td>
<td>---------</td>
<td>------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>199</td>
<td>Elkamel, Ali</td>
<td>Ordouei, Mohammad Hossein</td>
<td>Completed Program</td>
</tr>
<tr>
<td>200</td>
<td>Elkamel, Ali</td>
<td>Kantor, Ivan Daniel</td>
<td>Completed Program</td>
</tr>
<tr>
<td>201</td>
<td>Elkamel, Ali</td>
<td>Al Rafea, Kamal</td>
<td>Completed Program</td>
</tr>
<tr>
<td>202</td>
<td>Elkamel, Ali</td>
<td>Awad, Asmaa Abdallah Roby</td>
<td>Completed Program</td>
</tr>
<tr>
<td>203</td>
<td>Elkamel, Ali</td>
<td>Chan, Keziah Nga-Kay</td>
<td>Completed Program</td>
</tr>
<tr>
<td>204</td>
<td>Elkamel, Ali</td>
<td>Alsobhi, Saad</td>
<td>Completed Program</td>
</tr>
<tr>
<td>205</td>
<td>Elkamel, Ali</td>
<td>Alhumade, Hesham</td>
<td>Completed Program</td>
</tr>
<tr>
<td>206</td>
<td>Elkamel, Ali</td>
<td>Elsaid, Khaled</td>
<td>Completed Program</td>
</tr>
<tr>
<td>207</td>
<td>Elkamel, Ali</td>
<td>Azlah, Nada</td>
<td>Completed Program</td>
</tr>
<tr>
<td>208</td>
<td>Elkamel, Ali</td>
<td>Alnahdi, Amani</td>
<td>Completed Program</td>
</tr>
<tr>
<td>209</td>
<td>Elkamel, Ali</td>
<td>Abdul Razik, Abdul Halim</td>
<td>Completed Program</td>
</tr>
<tr>
<td>210</td>
<td>Elkamel, Ali</td>
<td>Peng, Dan</td>
<td>Completed Program</td>
</tr>
<tr>
<td>211</td>
<td>Elkamel, Ali</td>
<td>Alhameli, Falah</td>
<td>Completed Program</td>
</tr>
<tr>
<td>212</td>
<td>Elkamel, Ali</td>
<td>Elsholkami, Mohamed</td>
<td>Completed Program</td>
</tr>
<tr>
<td>ID</td>
<td>Last Name</td>
<td>First Name</td>
<td>Program Completion</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>---------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>213</td>
<td>Elkamel, Ali</td>
<td>Santander, Omar</td>
<td>Completed Program</td>
</tr>
<tr>
<td>214</td>
<td>Elkamel, Ali</td>
<td>Bseibsu, Ali</td>
<td>Completed Program</td>
</tr>
<tr>
<td>216</td>
<td>Elkamel, Ali</td>
<td>Alsubaie, Amal Saif Abdullah</td>
<td>Completed Program</td>
</tr>
<tr>
<td>217</td>
<td>Elkamel, Ali</td>
<td>Alzahrani, Mohammed</td>
<td>Completed Program</td>
</tr>
<tr>
<td>218</td>
<td>Elkamel, Ali</td>
<td>Alsubaie, Abdullah</td>
<td>Completed Program</td>
</tr>
<tr>
<td>222</td>
<td>Feick, Robert</td>
<td>Groulx, Mark</td>
<td>Completed Program</td>
</tr>
<tr>
<td>223</td>
<td>Feick, Robert</td>
<td>Zhang, Shanqi</td>
<td>Completed Program</td>
</tr>
<tr>
<td>224</td>
<td>Feick, Robert</td>
<td>Cowan, Terri</td>
<td>Completed Program</td>
</tr>
<tr>
<td>225</td>
<td>Feick, Robert</td>
<td>Fang, Bihui</td>
<td>Completed Program</td>
</tr>
<tr>
<td>226</td>
<td>Feick, Robert</td>
<td>Richards, Kenson</td>
<td>Completed Program</td>
</tr>
<tr>
<td>227</td>
<td>Feick, Robert</td>
<td>Huebner, James Philip</td>
<td>Completed Program</td>
</tr>
<tr>
<td>No.</td>
<td>Name of Supervisor</td>
<td>Name of Student</td>
<td>Completed Program</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------</td>
<td>-----------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>228</td>
<td>Feng, Xianshe</td>
<td>Bains, Anterjot Singh</td>
<td>Completed Program</td>
</tr>
<tr>
<td>229</td>
<td>Feng, Xianshe</td>
<td>Snow, Melanie B.</td>
<td>Completed Program</td>
</tr>
<tr>
<td>230</td>
<td>Feng, Xianshe</td>
<td>Bailey, Kevin</td>
<td>Completed Program</td>
</tr>
<tr>
<td>231</td>
<td>Feng, Xianshe</td>
<td>Yau, Kenneth</td>
<td>Completed Program</td>
</tr>
<tr>
<td>232</td>
<td>Feng, Xianshe</td>
<td>Szolga, William Steven</td>
<td>Completed Program</td>
</tr>
<tr>
<td>233</td>
<td>Feng, Xianshe</td>
<td>Kundu, Prodip</td>
<td>Completed Program</td>
</tr>
<tr>
<td>234</td>
<td>Feng, Xianshe</td>
<td>Farooq, Muhammad Usman</td>
<td>Completed Program</td>
</tr>
<tr>
<td>235</td>
<td>Feng, Xianshe</td>
<td>Zhang, Ying</td>
<td>Completed Program</td>
</tr>
<tr>
<td>236</td>
<td>Feng, Xianshe</td>
<td>Hu, Yijie</td>
<td>Completed Program</td>
</tr>
<tr>
<td>237</td>
<td>Feng, Xianshe</td>
<td>Eslami, Shahabedin</td>
<td>Completed Program</td>
</tr>
<tr>
<td>238</td>
<td>Feng, Xianshe</td>
<td>Celarek, Michael</td>
<td>Completed Program</td>
</tr>
<tr>
<td>239</td>
<td>Feng, Xianshe</td>
<td>Sun, Jingjing</td>
<td>Completed Program</td>
</tr>
<tr>
<td>240</td>
<td>Feng, Xianshe</td>
<td>Wu, Dihua</td>
<td>Completed Program</td>
</tr>
<tr>
<td>241</td>
<td>Feng, Xianshe</td>
<td>Huang, Yifeng</td>
<td>Completed Program</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Name</td>
<td>Program</td>
</tr>
<tr>
<td>-----</td>
<td>---------------</td>
<td>---------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>242</td>
<td>Feng,Xianshe</td>
<td>Guan,Min</td>
<td>Completed Program</td>
</tr>
<tr>
<td>243</td>
<td>Feng,Xianshe</td>
<td>Dutta Gupta, Samudra</td>
<td>Completed Program</td>
</tr>
<tr>
<td>244</td>
<td>Feng,Xianshe</td>
<td>Lai,Shuixiu</td>
<td>Completed Program</td>
</tr>
<tr>
<td>245</td>
<td>Feng,Xianshe</td>
<td>Chianugo, Godwin</td>
<td>Completed Program</td>
</tr>
<tr>
<td>246</td>
<td>Feng,Xianshe</td>
<td>Wu,Kai</td>
<td>Completed Program</td>
</tr>
<tr>
<td>247</td>
<td>Feng,Xianshe</td>
<td>Zhang,Boya</td>
<td>Completed Program</td>
</tr>
<tr>
<td>248</td>
<td>Feng,Xianshe</td>
<td>Eslamian, Mojtaba</td>
<td>Completed Program</td>
</tr>
<tr>
<td>249</td>
<td>Feng,Xianshe</td>
<td>Ahmed, Muhammad Nabeel</td>
<td>Completed Program</td>
</tr>
<tr>
<td>250</td>
<td>Feng,Xianshe</td>
<td>Zhao, Yuanzuo</td>
<td>Completed Program</td>
</tr>
<tr>
<td>251</td>
<td>Feng,Xianshe</td>
<td>Gangadharan, Swathi</td>
<td>Completed Program</td>
</tr>
<tr>
<td>252</td>
<td>Feng,Xianshe</td>
<td>Olufidipe, Oyefisayo</td>
<td>Completed Program</td>
</tr>
<tr>
<td>253</td>
<td>Feng,Xianshe</td>
<td>Widjaja, Sherlly Lovita</td>
<td>Completed Program</td>
</tr>
<tr>
<td>254</td>
<td>Feng,Xianshe</td>
<td>Tariq, Ali</td>
<td>Completed Program</td>
</tr>
<tr>
<td>255</td>
<td>Feng,Xianshe</td>
<td>Gao, Aoran</td>
<td>Completed Program</td>
</tr>
<tr>
<td>256</td>
<td>Feng,Xianshe</td>
<td>Qiu, Bo</td>
<td>Completed Program</td>
</tr>
<tr>
<td>257</td>
<td>Fowler, Michael</td>
<td>Lo, Joshua Kai Hong</td>
<td>Completed Program</td>
</tr>
<tr>
<td>No.</td>
<td>Name 1</td>
<td>Name 2</td>
<td>Completed Program</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>-------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>258</td>
<td>Fowler, Michael</td>
<td>Finley, Thomas Dylan</td>
<td>Completed Program</td>
</tr>
<tr>
<td>259</td>
<td>Fowler, Michael</td>
<td>Law, Kelvin Ho Yan</td>
<td>Completed Program</td>
</tr>
<tr>
<td>260</td>
<td>Fowler, Michael</td>
<td>Lui, Gregory</td>
<td>Completed Program</td>
</tr>
<tr>
<td>261</td>
<td>Fowler, Michael</td>
<td>Gaffney, Benjamin John</td>
<td>Completed Program</td>
</tr>
<tr>
<td>262</td>
<td>Fowler, Michael</td>
<td>Farkhondeh, Mohammad</td>
<td>Completed Program</td>
</tr>
<tr>
<td>263</td>
<td>Fowler, Michael</td>
<td>Dhanushkodi, Shankar Raman</td>
<td>Completed Program</td>
</tr>
<tr>
<td>265</td>
<td>Fowler, Michael</td>
<td>Catton, John William Albert</td>
<td>Completed Program</td>
</tr>
<tr>
<td>266</td>
<td>Fowler, Michael</td>
<td>Mathew, Manoj</td>
<td>Completed Program</td>
</tr>
<tr>
<td>267</td>
<td>Fowler, Michael</td>
<td>Mukherjee, Ushnik</td>
<td>Completed Program</td>
</tr>
<tr>
<td>268</td>
<td>Fowler, Michael</td>
<td>Scott, William</td>
<td>Completed Program</td>
</tr>
<tr>
<td>269</td>
<td>Fowler, Michael</td>
<td>Dosi, Manan</td>
<td>Completed Program</td>
</tr>
<tr>
<td>270</td>
<td>Fraser, Roydon A</td>
<td>Giannikouris, Michael</td>
<td>Completed Program</td>
</tr>
<tr>
<td>271</td>
<td>Fraser, Roydon A</td>
<td>El Sayed, Ahmad</td>
<td>Completed Program</td>
</tr>
<tr>
<td>272</td>
<td>Fraser, Roydon A</td>
<td>Singh, Gurhari Preet</td>
<td>Completed Program</td>
</tr>
<tr>
<td>No.</td>
<td>Name 1</td>
<td>Name 2</td>
<td>Completed Program</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------</td>
<td>-----------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>273</td>
<td>Fraser, Roydon A</td>
<td>Chan, Wen Yen</td>
<td>Completed Program</td>
</tr>
<tr>
<td>274</td>
<td>Fraser, Roydon A</td>
<td>Lawrence, Reece</td>
<td>Completed Program</td>
</tr>
<tr>
<td>275</td>
<td>Fraser, Roydon A</td>
<td>Adibi Asl, Hadi</td>
<td>Completed Program</td>
</tr>
<tr>
<td>276</td>
<td>Fraser, Roydon A</td>
<td>Ellsworth, Patrick Kenneth Stewart</td>
<td>Completed Program</td>
</tr>
<tr>
<td>277</td>
<td>Fraser, Roydon A</td>
<td>McLinnis, Paul William Charles</td>
<td>Completed Program</td>
</tr>
<tr>
<td>278</td>
<td>Fraser, Roydon A</td>
<td>Panchal, Satyam</td>
<td>Completed Program</td>
</tr>
<tr>
<td>279</td>
<td>Fraser, Roydon A</td>
<td>Samadani, Seyed Ehsan</td>
<td>Completed Program</td>
</tr>
<tr>
<td>280</td>
<td>Fraser, Roydon A</td>
<td>Mastali Majdabadi Kohneh, Mehrdad</td>
<td>Completed Program</td>
</tr>
<tr>
<td>281</td>
<td>Fraser, Roydon A</td>
<td>Ahmadi, Leila</td>
<td>Completed Program</td>
</tr>
<tr>
<td>282</td>
<td>Fraser, Roydon A</td>
<td>Kartha, Radhika Rajan</td>
<td>Completed Program</td>
</tr>
<tr>
<td>283</td>
<td>Fraser, Roydon A</td>
<td>Gonzalez Gonzalez, Jorge</td>
<td>Completed Program</td>
</tr>
<tr>
<td>284</td>
<td>Gaudet, Vincent</td>
<td>Chuang, Pierce I-Jen</td>
<td>Completed Program</td>
</tr>
<tr>
<td>285</td>
<td>Gaudet, Vincent</td>
<td>Crowley, Brendan</td>
<td>Completed Program</td>
</tr>
<tr>
<td>286</td>
<td>Gaudet, Vincent</td>
<td>Singh, Manpreet</td>
<td>Completed Program</td>
</tr>
<tr>
<td>287</td>
<td>Gaudet, Vincent</td>
<td>Jensen, Karl Andrew</td>
<td>Completed Program</td>
</tr>
<tr>
<td>Number</td>
<td>Last Name, First Name</td>
<td>Last Name, First Name</td>
<td>Completed Program</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------</td>
<td>-------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>288</td>
<td>Gaudet, Vincent</td>
<td>Ceroici, Christopher</td>
<td>Completed Program</td>
</tr>
<tr>
<td>289</td>
<td>Gaudet, Vincent</td>
<td>Hussein, Assem Shoukry Mohamed</td>
<td>Completed Program</td>
</tr>
<tr>
<td>290</td>
<td>Golab, Lukasz</td>
<td>El Gebaly, Kareem</td>
<td>Completed Program</td>
</tr>
<tr>
<td>291</td>
<td>Golab, Lukasz</td>
<td>Jiang, Yuheng</td>
<td>Completed Program</td>
</tr>
<tr>
<td>292</td>
<td>Golab, Lukasz</td>
<td>Feng, Guoyao</td>
<td>Completed Program</td>
</tr>
<tr>
<td>293</td>
<td>Golab, Lukasz</td>
<td>Zhang, Shuopeng</td>
<td>Completed Program</td>
</tr>
<tr>
<td>294</td>
<td>Golab, Lukasz</td>
<td>Yang, Yuke</td>
<td>Completed Program</td>
</tr>
<tr>
<td>295</td>
<td>Golab, Lukasz</td>
<td>Gao, Xiang</td>
<td>Completed Program</td>
</tr>
<tr>
<td>296</td>
<td>Golab, Lukasz</td>
<td>Miller, Reid</td>
<td>Completed Program</td>
</tr>
<tr>
<td>297</td>
<td>Golab, Lukasz</td>
<td>Rios, Ivan</td>
<td>Completed Program</td>
</tr>
<tr>
<td>298</td>
<td>Golab, Lukasz</td>
<td>Gao, Libo</td>
<td>Completed Program</td>
</tr>
<tr>
<td>299</td>
<td>Golab, Wojciech</td>
<td>McKenzie, Marlon</td>
<td>Completed Program</td>
</tr>
<tr>
<td>300</td>
<td>Golab, Wojciech</td>
<td>Chandail, Mukul</td>
<td>Completed Program</td>
</tr>
<tr>
<td>301</td>
<td>Golab, Wojciech</td>
<td>De, Sagnik</td>
<td>Completed Program</td>
</tr>
<tr>
<td>302</td>
<td>Golab, Wojciech</td>
<td>Ramaraju, Aditya</td>
<td>Completed Program</td>
</tr>
<tr>
<td>No.</td>
<td>Name of Student</td>
<td>Co-Student</td>
<td>Completion</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>303</td>
<td>Golab, Wojciech</td>
<td>Fan, Hua</td>
<td>Completed</td>
</tr>
<tr>
<td>304</td>
<td>Golab, Wojciech</td>
<td>Chatterjee, Shankha Subhra</td>
<td>Completed</td>
</tr>
<tr>
<td>305</td>
<td>Goldthorpe, Irene</td>
<td>Vafaei, Arash</td>
<td>Completed</td>
</tr>
<tr>
<td>306</td>
<td>Goldthorpe, Irene</td>
<td>Maheshwari, Nupur</td>
<td>Completed</td>
</tr>
<tr>
<td>307</td>
<td>Goldthorpe, Irene</td>
<td>Deignan, Geoffrey Jonathan</td>
<td>Completed</td>
</tr>
<tr>
<td>308</td>
<td>Goldthorpe, Irene</td>
<td>Hosseinzadeh Khaligh, Hadi</td>
<td>Completed</td>
</tr>
<tr>
<td>309</td>
<td>Goldthorpe, Irene</td>
<td>Atwa, Yahya</td>
<td>Completed</td>
</tr>
<tr>
<td>310</td>
<td>Goldthorpe, Irene</td>
<td>Madeira, Alexandra</td>
<td>Completed</td>
</tr>
<tr>
<td>311</td>
<td>Gracie, Robert R</td>
<td>Skiba, Oxana</td>
<td>Completed</td>
</tr>
<tr>
<td>312</td>
<td>Gracie, Robert R</td>
<td>Kapiturova, Maria</td>
<td>Completed</td>
</tr>
<tr>
<td>313</td>
<td>Gracie, Robert R</td>
<td>Mak, Eleanor Yi Kei</td>
<td>Completed</td>
</tr>
<tr>
<td>314</td>
<td>Gracie, Robert R</td>
<td>Sarkarfarshi, Mirhamed</td>
<td>Completed</td>
</tr>
<tr>
<td>315</td>
<td>Gracie, Robert R</td>
<td>Ladubec, Chris</td>
<td>Completed</td>
</tr>
<tr>
<td>316</td>
<td>Gracie, Robert R</td>
<td>Sayed, Sara</td>
<td>Completed</td>
</tr>
<tr>
<td>317</td>
<td>Gracie, Robert R</td>
<td>Fong, Norman</td>
<td>Completed</td>
</tr>
<tr>
<td>ID</td>
<td>Last Name, First Name</td>
<td>Last Name, First Name</td>
<td>Completed Program</td>
</tr>
<tr>
<td>----</td>
<td>----------------------</td>
<td>-----------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>318</td>
<td>Habib, Jasmin</td>
<td>Husband, Taryn</td>
<td>Completed Program</td>
</tr>
<tr>
<td>319</td>
<td>Hamdullahpur, Feridun</td>
<td>Younessi Sinaki, Maryam</td>
<td>Completed Program</td>
</tr>
<tr>
<td>320</td>
<td>Hamdullahpur, Feridun</td>
<td>Ozden, Adnan</td>
<td>Completed Program</td>
</tr>
<tr>
<td>321</td>
<td>Hipel, Keith W</td>
<td>Bristow, Michele Mei-Ting</td>
<td>Completed Program</td>
</tr>
<tr>
<td>323</td>
<td>Hipel, Keith W</td>
<td>Kinsara, Rami</td>
<td>Completed Program</td>
</tr>
<tr>
<td>324</td>
<td>Hipel, Keith W</td>
<td>He, Shawei</td>
<td>Completed Program</td>
</tr>
<tr>
<td>325</td>
<td>Hipel, Keith W</td>
<td>Matbouli, Yasser Talal M.</td>
<td>Completed Program</td>
</tr>
<tr>
<td>326</td>
<td>Hipel, Keith W</td>
<td>Aljefri, Yasir</td>
<td>Completed Program</td>
</tr>
<tr>
<td>327</td>
<td>Hipel, Keith W</td>
<td>Xiao, Yi</td>
<td>Completed Program</td>
</tr>
<tr>
<td>328</td>
<td>Hipel, Keith W</td>
<td>Garcia, Amanda</td>
<td>Completed Program</td>
</tr>
<tr>
<td>329</td>
<td>Hipel, Keith W</td>
<td>Sabtan, Bader</td>
<td>Completed Program</td>
</tr>
<tr>
<td>330</td>
<td>Hipel, Keith W</td>
<td>Alhindi, Taha Jaweed O</td>
<td>Completed Program</td>
</tr>
<tr>
<td>331</td>
<td>Ilyas, Ihab</td>
<td>Pound, Jeffrey</td>
<td>Completed Program</td>
</tr>
<tr>
<td>332</td>
<td>Ilyas, Ihab</td>
<td>Zhang, Ning</td>
<td>Completed Program</td>
</tr>
</tbody>
</table>
### Appendix VII – Highly Qualified Personnel (HQP)

