2017-2018
Annual Report
Year 3

NSERC Energy Storage Technology Network

Ryerson University
Centre for Urban Energy

NSERC CRSNG

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Zhihao Yu, University of New Brunswick, participates in the energy storage design challenge during NESTNet Week.

Introduction

Modern grid-scale energy storage is poised to transform the electricity system, bringing immense benefits to industries, utilities, governments and consumers.

A confluence of factors is driving this surge of interest in Canada, including:

- Advances in technology.
- Environmental concerns leading to a renewed focus on renewable energy.
- Aging electricity grid infrastructure that needs replacing.
- Immense potential of smart grid systems that enable intelligent energy management.

Energy storage (ES) has been identified by the Natural Sciences and Engineering Research Council of Canada (NSERC) as a priority within its strategic target areas because Canada's capacity to store energy is currently seen as an underdeveloped component in its energy management capabilities. Early-stage Canadian companies and products are now entering a market that is on the verge of tremendous predicted growth. The global energy storage market will double six times between 2016 and 2030, according to Bloomberg New Energy Finance (2017).

However, this global marketplace has multinational competition, and small and medium Canadian companies must be enabled to compete. A significant opportunity lies in positioning Canada to capitalize on the current momentum – similar to Denmark's capture of the first wave of the wind energy market – by developing a suite of technologies and systems to be commercialized by Canadian companies with trained, highly qualified personnel leading to employment and a robust economy.

Since 2015, the NSERC Energy Storage Technology Network (NESTNet) has been collaboratively exploring many different types of energy storage, including flywheels, lithium-ion batteries and compressed air, while determining how best to integrate these technologies into electricity grids. In addition, researchers consider the implications arising from the increasing adoption of ES and how consumers will perceive, adopt and interact with these technologies. By partnering with the private sector, NESTNet enables directed progress – without duplication of efforts – towards a strong domestic Canadian ES industry that is also competitive in the global marketplace.

Jill Powers from the California Independent System Operator delivers a speech at the Leading the Charge conference.

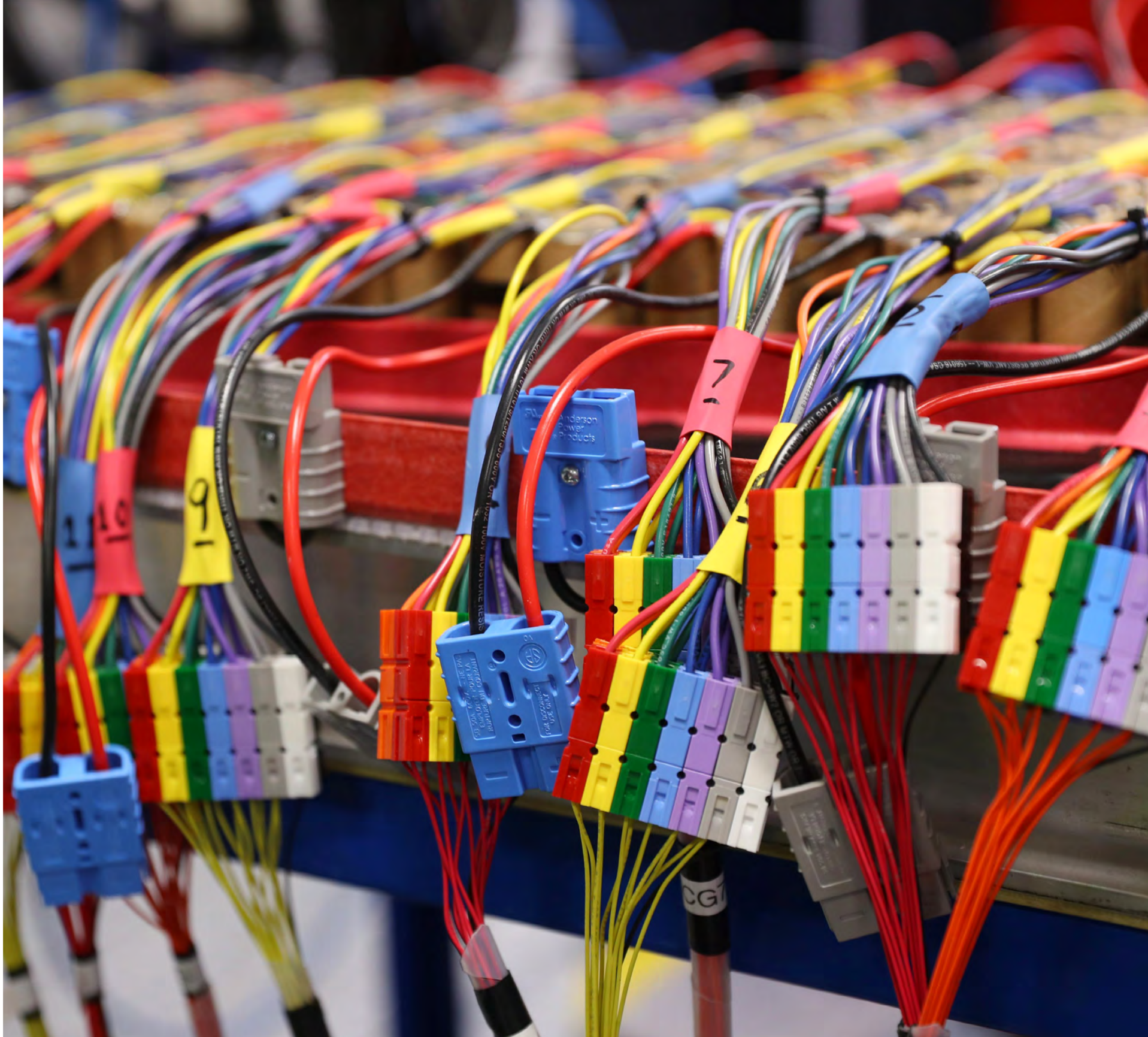
Mission and Vision

NESTNet's mission is to bring together leading academic, industry, utility and government stakeholders to develop, test, demonstrate and, ultimately, commercialize innovative ES technologies, products, processes and services through multidisciplinary and collaborative research and development.

To achieve its long-term vision of creating more reliable, environmentally friendly and efficient electric power systems, the network will work to increase the market penetration of Canadian-made ES technologies worldwide.

This mission and vision is directed at transformational change, and will be achieved by meeting goals critical to academic, public and private sector stakeholders over five years:

1. Generate fundamental ES knowledge.
2. Facilitate ES technology commercialization.
3. Train Canadian highly qualified personnel.
4. Strengthen and deepen existing research partnerships between Canadian organizations and academic researchers.