<table>
<thead>
<tr>
<th>No.</th>
<th>Name 1</th>
<th>Name 2</th>
<th>Program Status</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>333</td>
<td>Ilyas, Ihab</td>
<td>Galiullin, Artur</td>
<td>Completed Program</td>
<td>Query Answering Over Functional Dependency Repairs</td>
</tr>
<tr>
<td>334</td>
<td>Ilyas, Ihab</td>
<td>Chu, Xu</td>
<td>Completed Program</td>
<td>Scalable and Holistic Qualitative Data Cleaning</td>
</tr>
<tr>
<td>335</td>
<td>Ilyas, Ihab</td>
<td>Morcos, John</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>336</td>
<td>Ilyas, Ihab</td>
<td>Hoffmann, Hella-Franziska Renate</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>337</td>
<td>Ilyas, Ihab</td>
<td>Shadab, Anam</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>338</td>
<td>Jayaram, Sheshakamal</td>
<td>Bian, Shanshan</td>
<td>Completed Program</td>
<td>A Study of the Material Properties of Silicone Nanocomposites Developed by Electrospinning</td>
</tr>
<tr>
<td>339</td>
<td>Jayaram, Sheshakamal</td>
<td>Moonesan, Mohammad Saleh</td>
<td>Completed Program</td>
<td>A Study of Medium and High Voltage Form-Wound Coil Turn-to-Turn Insulation of Converter Fed Rotating Machines</td>
</tr>
<tr>
<td>340</td>
<td>Jayaram, Sheshakamal</td>
<td>Gad, Ahmed</td>
<td>Completed Program</td>
<td>A Study of Electrode Material Performance During Food Processing by Pulsed Electric Fields</td>
</tr>
<tr>
<td>341</td>
<td>Jayaram, Sheshakamal</td>
<td>Ghunem, Refat</td>
<td>Completed Program</td>
<td>A Study of the Erosion Mechanisms of Silicone Rubber Housing Composites</td>
</tr>
<tr>
<td>342</td>
<td>Jayaram, Sheshakamal</td>
<td>Devgan, Mantosh</td>
<td>Completed Program</td>
<td>Investigation of High Frequency Switching Transients on Wind Turbine Step Up Transformers</td>
</tr>
<tr>
<td>343</td>
<td>Jayaram, Sheshakamal</td>
<td>Kang, Jin Hee</td>
<td>Completed Program</td>
<td>Fabrication and Characterization of Nano Carbon-Based Electrochemical Double-Layer Capacitors</td>
</tr>
<tr>
<td>344</td>
<td>Jayaram, Sheshakamal</td>
<td>Khanali, Mahdi</td>
<td>Completed Program</td>
<td>Effects of Distorted Voltages on the Performance of Renewable Energy Plant Transformers</td>
</tr>
<tr>
<td>345</td>
<td>Jayaram, Sheshakamal</td>
<td>Anjum, Shaharyar</td>
<td>Completed Program</td>
<td>A Study on the Detection of Defects in Ceramic Insulators Based on Radio Frequency Signatures</td>
</tr>
<tr>
<td>346</td>
<td>Jewkes, Elizabeth M</td>
<td>Wheatley, David Michael</td>
<td>Completed Program</td>
<td>Inventory-Location Problems for Spare Parts With Time-Based Service Levels</td>
</tr>
<tr>
<td>347</td>
<td>Jewkes, Elizabeth M</td>
<td>Riaz, Muhammad Waqas</td>
<td>Completed Program</td>
<td>Two-Echelon Supply Chain Design for Spare Parts With Time Constraints</td>
</tr>
<tr>
<td>Appendix VII – Highly Qualified Personnel (HQP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>348</strong></td>
<td>Johnson, David A</td>
<td>Lam, Vivian</td>
<td>Completed Program</td>
<td>Development of Wind Resource Assessment Methods and Application to the Waterloo Region</td>
</tr>
<tr>
<td><strong>349</strong></td>
<td>Johnson, David A</td>
<td>Almutairi, Zeyad</td>
<td>Completed Program</td>
<td>Experimental Studies of the Hydrodynamics of Liquid Droplet Generation and Transport in Microchannels</td>
</tr>
<tr>
<td><strong>350</strong></td>
<td>Johnson, David A</td>
<td>Tam, Nicholas Lut Shou</td>
<td>Completed Program</td>
<td>An Aeroacoustic Study of Airfoil Self Noise for Wind Turbine Applications</td>
</tr>
<tr>
<td><strong>351</strong></td>
<td>Johnson, David A</td>
<td>Gharali, Kobra</td>
<td>Completed Program</td>
<td>Pitching Airfoil Study and Freestream Effects for Wind Turbine Applications</td>
</tr>
<tr>
<td><strong>352</strong></td>
<td>Johnson, David A</td>
<td>Abdelrahman, Ahmed</td>
<td>Completed Program</td>
<td>Development of a Wind Turbine Test Rig and Rotor for Trailing Edge Flap Investigation</td>
</tr>
<tr>
<td><strong>353</strong></td>
<td>Johnson, David A</td>
<td>Swytink-Binnema, Nigel</td>
<td>Completed Program</td>
<td>Digital Tuft Flow Visualization at an Outdoor Wind Turbine Test Site</td>
</tr>
<tr>
<td><strong>354</strong></td>
<td>Kazerani, Mehrdad</td>
<td>Wong, Noreen Nga-Yee</td>
<td>Completed Program</td>
<td>Design of Two-Stage Level-Two Bidirectional On-Board Battery Charger for Plugin Vehicles</td>
</tr>
<tr>
<td><strong>355</strong></td>
<td>Kazerani, Mehrdad</td>
<td>Morris, Jordan Francis</td>
<td>Completed Program</td>
<td>Design and Testing of a Bidirectional Smart Charger Prototype</td>
</tr>
<tr>
<td><strong>356</strong></td>
<td>Kazerani, Mehrdad</td>
<td>Dash, Prajna Paramita</td>
<td>Completed Program</td>
<td>A High-Performance Three-Phase Grid-Connected PV System Based On Multilevel Current Source Inverter</td>
</tr>
<tr>
<td><strong>357</strong></td>
<td>Kazerani, Mehrdad</td>
<td>Olivares, Daniel</td>
<td>Completed Program</td>
<td>An Energy Management System for Isolated Microgrids Considering Uncertainty</td>
</tr>
<tr>
<td><strong>358</strong></td>
<td>Kazerani, Mehrdad</td>
<td>Arriaga Marin, Mariano</td>
<td>Completed Program</td>
<td>Long-Term Renewable Energy Generation Planning for Off-Grid Remote Communities</td>
</tr>
<tr>
<td><strong>359</strong></td>
<td>Kazerani, Mehrdad</td>
<td>Ostadi, Amir</td>
<td>Completed Program</td>
<td>Optimal Sizing of Battery/Ultracapacitor-Based Energy Storage Systems in Electric Vehicles</td>
</tr>
<tr>
<td><strong>360</strong></td>
<td>Kazerani, Mehrdad</td>
<td>Zhuge, Kun</td>
<td>Completed Program</td>
<td>Development of an Efficient Hybrid Energy Storage System (HESS) for Electric and Hybrid Electric Vehicles</td>
</tr>
<tr>
<td><strong>361</strong></td>
<td>Kazerani, Mehrdad</td>
<td>Alnasir, Zuher</td>
<td>Completed Program</td>
<td>A Small-Scale Standalone Wind Energy Conversion System Featuring SCIG, CSI and a Novel Storage Integration Scheme</td>
</tr>
<tr>
<td><strong>362</strong></td>
<td>Kazerani, Mehrdad</td>
<td>Restrepo Restrepo, Mauricio</td>
<td>Completed Program</td>
<td>Smart Operation of Four-Quadrant Electric Vehicle Chargers in Distribution Grids</td>
</tr>
<tr>
<td>363</td>
<td>Kazerani, Mehrdad</td>
<td>Karimi, Elham</td>
<td>Completed Program</td>
<td>A Generalized Optimal Planning Platform for Microgrids of Remote Communities Considering Frequency and Voltage Regulation Constraints</td>
</tr>
<tr>
<td>364</td>
<td>Kazerani, Mehrdad</td>
<td>Wang, Haoduo</td>
<td>Completed Program</td>
<td>Design and Performance Evaluation of a Battery Simulator</td>
</tr>
<tr>
<td>365</td>
<td>Kazerani, Mehrdad</td>
<td>Alsanbawy, Mahmoud Ahmed Allam Sayed</td>
<td>Completed Program</td>
<td>Steady-State Analysis and Optimal Power Routing of Standalone Unbalanced Hybrid AC/DC Microgrids</td>
</tr>
<tr>
<td>366</td>
<td>Kazerani, Mehrdad</td>
<td>Abuaish, Ahmad</td>
<td>Completed Program</td>
<td>Assessment of Battery Capacity Fading in Partially-Decoupled Battery-Supercapacitor Hybrid Energy Storage System Topologies for Electric Vehicles</td>
</tr>
<tr>
<td>367</td>
<td>Keshav, Srinivasan</td>
<td>Oliver, Earl Albert</td>
<td>Completed Program</td>
<td>Enabling Censorship Tolerant Networking</td>
</tr>
<tr>
<td>368</td>
<td>Keshav, Srinivasan</td>
<td>Ardakanian, Omid</td>
<td>Completed Program</td>
<td>On the Control of Active End-Nodes in the Smart Grid</td>
</tr>
<tr>
<td>369</td>
<td>Keshav, Srinivasan</td>
<td>Carpenter, Tommy</td>
<td>Completed Program</td>
<td>Measuring &amp; Mitigating Electric Vehicle Adoption Barriers</td>
</tr>
<tr>
<td>370</td>
<td>Keshav, Srinivasan</td>
<td>Adepetu, Adedamola</td>
<td>Completed Program</td>
<td>Agent-Based Model Framework for Energy Policies</td>
</tr>
<tr>
<td>371</td>
<td>Keshav, Srinivasan</td>
<td>Matharu, Ray Manpreet</td>
<td>Completed Program</td>
<td>Personal Data Management in the Internet of Things</td>
</tr>
<tr>
<td>372</td>
<td>Keshav, Srinivasan</td>
<td>Gao, Xiang</td>
<td>Completed Program</td>
<td>SPOT: A Smart Personalized Office Thermal Control System</td>
</tr>
<tr>
<td>373</td>
<td>Keshav, Srinivasan</td>
<td>Singla, Sahil</td>
<td>Completed Program</td>
<td>On Using Storage and Genset for Mitigating Power Grid Failures</td>
</tr>
<tr>
<td>374</td>
<td>Keshav, Srinivasan</td>
<td>Rezaei, Elnaz</td>
<td>Completed Program</td>
<td>Energy Efficient RPL Routing Protocol in Smart Buildings</td>
</tr>
<tr>
<td>375</td>
<td>Keshav, Srinivasan</td>
<td>Rabbani Esfahani, Ali Mohammad</td>
<td>Completed Program</td>
<td>Practical Systems for Personal Thermal Comfort</td>
</tr>
<tr>
<td>376</td>
<td>Keshav, Srinivasan</td>
<td>Pat, Ankit</td>
<td>Completed Program</td>
<td>Towards Data Leveraged Behavioral Policy Design for Alleviating Peak Electricity Demand</td>
</tr>
<tr>
<td>377</td>
<td>Keshav, Srinivasan</td>
<td>Doroshenko, Mykhailo</td>
<td>Completed Program</td>
<td>Quantifying the Effects of Solar Panel Orientation on the Electrical Grid</td>
</tr>
<tr>
<td>ID</td>
<td>Name</td>
<td>First Name</td>
<td>Last Name</td>
<td>Program Name</td>
</tr>
<tr>
<td>----</td>
<td>-----------------------</td>
<td>------------</td>
<td>-----------</td>
<td>--------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>379</td>
<td>Khamesee, Behrad</td>
<td>Zamani</td>
<td>Nima</td>
<td>Bilateral Macro-Micro Teleoperation Using a Magnetic Actuation Mechanism</td>
</tr>
<tr>
<td>381</td>
<td>Khamesee, Behrad</td>
<td>Okyay</td>
<td>Ahmet</td>
<td>Cooperative Manipulation Using a Magnetically Navigated Microrobot and a Micromanipulator</td>
</tr>
<tr>
<td>382</td>
<td>Khamesee, Behrad</td>
<td>Asadi</td>
<td>Ehsan</td>
<td>Optimization of Thermoelectric Chalcogenides</td>
</tr>
<tr>
<td>383</td>
<td>Khamesee, Behrad</td>
<td>Al-Dulaimi</td>
<td>Thamir</td>
<td>Thermoelectric Properties of Ti0.5Zr0.25Hf0.25CoSn1-xSb5.4Te1.6 Based Thermoelectric Nanocomposites</td>
</tr>
<tr>
<td>384</td>
<td>Khamesee, Behrad</td>
<td>Zhang</td>
<td>Xiaodong</td>
<td>Magnesium Silicide Based Thermoelectric Nanocomposites</td>
</tr>
<tr>
<td>385</td>
<td>Khamesee, Behrad</td>
<td>Vanzant</td>
<td>Mathew</td>
<td>Thermoelectric Properties of Higher Manganese Silicides</td>
</tr>
<tr>
<td>ID</td>
<td>Name</td>
<td>Co-mentor</td>
<td>Program Status</td>
<td>Project Title</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------</td>
<td>-----------</td>
<td>----------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>393</td>
<td>Kleinke, Holger</td>
<td>Cheng, Xiaoyu</td>
<td>Completed</td>
<td>Sustainable Semiconductor Materials for Thermoelectric Energy Conversion</td>
</tr>
<tr>
<td>394</td>
<td>Lashgarian Azad, Nasser</td>
<td>Kim, Shinhoon</td>
<td>Completed</td>
<td>High-fidelity Modelling of an Electric Sport Utility Vehicle</td>
</tr>
<tr>
<td>395</td>
<td>Lashgarian Azad, Nasser</td>
<td>Vajedi, Mahyar</td>
<td>Completed</td>
<td>Real-Time Optimal Control of a Plug-In Hybrid Electric Vehicle Using Trip Information</td>
</tr>
<tr>
<td>396</td>
<td>Lashgarian Azad, Nasser</td>
<td>Chehresaz, Maryyeh</td>
<td>Completed</td>
<td>Modeling and Design Optimization of Plug-In Hybrid Electric Vehicle Powertrains</td>
</tr>
<tr>
<td>397</td>
<td>Lashgarian Azad, Nasser</td>
<td>Mozaffari, Ahmad</td>
<td>Completed</td>
<td>Predictive Control Strategies for Automotive Engine Coldstart Emission</td>
</tr>
<tr>
<td>398</td>
<td>Lashgarian Azad, Nasser</td>
<td>Masoudi, Yasaman</td>
<td>Completed</td>
<td>Real-Time Optimal Battery Thermal Management System Controller for Electric and Plug-in Hybrid Electric Vehicles</td>
</tr>
<tr>
<td>399</td>
<td>Lashgarian Azad, Nasser</td>
<td>Golchoubian, Parisa</td>
<td>Completed</td>
<td>Real-Time Energy Management of a Battery Electric Vehicle Hybridized with Supercapacitor</td>
</tr>
<tr>
<td>402</td>
<td>Lashgarian Azad, Nasser</td>
<td>Batra, Mohit</td>
<td>Completed</td>
<td>Dynamics and Model-Predictive Anti-Jerk Control of Connected Electric Vehicles</td>
</tr>
<tr>
<td>404</td>
<td>Lee, Hyung-Sool</td>
<td>Hou, Yu</td>
<td>Completed</td>
<td>Study of the Anaerobic Methane Oxidation Coupled to Nitrate Denitrification</td>
</tr>
<tr>
<td>405</td>
<td>Lee, Hyung-Sool</td>
<td>Deng, Qiaosi</td>
<td>Completed</td>
<td>Ammonia Removal and Recovery From Wastewater Using Natural Zeolite: An Integrated System for Regeneration by Air Stripping Followed Ion Exchange</td>
</tr>
<tr>
<td>406</td>
<td>Lee, Hyung-Sool</td>
<td>Reid, Robertson John</td>
<td>Completed</td>
<td>Electrogeneration of Hydrogen Peroxide for Applications in Water/Wastewater Treatment</td>
</tr>
<tr>
<td>407</td>
<td>Lee, Hyung-Sool</td>
<td>Gao, Yaohuan</td>
<td>Completed</td>
<td>Syntrophic Interactions Between Anode-Respiring Bacteria and Non-Anode-Respiring Bacteria in Microbial Electrochemical Cells</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Advisor</td>
<td>Completed Program</td>
<td>Project Title</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------------</td>
<td>------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>408</td>
<td>Lee, Hyung-Sool</td>
<td>Galib, Mohammed</td>
<td>Completed Program</td>
<td>Investigation of Performance of a Submerged Anaerobic Membrane Bioreactor (AnMBR) Treating Meat Processing Wastewater</td>
</tr>
<tr>
<td>409</td>
<td>Lee, Hyung-Sool</td>
<td>Dhar, Bipro Ranjan</td>
<td>Completed Program</td>
<td>Extracellular Electron Transport in Microbial Electrochemical Cells</td>
</tr>
<tr>
<td>410</td>
<td>Leonenko, Iouri (Yuri)</td>
<td>Joshi, Abhishek</td>
<td>Completed Program</td>
<td>Investigation of Multiple Well Injections for Carbon Dioxide Sequestration in Aquifers</td>
</tr>
<tr>
<td>411</td>
<td>Li, Xianguo</td>
<td>Pereira, Aaron Joseph</td>
<td>Completed Program</td>
<td>Investigation of Direct Injection Fuel Spray in High-Velocity Air Flows</td>
</tr>
<tr>
<td>412</td>
<td>Li, Xianguo</td>
<td>So, Queenie</td>
<td>Completed Program</td>
<td>Experimental Study on Multi-Hole Biodiesel Pulsed Spray in Cross Airflow</td>
</tr>
<tr>
<td>413</td>
<td>Li, Xianguo</td>
<td>Chen, Kaiwei</td>
<td>Completed Program</td>
<td>Heat Generation Measurements of Prismatic Lithium Ion Batteries</td>
</tr>
<tr>
<td>414</td>
<td>Li, Xianguo</td>
<td>Carnovale, Andrew</td>
<td>Completed Program</td>
<td>Investigation into the Effect of Thermal Management on the Capacity Fade of Lithium-ion Batteries</td>
</tr>
<tr>
<td>415</td>
<td>Li, Xianguo</td>
<td>Saha, Kaushik</td>
<td>Completed Program</td>
<td>Modelling of Cavitation in Nozzles for Diesel Injection Applications</td>
</tr>
<tr>
<td>416</td>
<td>Li, Xianguo</td>
<td>Panahi, Amir</td>
<td>Completed Program</td>
<td>Investigation of the Interactions of Particulate Matter with the Gas Diffusion Layer</td>
</tr>
<tr>
<td>417</td>
<td>Li, Xianguo</td>
<td>Shen, Yinqi</td>
<td>Completed Program</td>
<td>Mechanical Degradation of Membrane Electrode Assemblies in Proton Exchange Membrane Fuel Cells</td>
</tr>
<tr>
<td>418</td>
<td>Li, Xianguo</td>
<td>Wang, Jingyi</td>
<td>Completed Program</td>
<td>Experimental and Modeling Investigation of Thermal Behaviour and Performance of Lithium Ion Prismatic Cells at Cold-Start Temperatures</td>
</tr>
<tr>
<td>419</td>
<td>Li, Xianguo</td>
<td>Gauthier, Garrett</td>
<td>Completed Program</td>
<td>Nature-Inspired Polymers: Promising Materials for OTFT-Based Sensors</td>
</tr>
<tr>
<td>420</td>
<td>Li, Xianguo</td>
<td>Wang, Chen</td>
<td>Completed Program</td>
<td>Electrodeposition of p-Type Cuprous Oxide and its Application in Oxide Solar Cells</td>
</tr>
<tr>
<td>421</td>
<td>Li, Yuning</td>
<td>Quinn, Jesse Thomas Ernest</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>422</td>
<td>Li, Yuning</td>
<td>Yang, Yiyi</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>Name</td>
<td>Project Title</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>423</td>
<td>Li,Yuning</td>
<td>Development of New Building Blocks for Constructing Novel Polymer Semiconductors for Organic Thin Film Transistors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>424</td>
<td>Li,Yuning</td>
<td>Thiophene-S,S-dioxidized Indophenine for use in Organic Field-Effect Transistors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>425</td>
<td>Li,Yuning</td>
<td>High Performance n-Type Polymer Semiconductors for Printed Logic Circuits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>426</td>
<td>Li,Yuning</td>
<td>Influence of High Mobility Polymer Semiconductors in Organic Photovoltaics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>427</td>
<td>Li,Yuning</td>
<td>Development of New Nanostructurally Engineered Polymer Semiconductors for Organic Electronics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>428</td>
<td>Li,Yuning</td>
<td>Solution-Processable Oligomeric and Small Molecule Semiconductors for Organic Solar Cells</td>
<td></td>
<td></td>
</tr>
<tr>
<td>429</td>
<td>Li,Yuning</td>
<td>Novel N-Type Pi-Conjugated Polymers for All-Polymer Solar Cells</td>
<td></td>
<td></td>
</tr>
<tr>
<td>430</td>
<td>Li,Yuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>431</td>
<td>Li,Yuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>432</td>
<td>Li,Yuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>433</td>
<td>Li,Yuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>434</td>
<td>Li,Yuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>435</td>
<td>Li,Yuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>436</td>
<td>Li,Yuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>437</td>
<td>Lien,Fue-Sang S</td>
<td>Computational Acoustic Beamforming of Noise Source on Wind Turbine Airfoil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Lien,Fue-Sang S</td>
<td>Koda,Yusuke</td>
<td>Completed Program</td>
<td>Research Title</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>-------------</td>
<td>-------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>439</td>
<td>Lien,Fue-Sang S</td>
<td>Li,Zhe</td>
<td>Completed Program</td>
<td>Experimental Investigation on Tapping Noise in EVAP System of a Motor Vehicle</td>
</tr>
<tr>
<td>440</td>
<td>Lien,Fue-Sang S</td>
<td>Ma,Ping</td>
<td>Completed Program</td>
<td>Computational Acoustic Beamforming for Noise Source Identification for Small Horizontal Axis Wind Turbines</td>
</tr>
<tr>
<td>441</td>
<td>Lien,Fue-Sang S</td>
<td>Li,Chenguang</td>
<td>Completed Program</td>
<td>Numerical Modeling of Multiphase Flows With Applications to the Automotive Industry</td>
</tr>
<tr>
<td>442</td>
<td>Lien,Fue-Sang S</td>
<td>Mossa,Karim</td>
<td>Completed Program</td>
<td>Computational Modelling of Propeller Noise: NASA SR-7A Propeller</td>
</tr>
<tr>
<td>443</td>
<td>Lien,Fue-Sang S</td>
<td>Zeng,Qiulan</td>
<td>Completed Program</td>
<td>Numerical Schemes for 1-D Two-Phase Flows</td>
</tr>
<tr>
<td>444</td>
<td>Lien,Fue-Sang S</td>
<td>Nam,Jee-Whan</td>
<td>Completed Program</td>
<td>Non-Body Conformal Grid Methods for Large-Eddy Simulations of Compressible Flows and Their Applications in Computational Aeroacoustics</td>
</tr>
<tr>
<td>445</td>
<td>Lynes,Jennifer Kristin</td>
<td>Lasani,Leah Ann</td>
<td>Completed Program</td>
<td>The Current State of Green Building Standards and Interior Materials; Are These Processes Leading to Stronger Selections of Sustainable Materials?</td>
</tr>
<tr>
<td>446</td>
<td>Lynes,Jennifer Kristin</td>
<td>Amir,Samra</td>
<td>Completed Program</td>
<td>Have Green Teens Become Blue? Investigating Changes and Influences in Adolescent Attitudes Towards Electricity Conservation</td>
</tr>
<tr>
<td>447</td>
<td>Lynes,Jennifer Kristin</td>
<td>Donaher,Evonne Theresa Winchiu</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>448</td>
<td>Lynes,Jennifer Kristin</td>
<td>Gunn,Jennifer</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>450</td>
<td>Lynes,Jennifer Kristin</td>
<td>Hassani,Iman</td>
<td>Completed Program</td>
<td>The Relationship Between Demographics and Consumers' Propensity for Rewarding or Punishing a Company Based on its Social Responsibility</td>
</tr>
<tr>
<td>451</td>
<td>Lynes,Jennifer Kristin</td>
<td>Lobe,Leanne Barbara</td>
<td>Completed Program</td>
<td>Fostering Sustainable Business: CBSM as a Framework to Voluntarily Change Environmental Behaviours</td>
</tr>
<tr>
<td>Student ID</td>
<td>Last Name, First Name</td>
<td>Completed Program</td>
<td>Project Title</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------</td>
<td>-------------------</td>
<td>---------------</td>
<td></td>
</tr>
<tr>
<td>452</td>
<td>McPhee, John</td>
<td>Loh, Francis Chun Yu</td>
<td>Completed Program</td>
<td>Multi-Body Vehicle Dynamics Modeling for Drift Analysis</td>
</tr>
<tr>
<td>453</td>
<td>McPhee, John</td>
<td>Petersen, Willem</td>
<td>Completed Program</td>
<td>A Volumetric Contact Model for Planetary Rover Wheel/Soil Interaction</td>
</tr>
<tr>
<td>454</td>
<td>McPhee, John</td>
<td>Hall, Andrew James Peter</td>
<td>Completed Program</td>
<td>Formulation of a Path-Following Joint for Multibody System Dynamics</td>
</tr>
<tr>
<td>455</td>
<td>McPhee, John</td>
<td>Ing, Adam Henry</td>
<td>Completed Program</td>
<td>Automated Topology Synthesis and Optimization of Hybrid Electric Vehicle Powertrains</td>
</tr>
<tr>
<td>456</td>
<td>McPhee, John</td>
<td>Johnson, Daniel David Albin</td>
<td>Completed Program</td>
<td>A Three Dimensional Forward Dynamic Model of the Golf Swing</td>
</tr>
<tr>
<td>457</td>
<td>McPhee, John</td>
<td>Banerjee, Joydeep</td>
<td>Completed Program</td>
<td>Graph-Theoretic Sensitivity Analysis of Dynamic Systems</td>
</tr>
<tr>
<td>458</td>
<td>McPhee, John</td>
<td>Sharif Shourijeh, Mohammad</td>
<td>Completed Program</td>
<td>Optimal Control and Multibody Dynamic Modelling of Human Musculoskeletal Systems</td>
</tr>
<tr>
<td>459</td>
<td>McPhee, John</td>
<td>Brown, Peter Matthew</td>
<td>Completed Program</td>
<td>Contact Modelling for Forward Dynamics of Human Motion</td>
</tr>
<tr>
<td>460</td>
<td>McPhee, John</td>
<td>Liang, Yiteng</td>
<td>Completed Program</td>
<td>Integration of Finite Element Method With Multibody System Dynamics Using Symbolic Computation</td>
</tr>
<tr>
<td>461</td>
<td>McPhee, John</td>
<td>Mehrabi, Naser</td>
<td>Completed Program</td>
<td>Dynamics and Model-Based Control of Electric Power Steering Systems</td>
</tr>
<tr>
<td>462</td>
<td>McPhee, John</td>
<td>Sharif Razavian, Reza</td>
<td>Completed Program</td>
<td>A Human Motor Control Framework Based on Muscle Synergies</td>
</tr>
<tr>
<td>463</td>
<td>McPhee, John</td>
<td>Brown, Colin Patrick</td>
<td>Completed Program</td>
<td>Predictive Forward Dynamic Simulation of Manual Wheelchair Propulsion</td>
</tr>
<tr>
<td>464</td>
<td>McPhee, John</td>
<td>Ghannadi, Borna</td>
<td>Completed Program</td>
<td>Model-Based Control of Upper Extremity Human-Robot Rehabilitation Systems</td>
</tr>
<tr>
<td>465</td>
<td>McPhee, John</td>
<td>Jansen, Conor</td>
<td>Completed Program</td>
<td>Predictive Dynamic Simulation of Cycling Using Olympic Cyclist and Bicycle Models</td>
</tr>
<tr>
<td>466</td>
<td>Moresoli, Christine</td>
<td>Lai, Yung Priscilla</td>
<td>Completed Program</td>
<td>Development of Weak Cation Exchange Membrane Adsorber Materials for Protein Capture</td>
</tr>
<tr>
<td>#</td>
<td>Name1</td>
<td>Name2</td>
<td>Program Status</td>
<td>Project Title</td>
</tr>
<tr>
<td>----</td>
<td>----------------</td>
<td>--------------------------------</td>
<td>----------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>467</td>
<td>Moresoli,Christine</td>
<td>Zerin,Nagma</td>
<td>Completed Program</td>
<td>Dynamic Modelling of Cation Exchange Membrane Chromatography for Capturing Human Immunoglobulin G (lgG)</td>
</tr>
<tr>
<td>468</td>
<td>Moresoli,Christine</td>
<td>Hassel,Anna-Katharina</td>
<td>Completed Program</td>
<td>Protein Capture by Cation Exchange Membranes</td>
</tr>
<tr>
<td>469</td>
<td>Moresoli,Christine</td>
<td>Huang,Chu Yin</td>
<td>Completed Program</td>
<td>Extrusion-Based 3D Printing and Characterization of Edible Materials</td>
</tr>
<tr>
<td>470</td>
<td>Moresoli,Christine</td>
<td>Nasser Pourtakalo,Rasool</td>
<td>Completed Program</td>
<td>Development and Characterization of Poly (Lactic Acid)/Acetylated Starch Blends</td>
</tr>
<tr>
<td>472</td>
<td>Narasimhan,Sriram</td>
<td>Sychterz,Ann Christine</td>
<td>Completed Program</td>
<td>Vibration Characterisation of Aluminium Pedestrian Bridges</td>
</tr>
<tr>
<td>473</td>
<td>Narasimhan,Sriram</td>
<td>Topuzi,Dritan</td>
<td>Completed Program</td>
<td>Large Scale Testing and Modelling of Reinforced Concrete Flat Plate Systems in Seismic Areas</td>
</tr>
<tr>
<td>474</td>
<td>Narasimhan,Sriram</td>
<td>Sadhu,Ayan</td>
<td>Completed Program</td>
<td>Decentralized Ambient System Identification of Structures</td>
</tr>
<tr>
<td>475</td>
<td>Narasimhan,Sriram</td>
<td>Dey,Pampa</td>
<td>Completed Program</td>
<td>Evaluation and Calibration of Pedestrian Bridge Standards for Vibration Serviceability</td>
</tr>
<tr>
<td>476</td>
<td>Narasimhan,Sriram</td>
<td>Pantula,Shilpa Reddy</td>
<td>Completed Program</td>
<td>Automated Fault Diagnosis in Rotating Machinery</td>
</tr>
<tr>
<td>477</td>
<td>Nathwani,Jatin</td>
<td>Guler,Burak</td>
<td>Completed Program</td>
<td>A Regional Electricity Hub for Energy Transitions</td>
</tr>
<tr>
<td>478</td>
<td>Nathwani,Jatin</td>
<td>Gabriel,Amir</td>
<td>Completed Program</td>
<td>Forging Links Between Innovation and Sustainability: An Empirical Examination of the Effects on a Firm's Financial Performance</td>
</tr>
<tr>
<td>479</td>
<td>Nathwani,Jatin</td>
<td>Lavaee,Mohammad Saleh</td>
<td>Completed Program</td>
<td>Waste to Energy (WTE): Conventional and Plasma-assisted Gasification- Experimental and Modeling Studies</td>
</tr>
<tr>
<td>ID</td>
<td>Name</td>
<td>Completed Program</td>
<td>Project Title</td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>-----------------------</td>
<td>-------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>482</td>
<td>Nazar, Linda F</td>
<td>Black, Robert</td>
<td>The Impact of Degradation Reactions on Aprotic Metal-O2 Battery Performance</td>
<td></td>
</tr>
<tr>
<td>483</td>
<td>Nazar, Linda F</td>
<td>Evers, Scott Randall</td>
<td>Nanostructured Carbons and Additives for Improvement of the Lithium-Sulfur Battery Positive Electrode</td>
<td></td>
</tr>
<tr>
<td>484</td>
<td>Nazar, Linda F</td>
<td>He, Guang</td>
<td>Functional Materials for Rechargeable Li Battery and Hydrogen Storage</td>
<td></td>
</tr>
<tr>
<td>485</td>
<td>Nazar, Linda F</td>
<td>Fernandes, Russel Xavier</td>
<td>Towards a Better Understanding of the Na-02 Battery System</td>
<td></td>
</tr>
<tr>
<td>486</td>
<td>Nazar, Linda F</td>
<td>Tripathi, Rajesh</td>
<td>Novel High Voltage Electrodes for Li-ion Batteries</td>
<td></td>
</tr>
<tr>
<td>488</td>
<td>Nazar, Linda F</td>
<td>Talaie Pashiri, Elahe</td>
<td>Manganese and Iron-Based Layered Oxide Positive Electrodes for Sodium-Ion Batteries</td>
<td></td>
</tr>
<tr>
<td>489</td>
<td>Nazar, Linda F</td>
<td>Town, Kaitlin Erin MacIntosh</td>
<td>Silicon-Based Materials as Negative Electrodes for Li-ion Batteries</td>
<td></td>
</tr>
<tr>
<td>490</td>
<td>Nazar, Linda F</td>
<td>Adams, Brian</td>
<td>Development of the Aprotic Lithium-Oxygen Battery System</td>
<td></td>
</tr>
<tr>
<td>491</td>
<td>Nazar, Linda F</td>
<td>Cabelguen, Pierre-Etienne</td>
<td>Advanced Research on Lithium-Sulfur Batteries: Studies of Lithium Polysulfides</td>
<td></td>
</tr>
<tr>
<td>492</td>
<td>Nazar, Linda F</td>
<td>Pang, Quanquan</td>
<td>Advanced Electrodes and Electrolytes for Long-Lived and High-Energy-Density Lithium-Sulfur Batteries</td>
<td></td>
</tr>
<tr>
<td>493</td>
<td>Nazar, Linda F</td>
<td>Hart, Connor James</td>
<td>The Evolving Search for Positive Electrode Host Materials for the Li-S Battery</td>
<td></td>
</tr>
<tr>
<td>494</td>
<td>Nazar, Linda F</td>
<td>Houtarde, Diane</td>
<td>Synthesis of Sulfide-Based Solid Electrolytes for Application to All-Solid-State Lithium-Sulfur Batteries</td>
<td></td>
</tr>
<tr>
<td>495</td>
<td>Nazar, Linda F</td>
<td>Huang, He</td>
<td>Computational and Experimental Investigation Towards a Stable Lithium Metal Anode</td>
<td></td>
</tr>
<tr>
<td>Appendix VII – Highly Qualified Personnel (HQP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>496</td>
<td>Nazar, Linda F</td>
<td>Sudhakar, Niranjan</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>497</td>
<td>Nazar, Linda F</td>
<td>Ellis, Brian</td>
<td>Synthesis, Electrochemistry and Solid-Solution Behaviour of Energy Storage Materials Based on Natural Minerals</td>
<td></td>
</tr>
<tr>
<td>498</td>
<td>Ng, Flora T T</td>
<td>Baig, Aijaz</td>
<td>Development of a Green Heterogeneous-Catalyzed Process for the Production of ASTM-Standard Biodiesel From Multi-Feedstocks</td>
<td></td>
</tr>
<tr>
<td>499</td>
<td>Ng, Flora T T</td>
<td>Nguon, Olivier</td>
<td>Polymer-Stabilized Transition Metal Nanocatalysts: Synthesis, Characterization, and Applications</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>Ng, Flora T T</td>
<td>Jia, Lei</td>
<td>Oil Sands Bitumen Emulsion Upgrading by Using In Situ Hydrogen Generated Through the Water gas Shift Reaction</td>
<td></td>
</tr>
<tr>
<td>501</td>
<td>Ng, Flora T T</td>
<td>Liu, Yuanqing</td>
<td>Catalytic Glycerol Hydrogenolysis to Produce 1,2-propanediol With Molecular Hydrogen and in Situ Hydrogen Produced From Steam Reforming</td>
<td></td>
</tr>
<tr>
<td>502</td>
<td>Ng, Flora T T</td>
<td>Mai Thi Quynh, Chau</td>
<td>Catalytic Hydrogenolysis of Glycerol to 1-Propanol Using Bifunctional Catalysts in an Aqueous Media</td>
<td></td>
</tr>
<tr>
<td>503</td>
<td>Ng, Flora T T</td>
<td>Gaurav, Aashish</td>
<td>Catalytic Distillation: Modeling and Process Development for Fuels and Chemicals</td>
<td></td>
</tr>
<tr>
<td>504</td>
<td>Nimubona, Alain-Desire</td>
<td>Li, Hongxiu</td>
<td>Three Essays on the Economics of Innovation as Adaptation to Climate Change</td>
<td></td>
</tr>
<tr>
<td>505</td>
<td>Pan, Qinmin</td>
<td>Liu, Minghui</td>
<td>Hydrogenation of Nitrile and Olefinic Groups in Butadiene Rubbers</td>
<td></td>
</tr>
<tr>
<td>506</td>
<td>Pandey, Mahesh D</td>
<td>Consell, Ryan Adam</td>
<td>A Novel System for the Measurement of Dynamic Loading on a Bicycle Frame</td>
<td></td>
</tr>
<tr>
<td>507</td>
<td>Pandey, Mahesh D</td>
<td>Campbell, Graeme Edward</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>508</td>
<td>Pandey, Mahesh D</td>
<td>Felhaber, Ryan</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>509</td>
<td>Pandey, Mahesh D</td>
<td>Daigle, Olivier</td>
<td>The Effect of Woodpecker Damage on the Reliability of Wood Utility Poles</td>
<td></td>
</tr>
<tr>
<td>510</td>
<td>Pandey, Mahesh D</td>
<td>Raimbault, Jeremie Pierre</td>
<td>Modelling Fatigue Deterioration and Retrofitting in Bridge Management Systems</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Last Name, First Name</td>
<td>Completed Program</td>
<td>Title</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>----------------------</td>
<td>-------------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>511</td>
<td>Pandey, Mahesh D</td>
<td>Abu-Khajil, Amer</td>
<td>Completed Program</td>
<td>Reliability Assessment of Load Testing for Concrete Buildings</td>
</tr>
<tr>
<td>512</td>
<td>Pandey, Mahesh D</td>
<td>Zhang, Xufang</td>
<td>Completed Program</td>
<td>Efficient Computational Methods for Structural Reliability and Global Sensitivity Analyses</td>
</tr>
<tr>
<td>513</td>
<td>Pandey, Mahesh D</td>
<td>Deng, Jian</td>
<td>Completed Program</td>
<td>Fractional Stochastic Dynamics in Structural Stability Analysis</td>
</tr>
<tr>
<td>514</td>
<td>Pandey, Mahesh D</td>
<td>Zhang, Deyi</td>
<td>Completed Program</td>
<td>Stochastic Modelling and Analysis for Bridges Under Spatially Varying Ground Motions</td>
</tr>
<tr>
<td>515</td>
<td>Pandey, Mahesh D</td>
<td>Wang, Zhaoliang</td>
<td>Completed Program</td>
<td>Seismic Risk Analysis for Nuclear Energy Facilities</td>
</tr>
<tr>
<td>516</td>
<td>Pandey, Mahesh D</td>
<td>Li, Bo</td>
<td>Completed Program</td>
<td>Response Spectra for Seismic Analysis and Design</td>
</tr>
<tr>
<td>517</td>
<td>Pandey, Mahesh D</td>
<td>Yu, Shuo</td>
<td>Completed Program</td>
<td>Probabilistic Assessment of Common Cause Failure in Nuclear Power Plants</td>
</tr>
<tr>
<td>518</td>
<td>Pandey, Mahesh D</td>
<td>Balomenos, Georgios</td>
<td>Completed Program</td>
<td>Probabilistic Finite Element Analysis of Structures Using the Multiplicative Dimensional Reduction Method</td>
</tr>
<tr>
<td>519</td>
<td>Pandey, Mahesh D</td>
<td>Jiang, Wei</td>
<td>Completed Program</td>
<td>Direct Method of Generating Floor Response Spectra</td>
</tr>
<tr>
<td>520</td>
<td>Pandey, Mahesh D</td>
<td>Cai, Zhen</td>
<td>Completed Program</td>
<td>Seismic Fragility Analysis for Structures, Systems, and Components in Nuclear Power Plants</td>
</tr>
<tr>
<td>521</td>
<td>Pandey, Mahesh D</td>
<td>Manzana, Noldainerick Genaro</td>
<td>Completed Program</td>
<td>Stochastic Renewal Process Models for Structural Reliability Analysis</td>
</tr>
<tr>
<td>522</td>
<td>Pandey, Mahesh D</td>
<td>Madhusoothanan, Vimala Madhangi</td>
<td>Completed Program</td>
<td>Stochastic Environmental Modeling for Nuclear Waste Management</td>
</tr>
<tr>
<td>523</td>
<td>Parker, Paul</td>
<td>Tonbol, Amro Hassan</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>524</td>
<td>Parker, Paul</td>
<td>Paetz, Jennifer Anne</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>525</td>
<td>Parker, Paul</td>
<td>Halbe, Akanksha</td>
<td>Completed Program</td>
<td>Sustainable Technologies in the Hotel Industry: A Green Energy Case Study</td>
</tr>
<tr>
<td>Appendix VII – Highly Qualified Personnel (HQP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>526</td>
<td>Parker, Paul</td>
<td>Kraljevska, Elena</td>
<td>Completed Program</td>
<td>Estimated Benefits of Achieving Passivhaus and net Zero Energy Standards in the Region of Waterloo Residential Sector and the Barriers and Drivers to Achieve Them</td>
</tr>
<tr>
<td>527</td>
<td>Parker, Paul</td>
<td>Munroe, Callin Anne Marie</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>528</td>
<td>Parker, Paul</td>
<td>Damini, Tallia</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>529</td>
<td>Parker, Paul</td>
<td>Nieboer, Steven Jacob</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>530</td>
<td>Parker, Paul</td>
<td>Yan, Vivien Helena</td>
<td>Completed Program</td>
<td>Environmental Initiatives in the Hotel Industry: Environmental Certification and the Marginal Abatement Cost Curve (MACC)</td>
</tr>
<tr>
<td>531</td>
<td>Parker, Paul</td>
<td>Xu, Xiao</td>
<td>Completed Program</td>
<td>Exploring the use of Remote Sensing CO2 Data to Measure the CO2 Concentration Enhancements Caused by Coal-Fired Power Plants</td>
</tr>
<tr>
<td>532</td>
<td>Parker, Paul</td>
<td>Nathu, Riaz Husein</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>533</td>
<td>Parker, Paul</td>
<td>Khorrami Banadaki, Seyed Siamak</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>534</td>
<td>Parker, Paul</td>
<td>Zhao, Junna</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>535</td>
<td>Parker, Paul</td>
<td>Adeli, Nasim</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>536</td>
<td>Parker, Paul</td>
<td>Huber, Sara</td>
<td>Completed Program</td>
<td>Evaluating Tailored Feedback for Re-Engaging Residential Smart Grid Users: A Case Study in Milton, Ontario</td>
</tr>
<tr>
<td>537</td>
<td>Parker, Paul</td>
<td>Wang, Qi</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>538</td>
<td>Parker, Paul</td>
<td>Osman, Balikisu</td>
<td>Completed Program</td>
<td>Bringing Prosperity to the Poor: A Systematic Review of Microfinance and Agricultural Livelihoods in Sub-Saharan Africa</td>
</tr>
<tr>
<td>539</td>
<td>Parker, Paul</td>
<td>Sato, Mutsumi</td>
<td>Completed Program</td>
<td>Estimating Values of Integrated PV-Battery Systems for Single-Detached Residences in Japan</td>
</tr>
<tr>
<td>Appendix VII – Highly Qualified Personnel (HQP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<p>| 540 | Parker, Paul | Abu-Ashour, Ghaith S. M. | Completed Program | Assessing Socio-Economic Determinants of Energy-Saving Behaviour in Waterloo Region |
| 541 | Parker, Paul | Schnier, Jennifer Susan | Completed Program | |
| 542 | Parker, Paul | Shaw, Sherene Patricia | Completed Program | |
| 543 | Parker, Wayne Jeffery | Gray, Holly Erin | Completed Program | Phosphorus Removal and Recovery from Wastewater using Sorbent Technologies |
| 544 | Parker, Wayne Jeffery | Conidi, Daniela | Completed Program | The Effect of Solids Residence Time on Phosphorus Uptake in Co-Precipitation Systems Targeting Low Phosphorus Concentrations |
| 545 | Parker, Wayne Jeffery | Murray, Kyle | Completed Program | Fate of Select Pharmacologically Active Compounds in the Integrated Fixed Film Activated Sludge Process |
| 546 | Parker, Wayne Jeffery | Pileggi, Vincenzo | Completed Program | Investigation of the Performance of an Anaerobic Membrane Bioreactor in the Treatment of Mixed Municipal Sludge Under Ambient, Mesophilic and Thermophilic Operating Conditions |
| 547 | Parker, Wayne Jeffery | Xie, Biao | Completed Program | Investigation of the Impact of Mixing Intensity on Dissolved Oxygen Half Velocity Constants in a Sidestream Deammonification Environment |
| 548 | Parker, Wayne Jeffery | Ghalajkhani, Rosita | Completed Program | Fate Modeling of Xenobiotic Organic Compounds (XOCs) in Wastewater Treatment Plants |
| 549 | Parker, Wayne Jeffery | Dong, Qirong | Completed Program | Characterization of Anaerobic Membrane Bioreactors (AnMBR) Treating Municipal Wastewater |
| 550 | Parker, Wayne Jeffery | Jo, Hyungjun | Completed Program | Comparison of the Impacts of Thermal Pretreatment on Waste Activated Sludge Using Aerobic and Anaerobic Digestion |
| 551 | Parker, Wayne Jeffery | Albornoz, Antonio | Completed Program | Characterization of Acid Phase Anaerobic Digestion of Municipal Sludges to Improve Biological Nutrient Removal Processes |
| 552 | Parker, Wayne Jeffery | Ogunlaja, Olumuyiwa Omotola | Completed Program | Impact of Biological Nutrient Removal Process Operating and Design Conditions on the Removal of Micropollutants From Wastewater |</p>
<table>
<thead>
<tr>
<th>No.</th>
<th>Name 1</th>
<th>Name 2</th>
<th>Degree</th>
<th>Project Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>553</td>
<td>Parker, Wayne Jeffery</td>
<td>Abu-Obaid, Sara Salah</td>
<td>Completed Program</td>
<td>Characterization of Fouling of Tertiary Membranes Treating Secondary Effluent of Domestic Wastewater</td>
</tr>
<tr>
<td>554</td>
<td>Parker, Wayne Jeffery</td>
<td>Joshi, Priyanka Dilip</td>
<td>Completed Program</td>
<td>Effect of Pre-treatment Using Ultrasound and Hydrogen Peroxide on Digestion of Waste Activated Sludge in an Anaerobic Membrane Bioreactor</td>
</tr>
<tr>
<td>555</td>
<td>Parker, Wayne Jeffery</td>
<td>Sarwar, Rubaiya</td>
<td>Completed Program</td>
<td>Effect of Thermal Pretreatment on Digestibility of Thickenened Waste Activated Sludge and Primary Sludge in Two-stage Anaerobic Digestion</td>
</tr>
<tr>
<td>556</td>
<td>Parker, Wayne Jeffery</td>
<td>Archer, Gregory</td>
<td>Completed Program</td>
<td>Benchmarking the Sustainability of Sludge Handling Systems in Small Wastewater Treatment Plants in Ontario</td>
</tr>
<tr>
<td>557</td>
<td>Ponnambalam, Kumaraswamy</td>
<td>Eajal, Abdelsalam</td>
<td>Completed Program</td>
<td>The New AC/DC Hybrid Microgrid Paradigm: Analysis and Operational Control</td>
</tr>
<tr>
<td>559</td>
<td>Ponnambalam, Kumaraswamy</td>
<td>Chang, Lu</td>
<td>Completed Program</td>
<td>Optimization Models for Applications in Portfolio Management and Advertising Industry</td>
</tr>
<tr>
<td>560</td>
<td>Ponnambalam, Kumaraswamy</td>
<td>Manilachelvan, Poonkuzhali</td>
<td>Completed Program</td>
<td>Optimization Methods for Inventory and Supply Chain Management</td>
</tr>
<tr>
<td>562</td>
<td>Ponnambalam, Kumaraswamy</td>
<td>Farahani, Mohammadreza</td>
<td>Completed Program</td>
<td>Service Revenue Management in the Presence of Grouping Complementarities</td>
</tr>
<tr>
<td>563</td>
<td>Ponnambalam, Kumaraswamy</td>
<td>Janjua, Harveen</td>
<td>Completed Program</td>
<td>Fusion of Ice Thickness From Passive Microwave and Ice Ocean Model for Better Estimation</td>
</tr>
<tr>
<td>564</td>
<td>Ponnambalam, Kumaraswamy</td>
<td>Garcia Hernandez, Jorge Andres</td>
<td>Completed Program</td>
<td>Rule Derivation for Agent-Based Models of Complex Systems: Nuclear Waste Management and Road Networks Case Studies</td>
</tr>
<tr>
<td>565</td>
<td>Ponnambalam, Kumaraswamy</td>
<td>Sawh, Deitra</td>
<td>Completed Program</td>
<td>Financial Fraud Detection and Data Mining of Imbalanced Databases Using State Space Machine Learning</td>
</tr>
<tr>
<td>566</td>
<td>Prouzet, Eric</td>
<td>Cao, Edgar Bao Qi</td>
<td>Completed Program</td>
<td>Towards Designing Composite Membranes for CO₂ Separation: The Inclusion of Hybrid TiO₂-PEG Structures and the Study of Their Interfaces</td>
</tr>
<tr>
<td>-----</td>
<td>---------------</td>
<td>-----------------</td>
<td>------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>568</td>
<td>Prouzet, Eric</td>
<td>Hessien, Manal Amin Abdel Mogoud</td>
<td>Completed Program</td>
<td>Metal Oxide-Hierarchical Porous Silica Nanocomposites Prepared by Nanoemulsion Templating and Integrative Synthesis</td>
</tr>
<tr>
<td>569</td>
<td>Prouzet, Eric</td>
<td>Kinadjian, Natacha Monique Frederique</td>
<td>Completed Program</td>
<td>Integrative Chemistry Based Morphosyntheses of Hierarchical Composite Materials for Photovoltaic, Photocatalysis and Photoluminescence Applications</td>
</tr>
<tr>
<td>570</td>
<td>Radovanovic, Pavle</td>
<td>Shirman, Wade</td>
<td>Completed Program</td>
<td>Single White-Light-Emitting Nanostructures Based on Forster Resonance Energy Transfer: Development, Characterization and Applications</td>
</tr>
<tr>
<td>571</td>
<td>Radovanovic, Pavle</td>
<td>Hutfluss, Lisa Nicole</td>
<td>Completed Program</td>
<td>Studies in Pure and Transition Metal Doped Indium Oxide Nanocrystals</td>
</tr>
<tr>
<td>572</td>
<td>Radovanovic, Pavle</td>
<td>Wang, Ting</td>
<td>Completed Program</td>
<td>Investigation of Optical Properties of Nanostructured Transparent Conducting Oxides</td>
</tr>
<tr>
<td>573</td>
<td>Radovanovic, Pavle</td>
<td>Sabergharesou, Tahereh</td>
<td>Completed Program</td>
<td>Modeling Photoluminescence Decay Dynamics in Nanocrystals</td>
</tr>
<tr>
<td>574</td>
<td>Radovanovic, Pavle</td>
<td>Fernandes, Brian Leal</td>
<td>Completed Program</td>
<td>Probing the Electronic and Magnetic Properties of Transparent Semiconductor Nanowires Using X-Ray Absorption Spectroscopic Methods</td>
</tr>
<tr>
<td>575</td>
<td>Radovanovic, Pavle</td>
<td>Hegde, Manu</td>
<td>Completed Program</td>
<td>Manipulation of Electronic Band Structure by Doping Colloidal Gallium Oxide Nanocrystals and its Impact on Photocatalysis</td>
</tr>
<tr>
<td>576</td>
<td>Radovanovic, Pavle</td>
<td>Jin, Susi</td>
<td>Completed Program</td>
<td>Modulating Optical and Photocatalytic Properties of Transparent Metal Oxide Nanostructures via Defect Engineering</td>
</tr>
<tr>
<td>No</td>
<td>Name</td>
<td>Collaborator</td>
<td>Program Completion</td>
<td>Description</td>
</tr>
<tr>
<td>-----</td>
<td>---------------------------</td>
<td>--------------</td>
<td>--------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>579</td>
<td>Radovanovic, Pavle</td>
<td>Wang, Yunyan</td>
<td>Completed Program</td>
<td>Studies of the Growth Conditions, Plasmonic and Magnetoplasmonic Properties of Semiconductor Nanostructures</td>
</tr>
<tr>
<td>580</td>
<td>Radovanovic, Pavle</td>
<td>Fang, Hanbing</td>
<td>Completed Program</td>
<td>Manipulation of the Plasmonic Properties of n-Type Doped Colloidal Indium Oxide Nanocrystals</td>
</tr>
<tr>
<td>581</td>
<td>Radovanovic, Pavle</td>
<td>Howsaw, Enas Abdulrahman</td>
<td>Completed Program</td>
<td>Casting Shadow on the Photocatalytic Activity of Plasmonic Antimony Doped Tin Oxide Nanoparticles in Degrading Rhodamine 590</td>
</tr>
<tr>
<td>582</td>
<td>Ramahi, Omar</td>
<td>Ren, Zhao</td>
<td>Completed Program</td>
<td>Microwave Near-Field Probes to Detect Electrically Small Particles</td>
</tr>
<tr>
<td>583</td>
<td>Ramahi, Omar</td>
<td>Alqaht, Abdulaziz</td>
<td>Completed Program</td>
<td>Electrically Small Probe for Near-field Detection Applications</td>
</tr>
<tr>
<td>584</td>
<td>Ramahi, Omar</td>
<td>Albishi, Ali Mohammed</td>
<td>Completed Program</td>
<td>Ultrasensitive Microwave Near-Field Sensors for Detection, Imaging, and Material Characterization</td>
</tr>
<tr>
<td>585</td>
<td>Ramahi, Omar</td>
<td>Almoneef, Thamer</td>
<td>Completed Program</td>
<td>Electromagnetic Energy Transduction Using Metamaterials and Antennas</td>
</tr>
<tr>
<td>586</td>
<td>Ramahi, Omar</td>
<td>AlShareef, Mohammed</td>
<td>Completed Program</td>
<td>Electrically Small Particles for Energy Harvesting in the Infrared and Microwave Regimes</td>
</tr>
<tr>
<td>587</td>
<td>Ramahi, Omar</td>
<td>El Badawe, Mohamed</td>
<td>Completed Program</td>
<td>Metasurfaces for Antennas, Energy Harvesting, and Imaging</td>
</tr>
<tr>
<td>588</td>
<td>Ramahi, Omar</td>
<td>Ali, Abdulbaset</td>
<td>Completed Program</td>
<td>Intelligent Microwave Detection of Surface and Sub-Surface Anomalies</td>
</tr>
<tr>
<td>589</td>
<td>Ramahi, Omar</td>
<td>Ruphuy, Miguel Angel</td>
<td>Completed Program</td>
<td>Electrically Thin Lenses and Reflectors</td>
</tr>
<tr>
<td>590</td>
<td>Ramahi, Omar</td>
<td>Naosaba, Humayra</td>
<td>Completed Program</td>
<td>Negative Material Inspired Microwave Water Heating System</td>
</tr>
<tr>
<td>591</td>
<td>Ramahi, Omar</td>
<td>Aldosari, Mohammed</td>
<td>Completed Program</td>
<td>Wideband Rectenna System for Microwave Power Transfer</td>
</tr>
<tr>
<td>592</td>
<td>Rempel, Garry L</td>
<td>Liu, Weihang</td>
<td>Completed Program</td>
<td>Synthesis and Characterization of Poly-(Methyl Methacrylate) Nanoparticles with Ultrasound Assistance</td>
</tr>
<tr>
<td>593</td>
<td>Rosenberg, Catherine</td>
<td>Srikantha, Pirathayini</td>
<td>Completed Program</td>
<td>Impact of Elasticity in Domestic Appliances on Aggregate Residential Power Demands</td>
</tr>
<tr>
<td>#</td>
<td>Last Name, First Name</td>
<td>Last Name, First Name</td>
<td>Program Status</td>
<td>Title</td>
</tr>
<tr>
<td>----</td>
<td>----------------------------</td>
<td>-----------------------------------</td>
<td>------------------</td>
<td>---------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>594</td>
<td>Rosenberg, Catherine</td>
<td>Fooladivanda, Dariush</td>
<td>Completed Program</td>
<td>Comparison Between Static and Dynamic Modeling Approaches for Heterogeneous Cellular Networks</td>
</tr>
<tr>
<td>595</td>
<td>Rosenberg, Catherine</td>
<td>Ghimire, Jagadish</td>
<td>Completed Program</td>
<td>Heterogeneous Cellular Networks: From Resource Allocation to User Association</td>
</tr>
<tr>
<td>596</td>
<td>Rosenberg, Catherine</td>
<td>Meboob, Nafeesa</td>
<td>Completed Program</td>
<td>Smart Charging of Plug-in Electric Vehicles in Distribution Systems Considering Uncertainties</td>
</tr>
<tr>
<td>597</td>
<td>Rosenberg, Catherine</td>
<td>Xu, Zikun</td>
<td>Completed Program</td>
<td>A Design of Theft Detection Framework for Smart Grid</td>
</tr>
<tr>
<td>598</td>
<td>Rosenberg, Catherine</td>
<td>Mosharrafdehkordi, Sajjad</td>
<td>Completed Program</td>
<td>Planning for Small Cells in a Cellular Network</td>
</tr>
<tr>
<td>599</td>
<td>Rosenberg, Catherine</td>
<td>Barjesteh, Nasser</td>
<td>Completed Program</td>
<td>Duality Relations in Finite Queueing Models</td>
</tr>
<tr>
<td>600</td>
<td>Rowlands, Ian H</td>
<td>Shulist, Julia</td>
<td>Completed Program</td>
<td>Investigating the Relationship Between Householder’s Electricity Consumption and Engagement With Feedback</td>
</tr>
<tr>
<td>601</td>
<td>Rowlands, Ian H</td>
<td>Goody, Mark</td>
<td>Completed Program</td>
<td>Household Decision-Making Dynamics Associated with the Adoption of High-Involvement Renewable Energy Technologies: A Case Study of Consumer Experiences in the Adoption of Residential Ground Source Heat Pump Systems in Rural Southwestern Ontario (Canada)</td>
</tr>
<tr>
<td>602</td>
<td>Rowlands, Ian H</td>
<td>Bale, Andrea</td>
<td>Completed Program</td>
<td>Home Energy Coach Program: Lessons Learned From a Pilot Study in Waterloo Region, Ontario</td>
</tr>
<tr>
<td>603</td>
<td>Rowlands, Ian H</td>
<td>Chlobowski, Andrzej</td>
<td>Completed Program</td>
<td>Influence of Trust Concerns and Benefits of Visibility on Participation in Green Electricity Programs: A Case-Study of Residential Solar-PV Systems in Ontario</td>
</tr>
<tr>
<td>605</td>
<td>Rowlands, Ian H</td>
<td>Pizarro Pinochet, Jose Cristobal</td>
<td>Completed Program</td>
<td>Feathered Roots and Migratory Routes: Latin American Immigrants and Birds</td>
</tr>
<tr>
<td>606</td>
<td>Rowlands, Ian H</td>
<td>Belanger, Nicholas</td>
<td>Completed Program</td>
<td>A Canadian Smart Grid Pilot Project in Transition: A Case Study of Heat for Less</td>
</tr>
<tr>
<td>607</td>
<td>Saari, Rebecca Kaarina</td>
<td>Nasir, Filzah</td>
<td>Completed Program</td>
<td>Integration of Environmental Costs in Ontario’s Pavement Management Systems</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Completed Program</td>
<td>Project Description</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>---------------------------</td>
<td>------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>608</td>
<td>Salama, Magdy</td>
<td>Alhazmi, Yassir</td>
<td>Planning Model for Implementing Electric Vehicle Charging Infrastructure in Distribution System</td>
<td></td>
</tr>
<tr>
<td>609</td>
<td>Salama, Magdy</td>
<td>Hassen, Rania Khairy Mohammed</td>
<td>Local Phase Coherence Measurement for Image Analysis and Processing</td>
<td></td>
</tr>
<tr>
<td>610</td>
<td>Salama, Magdy</td>
<td>Saad, John Farid Hanna</td>
<td>Interactive Real Time Deep Brain Stimulation System</td>
<td></td>
</tr>
<tr>
<td>611</td>
<td>Salama, Magdy</td>
<td>Alsumaiti, Ameena Saad Sultan S.</td>
<td>Power Generation Shortage in Developing Countries: Causes, Challenges, and Solutions</td>
<td></td>
</tr>
<tr>
<td>612</td>
<td>Salama, Magdy</td>
<td>Ibrahim, Michael Naiem Abdelmassih</td>
<td>Using Wireless Communications To Enable Decentralized Analysis and Control of Smart Distribution Systems</td>
<td></td>
</tr>
<tr>
<td>613</td>
<td>Salama, Magdy</td>
<td>Aldhubaib, Hani Abdullah M.</td>
<td>Reliability Analysis of Power Systems Considering the Effect of Weather Variability</td>
<td></td>
</tr>
<tr>
<td>614</td>
<td>Salama, Magdy</td>
<td>ElNozahy, Mohamed Saad</td>
<td>Accommodating a High Penetration of PHEVs and PV Electricity in Residential Distribution Systems</td>
<td></td>
</tr>
<tr>
<td>616</td>
<td>Salama, Magdy</td>
<td>Eltantawy, Ayman Bahgat Abdelazim Ibrahim</td>
<td>Online Assessment of Distributed Generation Connection for Smart Grid</td>
<td></td>
</tr>
<tr>
<td>617</td>
<td>Salama, Magdy</td>
<td>Daif, Sally Rotby Nashed</td>
<td>Condition Assessment of Power Transformer Winding Insulation Based on Partial Discharge Detection</td>
<td></td>
</tr>
<tr>
<td>618</td>
<td>Salama, Magdy</td>
<td>Rajaei, Nazila</td>
<td>Fault Current Management in Power Systems Using Inverter Based Distributed Generators</td>
<td></td>
</tr>
<tr>
<td>619</td>
<td>Salama, Magdy</td>
<td>Labrini, Haytham</td>
<td>Graph-Based Model for Distribution Systems: Application to Planning Problem</td>
<td></td>
</tr>
<tr>
<td>620</td>
<td>Salama, Magdy</td>
<td>Mostafa, Haytham Aly Atteya Mohamed</td>
<td>Zonal Energy Management and Optimization System (ZEMOS) for Smart Grid Applications</td>
<td></td>
</tr>
<tr>
<td>621</td>
<td>Salama, Magdy</td>
<td>Mansour, Michael Mounir Sobhy</td>
<td>Smart Distribution Power Systems Reconfiguration Using a Novel Multi-Agent Approach</td>
<td></td>
</tr>
<tr>
<td>622</td>
<td>Salama, Magdy</td>
<td>Nassar, Mohammed Elsayed Nassar Abdo</td>
<td>Microgrid Enabling Towards the Implementation of Smart Grids</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Name2</td>
<td>Completed Program</td>
<td>Project Description</td>
</tr>
<tr>
<td>-----</td>
<td>------------------</td>
<td>---------------------------</td>
<td>---------------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>623</td>
<td>Salama, Magdy</td>
<td>Ahmed, Haytham Mohamed</td>
<td>Completed Program</td>
<td>Optimal Planning and Operation of AC-DC Hybrid Distribution Systems</td>
</tr>
<tr>
<td>624</td>
<td>Salehian, Armaghan</td>
<td>Ibrahimim, Mohammed</td>
<td>Completed Program</td>
<td>Design, Modelling and Fabrication of a Hybrid Energy Harvester</td>
</tr>
<tr>
<td>625</td>
<td>Salehian, Armaghan</td>
<td>Lao, Steven Baron</td>
<td>Completed Program</td>
<td>Wearable Tactile Pressure Sensing for Compression Garments and Control of Active Compression Devices</td>
</tr>
<tr>
<td>626</td>
<td>Salehian, Armaghan</td>
<td>Martin, Blake</td>
<td>Completed Program</td>
<td>Continuum Modelling and Vibration Analysis of String-Harnessed Structures</td>
</tr>
<tr>
<td>627</td>
<td>Salehian, Armaghan</td>
<td>Zarabi, Sid</td>
<td>Completed Program</td>
<td>Design and Development of a Self-contained and Non-Invasive Integrated System for Electricity Monitoring Applications</td>
</tr>
<tr>
<td>628</td>
<td>Salehian, Armaghan</td>
<td>Chan, Gary</td>
<td>Completed Program</td>
<td>Design and Testing of a GNSS Reflectometry CubeSat Payload for Monitoring Climate Change</td>
</tr>
<tr>
<td>629</td>
<td>Salehian, Armaghan</td>
<td>Bath, Dilpreet Singh</td>
<td>Completed Program</td>
<td>Low-Frequency Piezoelectric Energy Harvester with Novel 3D Folded Zigzag Design and High Power Density</td>
</tr>
<tr>
<td>630</td>
<td>Salehian, Armaghan</td>
<td>Pollock, Tim</td>
<td>Completed Program</td>
<td>Design, Modelling, Fabrication &amp; Testing of a Miniature Piezoelectric-Based EMF Energy Harvester</td>
</tr>
<tr>
<td>631</td>
<td>Salehian, Armaghan</td>
<td>Edher, Hamza</td>
<td>Completed Program</td>
<td>Design, Fabrication, and Testing of a Dielectric Elastomer Based Ambulatory Active Compression Device</td>
</tr>
<tr>
<td>632</td>
<td>Salehian, Armaghan</td>
<td>Fernandes, Egon</td>
<td>Completed Program</td>
<td>Design, Modelling, and Fabrication of a Low Frequency Piezoelectromagnetic Energy Harvester</td>
</tr>
<tr>
<td>633</td>
<td>Salehian, Armaghan</td>
<td>David, Salman</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>634</td>
<td>Sazonov, Andrei</td>
<td>Yang, Ruifeng</td>
<td>Completed Program</td>
<td>Energy Harvesting in Flexible and Semi-Transparent Hydrogenated Amorphous Silicon Solar Cells</td>
</tr>
<tr>
<td>635</td>