Message from the Board Chair

It gives me great pleasure to introduce NESTNet's 2017-2018 Annual Report, which allows me to reflect on how far the network has come in three short years.

NESTNet research has rapidly accelerated beyond the lab with technologies, policies and papers developed that are ready to be applied and adopted in the real world. You can read about these stories on the following pages.

This past summer, Ryerson University hosted another successful NESTNet Week, with more than 180 participants attending events across four days at Mattamy Athletic Centre, the historic former home of the Toronto Maple Leafs. We invited speakers from the California Independent System Operator and General Electric, as we look to strengthen ties with energy storage experts in the United States and around the world.

Also during NESTNet Week, students took part in a unique design challenge aimed at grounding their work in the particular and multifaceted challenges of energy storage.

In year three, NESTNet trained and developed almost 100 highly qualified personnel. These are the engineers, urban planners and policy experts that will drive the technology forward over the coming decades, enabling us to transition to a thriving clean-energy economy. Having met many of them during NESTNet Week, I know that the future is in safe hands.

NESTNet's 26 industry and government partners continue to provide their vital input and support. A special thanks to Hydro-Québec for hosting one of our three winter schools at their energy technology laboratory in Shawinigan, Que. And to Dalhousie University and the University of Waterloo who played host to the other two.

The progress of the network so far, under the leadership of Bala Venkatesh and the stewardship of my fellow board members, has been exciting to see. We will continue to deliver on our vision for a network that helps build a strong domestic energy storage industry that is also competitive in the global marketplace.

Neetika Sathe

Chair, NESTNet Board of Directors
Vice President, Advanced Planning, Alectra Inc.

Message from the Network Director

Welcome to the 2017-2018 Annual Report. Three years into the network's five-year mandate, we continue to deliver tangible outcomes — in the form of highly qualified personnel, intellectual property, patents, journal papers, conference presentations, networking events and communications — that are helping to supercharge Canada's energy storage industry.

While the exceptional research going on across NESTNet's four themes (of energy storage technologies, power converters, systems integration, and economics and policy) continues, we have also sharpened our focus on two areas that transcend every one of our 24 projects: commercialization and internationalization. The first "cross-theme" helps us identify products that are commercially viable, while the second helps us to strategically promote NESTNet to a global audience.

On the commercialization front, several projects have now successfully wrapped up and our efforts have turned towards commercializing the cutting-edge software and hardware that has been developed in university labs across Canada.

On the internationalization front, new funding from NSERC allowed us to develop collaborations with esteemed international researchers. It also allowed us to host world-class experts and speakers, put on international workshops, send our students overseas, and organize our first international mission, which headed to the U.K. in March 2018.

Making headway in these two areas will be critical to the network's overall success and I invite you to read more about our efforts on the following pages.

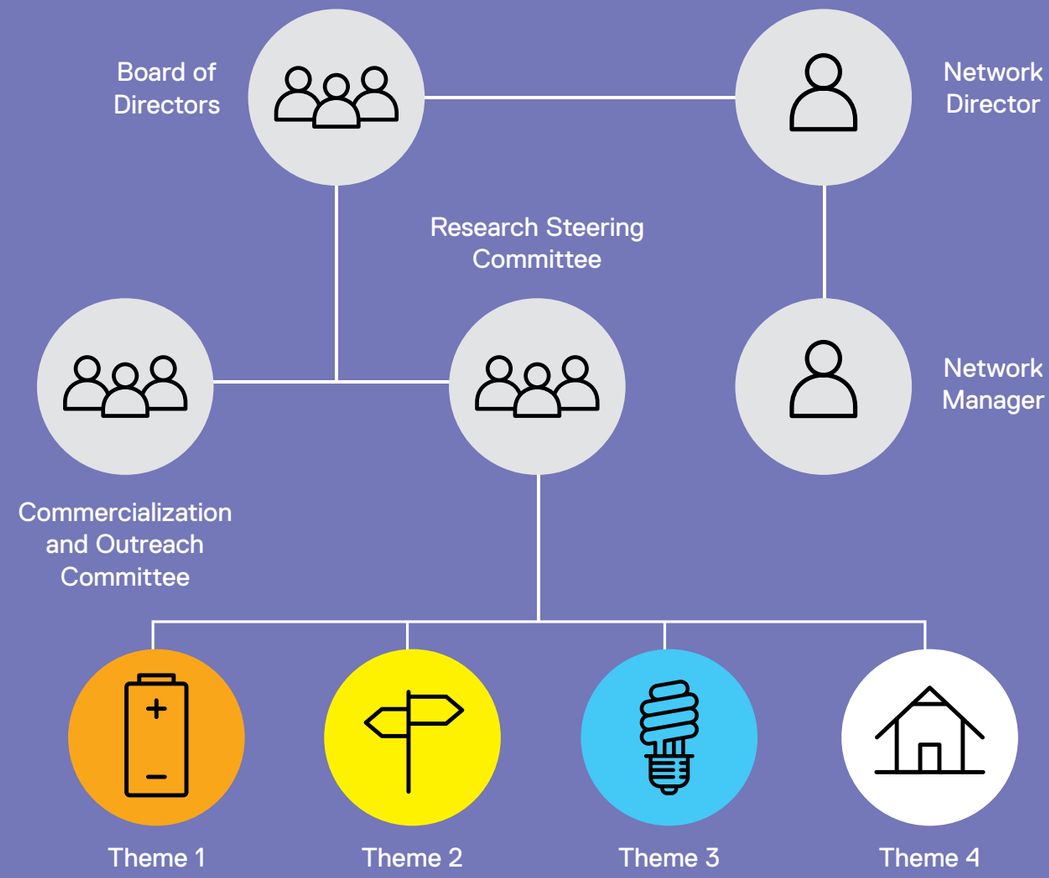
Above all else, NESTNet is about the people involved so I would also like to take this opportunity to thank all our members for their accomplishments over the past three years. I am blessed to be leading a network that features some the brightest minds in the country, who are open to collaborating with each other, learning from one another and, in turn, pushing the network forward every day.

Bala Venkatesh

Network Director, NESTNet
Academic Director, Centre for Urban Energy at Ryerson University
Professor, Electrical and Computer Engineering, Ryerson University

Membership and Governance

The board of directors has overall responsibility for the governance of the network. It is comprised of representatives from NESTNet's member organizations as well as independent experts from academia, industry and government.



As the network director, Bala Venkatesh coordinates network affairs and leads the overall implementation of project activities through his participation in research, dissemination and training of highly qualified personnel (HQP).