<td>Sazonov, Andrei</td>
<td>Zhang, Yuan</td>
<td>Completed Program</td>
<td>SiGe/Si Heterojunction Internal Photoemission Separate Absorption and Multiplication Avalanche Middle Wavelength Infrared Photodiode</td>
</tr>
<tr>
<td>636</td>
<td>Sazonov, Andrei</td>
<td>Khosropour, Alireza</td>
<td>Completed Program</td>
<td>Fabrication and Characterization of Microcrystalline Silicon Near Infrared Photodiode Detector Pixel Circuit on Glass Substrate for Large Area Electronics</td>
</tr>
<tr>
<td>637</td>
<td>Schneider, Gerald</td>
<td>Pezeshkpour, Pegah</td>
<td>Completed Program</td>
<td>Injection and Separation Evaluation for Microfluidic Protein and DNA Separation</td>
</tr>
<tr>
<td>Student ID</td>
<td>First Name</td>
<td>Last Name</td>
<td>Program</td>
<td>Title</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
<td>---------------</td>
<td>-------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>638</td>
<td>Sen,Anindya</td>
<td>Amery, Behnoush</td>
<td>Completed Program</td>
<td>Three Empirical Essays on Job Training, Income Support Programs, and Household Debt</td>
</tr>
<tr>
<td>639</td>
<td>Sen,Anindya</td>
<td>Memartolouie, Ghazal</td>
<td>Completed Program</td>
<td>Empirical Essays in Water and Electricity Use</td>
</tr>
<tr>
<td>640</td>
<td>Sen,Anindya</td>
<td>Zelaya, Mauricio Rene</td>
<td>Completed Program</td>
<td>The Role of Institutions on R&amp;D, FDI, and Economic Growth</td>
</tr>
<tr>
<td>641</td>
<td>Sen,Anindya</td>
<td>Ghaziaskar, Mohamad</td>
<td>Completed Program</td>
<td>Essays in Consumer Debt, Personal Saving Rate, and Household Insolvency in Canada</td>
</tr>
<tr>
<td>642</td>
<td>Sen,Anindya</td>
<td>Gao, Hang</td>
<td>Completed Program</td>
<td>Essays in Earnings, Academic Productivity, and School Competition</td>
</tr>
<tr>
<td>643</td>
<td>Sen,Anindya</td>
<td>Choi, Wai Hong</td>
<td>Completed Program</td>
<td>Essays on Competition in Energy Markets</td>
</tr>
<tr>
<td>644</td>
<td>Shen, Sherman</td>
<td>Zhou, Xinsheng</td>
<td>Completed Program</td>
<td>Low-Density Parity-Check Codes for Wireless Relay Networks</td>
</tr>
<tr>
<td>645</td>
<td>Shen, Sherman</td>
<td>Alsharif, Nizar H</td>
<td>Completed Program</td>
<td>Connectivity-Aware Routing in Vehicular Ad Hoc Networks</td>
</tr>
<tr>
<td>646</td>
<td>Shen, Sherman</td>
<td>Liu, Yongkang</td>
<td>Completed Program</td>
<td>Leveraging Cognitive Radio Networks Using Heterogeneous Wireless Channels</td>
</tr>
<tr>
<td>647</td>
<td>Shen, Sherman</td>
<td>Zhang, Xiaoxia</td>
<td>Completed Program</td>
<td>Cooperative Relaying and Resource Allocation in Future-Generation Cellular Networks</td>
</tr>
<tr>
<td>648</td>
<td>Shen, Sherman</td>
<td>Barua, Mrinmoy</td>
<td>Completed Program</td>
<td>Secure Data Aggregation and Access Control in Cloud Assisted eHealth Care System</td>
</tr>
<tr>
<td>649</td>
<td>Shen, Sherman</td>
<td>Qiao, Jian</td>
<td>Completed Program</td>
<td>Enabling Millimeter Wave Communication for 5G Cellular Networks: MAC-Layer Perspective</td>
</tr>
<tr>
<td>650</td>
<td>Shen, Sherman</td>
<td>Taha, Sanaa Mohamed Ahmed</td>
<td>Completed Program</td>
<td>Securing IP Mobility Management for Vehicular Ad Hoc Networks</td>
</tr>
<tr>
<td>651</td>
<td>Shen, Sherman</td>
<td>Liang, Xiaohui</td>
<td>Completed Program</td>
<td>Security and Privacy Preservation in Mobile Social Networks</td>
</tr>
<tr>
<td>652</td>
<td>Shen, Sherman</td>
<td>Shao, Jianqiao</td>
<td>Completed Program</td>
<td>A CSMA/CA Based MAC Layer Solution for Inter-WBAN Interference and Starvation</td>
</tr>
<tr>
<td>653</td>
<td>Shen, Sherman</td>
<td>Alam, Md Shamsul</td>
<td>Completed Program</td>
<td>Modeling and Performance Analysis of Relay-Based Cooperative OFDMA Networks</td>
</tr>
<tr>
<td>Student ID</td>
<td>Sponsor</td>
<td>Completed Program</td>
<td>Project Title</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>---------</td>
<td>-------------------</td>
<td>---------------</td>
<td></td>
</tr>
<tr>
<td>654</td>
<td>Shen, Sherman</td>
<td>Lu, Ning</td>
<td>Completed Program</td>
<td>Scaling Laws for Vehicular Networks</td>
</tr>
<tr>
<td>655</td>
<td>Shen, Sherman</td>
<td>Wang, Miao</td>
<td>Completed Program</td>
<td>Capacity Analysis in Different Systems Exploiting Mobility of VANETs</td>
</tr>
<tr>
<td>656</td>
<td>Shen, Sherman</td>
<td>Zheng, Zhongming</td>
<td>Completed Program</td>
<td>Resource Management in Green Wireless Communication Networks</td>
</tr>
<tr>
<td>657</td>
<td>Shen, Sherman</td>
<td>Shen, Qinghua</td>
<td>Completed Program</td>
<td>Resource Management in E-Health Systems</td>
</tr>
<tr>
<td>658</td>
<td>Shen, Sherman</td>
<td>Zhang, Ran</td>
<td>Completed Program</td>
<td>Radio Resource Management in LTE-Advanced Systems with Carrier Aggregation</td>
</tr>
<tr>
<td>659</td>
<td>Shen, Sherman</td>
<td>Tharaperiya Gamage, Amila Pradeep Kumara</td>
<td>Completed Program</td>
<td>Resource Allocation for Heterogeneous Wireless Networks</td>
</tr>
<tr>
<td>660</td>
<td>Shen, Sherman</td>
<td>He, Miao</td>
<td>Completed Program</td>
<td>Privacy-Preserving Multi-Quality Charging in V2G Network</td>
</tr>
<tr>
<td>661</td>
<td>Shen, Sherman</td>
<td>Zhang, Kuan</td>
<td>Completed Program</td>
<td>Security and Privacy for Mobile Social Networks</td>
</tr>
<tr>
<td>662</td>
<td>Shen, Sherman</td>
<td>Cheng, Nan</td>
<td>Completed Program</td>
<td>Opportunistic Spectrum Utilization for Vehicular Communication Networks</td>
</tr>
<tr>
<td>663</td>
<td>Shen, Sherman</td>
<td>Pei, Chengcheng</td>
<td>Completed Program</td>
<td>Channel-Based Physical Layer Authentication</td>
</tr>
<tr>
<td>664</td>
<td>Shen, Sherman</td>
<td>Abdallah, Asmaa</td>
<td>Completed Program</td>
<td>Security and Privacy in Smart Grid</td>
</tr>
<tr>
<td>665</td>
<td>Shen, Sherman</td>
<td>Ni, Jianbing</td>
<td>Completed Program</td>
<td>Security and Privacy Preservation in Mobile Crowdsensing</td>
</tr>
<tr>
<td>666</td>
<td>Simakov, David</td>
<td>Sun, Duo</td>
<td>Completed Program</td>
<td>Simulation-Based Analysis of a Sabatier Reactor for Conversion of CO2 into Renewable Natural Gas</td>
</tr>
<tr>
<td>667</td>
<td>Simakov, David</td>
<td>Khan, Faisal Mohamed</td>
<td>Completed Program</td>
<td>Transition Metal Carbides for Thermocatalytic Conversion of Carbon Dioxide via Reverse Water Gas Shift and Sabatier Reactions</td>
</tr>
<tr>
<td>668</td>
<td>Sivoththaman, Siva</td>
<td>Baldus-Jeursen, Christopher J</td>
<td>Completed Program</td>
<td>Heterojunction Photovoltaic Devices With Rapid Thermally Annealed Crystalline Thin Films</td>
</tr>
<tr>
<td>No.</td>
<td>Name of Student</td>
<td>Name of Mentor</td>
<td>Status</td>
<td>Title of Project</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>----------------</td>
<td>--------</td>
<td>-----------------</td>
</tr>
<tr>
<td>669</td>
<td>Sivoththaman, Siva</td>
<td>Samadzadeh Tarighat, Roohollah</td>
<td>Completed Program</td>
<td>A Novel Buried-Emitter Photovoltaic Cell for High Efficiency Energy Conversion</td>
</tr>
<tr>
<td>670</td>
<td>Sivoththaman, Siva</td>
<td>Esfandiarpour, Behzad</td>
<td>Completed Program</td>
<td>Integration of Nanostructures and Quantum Dots Into Spherical Silicon Solar Cells</td>
</tr>
<tr>
<td>671</td>
<td>Sivoththaman, Siva</td>
<td>Zhou, Manglai</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>672</td>
<td>Sivoththaman, Siva</td>
<td>Mohammad Sadeghi Jahed, Navid</td>
<td>Completed Program</td>
<td>Heterojunction Quantum Dot Solar Cells</td>
</tr>
<tr>
<td>673</td>
<td>Sivoththaman, Siva</td>
<td>Janfeshan, Bita</td>
<td>Completed Program</td>
<td>Development of Zinc Oxide Nanowires and Quantum dot Incorporation for Photovoltaic Applications</td>
</tr>
<tr>
<td>674</td>
<td>Sivoththaman, Siva</td>
<td>Mahmoudysepehr, Mohsen</td>
<td>Completed Program</td>
<td>Enhanced Ultra-Thin Film Nanocrystalline Silicon Photovoltaic Device Architectures</td>
</tr>
<tr>
<td>675</td>
<td>Sivoththaman, Siva</td>
<td>Moradi, Maziar</td>
<td>Completed Program</td>
<td>Polycrystalline Silicon Capacitive MEMS Strain Sensor for Structural Health Monitoring of Wind Turbines</td>
</tr>
<tr>
<td>676</td>
<td>Sivoththaman, Siva</td>
<td>Dashmiz, Shadi</td>
<td>Completed Program</td>
<td>Quantum Dots for Intermediate Band in Solar Cells</td>
</tr>
<tr>
<td>677</td>
<td>Sivoththaman, Siva</td>
<td>Tian, Lin</td>
<td>Completed Program</td>
<td>Development of Advanced Thin Films by PECVD for Photovoltaic Applications</td>
</tr>
<tr>
<td>678</td>
<td>Sivoththaman, Siva</td>
<td>Gao, Zhen</td>
<td>Completed Program</td>
<td>Silicon Based Heterojunction Solar Cells and Photodetectors</td>
</tr>
<tr>
<td>679</td>
<td>Sivoththaman, Siva</td>
<td>Liu, Fang</td>
<td>Completed Program</td>
<td>Separation and Purification of Valuable Chemicals from Simulated Hydrothermal Conversion Product Solution</td>
</tr>
<tr>
<td>680</td>
<td>Straube, John F</td>
<td>Vance, Emily Ruth</td>
<td>Completed Program</td>
<td>Development of a Design-Phase Assessment Tool for Double Façades in Retrofit Applications</td>
</tr>
<tr>
<td>681</td>
<td>Straube, John F</td>
<td>Ricketts, Lorne</td>
<td>Completed Program</td>
<td>Airflow in High-Rise Multi-Unit Residential Buildings</td>
</tr>
<tr>
<td>682</td>
<td>Straube, John F</td>
<td>Simonji, Joseph Paul</td>
<td>Completed Program</td>
<td>Development and Commissioning of a Large-scale Rotatable Guarded Hot Plate Apparatus</td>
</tr>
<tr>
<td>683</td>
<td>Straube, John F</td>
<td>Trainor, Trevor Michael</td>
<td>Completed Program</td>
<td>The Hygrothermal Performance of Exterior Insulated Wall Systems</td>
</tr>
<tr>
<td>684</td>
<td>Tan, Zhongchao</td>
<td>Alas, David</td>
<td>Completed Program</td>
<td>The Effects of Building Construction and HVAC Systems in Ontario on the Indoor Concentration of Airborne PM from</td>
</tr>
<tr>
<td>#</td>
<td>Name</td>
<td>Program Title</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>-----------------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>685</td>
<td>Tan,Zhongchao</td>
<td>Outdoor Origin, and Related Health Impacts and Cost Savings</td>
<td>Yu,Hesheng</td>
<td></td>
</tr>
<tr>
<td>686</td>
<td>Tan,Zhongchao</td>
<td>Absorption of Nitric Oxide From Flue Gas Using Ammoniacal Cobalt (II) Solutions</td>
<td>Yan,Chao</td>
<td></td>
</tr>
<tr>
<td>687</td>
<td>Tan,Zhongchao</td>
<td>Granular Filtration of Airborne NaCl Nanoparticles and Carbon Nanotubes</td>
<td>Tan,Ben Kinh</td>
<td></td>
</tr>
<tr>
<td>688</td>
<td>Tan,Zhongchao</td>
<td>Laboratory Evaluation of Low to Medium Cost Particle Sensors</td>
<td>Givehchi,Raheleh</td>
<td></td>
</tr>
<tr>
<td>689</td>
<td>Tan,Zhongchao</td>
<td>Filtration of NaCl and WOx Nanoparticles Using Wire Screens and Nanofibrous Filters</td>
<td>Min,Jing</td>
<td></td>
</tr>
<tr>
<td>690</td>
<td>Tan,Zhongchao</td>
<td>Quantifying the Effects of Winter Weather and Road Maintenance on Emissions and Fuel Consumptions</td>
<td>Bkari,Wala</td>
<td></td>
</tr>
<tr>
<td>691</td>
<td>Tan,Zhongchao</td>
<td>Modeling Nanoparticle Generation in a Corona Charger</td>
<td>Sung,Teresa</td>
<td></td>
</tr>
<tr>
<td>692</td>
<td>Tighe,Susan L</td>
<td>Oil Adsorption Performance and Efficiency Study on Novel Silane Functionalized Graphene Polyurethane Sponge</td>
<td>Konarski,Karolina</td>
<td></td>
</tr>
<tr>
<td>693</td>
<td>Tighe,Susan L</td>
<td>Mitigation of Climate Change Impacts on Runway Friction Kuujjuaq Airport</td>
<td>Korczak,Richard Christopher</td>
<td></td>
</tr>
<tr>
<td>694</td>
<td>Tighe,Susan L</td>
<td>Utilizing the Canadian Long-Term Pavement Performance (C-LTPP) Database for Asphalt Dynamic Modulus Prediction</td>
<td>Boone,Jonathan Nathan</td>
<td></td>
</tr>
<tr>
<td>696</td>
<td>Tighe,Susan L</td>
<td>Precast Concrete Inlay Panels: Rehabilitation Strategy for High-Volume Highways in Ontario</td>
<td>Hegazi,Mohamed</td>
<td></td>
</tr>
<tr>
<td>697</td>
<td>Tighe,Susan L</td>
<td>Evaluation of Cold Weather Performance of Rubber Modified Asphalt Placed in Ontario</td>
<td>Alyami,Zaid</td>
<td></td>
</tr>
<tr>
<td>698</td>
<td>Tighe,Susan L</td>
<td>Asset Valuation: A Performance Measure for Comprehensive Infrastructure Asset Management</td>
<td>Northmore,Andrew Bruce</td>
<td></td>
</tr>
<tr>
<td>#</td>
<td>Authors</td>
<td>Project Title</td>
<td>Status</td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-----------------</td>
<td></td>
</tr>
<tr>
<td>699</td>
<td>Tighe,Susan L</td>
<td>El-Hakim,Mohab</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>700</td>
<td>Tighe,Susan L</td>
<td>A Structural and Economic Evaluation of Perpetual Pavements: A Canadian Perspective</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>701</td>
<td>Tighe,Susan L</td>
<td>Comparing Cold In-Place Recycling (CIR) and Cold In-Place Recycling with Expanded Asphalt Mixture (CIREAM)</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>702</td>
<td>Tighe,Susan L</td>
<td>Development of Empirical and Mechanistic Empirical Performance Models at Project and Network Levels</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>703</td>
<td>Tighe,Susan L</td>
<td>Local Calibration of AASHTOWare Using Ontario Pavement Management System Data PMS2</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>704</td>
<td>Tighe,Susan L</td>
<td>Evaluating Unbonded Concrete Overlay for Usage on Ontario Residential Steets</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>705</td>
<td>Tighe,Susan L</td>
<td>Effect of Reclaimed Asphalt Pavement on Ontario hot mix Asphalt Performance</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>706</td>
<td>Tighe,Susan L</td>
<td>Innovative Evaluation of Crumb Rubber Asphalt and Recycled Asphalt Pavement</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>707</td>
<td>Tighe,Susan L</td>
<td>Development of Performance Models and Maintenance Standards of Urban Pavements for Network Management</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>708</td>
<td>Tighe,Susan L</td>
<td>Evaluation of Structural Dome Formwork Systems in Concrete Pavement Applications</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>709</td>
<td>Tighe,Susan L</td>
<td>Nanotechnology Applied in the Design of the Next Generation of Canadian Concrete Pavement Surfaces</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>710</td>
<td>Tighe,Susan L</td>
<td>Development of a Framework for Monitoring Long Term Performance of Perpetual Pavements</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>711</td>
<td>Tighe,Susan L</td>
<td>Development of Durability Performance Related Test Methods for Pervious Concrete Pavement</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>712</td>
<td>Tighe,Susan L</td>
<td>Improving Airport Runway Braking Analysis Through Innovative Modeling</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>713</td>
<td>Tighe,Susan L</td>
<td>Developing Cost-Effective Pavement Maintenance and Rehabilitation Schedules: Application of MEPDG-Based Distress Models and key Performance Index</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>714</td>
<td>Tighe,Susan L</td>
<td>Evaluation of x-ray Computed Tomography and Finite Element Models for Fatigue Experimental hot mix Asphalt Characterization</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Forename</td>
<td>Surname</td>
<td>Program Completed</td>
<td>Project Title</td>
</tr>
<tr>
<td>-----</td>
<td>----------</td>
<td>-----------------</td>
<td>-------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>714</td>
<td>Tighe, S</td>
<td>Varamini, Sina</td>
<td>Completed Program</td>
<td>Technical, Economic and Environmental Evaluation of Warm Mix Asphalt and Coloured Asphalt for Usage in Canada</td>
</tr>
<tr>
<td>716</td>
<td>Tighe, S</td>
<td>Averyanov, Sergey</td>
<td>Completed Program</td>
<td>Analysis of Construction Experience of Using Lightweight Cellular Concrete as a Subbase Material</td>
</tr>
<tr>
<td>717</td>
<td>Varin, R</td>
<td>Parviz, Roozbeh</td>
<td>Completed Program</td>
<td>Nanostructured Light Metal Hydrides Based on Li, Al, Na, B and N for Solid State Hydrogen Storage</td>
</tr>
<tr>
<td>718</td>
<td>Varin, R</td>
<td>Shirani Bidabadi, Amirreza</td>
<td>Completed Program</td>
<td>Nanostructured TM-Boron Based Hydrides for Solid State Hydrogen Storage (TM-Transition Metal)</td>
</tr>
<tr>
<td>719</td>
<td>Weber, O</td>
<td>Hunt, Chelsie Marie</td>
<td>Completed Program</td>
<td>Divesting and Re-Investing in a Greener Future for Canada</td>
</tr>
<tr>
<td>720</td>
<td>Weber, O</td>
<td>Fang, Tianjiao</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>721</td>
<td>Weber, O</td>
<td>Lin, Xiaoyu</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>722</td>
<td>Weber, O</td>
<td>Saraiva de Almeida, Victor Hugo</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>723</td>
<td>Weber, O</td>
<td>Acheta, Emmanuel Ojakol</td>
<td>Completed Program</td>
<td>Project Finance Contribution to Environmental and Social Sustainability. An Inquiry into the Implementation of the Equator Principles</td>
</tr>
<tr>
<td>724</td>
<td>Weber, O</td>
<td>Raj, Arun</td>
<td>Completed Program</td>
<td>The Relation Between Corporate Water Risk, Water Accounting and Financial Performance of Metal Mining Firms</td>
</tr>
<tr>
<td>725</td>
<td>Weber, O</td>
<td>Athari, Sara</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>726</td>
<td>Weber, O</td>
<td>Felix, Jason</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>727</td>
<td>Weber, O</td>
<td>Dumoe, Jonah Slunteh</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Advisor</td>
<td>Completed Program</td>
<td>Title</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>---------</td>
<td>-------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>728</td>
<td>Weber, Olaf</td>
<td>Saunders, Grace Helena</td>
<td>Completed Program</td>
<td>Accounting for Risks: Identifying Water Risks in the Food and Beverage Industry Using an Ecosystem Services Benchmarking Framework</td>
</tr>
<tr>
<td>729</td>
<td>Weber, Olaf</td>
<td>Oni, Olauwu</td>
<td>Completed Program</td>
<td>Banking on Financial Sector Sustainability Regulations</td>
</tr>
<tr>
<td>730</td>
<td>Weber, Olaf</td>
<td>Adeniyi, Ifedayo</td>
<td>Completed Program</td>
<td>An Assessment of Voluntary Codes of Conduct in the Financial Sector - A Case Study of the GABV, UNEP-FI and UNPRI</td>
</tr>
<tr>
<td>731</td>
<td>Weber, Olaf</td>
<td>Kholodova, Olena</td>
<td>Completed Program</td>
<td>Climate Change and the Canadian Financial Services Sector</td>
</tr>
<tr>
<td>732</td>
<td>Weber, Olaf</td>
<td>Cetinkaya, Dilan</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td>733</td>
<td>Wei, Lan</td>
<td>Abdelwahed, Amr Mohamed Samir Tosson</td>
<td>Completed Program</td>
<td>Addressing the RRAM Reliability and Radiation Soft-Errors in the Memory Systems</td>
</tr>
<tr>
<td>734</td>
<td>Wei, Lan</td>
<td>Zhang, Hao</td>
<td>Completed Program</td>
<td>Physics Based Virtual Source Compact Model of Gallium-Nitride High Electron Mobility Transistors</td>
</tr>
<tr>
<td>735</td>
<td>Wen, John Z.</td>
<td>Ahmadzadegan, Amir</td>
<td>Completed Program</td>
<td>Molecular Simulation of Chemically Reacting Flows Inside Micro/Nano-Channels</td>
</tr>
<tr>
<td>736</td>
<td>Wen, John Z.</td>
<td>Qi, Huixiu</td>
<td>Completed Program</td>
<td>Catalytic Combustion and NO Formation of Natural Gas</td>
</tr>
<tr>
<td>737</td>
<td>Wen, John Z.</td>
<td>Zhou, Qiong</td>
<td>Completed Program</td>
<td>Synthesis of Vertically-Aligned Zinc Oxide Nanowires and Their Applications as Photocatalysts</td>
</tr>
<tr>
<td>738</td>
<td>Wen, John Z.</td>
<td>Pan, Kang</td>
<td>Completed Program</td>
<td>Experimental Studies on Iron-Based Catalytic Combustion of Natural Gas</td>
</tr>
<tr>
<td>739</td>
<td>Wen, John Z.</td>
<td>Lesergent, Lauren</td>
<td>Completed Program</td>
<td>Tailoring the Ignition and Reaction Properties of Cu20 Thermite Nanolaminates</td>
</tr>
<tr>
<td>740</td>
<td>Wen, John Z.</td>
<td>Shokati, Ali Akbar</td>
<td>Completed Program</td>
<td>Dissimilar Joining of Carbon/Carbon Composites to Ti6A14V and Copper by Reactive Resistance Spot Welding</td>
</tr>
<tr>
<td>741</td>
<td>Wright, John L</td>
<td>Si Tu, Tian You</td>
<td>Completed Program</td>
<td>Development of a Modeling Software Tool to Optimize Energy Performance of Medium-Size Office Buildings at the Early Design Stage</td>
</tr>
<tr>
<td>No.</td>
<td>Name 1</td>
<td>Name 2</td>
<td>Status</td>
<td>Title</td>
</tr>
<tr>
<td>-----</td>
<td>--------------</td>
<td>-----------------</td>
<td>---------------</td>
<td>-------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>742</td>
<td>Wright, Derek</td>
<td>Imtiaz, Sakib</td>
<td>Completed</td>
<td>Analysis of Microcontroller Embedded SRAMs for Applications in Physical Unclonable Functions</td>
</tr>
<tr>
<td>743</td>
<td>Young, M Moo</td>
<td>Aghamohseni, Hengameh</td>
<td>Completed</td>
<td>Effect of Culture Conditions on the Glycosylation Pattern of mAb</td>
</tr>
<tr>
<td>744</td>
<td>Young, Steve</td>
<td>Vasil, Jeremy</td>
<td>Completed</td>
<td></td>
</tr>
<tr>
<td>745</td>
<td>Young, Steve</td>
<td>Na, Yilun</td>
<td>Completed</td>
<td>Corporate Social Performance of Firms in Conflict Mineral Global Supply Chains</td>
</tr>
<tr>
<td>746</td>
<td>Young, Steve</td>
<td>Fernandes, Shannon Rebecca</td>
<td>Completed</td>
<td>Deep Supply-Chain Engagement in Conflict Minerals</td>
</tr>
<tr>
<td>747</td>
<td>Young, Steve</td>
<td>Nlandu Bayekula, Jean Oscar</td>
<td>Completed</td>
<td>Tracing Conflict Minerals in the Great Lakes Region of Africa: Drivers, Barriers and Opportunities</td>
</tr>
<tr>
<td>748</td>
<td>Young, Steve</td>
<td>Li, Jingxi</td>
<td>Completed</td>
<td>Comparative Life Cycle Assessment of Single-Serve Coffee Packages in Ontario</td>
</tr>
<tr>
<td>749</td>
<td>Yu, Aiping</td>
<td>Ghannoum, AbdulRahman</td>
<td>Completed</td>
<td>Optical Properties of Lithiated Graphite in Relation to a Lithium Ion Battery Fiber Optic Sensor</td>
</tr>
<tr>
<td>750</td>
<td>Yu, Aiping</td>
<td>Kim, Brian Ki Hun</td>
<td>Completed</td>
<td>Development for Nickel Hydroxide/Oxide Composite for Applications in Next Generation Electrochemical Capacitors</td>
</tr>
<tr>
<td>751</td>
<td>Yu, Aiping</td>
<td>Jun, Yun-Seok</td>
<td>Completed</td>
<td>Development of Graphene-Based Electrically Conductive Polymer Nano-Composites</td>
</tr>
<tr>
<td>752</td>
<td>Yu, Aiping</td>
<td>Cumberland, Timothy Dexter Kim</td>
<td>Completed</td>
<td>Phosphoric Acid Doped Polybenzimidazoles-Based Membrane Electrode Assembly for a Highly Sensitive and Selective Acetone Gas Sensor</td>
</tr>
<tr>
<td>753</td>
<td>Zhao, Boxin</td>
<td>McDonald, Brendan Albert James</td>
<td>Completed</td>
<td>Pattern Transfer and Characterization of Biometric Micro-Structured Surfaces for Hydrophobic and Icephobic Applications</td>
</tr>
<tr>
<td>754</td>
<td>Zhao, Boxin</td>
<td>Trinidad, Ephraim Joshua</td>
<td>Completed</td>
<td>Evaluation of Hybrid Electrically Conductive Adhesives</td>
</tr>
<tr>
<td>755</td>
<td>Zhao, Boxin</td>
<td>Shahsavan, Hamed</td>
<td>Completed</td>
<td>Liquid Crystal Networks for Smart Biomimetic Micro/Nano Structured Adhesives</td>
</tr>
<tr>
<td>No.</td>
<td>Name(s)</td>
<td>Completed Program</td>
<td>Title</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>--------------------</td>
<td>-------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>756</td>
<td>Zhao, Boxin</td>
<td>Zhang, Wei</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Material and Surface Properties of Bio-Inspired Polydopamine and its Modified Polypyrrole Functional Nanocomposites</td>
<td></td>
</tr>
<tr>
<td>757</td>
<td>Zhao, Boxin</td>
<td>Liew, Kelvin Chia Wei</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fabrication and Characterization of Biomimetic Dry Adhesives Supported by Foam Backing Material</td>
<td></td>
</tr>
<tr>
<td>758</td>
<td>Zhao, Boxin</td>
<td>Neufeld, Ryan Alexander Epp</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Simulation-based Design of Temperature-responsive Nematic Elastomers</td>
<td></td>
</tr>
<tr>
<td>759</td>
<td>Zhao, Boxin</td>
<td>Meschi Amoli, Behnam</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of Advanced ECAs with Micro/Nano Hybrid Filler System: Filler Functionalization, Dispersion, and Conductivity Improvement</td>
<td></td>
</tr>
<tr>
<td>760</td>
<td>Zhao, Boxin</td>
<td>Gumfekar, Sarang</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Characterization of Silver-Polyaniline-Epoxy Conductive Adhesives</td>
<td></td>
</tr>
<tr>
<td>761</td>
<td>Zhao, Boxin</td>
<td>Pan, Zihe</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bio-Inspired Oleophobic/Conductive Micro/Nano Structures and Their Applications in Frozen Oil Adhesion Reduction</td>
<td></td>
</tr>
<tr>
<td>762</td>
<td>Zhuang, Weihua</td>
<td>Abboud, Khadige Hussein</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Node Cluster Stability in Vehicular ad hoc Networks</td>
<td></td>
</tr>
<tr>
<td>763</td>
<td>Zhuang, Weihua</td>
<td>Liang, Hao</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Resource Management in Delay Tolerant Networks and Smart Grid</td>
<td></td>
</tr>
<tr>
<td>764</td>
<td>Zhuang, Weihua</td>
<td>Gunawardena, Subodha Hettiachchi</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Voice Capacity and Data Response Time in Cognitive Radio Networks</td>
<td></td>
</tr>
<tr>
<td>765</td>
<td>Zhuang, Weihua</td>
<td>Mohammadizadeh, Neda</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cooperative End-to-End Congestion Control in Heterogeneous Wireless Networks</td>
<td></td>
</tr>
<tr>
<td>766</td>
<td>Zhuang, Weihua</td>
<td>Omar, Hassan Aboubakr</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Medium Access Control, Packet Routing, and Internet Gateway Placement in Vehicular Ad Hoc Networks</td>
<td></td>
</tr>
<tr>
<td>767</td>
<td>Zhuang, Weihua</td>
<td>Muhammad, Muhammad Ismail</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Radio Resource Management in a Heterogeneous Wireless Access Medium</td>
<td></td>
</tr>
<tr>
<td>768</td>
<td>Zhuang, Weihua</td>
<td>Bharati, Sailesh</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Link-Layer Cooperative Communication in Vehicular Networks</td>
<td></td>
</tr>
<tr>
<td>769</td>
<td>Zhuang, Weihua</td>
<td>Zhou, Yong</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>System Performance Analysis of Cooperative Communication in Wireless ad hoc Networks</td>
<td></td>
</tr>
<tr>
<td>770</td>
<td>Zhuang, Weihua</td>
<td>Rahimi Malekshan, Kamal</td>
<td>Completed Program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Spectrum and Energy Efficient Medium Access Control for Wireless Ad Hoc Networks</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Advisor</td>
<td>Program Completed</td>
<td>Project Title</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------</td>
<td>---------------</td>
<td>-------------------</td>
<td>-------------------------------------------------------------------</td>
</tr>
<tr>
<td>771</td>
<td>Zhuang, Weihua</td>
<td>Ye, Qiang</td>
<td>Completed Program</td>
<td>Adaptive Medium Access Control for Internet-of-Things Enabled Mobile Ad Hoc Networks</td>
</tr>
<tr>
<td>772</td>
<td>Zhuang, Weihua</td>
<td>Farmani, Farid</td>
<td>Completed Program</td>
<td>Frequency Control via Demand Response in Smart Grid</td>
</tr>
</tbody>
</table>
Appendix VIII: Visitors
Appendix VIII – Visitors

*WISE has hosted 622 visitors* (national and international) over five years including industry leaders, academics, and researchers.

*A snapshot of the visitors identified below indicates the breadth of interaction that we hosted.*

### 2015

<table>
<thead>
<tr>
<th>#</th>
<th>Visitor(s)</th>
<th>Organization(s)</th>
<th>Agenda</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sarah J. Brown, Associate Director</td>
<td>Interdisciplinary Centre on Climate Change (IC3), University of Waterloo (Canada)</td>
<td>World Wide Views on Climate &amp; Energy</td>
<td>March 24, 2015</td>
</tr>
<tr>
<td>2</td>
<td>Anthony Pierce, Professor</td>
<td>Department of Mathematics, University of British Columbia (Canada)</td>
<td>WISE Public Lecture</td>
<td>March 26, 2015</td>
</tr>
<tr>
<td>3</td>
<td>George Gross, Professor</td>
<td>University of Illinois (U.S.A)</td>
<td>WISE Public Lecture</td>
<td>April 17, 2015</td>
</tr>
<tr>
<td>4</td>
<td>Hugo Schotman, Senior Advisor Renewable Energy</td>
<td>Embassy of the Kingdom of the Netherlands in Canada (Canada)</td>
<td>Potential Collaboration on Renewable Energy projects</td>
<td>April 21, 2015</td>
</tr>
<tr>
<td>5</td>
<td>Elham Safaei Takhtehfouladi, Visiting Scientist and Margaret Vokes, Director</td>
<td>Fraunhofer UMSICHT, and Ontario Ministry of Economic Development and Trade (Germany and Canada)</td>
<td>Potential Collaboration on Renewable Energy projects</td>
<td>May 27, 2015</td>
</tr>
<tr>
<td>6</td>
<td>Michelle Kienitz, Business Development Specialist</td>
<td>Bioenterprise Corporation Canada</td>
<td>Potential Collaboration on Bioenergy, Biofuel, and biomass projects</td>
<td>May 28, 2015</td>
</tr>
<tr>
<td>7</td>
<td>Vanessa Pilotte, Director, Communications – North America</td>
<td>Brookfield Renewable (Canada)</td>
<td>Potential Collaboration on Renewable Energy projects</td>
<td>June 1, 2015</td>
</tr>
<tr>
<td>8</td>
<td>Zhong Li, Professor and Deputy Director</td>
<td>Key Lab of Coal Science &amp; Technology, Institute of Coal Chemical Engineering, Taiyuan University of Technology (China)</td>
<td>WISE Public Lecture</td>
<td>June 12, 2015</td>
</tr>
<tr>
<td>9</td>
<td>Krista Friesen, Vice President, Darren Fry, Director, Velma Grover, Adjunct</td>
<td>CPIA (Canada), Walker Environmental (Canada), McMaster</td>
<td>Resource Recovery Partnership Workshop 2015</td>
<td>June 24, 2015</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Organization</td>
<td>Comments</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>10</td>
<td>Mark Gillis</td>
<td>Element 1 (Canada)</td>
<td>Potential Collaboration on Bioenergy projects</td>
<td>June 26, 2015</td>
</tr>
<tr>
<td>12</td>
<td>Seyedbijan Mahbaz</td>
<td>InspecTerra Inc. (Canada)</td>
<td>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and concrete infrastructure projects</td>
<td>July 7, 2015</td>
</tr>
<tr>
<td>No.</td>
<td>Name and Title</td>
<td>Organization/Government</td>
<td>Activity/Event</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>--------------------------</td>
<td>----------------</td>
<td>------</td>
</tr>
<tr>
<td>13</td>
<td>Carole Champion, Director</td>
<td>Ontario Centres of Excellence (OCE) (Canada)</td>
<td>Advancing R&amp;D research projects in energy storage and renewable energy</td>
<td>July 10, 2015</td>
</tr>
<tr>
<td>14</td>
<td>Mohammadreza Jalali, Visiting Scientist</td>
<td>ETH Zurich (Switzerland)</td>
<td>Seminar: Small-scale Reservoir Stimulation Experiments in the Deep Underground Laboratory at the Grimsel Test Site, Switzerland</td>
<td>July 10, 2015</td>
</tr>
<tr>
<td>15</td>
<td>Seyedbijan Mahbaz, Co-Founder</td>
<td>Inspecterra Inc. (Canada)</td>
<td>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and concrete infrastructure projects</td>
<td>July 13, 2015</td>
</tr>
<tr>
<td>16</td>
<td>Sankaran Ramalingam, President</td>
<td>ENFUSE (Energy and Fuel Users Association of India) (India)</td>
<td>Potential Collaboration on Renewable Energy projects</td>
<td>July 17, 2015</td>
</tr>
<tr>
<td>17</td>
<td>Tony C.Y. Chung, Hwa-yaw TAM, and Kevin Chan, Faculty Members</td>
<td>XXXX, University of Saskatchewan (China and Canada)</td>
<td>Potential Collaboration with WISE faculty members on Renewable Energy projects</td>
<td>July 20, 2015</td>
</tr>
<tr>
<td>18</td>
<td>Jerry Leyte, Sales Manager – Central Region – Canada</td>
<td>Uponor (Canada)</td>
<td>Potential Collaboration on Geothermal Energy projects</td>
<td>July 21, 2015</td>
</tr>
<tr>
<td>19</td>
<td>Sankaran Ramalingam, President</td>
<td>ENFUSE (Energy and Fuel Users Association of India) (India)</td>
<td>Potential Collaboration on Renewable Energy projects</td>
<td>July 22, 2015</td>
</tr>
<tr>
<td>21</td>
<td>Tarek Abdel-Galil, Director, Grid Solutions</td>
<td>SNC-Lavalin Transmission &amp; Distribution (Canada)</td>
<td>Potential Collaboration on smart grid projects</td>
<td>July 24, 2015</td>
</tr>
<tr>
<td>22</td>
<td>Chistian Dötsch, Head of division of Energy</td>
<td>Fraunhofer UMSICHT (Germany)</td>
<td>Potential Collaboration on Renewable Energy projects</td>
<td>August 14, 2015</td>
</tr>
<tr>
<td>23</td>
<td>Muaaz Masood, CEO</td>
<td>Masood Energy Corporation (Canada)</td>
<td>Start-up venture (UW) collaborating on battery storage projects</td>
<td>August 24, 2015</td>
</tr>
<tr>
<td>24</td>
<td>Julie Wright, WGSI Executive</td>
<td>Perimeter Institute for Theoretical</td>
<td>Creating a consortium “The</td>
<td>September 3, 2015</td>
</tr>
<tr>
<td>#</td>
<td>Name and Title</td>
<td>Institution/University</td>
<td>Description</td>
<td>Date</td>
</tr>
<tr>
<td>----</td>
<td>----------------------------------------------------</td>
<td>---------------------------------</td>
<td>----------------------------------------------------------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>25</td>
<td>Vincent Wiegel, Professor</td>
<td>HAN University (Netherlands)</td>
<td>Visiting UW to explore options of collaboration in different areas of power and energy sector</td>
<td>September 8, 2015</td>
</tr>
<tr>
<td>26</td>
<td>Heather Bigelow, Operations Manager</td>
<td>Community CarShare (Canada)</td>
<td>Discussion of Drive4Data (D4D) program – WISE research initiative on Sustainable Mobility</td>
<td>September 8, 2015</td>
</tr>
<tr>
<td>27</td>
<td>Chris Beaver, Faculty Member</td>
<td>Sheridan College (Canada)</td>
<td>Potential Collaboration on Renewable Energy projects with WISE-UW</td>
<td>September 9, 2015</td>
</tr>
<tr>
<td>29</td>
<td>Joachim Knebel, Professor and Head of Division BL3</td>
<td>Karlsruhe Institute of Technology (KIT) (Germany)</td>
<td>Launch of Affordable Energy for Humanity (AE4H) – A Global Research Initiative</td>
<td>September 29, 2015</td>
</tr>
<tr>
<td>30</td>
<td>Paul Tamlin, Founder</td>
<td>Strategic Innovations (Canada)</td>
<td>Validation of energy producing system</td>
<td>September 30, 2015</td>
</tr>
<tr>
<td>31</td>
<td>Bala Venkatesh, Professor</td>
<td>Ryerson University (Canada)</td>
<td>WISE Public Lecture</td>
<td>September 30, 2015</td>
</tr>
<tr>
<td>32</td>
<td>Frits Dröge, Coordinator, Energy Transition Community</td>
<td>Hanze University of Applied Sciences (Netherlands)</td>
<td>Exploring various options of collaboration on power and energy projects</td>
<td>October 8, 2015</td>
</tr>
<tr>
<td>33</td>
<td>Anand Puppala, Professor and Associate Dean, Research</td>
<td>University of Texas at Arlington (U.S.A)</td>
<td>WISE Public Lecture</td>
<td>October 9, 2015</td>
</tr>
<tr>
<td>34</td>
<td>Joseph Lasowski, Environmental Engineer, Rockford Boyer, Man</td>
<td>CF Industries (U.S.A), Roxul (Canada), Walker Environmental (Canada), Advanced Chemical Technologies (Canada), NSERC (Canada),</td>
<td>Greenhouse Gases Workshop</td>
<td>October 12, 2016</td>
</tr>
<tr>
<td>#</td>
<td>Name</td>
<td>Role/Institution</td>
<td>Description</td>
<td>Date</td>
</tr>
<tr>
<td>----</td>
<td>--------------------</td>
<td>------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>35</td>
<td>Alejandra de Almeida, Research and Innovation Development Officer</td>
<td></td>
<td>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and concrete infrastructure projects</td>
<td>October 14, 2015</td>
</tr>
<tr>
<td>36</td>
<td>Armando Román, Director</td>
<td>Monterrey Institute of Technology (Mexico)</td>
<td>Visiting UW to explore options of collaboration in the power and energy discipline</td>
<td>October 15, 2015</td>
</tr>
<tr>
<td>37</td>
<td>Seyedbijan Mahbaz, Co-Founder</td>
<td>InspectTerra Inc. (Canada)</td>
<td>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and concrete infrastructure projects</td>
<td>October 20, 2015</td>
</tr>
<tr>
<td>38</td>
<td>Alexandra Pehlken, Faculty Member</td>
<td>Carl Von Ossietzky University (Germany)</td>
<td>Seminar: The Impact of ‘Energiewende’ on renewable energy in Germany</td>
<td>October 22, 2015</td>
</tr>
<tr>
<td>39</td>
<td>John Mulrooney, Director of Engineering and Shuvo Chowdhury, Smart Grid Project Lead</td>
<td>PowerStream (Canada)</td>
<td>Potential collaboration in the power and energy sector</td>
<td>October 30, 2015</td>
</tr>
<tr>
<td>40</td>
<td>Peter Zuuring, Business Development</td>
<td>EnTranCe Energy Transition Centre (Netherlands)</td>
<td>Potential collaboration in the energy discipline</td>
<td>November 5, 2015</td>
</tr>
<tr>
<td>41</td>
<td>Muaaz Masood, CEO</td>
<td>Masood Energy Corporation (Canada)</td>
<td>Start-up venture (UW) collaborating on battery storage projects</td>
<td>November 9, 2015</td>
</tr>
<tr>
<td>42</td>
<td>Doug Beynon, Entrepreneur-in-Residence</td>
<td>Conrad School of Entrepreneurship and Business, University of Waterloo (Canada)</td>
<td>Taiwan Tech/ITRI project --- Potential Collaboration between Taiwan education institute and WISE-UW in the energy discipline</td>
<td>November 13, 2015</td>
</tr>
<tr>
<td>43</td>
<td>Graham Campbell, President Andrew</td>
<td>Energy Council of Canada (ECC) (Canada)</td>
<td>Update on ECC Scholarship and Output</td>
<td>November 17, 2015</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Position</td>
<td>Organization</td>
<td>Activity</td>
</tr>
<tr>
<td>-----</td>
<td>------</td>
<td>----------</td>
<td>--------------</td>
<td>----------</td>
</tr>
<tr>
<td>44</td>
<td>Robert Therrien, NSERC Director</td>
<td></td>
<td>NSERC Scientific Committee (Canada)</td>
<td>NSERC Site Visit --- CRD CAES project</td>
</tr>
<tr>
<td>45</td>
<td>Muaaz Masood, CEO</td>
<td></td>
<td>Masood Energy Corporation (Canada)</td>
<td>Start-up venture (UW) collaborating on battery storage projects</td>
</tr>
<tr>
<td>46</td>
<td>Dean Xuereb, Field Operations Manager</td>
<td></td>
<td>PCL Construction (Canada)</td>
<td>Potential Collaboration on non-destructive testing (NDT) applications in the power and energy discipline</td>
</tr>
<tr>
<td>48</td>
<td>Team, Business Development</td>
<td></td>
<td>Ecologix Heating Technologies Inc. (Canada)</td>
<td>Potential Collaboration on non-destructive testing (NDT) in the HVAC discipline</td>
</tr>
<tr>
<td>49</td>
<td>Shaylene Nancekivell, Business Development Specialist</td>
<td></td>
<td>Ontario Centres of Excellence (OCE)</td>
<td>Exploring options of advancing mitacs applications in the power and energy discipline</td>
</tr>
<tr>
<td>50</td>
<td>Seyedbijan Mahbaz, Co-Founder</td>
<td></td>
<td>Inspecterra Inc. (Canada)</td>
<td>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and concrete infrastructure projects</td>
</tr>
<tr>
<td>51</td>
<td>Seyedbijan Mahbaz, Co-Founder</td>
<td></td>
<td>Inspecterra Inc. (Canada)</td>
<td>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and</td>
</tr>
</tbody>
</table>
2016