As the network manager, Karen Ho-Cespedes ensures the day-to-day operations of the network and supports the network director and the Research Steering Committee (RSC) in all responsibilities related to the network, including strategic planning and managing relationships.

Chaired by Neetika Sathe, the board of directors provides strategic guidance, counsel and foresight, and administrative and financial guidance. The board oversees NESTNet activities and approves the annual budget. The network director also sits on the board.

The research activities of the network are organized into four themes and led by F. Handan Tezel, Liuchen Chang, Claudio Cañizares and Miguel Anjos. The theme leaders are responsible for overseeing each theme's research projects and evaluating HQP research activities. New this year are two cross-themes: Internationalization led by Ian Rowlands, and Commercialization led by Jennifer MacInnis. The cross-theme leaders are responsible for developing and implementing strategies for the network's growth.

The RSC is comprised of the network director, theme leaders, partner representatives, and external academic experts to provide leadership and vision on the review and assessment of ongoing NESTNet research projects.

The purpose of the Commercialization and Outreach Committee (COC) is to identify potential technologies and intellectual property (IP) developed by network researchers for commercialization opportunities. The COC will be managing the technologies, focusing on technology transfer and commercialization, enabling and expediting demonstration opportunities, and promoting ES to the public.

Board of Directors

Neetika Sathe

Vice President, Advanced Planning

Alectra Inc. (Chair)

Bala Venkatesh

Network Director; Academic Director, Centre for Urban Energy; Professor, Department of Electrical and Computer Engineering

Ryerson University

Brian Hewson

Vice President, Consumer Protection and Industry Performance

Ontario Energy Board

Eric Deschenes

Executive Vice President, EP Division

ABB Canada

Liuchen Chang

Power Electronics Converters Leader; Professor, Department of Electrical and Computer Engineering

University of New Brunswick

Steven Liss

Vice President, Research and Innovation

Ryerson University

Sundar Venkataraman

Director

GE Energy Consulting

Tom Chapman

Market Design and Development

Independent Electricity System Operator

Usman Syed

Director, Conservation and Energy Efficiency

Ontario Ministry of Energy

Walmir Freitas

Professor

University of Campinas

Claire McAneney

Manager

NSERC (Non-Voting)

Karen Ho-Cespedes

Network Manager

Ryerson University (Non-Voting)

Research Steering Committee

Bala Venkatesh

Network Director; Academic Director, Centre for Urban Energy; Professor, Department of Electrical and Computer Engineering

Ryerson University

F. Handan Tezel

Energy Storage Technologies Leader; Professor, Department of Chemical and Biological Engineering

University of Ottawa

Liuchen Chang

Power Electronics Converters Leader; Professor, Department of Electrical and Computer Engineering

University of New Brunswick

Claudio Cañizares

Power Systems Integration Leader; Associate Director

Waterloo Institute for Sustainable Energy

Miguel Anjos

Economics and Policy Leader; Professor and Canada Research Chair, Polytechnique Montréal

INRIA International Chair

Jennifer MacInnis

Commercialization Leader; Senior Legal Counsel and Senior Director, Applied Research and Commercialization

Ryerson University

Ian Rowlands

Internationalization Leader; Professor; Associate Vice-President, International

University of Waterloo

Adam Tuck

Program Leader, Energy Storage for Grid Security and Modernization

National Research Council Canada

Christopher Jones

Senior Lecturer, Social and Environmental Psychology

University of Surrey

Hartley Springman

Manager, Strategic Policy and Research

Ontario Ministry of Energy

Mohamed El-Hawary

Professor

Dalhousie University

Nelson Martins

Assistant to the Director General; Research Consultant on Power System Analysis

The Electrical Energy Research Center

Pratap Revuru

Smart Grid Solution Architect

Schneider Electric Canada

Karen Ho-Cespedes

Network Manager

Ryerson University (Non-Voting)

Commercialization and Outreach Committee

Bala Venkatesh

Network Director; Academic Director, Centre for Urban Energy; Professor, Department of Electrical and Computer Engineering

Ryerson University

Adam Tuck

Program Leader, Energy Storage for Grid Security and Modernization

National Research Council Canada

Carmine Pizzurro

President and CTO

eCAMION Inc.

Gary Thompson

Lead, Generation Planning and System Studies Engineering and Investment Planning

Toronto Hydro

Geoff Osborne

Manager, Business Development

NRStor

Jennifer MacInnis

Commercialization Leader; Senior Legal Counsel and Senior Director, Applied Research and Commercialization

Ryerson University

Marcelo Sarkis

Senior Patent Agent

Prima IP

Pratap Revuru

Smart Grid Solution Architect

Schneider Electric Canada

Karen Ho-Cespedes

Network Manager

Ryerson University (Non-Voting)

Academic Partners

There are a total of 15 university partners participating in NESTNet.

Industry and Government Partners

There are a total of 13 industrial, utility and government partners participating in NESTNet.

Industry and Government Associate Members

There are a total of 13 industrial, utility and government associate members and collaborators participating in NESTNet.

MEMBERSHIP AND GOVERNANCE

NSERC ENERGY STORAGE TECHNOLOGY NETWORK

By the Numbers

The NSERC Energy Storage Technology Network (NESTNet) is committed to training the next generation to power the future of Canadian energy storage, as well as develop cutting-edge technologies and products for the Canadian utility sector.

In the third year of the network, outputs include:

99.5 highly qualified personnel (year three)

60 journal articles (through year three)

82 conference papers (through year three)

8 intellectual property/ patent filings (through year three)

Table 1: Total HQP in Year Three	Postdoctoral Fellow (PDF)	PhD	Master of Applied Science (MASc)	Undergraduate
Target	6	35	12	1
Actual	11.5	42	35	11

Table 2: HQP by Theme	Theme 1	Theme 2	Theme 3	Theme 4
	20	28	24.5	27

Table 3: Cumulative Outputs	Theme 1	Theme 2	Theme 3	Theme 4	Total
Journal articles	19	12	15	14	60
Conference papers	39	20	12	11	82
Patents	4	2	2	0	8
Technical reports	0	2	10	10	22
Wider impact	3	0	0	11	14
Total	65	36	39	46	186

Financials

Table 4: NSERC Funding	Cumulative Budget (2015-18)	Cumulative Expenses (2015-18) *	Year 3 Budget (2017-18)	Year 3 Expenses (2017-18) *
Theme 1	$666,000	$686,919	$221,400	$251,764.64
Theme 2	$636,500	$616,278	$231,500	$245,374.48
Theme 3	$660,500	$642,225	$260,500	$254,601.02
Theme 4	$778,300	$825,534	$260,500	$354,990.30
Central activities	$248,600	$183,301	$81,200	$89,136.42
International activities	$33,190	-	$33,190	-
Total	$3,023,090	$2,954,256	$1,088,390	$1,195,866.86