<table>
<thead>
<tr>
<th>#</th>
<th>Visitor(s)</th>
<th>Organization(s)</th>
<th>Agenda</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Olya Irzak, Early Stage Projects</td>
<td>Google X (now known as X) (Canada and U.S.A)</td>
<td>Discussion of emission reduction technologies (electric grid, transportation, non electrified industrial processes, and natural emissions)</td>
<td>January 5, 2016</td>
</tr>
<tr>
<td>2</td>
<td>Alan Almas, Entrepreneur/Retired</td>
<td>Independent Consultant (Canada)</td>
<td>Discussing the concept of energy recovery and storage system in a factory using presses or a building with elevators or escalators</td>
<td>January 11, 2016</td>
</tr>
<tr>
<td>3</td>
<td>David Rodrigues Navarro, New Business Development</td>
<td>Embraco (Brazil)</td>
<td>Exploring R&amp;D collaboration in the area(s) of renewable energy and sustainability</td>
<td>January 12, 2016</td>
</tr>
<tr>
<td>4</td>
<td>Pranab Shah, Business Development</td>
<td>Ontario Ministry of International Trade (Canada)</td>
<td>R&amp;D in the power and energy sector</td>
<td>January 12, 2016</td>
</tr>
<tr>
<td>5</td>
<td>Muaaz Masood, CEO</td>
<td>Masood Energy Corporation (Canada)</td>
<td>Start-up venture (UW) collaborating on battery storage projects</td>
<td>January 19, 2016</td>
</tr>
<tr>
<td>6</td>
<td>Mat Thijsen, Sustainability Coordinator</td>
<td>Faculty of Environment, UW (Canada)</td>
<td>Feasibility of geothermal energy projects on the campus of University of Waterloo</td>
<td>January 25, 2016</td>
</tr>
<tr>
<td>7</td>
<td>David Cork, President</td>
<td>Aspen Solar Management Inc. (Canada)</td>
<td>Microgrid Applications</td>
<td>February 1, 2016</td>
</tr>
<tr>
<td>8</td>
<td>Joel Quigley, Energy Efficiency, Conservation and Demand Management</td>
<td>Kitchener-Wilmot Hydro Inc. (Canada)</td>
<td>Potential Collaboration between WISE and KW Hydro</td>
<td>February 2, 2016</td>
</tr>
<tr>
<td>9</td>
<td>Klaus Dohring, President</td>
<td>Green Sun Rising Inc. (Canada)</td>
<td>R&amp;D – Solar Energy</td>
<td>February 4, 2016</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Institution/Position</td>
<td>Topic</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>10</td>
<td>Jennifer Miller, Director, Communications &amp; Marketing &lt;br&gt;Tom Siu, CEO, Rache Sullivan, Vice President, Finance</td>
<td>Mag-Tech Renewable Energies Inc. (Canada)</td>
<td>Energy Harvesting – Permanent Magnetic Power</td>
<td>February 9, 2016</td>
</tr>
<tr>
<td>12</td>
<td>Komal Habib, Postdoctoral</td>
<td>University of Southern Denmark (Denmark)</td>
<td>Wind Energy</td>
<td>February 18, 2016</td>
</tr>
<tr>
<td>13</td>
<td>Arcy Canumay, TravelWise Promotions Coordinator</td>
<td>Sustainable Waterloo Region (SWR) (Canada)</td>
<td>Electric Vehicle Charging Infrastructure</td>
<td>February 19, 2016</td>
</tr>
<tr>
<td>14</td>
<td>David Roewade, Sustainability Specialist</td>
<td>Region of Waterloo (Canada)</td>
<td>WISE future plan in energy infrastructure</td>
<td>February 19, 2016</td>
</tr>
<tr>
<td>15</td>
<td>Management Team</td>
<td>EllisDon (Canada)</td>
<td>Non-Destructive Testing (NDT) applications</td>
<td>February 24, 2016</td>
</tr>
<tr>
<td>16</td>
<td>Manuel Riemer, Associate Professor and Director, Centre for Community Research, Learning and Action; Director, Community, Environment and Justice Research Group and Allan Taylor, Program Development Manager</td>
<td>Sustainable Waterloo Region (SWR) and Wilfrid Laurier University (WLU)</td>
<td>Energy Research/Tenant Behaviour</td>
<td>March 2, 2016</td>
</tr>
<tr>
<td>17</td>
<td>Hélène Debéda, Associate Professor</td>
<td>University of Bordeaux in France (France)</td>
<td>Seminar: Screen Printing Technology: an alternative method for the development of MEMS actuators and sensors</td>
<td>March 8, 2016</td>
</tr>
<tr>
<td>#</td>
<td>Name</td>
<td>Position</td>
<td>Company/Association</td>
<td>Topic/Industry</td>
</tr>
<tr>
<td>----</td>
<td>-------------------------------</td>
<td>----------------------------</td>
<td>----------------------------------------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td>18</td>
<td>Jennifer Miller, Tom Siu, Rache Sullivan</td>
<td>Director, CEO, Vice President, Finance</td>
<td>Mag-Tech Renewable Energies Inc. (Canada)</td>
<td>Energy Harvesting – Permanent Magnetic Power</td>
</tr>
<tr>
<td>21</td>
<td>Jeffrey Fredenburgh</td>
<td>President</td>
<td>Alchemy Synergy Group, Inc. (Canada)</td>
<td>Battery Storage</td>
</tr>
<tr>
<td>22</td>
<td>Klas Bockasten</td>
<td>Principal</td>
<td>KEB Engineering (Canada)</td>
<td>District Energy Systems</td>
</tr>
<tr>
<td>23</td>
<td>Jeffrey Fredenburgh</td>
<td>President</td>
<td>Alchemy Synergy Group, Inc. (Canada)</td>
<td>Battery Storage</td>
</tr>
<tr>
<td>24</td>
<td>Steve Grasby, Jason Rioux, Stan Marco, Cara Clairman, Gitanjali DasGupta, Daryl Wilson</td>
<td>Research Scientist, Vice President, President &amp; CEO, President &amp; CEO, Head of Operations, President &amp; CEO</td>
<td>Natural Resources Canada (NRCan) (Canada), NRStor (Canada), GeoSmart Energy Inc. (Canada), Plug’ n Drive (Canada), Electrovaya (Canada), and Hydrogenics (Canada)</td>
<td>WISE Energy Day 2016</td>
</tr>
<tr>
<td>25</td>
<td>Steve Grasby</td>
<td>Research Scientist</td>
<td>Natural Resources Canada (NRCan) (Canada)</td>
<td>Geothermal Energy</td>
</tr>
<tr>
<td>26</td>
<td>Sankaran Ramalingam</td>
<td>President</td>
<td>ENFUSE (Energy and Fuel Users Association of India) (India)</td>
<td>Potential Collaboration on Renewable Energy projects</td>
</tr>
<tr>
<td>28</td>
<td>Teresa Giang</td>
<td>Business</td>
<td>Uponor (Canada)</td>
<td>Geothermal Energy Piles</td>
</tr>
<tr>
<td>No.</td>
<td>Name &amp; Role</td>
<td>Organization</td>
<td>Industry/Project</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>-------------</td>
<td>--------------</td>
<td>------------------</td>
<td>------------</td>
</tr>
<tr>
<td>29</td>
<td>Karim Nazarali, Vice President, Standards, Development, Peter Glowacki, Project Manager, Muktha Tumkur, Project Manager, Clifton Rondeau, Program Manager, Energy Efficiency, and Brent Hartman, Program Manager, Alternativa Energy</td>
<td>CSA Group</td>
<td>Renewable Energy</td>
<td>April 14, 2016</td>
</tr>
<tr>
<td>30</td>
<td>Jeffrey Fredenburgh, President, Ian Clifford, CEO, Kevin Spall, Director</td>
<td>Alchemy Synergy Group, Inc. and EEStor Inc., (Canada)</td>
<td>Battery Storage</td>
<td>April 15, 2016</td>
</tr>
<tr>
<td>31</td>
<td>Muaaz Masood, CEO</td>
<td>Masood Energy Corporation (Canada)</td>
<td>Start-up venture (UW) collaborating on battery storage projects</td>
<td>April 19, 2016</td>
</tr>
<tr>
<td>32</td>
<td>Paul Mertes, President and CEO</td>
<td>CircuitMeter Inc. (Canada)</td>
<td>WISE Public Lecture</td>
<td>May 3, 2016</td>
</tr>
<tr>
<td>33</td>
<td>Joe Gordon, Vice President, Product Innovation</td>
<td>SOTI Research</td>
<td>Internet of Things (IOT)</td>
<td>May 12, 2016</td>
</tr>
<tr>
<td>34</td>
<td>Guy Newsham, Principal Research Officer</td>
<td>National Research Council Canada (Canada)</td>
<td>Saving Energy in Buildings by Detecting Occupancy: The Role of IoT</td>
<td>May 13, 2016</td>
</tr>
<tr>
<td>35</td>
<td>Herbert Haller, Vice President, Engineering &amp; Stations, Dorothy Moryc, Manager of Distribution Engineering, Rocket Wei, Stations Engineering &amp;</td>
<td>Waterloo North Hydro (WNH) (Canada)</td>
<td>NSERC Strategic Project Grant – Advanced Information and Communication Systems for Smart Grid</td>
<td>May 16, 2016</td>
</tr>
<tr>
<td>No.</td>
<td>Name(s)</td>
<td>Company/Position</td>
<td>Topic</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>---------</td>
<td>-----------------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>36</td>
<td>Klas Bockasten, Principal</td>
<td>KEB Engineering (Canada)</td>
<td>District Energy Systems</td>
<td>May 20, 2016</td>
</tr>
<tr>
<td>38</td>
<td>Michael Voll, Sector Leader, Power – Ontario, Mehrdad Boloorchi, Principal, Discipline Leader-Power, Luminita Silvestru, Discipline Leader, Hassan Fayaz, Senior Systems Engineer</td>
<td>Stantec Consulting Ltd. (Canada)</td>
<td>Potential Collaboration between WISE-UW and Stantec</td>
<td>May 31, 2016</td>
</tr>
<tr>
<td>39</td>
<td>Justin Eichel, Technical Director</td>
<td>Miovision Technologies (Canada)</td>
<td>Self powered energy systems to support traffic control</td>
<td>June 1, 2016</td>
</tr>
<tr>
<td>40</td>
<td>Michael Voll, Sector Leader, Power, Ontario, Hassan Fayaz, Senior Systems Engineer, Mehrdad Boloorchi, Principal, Discipline Leader-Power, Andrew Rees, Electrical Technologist, and Kenny Smith, Senior Associate</td>
<td>Stantec Consulting Ltd. (Canada)</td>
<td>Potential Collaboration between WISE-UW and Stantec</td>
<td>June 3, 2016</td>
</tr>
<tr>
<td>41</td>
<td>Justin Eichel, Technical Director</td>
<td>Miovision Technologies (Canada)</td>
<td>Self powered energy systems to support traffic control</td>
<td>June 3, 2016</td>
</tr>
<tr>
<td>42</td>
<td>Carol Hochu, President &amp; CEO, Krista Friesen, Vice President, Peter Hargreave</td>
<td>CPIA (Canada), Policy Integrity Inc. (Canada), NSERC (Canada), City of London (Canada), Kelleher</td>
<td>Resource Recovery Partnership Workshop 2016</td>
<td>June 23, 2016</td>
</tr>
<tr>
<td>Visitor</td>
<td>Affiliation</td>
<td>Event</td>
<td>Date</td>
<td></td>
</tr>
<tr>
<td>---------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>--------------------</td>
<td></td>
</tr>
<tr>
<td>Vic Burconak, President and CEO</td>
<td>Koben Systems Inc. (Canada)</td>
<td>Electric vehicle charging infrastructure</td>
<td>June 24, 2016</td>
<td></td>
</tr>
<tr>
<td>Julian Cleary, Postdoctoral Fellow</td>
<td>University of Toronto (Canada)</td>
<td>WISE Public Lecture</td>
<td>June 28, 2016</td>
<td></td>
</tr>
<tr>
<td>Kim Arnold, Owner and Business Development Manager</td>
<td>Crux Content Group (Canada)</td>
<td>Low Carbon Mobility Initiative</td>
<td>July 12, 2016</td>
<td></td>
</tr>
<tr>
<td>Mehrdad Boloorchi, Principal, Discipline Leader-Power, Luminita Silvestru, Discipline Leader, Hassan Fayaz, Senior</td>
<td>Stantec Consulting Ltd. (Canada)</td>
<td>Potential Collaboration between WISE-UW and Stantec</td>
<td>July 13, 2016</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Affiliation</td>
<td>Event</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------------</td>
<td>-----------------------------------</td>
<td>----------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>48</td>
<td>Kim Arnold, Owner and Business Development Manager</td>
<td>Crux Content Group (Canada)</td>
<td>Low Carbon Mobility Initiative</td>
<td>July 15, 2016</td>
</tr>
<tr>
<td>49</td>
<td>Kim Arnold, Owner and Business Development Manager</td>
<td>Crux Content Group (Canada)</td>
<td>Low Carbon Mobility Initiative</td>
<td>July 21, 2016</td>
</tr>
<tr>
<td>50</td>
<td>Jeff Lloyd, President</td>
<td>Almita Piling (Canada)</td>
<td>WISE Public Lecture</td>
<td>July 22, 2016</td>
</tr>
<tr>
<td>51</td>
<td>Michael Voll, Sector Leader, Power, Ontario</td>
<td>Stantec Consulting Ltd. (Canada)</td>
<td>EV charging infrastructure on UW Campus</td>
<td>July 22, 2016</td>
</tr>
<tr>
<td>52</td>
<td>Laura Rees, Executive Director</td>
<td>Council for Clean and Reliable Energy (CCRE) (Canada)</td>
<td>Industry-Academic Event Discussion</td>
<td>July 27, 2016</td>
</tr>
<tr>
<td>53</td>
<td>Joseph Tam, CBDO and Ahsan ul Alam, CEO</td>
<td>Electrefy (Canada)</td>
<td>EV charging infrastructure</td>
<td>July 27, 2016</td>
</tr>
<tr>
<td>54</td>
<td>Madjid Soltani, Research Associate</td>
<td>John Hopkins University (U.S.A)</td>
<td>WISE Public Lecture</td>
<td>August 4, 2016</td>
</tr>
<tr>
<td>55</td>
<td>Kobra Gharali, Assistant Professor</td>
<td>University of Tehran (Iran)</td>
<td>R&amp;D Discussion</td>
<td>August 8, 2016</td>
</tr>
<tr>
<td>56</td>
<td>Muaaz Masood, CEO</td>
<td>Masood Energy Corporation (Canada)</td>
<td>Start-up venture (UW) collaborating on battery storage projects</td>
<td>August 12, 2016</td>
</tr>
<tr>
<td>57</td>
<td>Kobra Gharali, Assistant Professor</td>
<td>University of Tehran (Iran)</td>
<td>WISE Public Lecture</td>
<td>August 16, 2016</td>
</tr>
<tr>
<td>#</td>
<td>Name</td>
<td>Organization</td>
<td>Activity Description</td>
<td>Date</td>
</tr>
<tr>
<td>----</td>
<td>-----------------------</td>
<td>---------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>60</td>
<td>David Roewade</td>
<td>Region of Waterloo (Canada)</td>
<td>Discussion on Smart Grid Research Projects/$5 million Energy Innovation Program</td>
<td>August 30, 2016</td>
</tr>
<tr>
<td>61</td>
<td>Theresa Cooke</td>
<td>Siemens Canada (Canada)</td>
<td>R&amp;D Collaboration</td>
<td>August 31, 2016</td>
</tr>
<tr>
<td>63</td>
<td>Amir Iravani</td>
<td>Dillon Consulting Ltd. (Canada)</td>
<td>Wind Energy</td>
<td>September 21, 2016</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Role/Position</td>
<td>Organization/Institution</td>
<td>Visit Description</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------</td>
<td>---------------------------------------------------</td>
<td>--------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>64</td>
<td>Claudio Vergara</td>
<td>Postdoctoral Associate</td>
<td>MIT Tata Center for Technology and Design (U.S.A)</td>
<td>WISE Public Lecture</td>
</tr>
<tr>
<td>65</td>
<td>Jeff Peters</td>
<td>CTO/Executive Director</td>
<td>Callisto Integration</td>
<td>Solar Energy</td>
</tr>
<tr>
<td>66</td>
<td>Seyedbijan Mahbaz</td>
<td>Co-Founder</td>
<td>InspecTerra Inc. (Canada)</td>
<td>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and concrete infrastructure projects</td>
</tr>
<tr>
<td>67</td>
<td>Seyedbijan Mahbaz</td>
<td>Co-Founder</td>
<td>InspecTerra Inc. (Canada)</td>
<td>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and concrete infrastructure projects</td>
</tr>
<tr>
<td>68</td>
<td>Seyedbijan Mahbaz</td>
<td>Co-Founder</td>
<td>InspecTerra Inc. (Canada)</td>
<td>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and concrete infrastructure projects</td>
</tr>
<tr>
<td>69</td>
<td>Andrew Hejnar</td>
<td>Energy Manager</td>
<td>3M Canada (Canada)</td>
<td>Brockville Combined Heat and Power (CHP) plant</td>
</tr>
<tr>
<td>71</td>
<td>Sankaran Ramalingam</td>
<td>President</td>
<td>ENFUSE (Energy and Fuel Users Association of India) (India)</td>
<td>Potential Collaboration on Renewable Energy projects</td>
</tr>
<tr>
<td>Name of Visitor</td>
<td>Title/Position</td>
<td>Organization(s)</td>
<td>Field of Interest</td>
<td>Date of Visit</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------</td>
<td>------------------</td>
<td>------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Support Administator and her team</td>
<td></td>
<td>Technology Canada (SDTC) (Canada)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>73 Delegation (Team)</strong></td>
<td></td>
<td>Czech Technical University in Prague (Czech Republic)</td>
<td>Renewable Energy</td>
<td>November 2, 2016</td>
</tr>
<tr>
<td><strong>74 Doug Mochrie, President</strong></td>
<td></td>
<td>Holeshott Media (Canada)</td>
<td>Renewable Energy/Digital Platform</td>
<td>November 7, 2016</td>
</tr>
<tr>
<td><strong>75 Daniela Roeper, Founder</strong></td>
<td></td>
<td>Borealis Wind (Canada)</td>
<td>Wind Energy</td>
<td>November 8, 2016</td>
</tr>
<tr>
<td><strong>76 Andrew White, CEO</strong></td>
<td></td>
<td>Char Technologies (Canada)</td>
<td>Bioenergy</td>
<td>November 9, 2016</td>
</tr>
<tr>
<td><strong>77 Rajiv R. Vederah, Managing Director and his team</strong></td>
<td></td>
<td>Avantha Group/Thapar Institute of Engineering and Technology (India)</td>
<td>Renewable Energy</td>
<td>November 15, 2016</td>
</tr>
<tr>
<td><strong>78 Laura Rees, Executive Director</strong></td>
<td></td>
<td>Council for Clean and Reliable Energy (CCRE) (Canada)</td>
<td>Industry-Academic Event Discussion</td>
<td>November 16, 2016</td>
</tr>
<tr>
<td><strong>79 Josipa Petrunic, Executive Director and CEO</strong></td>
<td></td>
<td>Canadian Urban Transit Research &amp; Innovation Consortium (CUTRIC) (Canada)</td>
<td>Electrification of Transport</td>
<td>November 17, 2016</td>
</tr>
<tr>
<td><strong>80 Paul M. Grod, President &amp; CEO</strong></td>
<td></td>
<td>Rodan Energy Solutions (Canada)</td>
<td>WISE Public Lecture</td>
<td>November 22, 2016</td>
</tr>
<tr>
<td><strong>81 Sivakumar Kuppuswamy, Research Assistant/Graduate Student</strong></td>
<td></td>
<td>Faculty of Environment, University of Waterloo (Canada)</td>
<td>Climate Change and Sustainability</td>
<td>November 23, 2016</td>
</tr>
<tr>
<td><strong>82 Colin Andersen, Chair, Mark Henderson, Executive Vice President, Asset Management and Chief Operating Officer, Paul Murphy, Board Chair, Josipa Petrunic, Executive Director &amp; CEO, Hartmut Schmeck, Professor, Brian</strong></td>
<td></td>
<td>Energy Council of Canada (Canada), PowerStream Inc. (Canada), Advanced Energy Centre (Canada), CUTRIC (Canada), KIT (Germany), PricewaterhouseCoopers (Canada), SDTC (Canada), Enbridge Inc. (Canada), Gowing WLG (Canada) LLP (Canada), and CCRE (Canada)</td>
<td>Annual Technology Innovation and Policy Forum 2016</td>
<td>November 24, 2016</td>
</tr>
</tbody>
</table>
Appendix VIII – Visitors

<table>
<thead>
<tr>
<th>#</th>
<th>Visitor(s)</th>
<th>Organization(s)</th>
<th>Agenda</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Doug Mochrie, President</td>
<td>Holeshot1 Media (Canada)</td>
<td>Renewable Energy/Digital Platform</td>
<td>January 4, 2017</td>
</tr>
<tr>
<td>2</td>
<td>Seyedbijan Mahbaz, Co-Founder</td>
<td>InspecTerra Inc. (Canada)</td>
<td>Discussion on Potential collaboration with the Ministry of Transportation (MTO)</td>
<td>January 19, 2017</td>
</tr>
<tr>
<td>3</td>
<td>Benjamin Grunfeld</td>
<td>Navigant (Canada)</td>
<td>WISE Public Lecture</td>
<td>January 25, 2017</td>
</tr>
<tr>
<td>Managing Director</td>
<td>Company/Role</td>
<td>Topic</td>
<td>Date</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>--------------</td>
<td>-------</td>
<td>------------</td>
<td></td>
</tr>
<tr>
<td>5 Jennifer Miller, Director, Communications &amp; Marketing Tom Siu, CEO, and Richard Hepburn, CEO</td>
<td>Mag-Tech Renewable Energies Inc. (Canada)</td>
<td>Energy Harvesting – Permanent Magnetic Power</td>
<td>February 23, 2017</td>
<td></td>
</tr>
<tr>
<td>6 Marie Helen Kinzelin, International Cooperation &amp; Offset Senior Executive, and Kevin Tetreault, Consultant</td>
<td>MBDA Systems (France), Capital Hill (Canada)</td>
<td>Smart Grid Applications</td>
<td>March 14, 2017</td>
<td></td>
</tr>
<tr>
<td>7 Sivakumar Kuppuswamy, General Manager</td>
<td>RWH Engineering Inc. (Canada)</td>
<td>Resiliency and Sustainability in Energy Systems</td>
<td>March 20, 2017</td>
<td></td>
</tr>
<tr>
<td>8 Seyedbijan Mahbaz, Co-Founder</td>
<td>InspecTerra Inc. (Canada)</td>
<td>Discussion on Potential collaboration with the Ministry of Transportation (MTO)</td>
<td>March 27, 2017</td>
<td></td>
</tr>
<tr>
<td>9 Ian Lipton, President &amp; COO, Tim Gibbins, Business Development Manager, Rawlson O'Neil King, Communications Director, Adrian Conrad, COO, J. David McAuley, President &amp; Founder, Andrew Crees, Program Manager, Chris Henderson,</td>
<td>The Carbon Accounting Company (Canada), OCE (Canada), CABA (Canada), The Cora Group (Canada), David McAuley Architect Inc. (Canada), CSA Group (Canada), Lumos Clean Energy Advisors (Canada), IESO (Canada), and Green Sun Rising Inc. (Canada)</td>
<td>WISE Energy Day 2017</td>
<td>March 30, 2017</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Organization</td>
<td>Event Type</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------------------</td>
<td>------------------------------------------------------</td>
<td>-------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>10</td>
<td>Mathew Reive, Principal Knowledge Exchange Fellow</td>
<td>University of Strathclyde (United Kingdom)</td>
<td>Potential research collaboration on renewable energy projects</td>
<td>March 31, 2017</td>
</tr>
<tr>
<td>11</td>
<td>Eswar Prasad, Chairman and Adjunct Professor</td>
<td>Piemades, Inc. and University of Toronto (Canada)</td>
<td>WISE Public Lecture</td>
<td>April 18, 2017</td>
</tr>
<tr>
<td>12</td>
<td>Peter Russell, President and CEO</td>
<td>RestCo. (Canada)</td>
<td>WISE Public Lecture</td>
<td>April 19, 2017</td>
</tr>
<tr>
<td>13</td>
<td>Bill Bailie, Senior Vice President</td>
<td>Almita Piling Inc. (Canada)</td>
<td>R&amp;D collaboration on geothermal pile foundations</td>
<td>April 20, 2017</td>
</tr>
<tr>
<td>14</td>
<td>David Morris, Founder</td>
<td>Colab (Canada)</td>
<td>Potential R&amp;D collaboration on clean technologies</td>
<td>April 28, 2017</td>
</tr>
<tr>
<td>15</td>
<td>John Quigley, Professor and Department Head</td>
<td>University of Strathclyde (United Kingdom)</td>
<td>Potential R&amp;D collaboration in renewable energy projects</td>
<td>May 3, 2017</td>
</tr>
<tr>
<td>16</td>
<td>Muaaz Masood, CEO</td>
<td>Masood Energy Corporation (Canada)</td>
<td>Start-up venture (UW) collaborating on battery storage projects</td>
<td>May 4, 2017</td>
</tr>
<tr>
<td>17</td>
<td>Jason Thompson, Faculty Liaison: Science</td>
<td>University of Waterloo (Canada)</td>
<td>Electric Vehicle (EV) charging infrastructure</td>
<td>May 8, 2017</td>
</tr>
<tr>
<td>18</td>
<td>Tim Gibbins, Business Development Manager</td>
<td>Ontario Centres of Excellence (Canada)</td>
<td>Potential collaboration on renewable energy projects</td>
<td>May 8, 2017</td>
</tr>
<tr>
<td>19</td>
<td>Cat Adalay, CEO</td>
<td>Aurea (Canada)</td>
<td>Wind Energy</td>
<td>May 9, 2017</td>
</tr>
<tr>
<td>20</td>
<td>University of Louisville (Kentucky) Delegation, Faculty Members and Industry Liaison Officers</td>
<td>University of Louisville (U.S.A)</td>
<td>Potential collaboration on renewable energy projects</td>
<td>May 9, 2017</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Organization</td>
<td>Topic</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------------</td>
<td>--------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>21</td>
<td>Mat Thijssen, Sustainability Coordinator</td>
<td>University of Waterloo (Canada)</td>
<td>Discussing sustainability on UW campus</td>
<td>May 15, 2017</td>
</tr>
<tr>
<td>22</td>
<td>Sankaran Ramalingam, President</td>
<td>ENFUSE (Energy and Fuel Users Association of India) (India)</td>
<td>Potential Collaboration on Renewable Energy projects</td>
<td>May 16, 2017</td>
</tr>
<tr>
<td>23</td>
<td>David Morris, Founder</td>
<td>Colab (Canada)</td>
<td>Potential R&amp;D collaboration on clean technologies</td>
<td>May 17, 2017</td>
</tr>
<tr>
<td>24</td>
<td>Joshua Hodgson, Counsellor – Science, Technology and Innovation</td>
<td>Canadian Consulate Tokyo (Japan/Canada)</td>
<td>Potential R&amp;D collaboration on clean technologies</td>
<td>May 18, 2017</td>
</tr>
<tr>
<td>25</td>
<td>Matthew Peloso, CEO and Founder</td>
<td>Sun Electric Pte. Ltd.</td>
<td>WISE Public Lecture</td>
<td>May 19, 2017</td>
</tr>
<tr>
<td>26</td>
<td>Rory Nelson, Entrepreneur</td>
<td>Qovy Construction (Canada)</td>
<td>Potential R&amp;D collaboration on renewable energy projects</td>
<td>May 23, 2017</td>
</tr>
<tr>
<td>27</td>
<td>David Cardin, Director</td>
<td>Gateway Advisors Ltd. (Canada)</td>
<td>Potential R&amp;D collaboration on net zero homes</td>
<td>May 24, 2017</td>
</tr>
<tr>
<td>28</td>
<td>Siva Kumar Kuppuswamay, General Manager</td>
<td>RWH Engineering (Canada)</td>
<td>Potential R&amp;D collaboration on geotechnical engineering projects</td>
<td>May 26, 2017</td>
</tr>
<tr>
<td>29</td>
<td>David Cardin, Director</td>
<td>Gateway Advisors Ltd. (Canada)</td>
<td>Potential R&amp;D collaboration on net zero homes</td>
<td>May 30, 2017</td>
</tr>
<tr>
<td>30</td>
<td>Rory Nelson, Entrepreneur</td>
<td>Qovy Construction (Canada)</td>
<td>Potential R&amp;D collaboration on renewable energy projects</td>
<td>May 31, 2017</td>
</tr>
<tr>
<td>31</td>
<td>Saied Pirasteh, Founder</td>
<td>GRMC Inc. (U.S.A)</td>
<td>Discussion on Tiltmeter Dynamic Infrastructure Monitoring, and Static Infrastructure Condition Assessment Using Magnetometer Technology</td>
<td>June 5, 2017</td>
</tr>
<tr>
<td>32</td>
<td>Carol Hochu, President &amp; CEO, Joe Hruska, Vice President, Rachel Morier</td>
<td>CPIA (Canada), Packaging Consortium (Canada), Greenblue (U.S.A), NSERC (Canada),</td>
<td>Resource Recovery Partnership Workshop 2017</td>
<td>June 6, 2017</td>
</tr>
<tr>
<td>Appendix VIII – Visitors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>City of Toronto (Canada), Envise Consulting Inc. (Canada), University of Ontario Institute of Technology (Canada), American Chemistry Council (U.S.A),</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Director of Sustainability,</strong> <strong>Kelly Cramer,</strong> <strong>Senior Manager,</strong> <strong>Alejandra de Almeida,</strong> <strong>Research &amp; Innovation Development Officer,</strong> <strong>Kris Hornburg,</strong> <strong>Senior Project Manager,</strong> <strong>Fergal McDonough,</strong> <strong>President,</strong> <strong>Daniel Hoornweg,</strong> <strong>Professor,</strong> <strong>Sarah Lindsay,</strong> <strong>Manager,</strong> <strong>Erik Veneman,</strong> <strong>Vice President,</strong> <strong>Innovation and Growth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Guelph Hydro (Canada)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Potential research collaboration on energy efficient building infrastructure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>June 14, 2017</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Jennifer Miller,</strong> <strong>Director,</strong> <strong>Communications &amp; Marketing,</strong> <strong>and Tom Siu,</strong> <strong>CEO</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mag-Tech Renewable Energies Inc. (Canada)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Energy Harvesting – Permanent Magnetic Power</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>June 14, 2017</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Laura Rees,</strong> <strong>Executive Director</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Council for Clean and Reliable Energy (CCRE) (Canada)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Industry-Academic Event Discussion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>June 15, 2017</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Robert Shorten,</strong> <strong>Professor &amp; Chair</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>University College Dublin (Ireland)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>WISE Public Lecture</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>June 26, 2017</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mario Pinto,</strong> <strong>President</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Natural Sciences and Engineering Research Council (NSERC)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Visit to UW</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>June 28, 2017</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hélène Debéda,</strong> <strong>Associate Professor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>University of Bordeaux (France)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>WISE Public Lecture</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>June 28, 2017</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Clinton Moss,</strong> <strong>President</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Marksman Ranging Technologies, Scientific Drilling (Canada)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>WISE Public Lecture</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>July 5, 2017</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MohammadReza Jalali,</strong> <strong>Lecturer &amp; Researcher</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Swiss Federal Institute of Technology (ETH) (Switzerland)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>WISE Public Lecture</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>July 5, 2017</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Name and Designation</td>
<td>Institution and Location</td>
<td>Event</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>----------------------</td>
<td>--------------------------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>41</td>
<td>Madjid Soltani, Assistant Professor</td>
<td>K.N. Toosi University (Iran)</td>
<td>Renewable Energy</td>
<td>July 5, 2017</td>
</tr>
<tr>
<td>42</td>
<td>Sankaran Ramalingam, President</td>
<td>ENFUSE (Energy and Fuel Users Association of India) (India)</td>
<td>Potential Collaboration on Renewable Energy projects</td>
<td>July 6, 2017</td>
</tr>
<tr>
<td>43</td>
<td>Benjamin Canning, President</td>
<td>Growing North (Canada)</td>
<td>WISE Public Lecture</td>
<td>July 11, 2017</td>
</tr>
<tr>
<td>44</td>
<td>Kobra Gharali, Assistant Professor</td>
<td>University of Tehran (Iran)</td>
<td>R&amp;D Discussion on renewable energy projects</td>
<td>July 14, 2017</td>
</tr>
<tr>
<td>45</td>
<td>Siva Kumar Kuppuswamay, General Manager, and Martin Halliwell, President</td>
<td>RWH Engineering (Canada)</td>
<td>Potential R&amp;D collaboration on geotechnical engineering projects</td>
<td>July 24, 2017</td>
</tr>
<tr>
<td>46</td>
<td>Tony Chang, Managing Partner, and Loretta Yuen, Director, Chinese Services Group</td>
<td>Redbridge Capital Inc., and Deloitte (Canada)</td>
<td>Renewable Energy projects</td>
<td>August 1, 2017</td>
</tr>
<tr>
<td>47</td>
<td>Mahdi Shahbakhti, Associate Professor</td>
<td>Michigan Technological University (U.S.A)</td>
<td>WISE Public Lecture</td>
<td>August 2, 2017</td>
</tr>
<tr>
<td>49</td>
<td>Katherine Peretick, Director of Engineering</td>
<td>NRStor (Canada)</td>
<td>Geothermal Energy</td>
<td>August 23, 2017</td>
</tr>
<tr>
<td>50</td>
<td>Peter Miller, Regional Wind Site Manager, Northeast Region</td>
<td>Next Era Energy (Canada)</td>
<td>Wind Energy</td>
<td>August 31, 2017</td>
</tr>
<tr>
<td>51</td>
<td>Laura Rees, Executive Director</td>
<td>Council for Clean and Reliable Energy (CCRE) (Canada)</td>
<td>Industry-Academic Event Discussion</td>
<td>September 8, 2017</td>
</tr>
<tr>
<td>52</td>
<td>Derek Satnik, Vice President of Technology, Smart Communities</td>
<td>S2e Technologies Inc. (Canada)</td>
<td>Green Infrastructure projects</td>
<td>September 8, 2017</td>
</tr>
<tr>
<td>No.</td>
<td>Name and Title</td>
<td>Organization</td>
<td>Activity</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>--------------</td>
<td>----------</td>
<td>------</td>
</tr>
<tr>
<td>53</td>
<td>Nirupa Balendran, Conservation Energy Manager</td>
<td>Newmarket-Tay Power Distribution Inc. (Canada)</td>
<td>WISE Public Lecture</td>
<td>September 11, 2017</td>
</tr>
<tr>
<td>55</td>
<td>Andrew Hejnar, Energy Manager</td>
<td>3M Canada (Canada)</td>
<td>Brockville Combined Heat and Power (CHP) plant</td>
<td>September 12, 2017</td>
</tr>
<tr>
<td>56</td>
<td>Adrian Conrad, COO</td>
<td>The Cora Group (Canada)</td>
<td>Energy Efficient Buildings</td>
<td>September 13, 2017</td>
</tr>
<tr>
<td>57</td>
<td>Muaaz Masood, CEO</td>
<td>Masood Energy Corporation (Canada)</td>
<td>Start-up venture (UW) collaborating on battery storage projects</td>
<td>September 14, 2017</td>
</tr>
<tr>
<td>58</td>
<td>Kanjo Melo, Member</td>
<td>University of Waterloo's Energy Network, UW (Canada)</td>
<td>Collaboration on renewable energy projects – undergraduate level</td>
<td>September 20, 2017</td>
</tr>
<tr>
<td>59</td>
<td>Seyedbijan Mahbaz, Co-Founder</td>
<td>InspecTerra Inc. (Canada)</td>
<td>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and concrete infrastructure projects</td>
<td>September 20, 2017</td>
</tr>
<tr>
<td>60</td>
<td>Pooneh Maghoul, Assistant Professor, Steve Grasby, Research Scientist, Jasmin Raymond, Professor, Thomas Kohl, Professor &amp; Division Leader, Joe Howe, Executive Director &amp; Professor, María Sigriður Guðjónsdóttir, Professor &amp; Head, John McLennan, Associate Professor, Craig Dunn, Chief</td>
<td>University of Manitoba (Canada), NRCan (Canada), INRS (Canada), KIT (Germany), University of Chester (United Kingdom), Reykjavik University (Iceland), University of Utah (U.S.A), Borealis Geopower (Canada), DEEP (Canada), Epoch Energy Development (Canada), Geosource Energy Inc. (Canada), C-FER Technologies (Canada), NSERC (Canada), OCE</td>
<td>Geothermal Symposium (WISE Event)</td>
<td>September 26, 2017</td>
</tr>
<tr>
<td>Appendix VIII – Visitors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>61</strong></td>
<td><strong>Seyedbijan Mahbuz</strong>, Co-Founder</td>
<td><strong>InspectTerra Inc.</strong> (Canada)</td>
<td><strong>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and concrete infrastructure projects</strong></td>
<td><strong>September 28, 2017</strong></td>
</tr>
<tr>
<td><strong>62</strong></td>
<td><strong>Madjid Soltani</strong>, Assistant Professor</td>
<td><strong>K.N. Toosi University (Iran)</strong></td>
<td><strong>Renewable Energy</strong></td>
<td><strong>September 28, 2017</strong></td>
</tr>
<tr>
<td><strong>63</strong></td>
<td><strong>Madjid Soltani</strong>, Assistant Professor</td>
<td><strong>K.N. Toosi University (Iran)</strong></td>
<td><strong>Renewable Energy</strong></td>
<td><strong>September 29, 2017</strong></td>
</tr>
<tr>
<td><strong>64</strong></td>
<td><strong>Raghavendra Nambinayakana halli Hanumanthaiah</strong>, Entrepreneur/M.BET Candidate</td>
<td><strong>University of Waterloo (Canada)</strong></td>
<td><strong>Geothermal Energy</strong></td>
<td><strong>September 29, 2017</strong></td>
</tr>
<tr>
<td><strong>65</strong></td>
<td><strong>Laura Rees</strong>, Executive Director</td>
<td><strong>Council for Clean and Reliable Energy (CCRE) (Canada)</strong></td>
<td><strong>Industry-Academic Event Discussion</strong></td>
<td><strong>October 4, 2017</strong></td>
</tr>
<tr>
<td><strong>66</strong></td>
<td><strong>Kanj Melo</strong>, Member</td>
<td><strong>University of Waterloo’s Energy Network, UW (Canada)</strong></td>
<td><strong>Collaboration on renewable energy projects – undergraduate level</strong></td>
<td><strong>October 5, 2017</strong></td>
</tr>
<tr>
<td><strong>67</strong></td>
<td><strong>Neil Freeman</strong>, Director <strong>Paula Mayor</strong>, President, and <strong>Norm Fraser</strong>, Director</td>
<td><strong>Blue Box Technology (Canada)</strong></td>
<td><strong>Distributed energy generation solutions</strong></td>
<td><strong>October 6, 2017</strong></td>
</tr>
<tr>
<td>No.</td>
<td>Name, Position, Institution</td>
<td>University/Location</td>
<td>Activity</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------------</td>
<td>---------------------</td>
<td>----------</td>
<td>------</td>
</tr>
<tr>
<td>68</td>
<td>Raghavendra Nambinayakana Halli Hanumanthaiah, and Andrew Bartle, Entrepreneur/M BET Candidate</td>
<td>University of Waterloo (Canada)</td>
<td>Feasibility Study of Geothermal Energy in British Columbia</td>
<td>October 11, 2017</td>
</tr>
<tr>
<td>69</td>
<td>Adrian Conrad, COO</td>
<td>The Cora Group (Canada)</td>
<td>Stouffville project (Retirement home – net zero facility)</td>
<td>October 12, 2017</td>
</tr>
<tr>
<td>70</td>
<td>Raghavendra Nambinayakana Halli Hanumanthaiah, and Andrew Bartle, Entrepreneur/M BET Candidate</td>
<td>University of Waterloo (Canada)</td>
<td>Feasibility Study of Geothermal Energy in British Columbia</td>
<td>October 12, 2017</td>
</tr>
<tr>
<td>71</td>
<td>Ashley Hannon, Business Development Specialist</td>
<td>Mitacs (Canada)</td>
<td>Renewable Energy</td>
<td>October 18, 2017</td>
</tr>
<tr>
<td>72</td>
<td>Siva Kumar Kuppuswamay, General Manager</td>
<td>RWH Engineering (Canada)</td>
<td>R&amp;D collaboration on geotechnical engineering projects</td>
<td>October 19, 2017</td>
</tr>
<tr>
<td>73</td>
<td>Madjid Soltani, Assistant Professor</td>
<td>K.N. Toosi University (Iran)</td>
<td>MOU Discussion</td>
<td>October 20, 2017</td>
</tr>
<tr>
<td>74</td>
<td>David Comerford, Strathclyde Chancellor’s Fellow, Grant Allan, Senior Lecturer, John Quigley, Professor and Department Head, Kerem Akartunali, Reader, Stuart McIntyre, Senior Lecturer, Alexander Dickson, Senior Lecturer, and Matthew Revie, Principal Knowledge Exchange Fellow</td>
<td>University of Strathclyde (United Kingdom)</td>
<td>University of Strathclyde Workshop</td>
<td>October 23 and 24, 2017</td>
</tr>
<tr>
<td>Visitor</td>
<td>Title</td>
<td>Affiliation</td>
<td>Event Type</td>
<td>Date</td>
</tr>
<tr>
<td>---------</td>
<td>-------</td>
<td>-------------</td>
<td>------------</td>
<td>------</td>
</tr>
<tr>
<td>Marc Brouillette</td>
<td>Principal Consultant</td>
<td>Strategic Policy Economics (Canada)</td>
<td>WISE Public Lecture</td>
<td>October 24, 2017</td>
</tr>
<tr>
<td>Laura Rees</td>
<td>Executive Director</td>
<td>Council for Clean and Reliable Energy (CCRE) (Canada)</td>
<td>Industry-Academic Event Discussion</td>
<td>October 25, 2017</td>
</tr>
<tr>
<td>Martin Vroegh</td>
<td>Senior Director, Greenhouse Gas Reduction Technologies</td>
<td>Ontario Centres of Excellence (Canada)</td>
<td>WISE Public Lecture</td>
<td>October 26, 2017</td>
</tr>
<tr>
<td>Raghavendra Nambinayakana Hanumanthaiah and Andrew Bartle</td>
<td>Entrepreneur/MBET Candidate</td>
<td>University of Waterloo (Canada)</td>
<td>Feasibility Study of Geothermal Energy in British Columbia</td>
<td>October 26, 2017</td>
</tr>
<tr>
<td>Madjid Soltani</td>
<td>Assistant Professor</td>
<td>K.N. Toosi University (Iran)</td>
<td>MOU Discussion</td>
<td>November 6, 2017</td>
</tr>
<tr>
<td>Laura Rees</td>
<td>Executive Director</td>
<td>Council for Clean and Reliable Energy (CCRE) (Canada)</td>
<td>Industry-Academic Event Discussion</td>
<td>November 8, 2017</td>
</tr>
<tr>
<td>Pamela Jones, Ron Dizy, Alif Gilani, Paul Grod, Colin Kelleher, Ingo Mauser, Malcom McCulloch, Julie Morin, Michael Nobrega, Paul Pauze</td>
<td>Director, Managing Director, Head of Engineering, President and CEO, CEO, Research Associate, Professor, Internet of Things Solutions Specialist, Chair of the Board, Vice President, Business Development</td>
<td>Canadian Electricity Association (Canada), MaRS Cleantech - Advanced Energy Centre (Canada), Siemens Canada (Canada), Rodan Energy Solutions (Canada), Kelleher Group (U.S.A), KIT (Germany), University of Oxford (United Kingdom), Microsoft Canada (Canada), OCE (Canada), Innovus Power Inc. (U.S.A), Alelectra Energy Solutions (Canada), Enbridge Inc. (Canada), Gowling WLG (Canada) LLP (Canada), and CCRE (Canada)</td>
<td>Annual Technology Innovation and Policy Forum 2017</td>
<td>November 9, 2017</td>
</tr>
<tr>
<td>No.</td>
<td>Name &amp; Title</td>
<td>Organization</td>
<td>Topic</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>--------------</td>
<td>--------------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>82</td>
<td>Jennifer Miller, Director, Communications &amp; Marketing and Tom Siu, CEO</td>
<td>Mag-Tech Renewable Energies Inc. (Canada)</td>
<td>Energy Harvesting – Permanent Magnetic Power</td>
<td>November 13, 2017</td>
</tr>
<tr>
<td>83</td>
<td>Nadia Hazime, Client Relationship and Project Coordinator</td>
<td>Efficiency Capital (Canada)</td>
<td>Net zero homes</td>
<td>November 16, 2017</td>
</tr>
<tr>
<td>84</td>
<td>Erik Veneman, Vice President, Innovation and Growth</td>
<td>Guelph Hydro (Canada)</td>
<td>WISE Public Lecture</td>
<td>November 21, 2017</td>
</tr>
<tr>
<td>85</td>
<td>Nehema Misola, Vice President, External Affairs</td>
<td>Iloilo Science and Technology University (Philippines)</td>
<td>Potential collaboration on clean technology programs</td>
<td>November 21, 2017</td>
</tr>
<tr>
<td>86</td>
<td>Seyedbijan Mahbaz, Co-Founder</td>
<td>InspectTerra Inc. (Canada)</td>
<td>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and concrete infrastructure projects</td>
<td>November 29, 2017</td>
</tr>
<tr>
<td>87</td>
<td>Jonathan Baugh, Associate Professor</td>
<td>Institute for Quantum Computing, UW (Canada)</td>
<td>DRDC grant application guidance and feedback</td>
<td>November 29, 2017</td>
</tr>
<tr>
<td>88</td>
<td>Madjid Soltani, Assistant Professor</td>
<td>K.N. Toosi University (Iran)</td>
<td>MOU Discussion</td>
<td>November 30, 2017</td>
</tr>
<tr>
<td>89</td>
<td>Walter McLean, Former Canadian Politician, and Zebra Kasete</td>
<td>Government of Canada and Dundee Precious Metals (Canada)</td>
<td>R&amp;D collaboration in renewable energy projects</td>
<td>December 1, 2017</td>
</tr>
</tbody>
</table>
### Appendix VIII – Visitors