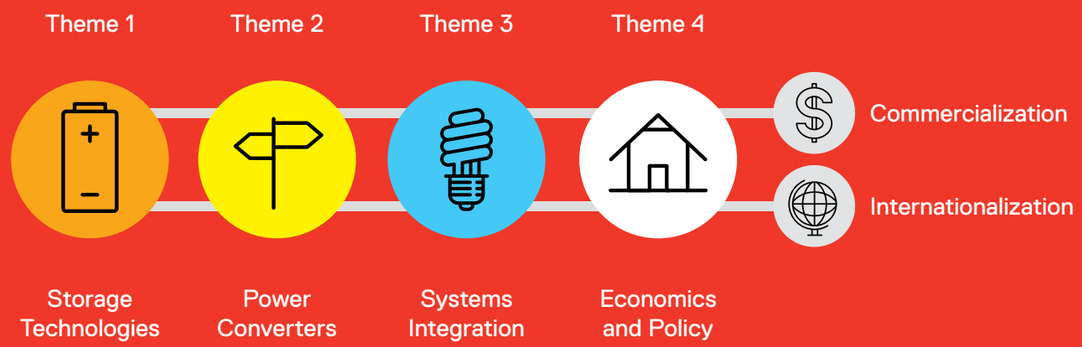
Table 5: Industry/ Government Partner Contributions	Cumulative Budget (2015-18)	Cumulative Expenses (2015-18) *
Theme 1	$619,863	$548,668
Theme 2	$3,000	-
Theme 3	$710,000	$672,448
Theme 4	-	-
Central activities	$15,000	-
Total	$1,347,863	$1,221,116

* Numbers are extrapolated from financial data to March 31, 2018.

Students participating at the energy storage design challenge during NESTNet Week.

Themes and Progress

The 24 NESTNet projects are divided into four interrelated research themes addressing the critical challenges facing energy storage in Canada. There are also two cross-themes that transcend the four research themes. Commercialization helps us identify products that are commercially viable, while Internationalization helps us strategically promote NESTNet to a global audience.



Theme 1 Projects and Highlights

Theme Leader
F. Handan Tezel, University of Ottawa

Theme
Energy Storage Technologies

In this theme, research is focused on batteries (thermal management systems and innovative housing designs), flywheels (designs and modelling), compressed air energy storage (CAES) (underwater designs and operation), thermal storage (materials and system designs), and hybrid ES models.

F. Handan Tezel, Theme 1 leader.

Project 1.1
Hybrid Multi-Level Grid-Scale Battery Thermal Management System

Project 1.2
Fabrication, Mathematical Modelling, Design and Testing of Flywheels for Grid-Scale ES

Project 1.3
Design and Testing of an Innovative Energy Accumulator for Underwater Compressed Air Energy Storage

Project 1.4
Thermal ES in Adsorbent Beds for Space Heating and Cooling

Project 1.5
Hybrid ES System Designs

Project 1.6
Design of Pole-Top ES

Project 1.1

Hybrid Multi-Level Grid-Scale Battery Thermal Management System

Project Description

This project aims to develop a novel and custom-designed BTMS solution for thermal management of large-scale battery systems for grid applications that can maintain the temperature of the batteries within the recommended range under various loads and climate conditions. The BTMS should be compact, cost-effective, and reliable with minimal maintenance and packaging requirements. It must also promise low parasitic power requirements and be able to operate under variable climatic conditions.

Progress

Graphite heatsinks and heat spreaders have been designed and tested. Simulation results were validated using experimental results. The project team has studied heat performance of the battery, and designed, optimized and tested a cooling system at the cell level, and conducted electric vehicle life cycle analysis. Outcomes (cumulative): 4 journal papers, 2 journal papers submitted, 27 accepted conference papers, 1 exhibit (BCTECH Summit) and 3 news articles.

Project Leader

Majid Bahrami, Simon Fraser University

Collaborators

F. Handan Tezel, University of Ottawa
Liuchen Chang, University of New Brunswick

Highly Qualified Personnel (Year 3)

Mehran Ahmadi (Postdoctoral fellow)
Claire McCague (Postdoctoral fellow - participating, not funded)
Martin Cermak (PhD)
Mina Rouhani (PhD)
Anil Stephen (PhD)
Hesam Bahrehmand (PhD)
Abdul Majid (Undergraduate)

Project 1.2

Fabrication, Mathematical Modelling, Design and Testing of Flywheels for Grid-Scale ES

Project Description

This project aims to develop mathematical models of flywheel systems considering energy losses, discrete design variables, rotor dynamic effects and novel material systems. A flywheel system with an energy capacity of 0.25 kWh will be fabricated, characterized and tested to validate and optimize models.

Progress

A flywheel testing enclosure has been constructed. Development of a composite flywheel system for 0.25 kWh has commenced. A flywheel numerical model and a comparative analysis of composite and metal flywheels were developed. Fabrication and testing of composite flywheel demonstrator are completed. Outcomes (cumulative): 3 published journal papers (1 under review), 2 conference papers.

Project Leader

Marc Secanell Gallart, University of Alberta

Collaborators

Pierre Mertiny, University of Alberta
Liuchen Chang, University of New Brunswick
Magdy Salama, University of Waterloo

Highly Qualified Personnel (Year 3)

Miles Skinner (MASc)
Vaishnavi Kale (MASc)
Danica Sun (MASc)

Project 1.3

Design and Testing of an Innovative Energy Accumulator for Underwater Compressed Air Energy Storage (CAES)

Project Description

Operational and market conditions for the world's first grid-connected underwater energy storage facility will be studied in detail. A transient, advanced exergy approach will be applied to assess facility production efficiency. The commercial aspects of operation will then be co-optimized with production based on mutually advantageous opportunities revealed through thermodynamic and market analysis.

Progress

The project is completed. Outcomes (cumulative): 4 journal papers, 2 journal papers submitted, 3 conference papers, co-chaired 2 workshops.

Project Leader

Rupp Carriveau, University of Windsor

Collaborators

David Ting, University of Windsor
Lindsay Miller, University of Windsor
Scott Harper, Wind Energy Institute of Canada
Seamus Garvey, University of Nottingham
Tonio Sant, University of Malta
Andrew McGillis, Hydrostor
F. Handan Tezel, University of Ottawa
Mark Winfield, York University
Ian Rowlands, University of Waterloo

Highly Qualified Personnel (Year 3)

Maziar Mosavati (PhD)
Sara Alhasan (MASc)
Mehdi Ebrahimi (PDF)
Zhiwen Wang (PhD)

Project 1.4

Thermal ES in Adsorbent Beds for Space Heating and Cooling

Project Description

In this project, promising new adsorbent materials will be examined, modelled and optimized to increase energy density (by four to five times greater than current materials) in order to improve the economic viability of adsorption-based systems for space heating and cooling applications.

Progress

Experimental setup was upgraded with a system control program to control the system and record data. Outcomes (cumulative): 2 journal papers, 2 journal papers submitted, 14 conference papers.

Project Leader

F. Handan Tezel, University of Ottawa

Collaborators

Tariq Iqbal, Memorial University
Miguel Anjos, Polytechnique Montréal
Majid Bahrami, Simon Fraser University

Highly Qualified Personnel (Year 3)

Ye Hua (Postdoctoral fellow)
Tatum Alenko (MASc)
Isabelle Anna Eid-Holm (Undergraduate)
Di Dyllen Wu (MASc)
Eniayo Ayoola (Undergraduate)
Amanda Godin (Undergraduate)
Emma Harrison (Undergraduate)

Project 1.5

Hybrid ES System Designs

Project Description

This research aims to develop hybrid ES systems, where several types and sizes of ES systems are combined to provide a composite storage solution. The first objective is to develop an optimization solution that provides the optimal hybrid design of an ES system combining two or more storage elements to provide certain performance metrics and features at the lowest cost, and with the longest life and highest reliability. The second objective of this research is to develop scheduling methods for the developed hybrid systems to deliver the required services, while maximizing asset life.

Progress

Analysis of various ES elements to determine their dynamic characteristics and development of mathematical models for the optimal design of the hybrid ES system have been completed. Outcomes (cumulative): 5 journal papers, 1 journal paper submitted, 2 patent filings.

Project Leader

Bala Venkatesh, Ryerson University

Highly Qualified Personnel (Year 3)

Amr Adel (PhD)
Ayman Elkasrawy (PhD)
Kamran Masteri Farahani (PhD)
Mohammadreza Vatani (PhD)

Collaborators

Bin Wu, Ryerson University
Reza Iravani, University of Toronto

Project 1.6

Design of Pole-Top ES

Project Description

Development and testing (both in the laboratory and in the partnering utility) of an ES solution that can be mounted on the utility pole, adjacent to pole-top transformers. The pole-top ES solution is housed in a cabinet containing the power converter and with lithium-ion batteries.

Progress

The two-year project has been completed. Results show acceptable performance of the unit for load curve smoothing and peak shaving of the distribution transformer. Installation of the unit on a Toronto Hydro utility pole was completed in August 2016 and successfully field tested until February 2017. Outcomes (cumulative): 4 journal papers, 1 conference paper, 2 patents, 1 video.

Project Leader

Bala Venkatesh, Ryerson University

Highly Qualified Personnel (Year 3)

N/A

Collaborators

Bin Wu, Ryerson University
David Xu, Ryerson University
Majid Bahrami, Simon Fraser University

Theme 2 Projects and Highlights

Theme Leader
Liuchen Chang, University of New Brunswick

Theme
Power Electronics Converters

Research in this theme focuses on power electronic converters, including modular converters, digital controllers, supervisory controllers, supervisory control and data acquisition (SCADA) systems, and power electronics for repurposed electric vehicle batteries.

Vijay Sood (second from left), Project 2.2 leader, with students (from left to right) Mohammed Yasin Ali, Jigneshkumar Patel and Faizan Khan.

PROJECT THEMES AND HIGHLIGHTS
NSERC ENERGY STORAGE TECHNOLOGY NETWORK

Project 2.1

Modular Architecture and Functionality of ES Power Converters

Project Description

The objectives of this project are to 1) develop advanced power converter architectures for ES systems (battery and flywheel systems, etc.) with modular design, bi-directional power flow and embedded fault diagnosis algorithms, and 2) to develop enhanced grid support functions for power system operation (such as anti-islanding, voltage support, real power control, and black start, etc.).

Progress

The project team finished grid support functions of smart inverters for ES systems and completed onboard fault diagnosis algorithms to detect open circuit faults without additional voltage and current sensors. They have also advanced the power converter architectures design. They cooperated with researchers in Project 2.2 to test the digital control system of power converters for ES applications and cooperated with researchers in Project 2.4 to validate the remote control of power converters for ES applications. Outcomes (cumulative): 4 journal papers, 6 conference papers, 1 U.S. provisional patent filing.

Project Leader

Liuchen Chang, University of New Brunswick

Collaborators

David Xu, Ryerson University
Vijay Sood, UOIT
Saleh Saleh, University of New Brunswick
Bala Venkatesh, Ryerson University

Highly Qualified Personnel (Year 3)

Xin Zhao (Postdoctoral fellow)
Guanhong Song (PhD)
Shuang Xu (PhD)
Katelin Spence (MASc candidate)
Zhihao Yu (MASc)

Project 2.2

Digital Control Systems of Power Converters for ES

Project Description

Project Description: The objectives of this project are to develop advanced digital control systems for power converters in ES applications, including fully digital control hardware and software; an upper-level energy management controller; and a communication system.

Progress

The project team is in the process of developing a digital controller based on a TI Microcontroller F28069M Launchpad kit for a three-phase inverter and a control system. Outcomes (cumulative): 2 conference papers, 1 technical report.

Project Leader

Vijay Sood, UOIT

Collaborators

David Xu, Ryerson University
Tariq Iqbal, Memorial University
Liuchen Chang, University of New Brunswick

Highly Qualified Personnel (Year 3)

Jigneshkumar Patel (PhD)
Faizan Khan (MASc)
Mohammed Yasin Ali (MASc)

Project 2.3

Coordinated Operation of Multiple Storage Units and Technologies

Project Description

This project aims to develop supervisory-control and protection strategies and algorithms for 1) heterogeneous storage systems (i.e. battery and flywheel sub-units), and 2) for homogeneous storage systems (i.e. multiple battery storage units). The envisioned development serves as the interface between the utility command signals (Theme 3) and the required ES units' controls/operation (Projects 2.1 and 2.2), considering requirements of end users (Project 1.5).

Progress

The project team developed an integrated battery and flywheel storage system. A study system for coordinated operation of multiple batteries with multi-microgrids and a microgrid simulation system for the application of battery and flywheel for autonomous microgrids have been established. Outcomes (cumulative): 6 journal papers, 3 conference papers, 1 IP, 1 technical report (book).