<table>
<thead>
<tr>
<th>#</th>
<th>Visitor(s)</th>
<th>Organization(s)</th>
<th>Agenda</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td><strong>Nehema Misola, Vice President, External Affairs</strong></td>
<td>Iloilo Science and Technology University (Philippines)</td>
<td>Potential collaboration on clean technology programs</td>
<td>December 4, 2017</td>
</tr>
<tr>
<td>91</td>
<td><strong>Visitors from Shandong Jianzhu University</strong></td>
<td>Shandong Jianzhu University (China)</td>
<td>R&amp;D collaboration in renewable energy projects</td>
<td>December 5, 2017</td>
</tr>
<tr>
<td>92</td>
<td><strong>Sir Jim McDonald, Professor, Principal &amp; Vice-Chancellor</strong></td>
<td>University of Strathclyde (United Kingdom)</td>
<td>R&amp;D collaboration in renewable energy projects</td>
<td>December 8, 2017</td>
</tr>
</tbody>
</table>

### 2018

<table>
<thead>
<tr>
<th>#</th>
<th>Visitor(s)</th>
<th>Organization(s)</th>
<th>Agenda</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Adonis Yatchew, Professor</strong></td>
<td>University of Toronto (Canada)</td>
<td>WISE Public Lecture</td>
<td>January 25, 2018</td>
</tr>
<tr>
<td>2</td>
<td><strong>Tim Peters, Contract Specialist</strong></td>
<td>Amersco Canada Inc. (Canada)</td>
<td>R&amp;D collaboration on net zero buildings</td>
<td>January 26, 2018</td>
</tr>
<tr>
<td>3</td>
<td><strong>Nasrin Sadeghianpourhamami, Visiting Scientist</strong></td>
<td>Ghent University (Belgium)</td>
<td>R&amp;D collaboration on power systems</td>
<td>February 2, 2018</td>
</tr>
<tr>
<td>4</td>
<td><strong>Raghavendra Nambinayakana halli Hanumanthaiah, Entrepreneur/MBET Candidate</strong></td>
<td>University of Waterloo (Canada)</td>
<td>Geothermal Energy</td>
<td>February 7, 2018</td>
</tr>
<tr>
<td>5</td>
<td><strong>Chris Beaver, Faculty Member</strong></td>
<td>Sheridan College Institute of Technology &amp; Advanced Learning (Canada)</td>
<td>Potential partnership on net zero buildings and assessment</td>
<td>February 8, 2018</td>
</tr>
<tr>
<td>6</td>
<td><strong>Tim Peters, Contract Specialist</strong></td>
<td>Amersco Canada Inc. (Canada)</td>
<td>R&amp;D collaboration on net zero buildings</td>
<td>February 8, 2018</td>
</tr>
<tr>
<td>7</td>
<td><strong>Mehmet Ferdiner, Manager, Energy Modelling Services</strong></td>
<td>Building Knowledge Canada (Canada)</td>
<td>WISE Public Lecture</td>
<td>February 13, 2018</td>
</tr>
<tr>
<td>8</td>
<td><strong>Chandra Ramadurai, CEO</strong></td>
<td>Efficiency Capital</td>
<td>WISE Public Lecture</td>
<td>February 22, 2018</td>
</tr>
<tr>
<td>No.</td>
<td>Name and Position</td>
<td>Organization/Group</td>
<td>Collaboration Description</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------------------------</td>
<td>---------------------------------------------</td>
<td>------------------------------------------------------------------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>9</td>
<td><strong>Siva Kumar Kuppuswamy</strong>, General Manager</td>
<td>RWH Engineering (Canada)</td>
<td>R&amp;D collaboration on geotechnical engineering projects</td>
<td>February 23, 2018</td>
</tr>
<tr>
<td>10</td>
<td><strong>Seyedbijan Mahbaz</strong>, Co-Founder</td>
<td>Inspecterra Inc. (Canada)</td>
<td>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and concrete infrastructure projects</td>
<td>February 27, 2018</td>
</tr>
<tr>
<td>11</td>
<td><strong>David Martinello</strong>, Engineering Project Analyst</td>
<td>Energy Plus (Canada)</td>
<td>Potential R&amp;D collaboration on solar energy</td>
<td>March 5, 2018</td>
</tr>
<tr>
<td>12</td>
<td><strong>Stan Marco</strong>, President and CEO, and <strong>Stephen Marco</strong>, Operations Manager</td>
<td>GeoSmart Energy Inc. (Canada)</td>
<td>Geothermal Energy on UW Campus</td>
<td>March 14, 2018</td>
</tr>
<tr>
<td>13</td>
<td><strong>Oleg Stukalov</strong>, Business Development Manager, <strong>Lisa Pokrajac</strong>, Assistant Director, Research Programs</td>
<td>Waterloo Institute for Nanotechnology, UW (Canada)</td>
<td>Energy and Nanotechnology collaborative projects</td>
<td>March 16, 2018</td>
</tr>
<tr>
<td>14</td>
<td><strong>Tim Peters</strong>, Business Development Manager, <strong>Tim Cresswell</strong>, Vice President, Strategic Infrastructure Development, <strong>Mark Wilhelm</strong>, Sustainability and Climate Neutrality Consultant, <strong>Sam Boyajian</strong>, Vice President – Central Region, <strong>Enzo Colangelo</strong>, Vice President, Project Development and Risk Management</td>
<td>Ameresco Canada Inc. (Canada)</td>
<td>R&amp;D collaboration on net zero buildings</td>
<td>March 22, 2018</td>
</tr>
<tr>
<td>No.</td>
<td>Name and Title</td>
<td>Organization</td>
<td>Topic</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>---------------</td>
<td>-------</td>
<td>------------</td>
</tr>
<tr>
<td>15</td>
<td><strong>Carl Rodgers</strong>, Manager, Sustainability &amp; Building Energy Performance + Environment</td>
<td>Greater Toronto Airports Authority (Canada)</td>
<td>Smart and efficient infrastructure</td>
<td>March 23, 2018</td>
</tr>
<tr>
<td>16</td>
<td><strong>Sandy McArthur</strong>, Director, <strong>Peter Howard</strong>, Vice President, <strong>Robert Niven</strong>, CEO/Founder, <strong>John Wilkinson</strong>, Senior Vice President, <strong>Amber Scott</strong>, Founder and Chief, and <strong>Marek Laskowski</strong>, Adjunct Professor</td>
<td>Jaza Energy (Canada), Pond Technologies Inc. (Canada), CarbonCure (Canada), Greenfield Global (Canada), Outlier Solutions Inc. (Canada), and York University (Canada),</td>
<td></td>
<td>March 27, 2018</td>
</tr>
<tr>
<td>17</td>
<td><strong>Mat Thijssen</strong>, Sustainability Coordinator</td>
<td>Faculty of Environment, UW (Canada)</td>
<td>Green infrastructure projects on UW Campus</td>
<td>April 9, 2018</td>
</tr>
<tr>
<td>18</td>
<td><strong>Mat Thijssen</strong>, Sustainability Coordinator</td>
<td>Faculty of Environment, UW (Canada)</td>
<td>EV charging infrastructure</td>
<td>April 23, 2018</td>
</tr>
<tr>
<td>19</td>
<td><strong>Alex Berruti</strong>, Senior Product Engineer</td>
<td>Innovative Steam Technologies (IST) (Canada)</td>
<td>WISE Public Lecture</td>
<td>April 24, 2018</td>
</tr>
<tr>
<td>20</td>
<td><strong>Dan Schumacher</strong>, Founder</td>
<td>Danplanfandango (Canada)</td>
<td>Net zero homes</td>
<td>April 25, 2018</td>
</tr>
<tr>
<td>21</td>
<td><strong>Bill Hooykaas</strong>, Director <strong>John Dixon</strong>, President and Owner (70+ participants)</td>
<td>Tesla Owners Club – Ontario (Canada)</td>
<td>Tesla Event/EV charging infrastructure and sustainable mobility</td>
<td>May 1, 2018</td>
</tr>
<tr>
<td>22</td>
<td><strong>Elham Akhavan</strong>, Technical Staff, and <strong>Gary Stevens</strong>, Chief Scientist</td>
<td>S2e Technologies (Canada)</td>
<td>EV charging infrastructure</td>
<td>May 4, 2018</td>
</tr>
<tr>
<td>23</td>
<td><strong>Hiren Kishorkumar Gagnani</strong>, UW Student</td>
<td>Electrical and Computer Engineering, UW (Canada)</td>
<td>Power quality and control</td>
<td>May 16, 2018</td>
</tr>
<tr>
<td>24</td>
<td><strong>Joe Lyng</strong>, General Manager</td>
<td>Emerald EFW (Canada)</td>
<td>Hydrogen</td>
<td>May 17, 2018</td>
</tr>
<tr>
<td>No.</td>
<td>Name and Title</td>
<td>Organization</td>
<td>Collaboration Focus</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>--------------</td>
<td>---------------------</td>
<td>----------</td>
</tr>
<tr>
<td>25</td>
<td>Sankaran Ramalingam, President</td>
<td>ENFUSE (Energy and Fuel Users Association of India) (India)</td>
<td>Potential Collaboration on Renewable Energy projects</td>
<td>May 25, 2018</td>
</tr>
<tr>
<td>26</td>
<td>Ian Miles, President and CEO, and Umar Waqas, Director, Engineering Services</td>
<td>Energy Plus (Canada)</td>
<td>Smart grid applications, and distributed energy generation</td>
<td>May 25, 2018</td>
</tr>
<tr>
<td>27</td>
<td>Lala Agamirov, Researcher</td>
<td>N/A</td>
<td>Piezoelectric materials</td>
<td>May 30, 2018</td>
</tr>
<tr>
<td>28</td>
<td>David Cardin, Director</td>
<td>Gateway Advisors Ltd. (Canada)</td>
<td>Potential R&amp;D collaboration on net zero homes</td>
<td>June 8, 2018</td>
</tr>
<tr>
<td>29</td>
<td>Denis Gendron, President and CEO</td>
<td>Claire Lasers Corporation (Canada)</td>
<td>Oil and Gas</td>
<td>June 14, 2018</td>
</tr>
<tr>
<td>30</td>
<td>Denis Gendron, President and CEO</td>
<td>Claire Lasers Corporation (Canada)</td>
<td>Oil and Gas</td>
<td>June 20, 2018</td>
</tr>
<tr>
<td>31</td>
<td>Carol Hochu, President &amp; CEO, Joe Hruska, Vice President, Jay Stanford, Director, Stephen Sikra, Section Head, Craig Foster, Principal, Umberto Arena, Professor, Dan Lantz, CEO, Marco Castaldi, Professor, Franco Berruti, Professor, Norman Lee, Director, Peter Hargreave, President, Micheal Rich, Technical Advisor, and Michael Appleby, President</td>
<td>CPIA (Canada), City of London (Canada), Proctor and Gamble (Canada), Craig Foster &amp; Associates (Canada), University of Campania Luigi Vanvitelli (Italy), Scout Environmental (Canada), City College of New York (U.S.A), University of Western Ontario (Canada), Region of Peel (Canada), Policy Integrity Inc. (Canada), and Redican (Canada)</td>
<td>Resource Recovery Partnership Conference 2018</td>
<td>June 21 &amp; 22, 2018</td>
</tr>
<tr>
<td>32</td>
<td>Joe Lyng, General Manager</td>
<td>Emerald EFW (Canada)</td>
<td>Hydrogen</td>
<td>July 10, 2018</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Position/Role</td>
<td>Organization/Association</td>
<td>Event/Discussion</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------</td>
<td>---------------------------------------------------</td>
<td>----------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>33</td>
<td>Laura Rees</td>
<td>Executive Director</td>
<td>Council for Clean and Reliable Energy (CCRE) (Canada)</td>
<td>Industry-Academic Event Discussion</td>
</tr>
<tr>
<td>34</td>
<td>Claude Guérin</td>
<td>International Senior Project Manager</td>
<td>Total Eco Energy (Canada)</td>
<td>R&amp;D in solar energy</td>
</tr>
<tr>
<td>35</td>
<td>Sankaran Ramalingam</td>
<td>President</td>
<td>ENFUSE (Energy and Fuel Users Association of India) (India)</td>
<td>WISE Public Lecture</td>
</tr>
<tr>
<td>36</td>
<td>Ann Lin</td>
<td>Vice President and her team</td>
<td>Changfeng Energy (Canada)</td>
<td>R&amp;D collaboration in smart city infrastructure</td>
</tr>
<tr>
<td>37</td>
<td>Ann Lin</td>
<td>Vice President and her team</td>
<td>Changfeng Energy (Canada)</td>
<td>R&amp;D collaboration in smart city infrastructure</td>
</tr>
<tr>
<td>38</td>
<td>Michael Rich</td>
<td>Technical Advisor, and Gary Kay, Entrepreneur</td>
<td>Redican (Canada), and Independent Consultant (Canada)</td>
<td>Clean Energy</td>
</tr>
<tr>
<td>39</td>
<td>David Thompson</td>
<td>Project Manager</td>
<td>Walker Environmental (Canada)</td>
<td>WISE Public Lecture</td>
</tr>
<tr>
<td>40</td>
<td>Sankaran Ramalingam</td>
<td>President</td>
<td>ENFUSE (Energy and Fuel Users Association of India) (India)</td>
<td>Potential Collaboration on Renewable Energy projects</td>
</tr>
<tr>
<td>41</td>
<td>Eddy Chui</td>
<td>Director at CanmetENERGY</td>
<td>NRCan (Canada)</td>
<td>Clean Energy projects</td>
</tr>
<tr>
<td>42</td>
<td>Madjid Soltani</td>
<td>Assistant Professor</td>
<td>K.N. Toosi University (Iran)</td>
<td>Clean Energy projects</td>
</tr>
<tr>
<td>43</td>
<td>Siva Kumar Kuppuswamay</td>
<td>Founder</td>
<td>Footprint Engineering (Canada)</td>
<td>R&amp;D collaboration on geotechnical engineering projects</td>
</tr>
<tr>
<td>44</td>
<td>Denis Gendron</td>
<td>President and CEO</td>
<td>Claire Lasers Corporatio (Canada)</td>
<td>Oil and Gas</td>
</tr>
<tr>
<td>45</td>
<td>Colin Russell</td>
<td>Manager, Program Development and Partnerships, Catherine Burns, Professor and Executive Director, and</td>
<td>Centre for Bioengineering &amp; Biotechnology, UW (Canada)</td>
<td>Bioenergy and nano energy projects</td>
</tr>
<tr>
<td>No.</td>
<td>Name and Title</td>
<td>Organization</td>
<td>Topic</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>--------------</td>
<td>-------</td>
<td>--------------</td>
</tr>
<tr>
<td>46</td>
<td>Oleg Stukalov, Business Development Manager</td>
<td>ENFUSE (Energy and Fuel Users Association of India) (India)</td>
<td>Potential Collaboration on Renewable Energy projects</td>
<td>August 3, 2018</td>
</tr>
<tr>
<td>47</td>
<td>Sankaran Ramalingam, President</td>
<td>ENFUSE (Energy and Fuel Users Association of India) (India)</td>
<td>Potential Collaboration on Renewable Energy projects</td>
<td>August 7, 2018</td>
</tr>
<tr>
<td>48</td>
<td>Elham Akhavan, Technical Staff, and Gary Stevens, Chief Scientist</td>
<td>S2e Technologies (Canada)</td>
<td>EV charging infrastructure</td>
<td>August 8, 2018</td>
</tr>
<tr>
<td>49</td>
<td>Jaan Timusk, Professor Emeritus (Retired)</td>
<td>University of Toronto (Canada)</td>
<td>WISE Public Lecture</td>
<td>August 14, 2018</td>
</tr>
<tr>
<td>50</td>
<td>Colin Russell, Manager, Program Development and Partnerships,</td>
<td>Centre for Bioengineering &amp; Biotechnology, UW (Canada)</td>
<td>Bioenergy projects</td>
<td>August 15, 2018</td>
</tr>
<tr>
<td>51</td>
<td>Claude Guérin, International Senior Project Manager</td>
<td>Total Eco Energy (Canada)</td>
<td>R&amp;D in solar energy</td>
<td>August 16, 2018</td>
</tr>
<tr>
<td>52</td>
<td>Mohan McLelland, Technical Services</td>
<td>Chemtura Co. (Canada)</td>
<td>Waste-to-Energy</td>
<td>August 22, 2018</td>
</tr>
<tr>
<td>53</td>
<td>Doug Beynon, Co-Founder, CEO and Director</td>
<td>Advanced Chemical Technologies (Canada)</td>
<td>Green Methanol project</td>
<td>August 23, 2018</td>
</tr>
<tr>
<td>54</td>
<td>Chandra Ramadurai, CEO, and Matthew Zipchen, President</td>
<td>Efficiency Capital</td>
<td>Net zero homes</td>
<td>September 10, 2018</td>
</tr>
<tr>
<td>55</td>
<td>Laura Rees, Executive Director</td>
<td>Council for Clean and Reliable Energy (CCRE) (Canada)</td>
<td>Industry-Academic Event Discussion</td>
<td>September 11, 2018</td>
</tr>
<tr>
<td>56</td>
<td>Jason Jonkman, Senior Engineer</td>
<td>NREL (U.S.A)</td>
<td>WISE Public Lecture</td>
<td>September 20, 2018</td>
</tr>
<tr>
<td>57</td>
<td>Scott Morris, Founder</td>
<td>eTed Solutions (Canada)</td>
<td>Energy Harvesting</td>
<td>September 26, 2018</td>
</tr>
<tr>
<td>58</td>
<td><strong>Vikram Singh</strong>, Director of Advanced Planning</td>
<td>Alectra Utilities</td>
<td>WISE Public Lecture</td>
<td>September 28, 2018</td>
</tr>
<tr>
<td>59</td>
<td><strong>Scott Morris</strong>, Founder</td>
<td>eTed Solutions (Canada)</td>
<td>Energy Harvesting</td>
<td>October 3, 2018</td>
</tr>
<tr>
<td>60</td>
<td><strong>Scott Morris</strong>, Founder</td>
<td>eTed Solutions (Canada)</td>
<td>Energy Harvesting</td>
<td>October 9, 2018</td>
</tr>
<tr>
<td>61</td>
<td><strong>Subhi Alsayed</strong>, VP Sustainable Development</td>
<td>Mattamy Homes (Canada)</td>
<td>Net zero homes</td>
<td>October 10, 2018</td>
</tr>
<tr>
<td>62</td>
<td><strong>Pierre Pinson</strong>, Professor</td>
<td>Technical University of Denmark (Denmark)</td>
<td>WISE Public Lecture</td>
<td>October 10, 2018</td>
</tr>
<tr>
<td>63</td>
<td><strong>Glenn Sutton</strong>, Former Mayor of Kincardine</td>
<td>Government of Canada (Canada)</td>
<td>EV charging infrastructure</td>
<td>October 12, 2018</td>
</tr>
<tr>
<td>64</td>
<td><strong>Seyedbijan Mahbaz</strong>, Co-Founder</td>
<td>Inspecterra Inc. (Canada)</td>
<td>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and concrete infrastructure projects</td>
<td>October 12, 2018</td>
</tr>
<tr>
<td>65</td>
<td><strong>Seyedbijan Mahbaz</strong>, Co-Founder</td>
<td>Inspecterra Inc. (Canada)</td>
<td>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and concrete infrastructure projects</td>
<td>October 15, 2018</td>
</tr>
<tr>
<td>66</td>
<td><strong>Seyedbijan Mahbaz</strong>, Co-Founder</td>
<td>Inspecterra Inc. (Canada)</td>
<td>Start-up venture (UW) collaborating on non-destructing testing (NDT) of wood poles and concrete infrastructure projects</td>
<td>October 16, 2018</td>
</tr>
<tr>
<td>67</td>
<td><strong>Subhi Alsayed</strong>, VP Sustainable Development</td>
<td>Mattamy Homes (Canada)</td>
<td>Net zero homes</td>
<td>October 24, 2017</td>
</tr>
<tr>
<td>68</td>
<td><strong>Craig Applegath</strong>, Principal, <strong>Subhi Alsayed</strong>, VP Sustainable Development, <strong>Adrian Conrad</strong>, COO, <strong>Adrian Wang</strong>, Director, <strong>Richard</strong></td>
<td>Architect FRAIC DIALOG (Canada), Mattamy Homes (Canada), The Cora Group (Canada), Tridel (Canada), Bird Construction (Canada), NSERC</td>
<td>Building Science Symposium</td>
<td>October 31, 2018</td>
</tr>
<tr>
<td>Appendix VIII – Visitors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Marshall</strong>, Design Manager, <strong>Alejandra de Almeida</strong>, Research &amp; Innovation Development Officer, <strong>Steve Kemp</strong>, Principal, <strong>Rob Quattrociocchi</strong>, Manager, <strong>Stephen Montgomery</strong>, Manager, <strong>Dan de la Mothe</strong>, Manager, <strong>Antoine Habellion</strong>, Manager, <strong>Andrew Oding</strong>, General Manager, <strong>Andy Goyda</strong>, Manager, <strong>Hannah Thevapalan</strong>, Project Manager, <strong>Scott Armstrong</strong>, Senior Facade Specialist, and <strong>Ian Hamilton</strong>, Reader in Energy Epidemiology (Canada), RDH Building Science (Canada), EllisDon (Canada), PCL Constructors Canada Inc. (Canada), Melloul-Blamey Construction Inc. (Canada), Rockwool (Canada), Building Knowledge Canada (Canada), Owens Corning Canada LP (Canada), and UCL Energy Institute (United Kingdom)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>69 <strong>Council for Clean and Reliable Energy (CCRE)</strong>, Members and WISE Advisory Council, Members</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70 <strong>Ingrid Ott</strong>, Professor, <strong>Raymond Tracey</strong>, CEO, <strong>Joshua Wong</strong>, CEO, <strong>Elizabeth Monoian</strong> and <strong>Robert Ferry</strong>, Founding Co-Directors, <strong>John KIT (Germany)</strong>, Essex Power (Canada), Opus One Solutions (Canada), The Land Art Generator Initiative (U.S.A), Canadian Gas Association (Canada), Microsoft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Government, Industry, and Not-for profit</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Larry Smith Lab, UW – Potential Collaboration</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>November 6, 2018</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>November 7, 2018</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Name(s)</td>
<td>Position(s)</td>
<td>Company/University/Institution</td>
<td>Event/Project</td>
</tr>
<tr>
<td>-----</td>
<td>---------</td>
<td>-------------</td>
<td>---------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>71</td>
<td>Elizabeth Monoian &amp; Robert Ferry</td>
<td>Founders</td>
<td>Land Art Generator Initiative (U.S.A)</td>
<td>WISE Public Lecture</td>
</tr>
<tr>
<td>72</td>
<td>Dana Gies</td>
<td>Director of Marketing and Business Development, and Stefanie Bruinsma</td>
<td>Mechanical and Mechatronics Engineering, UW (Canada), and Dean's Office, UW (Canada)</td>
<td>Energy projects</td>
</tr>
<tr>
<td>73</td>
<td>Ann Lin, Vice President and her team, and Adrian Conrad, COO</td>
<td></td>
<td>Changfeng Energy (Canada), and The Cora Group</td>
<td>R&amp;D collaboration in smart city infrastructure</td>
</tr>
</tbody>
</table>
Appendix IX: WISE Contribution to UW Strategic Plan
A Bridge to the World –