Project Leader

Reza Iravani, University of Toronto

Collaborators

Liuchen Chang, University of New Brunswick
Vijay Sood, University of Ontario Institute of Technology
Amir Yazdani, Ryerson University

Highly Qualified Personnel (Year 3)

Arman Ghasemi (PhD)
Sherif Helmy (PhD)
Mostafa Mohsen (PhD)
Hoda Youssef (MASc)
Zhi Zhong (Undergraduate)
Rana Hosseini (PhD)
Mubarek Abdela (MASc)
Chandini Chandrabalan (Undergraduate)
Farid Chalabi (Undergraduate)
Kamran Akbari (PhD)

Project 2.4

SCADA Interface for ES Systems

Project Description

Research aims to develop an innovative SCADA interface for smart grids that enables remote control of grid-tied converters for ES, and facilitates control and communication methods.

Progress

Design of a low-cost SCADA system based on internet of things (IoT) technology has been completed. The project team also demonstrated remote control and data logging of an inverter. A design of a SCADA system based on local open source server was demonstrated. A design has been demonstrated in the lab and it was tested at the University of New Brunswick along with a UNB inverter. A SCADA version 2 will be developed in Year 4. Outcomes (cumulative): 1 journal paper accepted, 1 journal paper under review, 8 conference papers.

Project Leader

Tariq Iqbal, Memorial University

Collaborators

Liuchen Chang, University of New Brunswick
Vijay Sood, UOIT
Reza Iravani, University of Toronto

Highly Qualified Personnel (Year 3)

Sarinda Jayasinghe (MASc)
Terashimla Kublathara (MASc)
Lawrence Aghenta (MASc)
Amjad Iqbal (MASc)
Rasha Rabanni (MASc)

PROJECT THEMES AND HIGHLIGHTS

NSERC ENERGY STORAGE TECHNOLOGY NETWORK

Project 2.5

Control Systems for Second-Life Batteries for Grid-Scale ES

Project Description

A new concept is to repurpose various electric vehicle (EV) batteries by separately connecting them to a multi-channel power converter, which is able to handle various used batteries of differing capabilities. With this project, the principal research objective is to develop a new control strategy to utilize the best EV battery packs depending upon the specific electricity grid service requirements. We use the EV battery variants promoted by worldwide automotive manufacturers. We are including and optimizing grid-storage control for each of four lithium-ion chemistries (LMO, NMC, NCA, LFP), three cell formats (cylindrical, pouch, prismatic), three thermal systems (passive, air, liquid) and operating in both peak-shaving and frequency regulation services. The principal outcome is a new map matrix defining the performance characteristics of the widely varying pack designs, and an optimized controller to coordinate a "mixed battery array."

Progress

A new "mixed battery array" concept has been developed. Seven battery packs have been acquired and underwent reference case testing, including the use of thermal conditions systems (air and liquid). The batteries were subject to grid storage services of peak-shaving and frequency regulation and their performance was mapped and contrasted at various rates/bids. A performance degradation study of batteries operating in these two services is underway. A "stacked-service" optimized control algorithm for the mixed battery array is presently in development and will be flexible to accommodate the results of the degradation study. HQP at the postdoctoral, PhD, MASc, and undergraduate levels have been trained in research methods, high-voltage battery testing (including standard operating procedures and personal protective equipment), data collection and analysis, and reporting. Outcomes (cumulative): 4 journal articles in preparation (publication has been delayed by issues encountered during testing which required a re-test that takes months to complete).

Project Leader

Lukas Swan, Dalhousie University

Collaborators

Liuchen Chang, University of New Brunswick
Reza Iravani, University of Toronto

Highly Qualified Personnel (Year 3)

Blenson Paul (PhD)
Chris White (PhD
Ben Thompson (MASc) (completed)
Mark Elliott (MASc)
Chad LeRue (Undergraduate)

Theme 3 Projects and Highlights

Theme Leader
Claudio Cañizares, University of Waterloo

Theme
Power Systems Integration

Research in this theme will enable the seamless integration of energy storage into power systems by developing planning tools, operational tools, protection systems, power quality mitigation solutions and reliability benchmarks.

Claudio Cañizares, Theme 3 leader.

Project 3.1
Optimal Planning for ES Facilities in Transmission Systems

Project 3.2
Optimal Planning of ES in Distribution Systems Considering Feeder Investment Model

Project 3.3
ES Device Protection

Project 3.4
Integration of ES for Improving Power Quality (PQ) of Smart Distribution Systems

Project 3.5
Operation and Control of Power Systems with ES Systems

Project 3.6
Reliability Modelling and Assessment of Power Systems with ES Systems

Project 3.7
Integration of ES for Improving Power Quality of Smart Distribution Systems

Project 3.1

Optimal Planning for ES Facilities in Transmission Systems

Project Description

Deterministic co-optimization models will be built for sizing and siting of ES facilities, considering many services and technologies. The models will be built for both utility-owned ES facilities as well as investor-owned merchant facilities. The deterministic models will then be extended to include sources of uncertainty in power systems operation and planning. Stochastic versions of the deterministic models will be developed using techniques such as robust optimization or approximate chance-constrained optimization that make use of convexity and hence can be solved efficiently.

Progress

The project team is currently creating a model for co-simulation optimization with an ES model and working on the deterministic model for ES planning. Also, a literature review of ES technologies was completed. Outcomes (cumulative): 6 journal papers, 4 journal papers submitted, 2 conference papers.

Project Leader

Hamid Zareipour, University of Calgary

Highly Qualified Personnel (Year 3)

Ahmed Chaouachi (PhD)
Shubhrajit Bhattacharjee (PhD)

Collaborators

Miguel Anjos, Polytechnique Montréal
Amit Kumar, University of Alberta
William Rosehart, University of Calgary
Andrew Knight, University of Calgary
Patrice Marcotte, Université de Montréal

Project 3.2

Optimal Planning of ES in Distribution Systems Considering Feeder Investment Model

Project Description

Research will focus on the development of a new algorithm for the feeder investment model for distribution systems, including optimal location and size of ES systems. The algorithm will ensure that all customer loads and renewables are fully connected and reliably serviced over the plan period. The algorithm will minimize the annual amortized cost of investment for the utility considering both purchases of feeders and ES units.

Progress

The two-year project has been completed and includes a feeder investment model for distribution systems analysis; study of battery ES system (BESS) and its market price projections; and a feeding investment model with BESS. Outcomes (cumulative): 2 journal papers, 3 technical reports, 1 patent in progress.