Innovation for Global Impact

Objective

To marshal our capacity for innovation to solve the most high-impact global problems, for achieving sustainable development and to deliver a high quality of life for all.

Authors

Jatin Nathwani
Professor and Ontario Research Chair in Public Policy for Sustainable Energy, Faculty of Engineering and Faculty of Environment, Executive Director, Waterloo Institute for Sustainable Energy

Nigel Moore
Manager of Global Programs & Initiatives, Waterloo Institute for Sustainable Energy

Submitted for consideration: August 28 2018

About this document

This concept note presents a vision for consideration by the University of Waterloo community to help inform and shape the University of Waterloo strategic planning process – ‘Bridge to 2020’. It is not an official UW document but is provided as an input to the President’s request to assist with the strategic planning process.
The University of Waterloo has established itself as the top innovation university in Canada. Over the past 60 years we have developed a culture defined by ingenuity, creativity, technical know-how and risk-taking. The world needs change-agents with precisely these qualities, but suffused with empathy and a commitment to address problems of social and economic disparity and environmental sustainability. These endemic issues undermine our quality of life and have disproportionately negative impacts on vulnerable populations at home and abroad while posing existential risks to the health of human and natural systems. They include food and water security, conflict and migration, climate change and environmental degradation, and access to quality education, healthcare, sanitation and energy services.

We believe that the University of Waterloo is bound by duty and opportunity to direct its capacity for innovation to meeting these challenges. Through collaborative interdisciplinary innovation, and social entrepreneurship as a means to deploy solutions, the University can commit its strengths to becoming a global leader in ‘innovation for human betterment’.

Innovation to serve a noble purpose ought to be a hallmark of every institution of higher learning. From underserved indigenous communities in Canada whose ability to thrive is undermined by a host of urgent and debilitating challenges, to displaced and impoverished communities all over the world that are increasingly vulnerable to economic and environmental upheaval, Waterloo innovation can and should play a catalyzing role in unlocking human potential and uncovering new opportunities for socially and environmentally responsible development. It is the guiding light of these vital issues – not the flicker of industry fads – that should draw our institution’s gaze over both the long and short term. The ‘spirit of why not’ – our institutional mantra – should guide us in this regard. If not us, who? If not now, when?

The university will benefit from an approach to innovation that aims at addressing collective global problems with a purpose explicitly linked to improving quality of life. We will fuel the intellectual journey of our researchers, teachers, students, and staff by focussing their attention toward the most wicked, and therefore worthy, of problems. The benefits to Waterloo’s international reputation, campus culture, and the quality and relevance of our teaching and research activities will be significant.

To realize these benefits does not require an overhaul of the University’s current strategy, but it requires building on our existing strengths. Waterloo will differentiate itself by deploying what already makes us unique to create novel pathways for solving critical global problems. Technology innovation, entrepreneurship, and experiential learning are three pillars of the Waterloo approach that will serve us particularly well as we build this approach together.

We believe that Waterloo has an opportunity to redefine the innovation narrative: making it more purposeful, inclusive and collaborative. In doing so we will inspire the next generation of Waterloo students and faculty to become a powerful force for good in the world. Accelerating and deploying this innovation on a large scale will improve quality of life for communities and individuals all over the world, no matter how impoverished or disadvantaged. Our solutions will help ensure global environmental sustainability, economic prosperity, and social equity. This is a purpose suitable for an institution with ambitions as lofty as ours.
Leveraging the current ecosystem

The University’s next strategic plan must do two things: it must inspire the whole campus towards a common, worthy, and bold vision; and it must articulate practical pathways toward realizing the vision, building on past success.

STEM education and technology innovation

The University is a leader in STEM education and technology innovation. Increasingly, we see technology playing a vital role in both uncovering and helping to solve, through myriad ingenious applications, issues that range from food and water security, to climate change, and the delivery of quality health and education for all. A recent and exciting example is in the area of clean energy deployment to address energy poverty. Through a combination of advances in solar photovoltaics, energy storage, electronics and innovations in software and digital finance, affordable and efficient solar energy technology is now lighting up hundreds of thousands of homes across sub-Saharan Africa and developing Asia. Through the University of Waterloo’s ‘Affordable Energy for Humanity Initiative’, we have seen firsthand the revolutionary progress that STEM innovators can create when they direct their attention toward human betterment. Waterloo’s capacity for technological innovation is needed on the world stage, representing a significant opportunity for recognition as a globally impactful hub of ‘tech for good’.

Entrepreneurship

To deploy globally impactful solutions at scale requires another set of capacities beyond the STEM disciplines. Entrepreneurship in particular has become an important vehicle for bringing cutting edge innovations out of the lab and into the field, particularly in an age where public sector leadership of humanitarian issues is rarely of the scale needed to break the back of entrenched challenges. Many of the pioneers of the current off-grid solar revolution are ‘social entrepreneurs’ who got their start in university labs at MIT, Oxford, Berkeley, and other institutions of higher learning where their early ideas found the support they needed to grow into financially sustainable and socially responsible technology enterprises. The world needs an army of these social entrepreneurs, and universities can be critical players in supporting their development. As a leader in entrepreneurship education, Waterloo is again poised to exploit this opportunity for global leadership, which will require a strategic commitment to create a world-class support structure for budding social entrepreneurs.

Co-operative education

As a flagship strength of the university, the next strategic plan must leverage co-op and experiential education programs. From our perspective, the co-op program is perfectly placed to create ‘thousands of bridges to the world’, through an ambitious program that recruits impactful companies, NGOs, and other organizations that are on the cutting edge of sustainable development innovation as hosts for our co-op students. Co-op students will benefit from their awareness of international issues and embeddedness within enterprises that are tackling them, while also bringing this experiential knowledge back to campus where they can continue their educational and entrepreneurial journeys to help solve them.

Drawing once again from our own experience in the clean energy sector, WISE has already established an international internship program for UW co-op students that will send 40+ undergraduates to work as paid interns at clean energy social enterprises
that operate in the developing world. Students have already completed or begun internships in Nigeria, Ghana, Uganda, South Africa, Nepal, Malaysia, South Africa and the UK. This program, which receives external funding that is solely directed toward subsidizing the cost for companies to hire our students by providing the students a scholarship, is a model that could be applied across the sustainable development sector. We are working with on-campus partners such as St. Paul’s Greenhouse Social Impact Incubator to support these students in continuing to work on the problems that they learn about in their co-op experiences abroad once they return to campus.

By matching on-campus resources with external funding the university can create a pipeline of these opportunities, of which we are certain there is considerable and growing demand within the student body. Co-op is already our largest selling point for undergraduate recruitment. We believe that the next generation of prospective students will value access to co-op experiences that allow them to engage with the global issues that they come to university inspired to solve.

**Hands-on learning**

Access to hands-on learning opportunities is already a hallmark of the university. Capstone projects, project-based courses, and student-led teams and clubs not only provide great learning experiences for students, but often result in insights and innovations that find application beyond the classroom. As such, the university’s commitment to enhancing the variety and depth of hands-on, team-based learning opportunities available to students can support the vision described here. A concerted effort should be made to grow the number of project-based course offerings, increase the interdisciplinary focus of capstone and final year projects, and recruit partner organizations that can assist in supplying a pipeline of important problems for students (and professors) to collaborate and help solve. This approach to learning puts a premium on collaboration instead of competition, and teamwork over individual accomplishment. Such an offering would enrich the student experience through increased awareness of global challenges that they care about, and opportunities to make a difference.

**Ideas and approaches**

**Problem-based research**

Design and deployment of technologies and interventions for communities that are impoverished, remote and disconnected from global supply chains is incredibly challenging. The complex economic and social dimensions inherent in these issues necessitates a problem-based interdisciplinary approach to research and learning. The university can leverage the need for a holistic and collaborative approach to innovation as a means to ‘expand the innovation narrative’ to become more deliberately inclusive of non-STEM disciplines. Insights from across social science disciplines and the humanities are critical to the design of innovations with positive sociocultural, economic and environmental outcomes.

Taking this a step further, the university has an opportunity to become a leader in ‘transdisciplinary’ research, wherein non-expert communities such as those that would be the end-user or receptors of a technological or other intervention are invited into the research process to help scope and frame the problem from the outset. Partnerships with community-based organizations that are on the frontlines of critical global
sustainable development issues would aid the development of a Waterloo approach to transdisciplinary action research.

The university should also recognize and enhance the positive role that research centres and institutes can foster in advancing problem-based interdisciplinary research to become ‘curators’ of Waterloo’s research, learning and outreach in these areas. Research centres and institutes can also be relied upon for partnership building.

**Vertically integrated projects (VIPs)**

Vertical integration is a useful model for structuring problem-based research activities that are inclusive of many organizational units, researchers, and students, so as to build and transmit knowledge over the long term. VIPs can be established to address a specific problem in a particular domain (for example, a Sustainable Development Goal), with various research, student and support groups contributing to knowledge creation, solutions development and outreach activities relevant to that domain. Research centres, institutes or staffed research support units can act as network facilitators and partnership builders both within the VIP and externally, and through organizing guest lectures, events, and other activities that ‘bring the world to Waterloo’. Expertise is maintained and built up over time as individuals cycle in and out of the VIP, and as research and entrepreneurial spin-offs, insights to support political decision-making and other outcomes are delivered over time. VIPs where students from all levels and faculty members from across disciplines with an interest in a specific problem area are able to engage in this way relies on the existence of a clear ‘front door’ and staff support to encourage collaboration and diffusion of knowledge across the network.

This idea is not new. A consortium of 24 leading engineering schools across the US has implemented the VIP model over the past several years. Georgia Tech, for example, is now home to over 50 VIPs that span the research landscape, “uniting undergraduate education and faculty-led research in a team-based context...[to] create long term research and development experiences...cultivate leadership and mentoring...[and] benefit faculty research programs.”

**Social enterprise incubation**

At Waterloo, we already have an enviable incubation and acceleration ecosystem and strong entrepreneurial spirit within the faculty and student body. The next step is to build a more substantive support system for social entrepreneurs, particularly those interested in international sustainable development. This process has already begun and is being championed by a number of faculty and staff members across the campus (e.g. St. Paul’s Greenhouse Social Impact Incubator, The Epp Peace Incubator Program), but more co-ordination and resources are needed, especially with regard to international networking and mentorship that is specifically tailored for international social enterprise.

The proliferation of ‘challenge competitions’ (such as The Hult Prize and The World’s Challenge Challenge) that focus on social innovation illustrates a growing trend toward innovation and entrepreneurship as mechanisms for solving global grand challenges. Their popularity amongst UW students, and the success these teams have already had, is an indication that there is strong demand for a more co-ordinated campus-wide effort to support social innovation and enterprise.
With these activities in place, Waterloo can become the next hotbed of STEM innovation and social entrepreneurship for humanitarian change. Our success stories will become our global calling cards.

**Humanitarian engineering**

Waterloo is also well-placed to become a leader in a new engineering sub-discipline that is currently being championed elsewhere. ‘Humanitarian engineering’ minors, certificates and other emphases have been established at a number of leading engineering schools abroad, notably amongst large public universities in the United States such as UC Berkeley, Penn State and Ohio State. The sub-discipline integrates social science driven understanding of end-use communities with novel design concepts such as ‘frugal innovation’ and ‘user-centric design’ to develop an engineering pedagogy that is uniquely tailored to innovation for poverty-stricken and resource-constrained settings. As the best engineering school in a country that does not have a significant humanitarian engineering program at any other university, Waterloo could champion its own approach and gain international recognition as an innovator in ‘engineering for humanitarian change’.

**The Sustainable Development Goals (SDGs)**

The United Nations Sustainable Development Goals (SDGs) are a useful and well-recognized framework through which to identify and champion issues of consequence at both global and local scales. By embedding Waterloo’s new strategic emphasis within the 17 SDGs, we can better ensure both the internal coherence and international relevance of the proposed activities outlined above.

We should be emboldened in this regard by the fact that Waterloo has become the Canadian host institution of the Sustainable Development Solutions Network (within the Faculty of Environment). A number of research centres and institutes (notably WISE and the Waterloo Institute for Nanotechnology) are already beginning to use the SDGs as a framework for illustrating the significance of their work. As mentioned above, VIPs could be established according to the 17 SDGs, and act as nodes for research, teaching, entrepreneurial and other activities of relevance to the ‘global goals’ to congeal.

**Benefits to the UW community**

Pursuit of the ‘Bridge to the World’ vision outlined here will benefit the university and its various stakeholders in a variety of ways, both big and small.

**International prestige**

Waterloo has achieved an unparalleled position domestically as Canada’s top innovation university, and one of the best all-around post-secondary institutions in the country. Abroad, the university’s reputation is solid and trending in the right direction, but does not yet match our ambitions. The university needs more international success stories, and international partnerships and activities that bear these success stories as fruit. Employing the SDGs as a guiding and internationally recognized framework through which to communicate our accomplishments will aid us in this regard. As will our ability to produce visionary social entrepreneurs who harness the technological
know-how and deep understanding of end-use communities that they gain from their Waterloo education. We believe that through leading by example to serve the global community, our reputation abroad will significantly benefit. By seeking real-world impact we will gain the greater international prestige that we seek.

**Attracting global ambassadors**

The university will benefit from attracting worldly graduate students and globally recognized faculty who come to see Waterloo as an ‘institution with a noble purpose’, where their work will contribute to broader efforts to deliver tangible, impactful solutions to the problems that they have defined their career to solve.

Amongst incoming undergraduate students as well, a Waterloo education will grow in attractiveness. Young people are more aware than ever of the global issues that Waterloo will position itself to take a leadership role in tackling. By engaging incoming students as ‘global citizens’, empowering them to engage in hands-on learning about the issues that they care about, and creating pathways for their participation in cross-university initiatives to develop solutions, we will not only attract the brightest students but empower them to become global change-makers. They will become the university’s next generation of ‘global ambassadors’.

**Expanding the innovation narrative beyond the STEM disciplines**

The vision also brings non-STEM disciplines and departments more firmly into the innovation narrative of the university, organizing the university’s activities around problems and vertically integrated interdisciplinary teams rather than discrete disciplinary units. This transition will benefit the research environment by not only providing greater access to the research enterprise for students, but also by linking entrepreneurship activities more closely with research outcomes and encouraging research with a greater chance for impact. Waterloo will combine technological and social innovation to create holistic and robust solutions to previously insurmountable real-world challenges. This collaborative socio-technical innovation process promises to reinvigorate and improve the saliency of scholarship at the university and better allow us to become more than the sum of our parts.

**Collaboration over competition for student health and learning**

The university must also develop a strategy to combat unhealthy competition and isolation within the undergraduate student body, particularly in the STEM faculties. While some level of stress is impossible to reduce in rigorous academic programs, there are alternative methodologies of teaching and learning that may allay some of the isolation that is felt by far too many of our brightest students. By encouraging collaboration and team-based learning the university can better deliver to students an education that is purposeful, provides a sense of accomplishment and satisfaction, and teaches the teamwork skills that will be demanded of them after they graduate.

Reducing isolation and providing a more social educational environment for students will also aid their ability to contribute effectively in a world that is characterised by constant communication and connection, as well as by ambiguity, uncertainty and rapid change.
Gender

The university is a member of the global HeForShe campaign and has taken significant efforts to attract and retain more female students in STEM and entrepreneurship programs, where they are currently under-represented. The vision carries forward this commitment in two significant ways, potentially leading to a step-change in Waterloo’s efforts in this regard.

First, there is concrete evidence that STEM programs with a social or environmental lens attract and retain greater numbers of female students. This has been the case at both Penn State and Ohio State University, where new minor programs in humanitarian engineering achieved approximately 50% female enrollment without any special recruitment effort. Second, gender is increasingly seen as an important lens through which to understand the SDGs (one of which is gender equality). Development practitioners have found success in achieving other SDGs through an approach that has women’s empowerment at its heart. We see this in the clean energy sector, where empowerment of female entrepreneurs within target communities has often led to better development outcomes than projects that do not employ such a strategy. As a HeForShe member and a champion of innovation for global impact, Waterloo could become a leading global force in shaping socially and environmentally responsible development that empowers women and girls.

Indigenization

Waterloo should similarly seize an opportunity to align this vision with our indigenization strategy. Many indigenous communities in Canada face significant and confounding social, environmental and development challenges. By establishing deep dialogues and working collaboratively with communities to help solve them, we will not only have an impact here at home, but be able to integrate what is learned from these experiences in order to refine and enhance the collaborative innovation approach that Waterloo will champion at the global level. Recent work at WISE in collaboration with the Waterloo Global Science Initiative (WGSI) on the topic of energy poverty in off-grid indigenous communities highlighted the notable challenges that are faced by remote communities in Canada, as well as the immense opportunities for collaborative innovation that exist to overcome such challenges (see ‘The OpenAccess Energy Blueprint’ – Chapter 6).

As we advance our new indigenization strategy it would be a highly positive step for the University to recognize the valuable role that Waterloo innovation could play in creating new sources of economic and social value within resource-constrained communities.

Alignment with existing objectives

The vision also delivers upon the themes and primary objectives of the previous strategic plan, namely:

- **Internationalization**: “Educate graduates uniquely prepared to address the challenges and opportunities of the 21st century” & “Seek global awareness of Waterloo’s research and teaching expertise”
- **Entrepreneurship**: “Promote innovation and entrepreneurship that spans a wide range of needs, including social, political, health, environmental and technological” & “Facilitating student, faculty and staff entrepreneurship in a broad range of fields, including social entrepreneurship”
Appendix IX – WISE Contribution to Strategic Plan

- **Transformational Research**: “Identify and seize opportunities to lead in new/emerging areas” & “Increase interdisciplinary and transdisciplinary research at the global, national and local scale”
- **Experiential Education**: “Educate outstanding and world-ready graduates whose skills are in high demand globally” & “Expand experiential learning to include service-based activities and international programs”

**In conclusion**, to advance such a vision requires a wider conversation within the University of Waterloo community to begin to formulate next steps in developing such a strategy. This will require reviewing best practices across post-secondary institutions that have undertaken program and curriculum development that reflect similar priorities. Below and in the accompanying annexes, we include a summary of our own research findings in this regard, to provide initial insights for a broader engagement and program design process at UW.

**Background research, resources and peers to learn from**

WISE has undertaken extensive research to investigate the methodologies employed by universities that have become recognized leaders in sustainable development, humanitarian engineering, social innovation and social entrepreneurship. This research was conducted in order to inform WISE’s ‘Affordable Energy for Humanity Initiative’. Our findings are based on extensive interviews with key university administrators and faculty who lead top programs, alongside secondary research. The insights gained have inspired us to develop this document to support the next phase of the strategic planning process at UW.

**Accompanying documents**

Accompanying this document are three additional documents (Please see below Annexes) with more information about the research and activities that undergird the strategic vision:

- **Annex 1** – Research notes summarizing relevant initiatives at ten leading global universities, utilizing a common framework to compare their development innovation and entrepreneurship activities.
- **Annex 3** – 4-page brief summarizing research findings that was presented to the WISE board in January 2018

**Peers and resources**
A number of initiatives elucidated in the attached documents are briefly noted below, with key resources noted for further interest. WISE is in consistent contact with many of the leading voices in this area, including the authors of many of the resources listed below.

✓ The **Vertically Integrated Projects Consortium** includes 24 US universities who have established various VIP programs that foster innovation by involving students in challenging projects embedded in long-term faculty research efforts.

  **Resources:** “Systemic Reform in Higher Education: The Vertically Integrated Projects Consortium” (presentation by Consortium Director Ed Coyle) & “Vertically Integrated Projects (VIP) Programs: Multidisciplinary Projects with Homes in Any Discipline” (paper presented at 2017 American Society for Engineering Education Annual Conference & Exposition)

✓ **Arizona State University** has undertaken a transformation to become a ‘New American University’. Led by their president Dr. Michael Crow, this process has seen the university break down disciplinary barriers and create problem-driven research and teaching streams that interface deeply with external stakeholders. Themes of social innovation and sustainability have become deeply embedded in the University’s core structure. ASU has recently been ranked the top US University for innovation.

  **Resources:** [https://newamericanuniversity.asu.edu/](https://newamericanuniversity.asu.edu/) & “Designing the New American University” (Book by Dr. Michael Crow)

✓ **The Massachusetts Institute of Technology (MIT)** is home to a number of world leading centers and labs at the forefront of research and action related to poverty alleviation, technology for development and social enterprise. These include D-Lab, The Tata Center for Technology and Design, The Legatum Center for Development and Entrepreneurship, and the MIT Innovation Initiative.

  **Resources:** See links above and research note on MIT for more information & “The Global State of the Art in Engineering Education” (a report of the ‘New Engineering Education Transformation’, an MIT initiative)

✓ **TU Delft** is recognized as a leader in reforming engineering education to be collaborative and team-based, and to encourage interdisciplinary systems thinking and creativity. Spearheading this effort is aerospace engineering professor Aldert Kamp, whose department was singled out in the MIT New Engineering Education Transformation study as a leading example of forward thinking engineering education.

  **Resources:** “Engineering Education in the Rapidly Changing World: Rethinking the Vision for Higher engineering Education” (book by TU Delft Aerospace Engineering Professor Dr. Aldert Kamp)

✓ **Duke University**’s fundamental commitment to ‘knowledge in service to society’, and the academic culture that this focus has helped to create, underpins a robust network of programs on campus in the area of social innovation and entrepreneurship, international development, and civic engagement.

  **Resources:** See research note on Duke for more information & “Scaling Pathways” (a report from the Duke Centre for the Advancement of Social Entrepreneurship on a $44.5 million USAID/Skoll Foundation program to invest in social enterprises)
Aalto University in Finland houses a number of centres, programs and projects on the theme of global sustainable development. An umbrella organization, Aalto Global Impact, co-ordinates the ecosystem. Activities include a student-centered incubator for social enterprise, a capacity-building exchange program with developing world universities and a transdisciplinary research project called ‘New Global’ that develops locally co-created sustainable development solutions in a number of developing world regions. A ‘systems’ approach is employed, valuing deep and prolonged partnerships.

Resources: “New Global” (website) & “Aalto Global Impact” (website)

The Miller Centre for Social Entrepreneurship at Santa Clara University is the largest university-based social enterprise accelerator in the world. Over 700 social entrepreneur alumni that have raised over $500M of capital for their ventures to date. Students participate in experiential learning opportunities with enterprises in the network through fellowships. Beyond the Miller Center, the School of Engineering houses the ‘Frugal Innovation Hub’ which is a touchpoint for humanitarian engineering on campus.

Resources: “Action Research for Social Entrepreneurship Education” (white paper about the center’s strategy by affiliated faculty members)

The Blum Center for Developing Economies at UC Berkeley hosts initiatives including the Berkeley Development Impact Lab (DIL), which brings together interdisciplinary teams to develop innovations to fight poverty. DIL provides seed funding for projects, convenes stakeholders and offers support for early-stage development innovators. The Blum Center also hosts Big Ideas @Berkeley, a social innovation competition with nearly 700 students participating annually.

Resources: “Development Engineering Toolkit” (a guide featuring lessons learned on launching a development engineering program that unites the social sciences and engineering) & “Big Ideas Toolkit” (a best practices guide for running social innovation competitions on campus).

Penn State University’s Humanitarian Engineering and Social Entrepreneurship program takes students on a technology-driven social enterprise journey that begins with basic training on social entrepreneurship and humanitarian engineering, allows them to experience development issues firsthand, and culminates with the development of real social ventures and deep scholarly research into their impacts.

Resources: “Solving Problems that Matter (and Getting Paid for it)” (Book on career opportunities for STEM students in the sustainable development sector edited by HESE founding director Dr. Khanjan Mehta)

Ohio State University’s Humanitarian Engineering Center exposes students to concrete humanitarian/development challenges through unique courses, a minor for engineering students, a dedicated scholarship program, and opportunities for international field work at project sites.

Resources: “Humanitarian Engineering at The Ohio State University: Lessons Learned in Enriching Education While Helping People” (Journal article by affiliated faculty members)