Project Leader

Bala Venkatesh, Ryerson University

Highly Qualified Personnel (Year 3)

N/A

Collaborators

Bob Singh, Ryerson University
Claudio Cañizares, University of Waterloo
Amit Kumar, University of Alberta

Project 3.3

ES Device Protection

Project Description

This research will develop and test new protection architectures for ES systems, digitally implemented to be embedded within the main ES systems controller. This architecture is required for the development of fault detection and classification methods based on signature extraction, rather than magnitudes of voltages or currents. The desired fault detection and classification methods will be based on processing current signals obtained from the main ES system controller to facilitate full embedding.

Progress

The project team is implementing the phaselet filter bank to process currents collected from a lab-scale 5 kW storage system (for a wind turbine), and a 10 kW storage system (for grid connection). These two lab scale storage systems are used to test the responses of the developed phaselet-based protection for different fault and non-fault conditions. They have completed the development, implementation, and testing of phaselet-based digital protective relays for stand-alone and coordinated architectures. Outcomes (cumulative): 9 journal papers and 16 peer-reviewed conference papers.

Project Leader

Saleh Saleh, University of New Brunswick

Highly Qualified Personnel (Year 3)

Christiane Richard (MASc)
Ryan McSheffery (MASc) (completed)
Ryan Meng (MASc) (completed)
Xavier St-Onge (MASc)
Jay Buckler (MASc)
Katie McDonald (Undergraduate)
Boris Vega (Visiting scholar)

Collaborators

Eduardo Castillo Guerra, University of New Brunswick
Liuchen Chang, University of New Brunswick
Reza Iravani, University of Toronto

Project 3.4

Integration of ES for Improving Power Quality of Smart Distribution Systems

Project Description

Research will develop novel solutions to overcome PQ issues (due to switching, load cycling or intermittency of renewables) using ES systems. Another goal is to study the impact of integrating different ES technologies (dedicated for grid-related PQ issues) on smart grid; under low- or high-loading conditions.

Progress

Two studies have been started, Harmonic mitigation using optimally placed, of energy storage systems for solving voltage-sag problems. Outcomes (cumulative): 3 journal papers, 2 conference papers.

Project Leader

Magdy Salama, University of Waterloo

Collaborators

Tarek El-Fouly, CanmetENERGY and University of Waterloo
Saleh Saleh, University of New Brunswick
Liuchen Chang, University of New Brunswick
Ahmed Awad, CanmetENERGY
Mohamed Ahmed, SNC-Lavalin and University of Waterloo

Highly Qualified Personnel (Year 3)

Ahmed Mustafa (PhD)
Mohamed Hamouda (PhD)
Haytham Rafaat Ibrahim (MASc)
Sherin Helal (MASc)
Mahmoud Othman (PDF)

Project 3.5

Operation and Control of Power Systems with ES Systems

Project Description

In this research, mathematical models of ES systems will be developed that account for operational features and constraints, and be combined with power systems optimization algorithms meant for daily operations. Such ES system models will be integrated into existing optimization models and simulation tools for power systems operation and control. These models will be used to evaluate the contribution and impact of ES systems on the overall power system operation. At the distribution system level, optimal operation will examine and derive benefits from ES systems to manage increased renewable integration, feeder loading management, arbitrage, etc. At the transmission level, optimal operation will examine the use of ES for frequency regulation, energy arbitrage, etc.

Progress

The project team completed modelling flywheel technology and continues with modelling battery and CAES technology. They have signed an NDA with IESO to get information and collaborate on energy storage models for Ontario's grid and regulation studies and initiatives. Outcomes (cumulative): 1 journal paper submitted and 1 in preparation, and 1 conference paper accepted.

Project Leader

Claudio Cañizares, University of Waterloo

Collaborators

Kankar Bhattacharya, University of Waterloo
Bala Venkatesh, Ryerson University
Miguel Anjos, Polytechnique Montréal
Rupp Carriveau, University of Windsor

Highly Qualified Personnel (Year 3)

Mariano Arriaga (Postdoctoral fellow)
Chioma Anierobi (PhD)
Fabian Calero (PhD)
Ivan Calero (PhD)
Noela Sofia Guzman (PhD)
Dario Peralta (MASc)
William Mendieta (MASc)
Matheus Zambroni de Souza (PhD)

Project 3.6

Reliability Modelling and Assessment of Power Systems with ES Systems

Project Description

New reliability models will be developed for battery, CAES, flywheel and thermal ES systems. Probabilistic techniques will be developed to incorporate market scenarios and operating strategies in quantifying adequacy benefits of ES systems with largescale renewables penetration. Value-based reliability of different ES technologies and capacity credit increments of renewables due to ES systems will be analyzed, providing invaluable investment decision information. New methodologies will be proposed to incorporate the aforementioned factors, assess the implications of operating reserve requirements and response capabilities, and quantify the impact and worth of ES systems.

Progress

The basic reliability modelling of CAES, flywheel and battery has been done. Another project on energy storage reliability impacts on distributed generation system is in progressing well with a manuscript for journal submission in progress. Outcomes (cumulative): 1 journal paper submitted, 5 conference papers.

Project Leader

Rajesh Karki, University of Saskatchewan

Collaborators

Bala Venkatesh, Ryerson University
Claudio Cañizares, University of Waterloo

Highly Qualified Personnel (Year 3)

Prajjwal Gautam (MASc)
Safal Bhattarai (MASc)
Saket Adhikari (MASc)
Tej Krishna Shrestha (PhD)
Prasanna Piya (PhD)

Project 3.7

Capacity Markets for ES – Design and Implementation

Project Description

Research aims to analyze the potential of ES to provide services such as demand response, ramping, frequency regulation, etc., given that ES can act as both a load and a generator. With knowledge of the potential of ES solutions, this research will examine and develop capacity markets for ES considering various services.

Progress

ES self-scheduling model was created. The model optimizes the ES operation to achieve maximum profit to the ES owner. Outcomes (cumulative): 6 journal papers submitted, 1 journal paper in progress, 1 conference paper, 1 conference paper in progress, 1 patent in progress, 6 technical reports.

Project Leader

Bala Venkatesh, Ryerson University

Collaborators

Kankar Bhattacharya, University of Waterloo
F. Handan Tezel, University of Ottawa
Rupp Carriveau, University of Windsor
Amit Kumar, University of Alberta

Highly Qualified Personnel (Year 3)

Chandrabhanu Opathella (Postdoctoral fellow)

PROJECT THEMES AND HIGHLIGHTS
NSERC ENERGY STORAGE TECHNOLOGY NETWORK

Theme 4 Projects and Highlights

Theme Leader
Miguel Anjos, Polytechnique Montréal

Theme
Economics and Policy

This theme investigates and provides solutions for techno-economic challenges in the successful integration of ES into power systems. In addition, it examines policy, regulatory and social challenges faced by storage solutions to enable successful uptake by utilities and societies.

Miguel Anjos (third from left), theme 4 leader, with project leaders including Kankar Bhattacharya (left), Amit Kumar (second from left), and Ian Rowlands (right) at the joint winter school. Also pictured (centre to right) are F. Handan Tezel, Bala Venkatesh, Karen Ho-Cespedes, and (seated) researchers from Hydro-Québec.

Project 4.1

Development of Life Cycle Net Energy Ratio of ES Technologies

Project Description

This project aims to assess ES pathways in terms of the ratio of energy input to output to calculate how much energy is required over a life cycle to store a unit of energy from a particular energy source. The ratio of energy input to energy output through a particular pathway is referred to as net energy ratio (NER). First, a life cycle assessment (LCA) framework of ES technologies specific to Canada will be developed and used to create LCA models for the various storage solutions. Then a comparative assessment of NER and greenhouse gas (GHG) emissions for ES technologies will be undertaken.

Progress

The project team has developed a bottom-up data intensive life cycle assessment and net energy ratio model to assess the greenhouse gas emissions and energy effectiveness of mechanical and thermal storage systems. The team has also completed work on life cycle assessment of mechanical and thermal storage systems. Research on techno-economic and life cycle assessment of battery storage system has started. Outcomes (cumulative): 2 journal papers.

Project Leader
Amit Kumar, University of Alberta

Collaborators
Bala Venkatesh, Ryerson University
Rajesh Karki, University of Saskatchewan

Highly Qualified Personnel (Year 3)
Abayomi Oni (MASc)
Sahil Kapila (MASc)
Spandan Thaker (MASc)
Mustafizur Rahman (PhD)

Project 4.2

Modelling Electricity Market Prices Considering Large-Scale ES Penetration

Project Description

This project aims to build techno-economic models for estimating the price impacts of the large-scale integration of ES in competitive electricity markets.

Progress

The project team has completed a literature review of batteries for grid-scale application and building of a database for the available real-life market data from two electricity markets in Canada and one from a New York state market. Collaborations began with Hamid Zareipour, University of Calgary. Outcomes (cumulative): 2 journal papers, 1 journal paper submitted, 1 journal paper under revision.

Project Leader
Miguel Anjos, Polytechnique Montréal

Collaborators
Hamid Zareipour, University of Calgary
Kankar Bhattacharya, University of Waterloo
Mohamed Ahmed, SNC-Lavalin and University of Waterloo

Highly Qualified Personnel (Year 3)
Payam Zamani (PhD)
Soroush Shafiee (PhD)
Adrien Barbry (MASc)
Nima Sarajpoor (PhD)
Valérie Provost (MASc)
Marie Pied (MASc)

Project 4.3

Provision of Ancillary Services by ES Systems

Project Description

This project will examine the role of ES solutions as ancillary service providers and their integration with the grid system. Research will be undertaken to determine cost structures and appropriate pricing mechanisms for these services, and the contribution and impact of ES systems on the overall power system operation. At the distribution system level, optimal operation will examine and derive benefits from ES systems to manage increased renewable integration, feeder loading management, arbitrage, etc. At the transmission level, optimal operation will examine the use of ES for frequency regulation, energy arbitrage, etc.

Progress

Work is underway on several fronts: 1) development of a comprehensive energy management system (EMS) including pumped storage hydro to examine its participation in frequency regulation services, and 2) development of a joint auction model for demand response (DR) for energy and spinning reserve provisions. Outcomes (cumulative): 2 journal papers, 1 book chapter, 1 journal paper (in revision), 1 conference paper.

Project Leader

Kankar Bhattacharya, University of Waterloo

Highly Qualified Personnel (Year 3)

Hisham Alharbi (PhD)
Nitin Padmanabhan (PhD)
Dario Peralta (PhD)
Omar Alrumayh (PhD)

Collaborators

Steven Wong, CanmetENERGY
Miguel Anjos, Polytechnique Montréal
Hamid Zareipour, University of Calgary
Mark Winfield, York University

Project 4.4

Optimal Brokerage Models for the Grid Integration of ES

Project Description

The objective is to investigate different brokerage models for integrating ES into power systems, and to test the applicability and potential impact of such models using real-world data from Canadian settings. Capacity credit increments of renewables due to ES systems will be analyzed, providing invaluable investment decision information. New methodologies will be proposed to incorporate the aforementioned factors, assess the implications of operating reserve requirements and response capabilities, and quantify the impact and worth of ES systems.

Progress

So far, an exact method that addresses three challenges for integrating distributed ES – coordination, scalability and heterogeneity – has been designed. A study was carried out on how the presence of a storage operator in an energy market could stabilize the price of energy during peak demand periods and help avoid blackouts. Outcomes (cumulative): 2 journal papers under review.

Project Leader

Miguel Anjos, Polytechnique Montréal

Highly Qualified Personnel (Year 3)

Mariana Rocha (PhD)
Mathieu Tanneau (PhD)
Martim Joyce-Moniz (PDF)
Mathieu Besançon (PhD)
Ilaria Salerno (MASc)

Collaborators

Gilles Savard, Polytechnique Montréal
Michel Gendreau, Polytechnique Montréal
Bala Venkatesh, Ryerson University

Project 4.5

Towards Federal and Provincial ES Policy Frameworks for Canada

Project Description

1) Assess existing legislative and policy frameworks at the federal and provincial levels as they relate to the development and use of ES technologies, particularly in support of the large-scale integration of low impact but intermittent renewables, such as wind and solar energy. 2) Make policy framework recommendations at the federal and provincial levels to advance the further development and deployment of ES technologies in an environmentally and economically sustainable manner for the purpose of facilitating the large-scale integration of intermittent renewable energy technologies.

Progress

The project team completed development of a template for the comparative analysis of public policies related to ES in multiple jurisdictions. They organized and presented three panels (Community Energy Planning, the Future of Energy Systems, and Ontario's Long-Term Electricity Plan) focused on ES policy issues at the Ontario Climate Symposium, May 11-12, 2017. A policy scan for Canada, the U.S. and the European Union was completed with 3 working papers published. A policy overview paper was published in Energy Policy. A second closely related paper has been published in Renewable and Sustainable Energy Reviews, and a book chapter on Ontario electricity policy, including developments related to energy storage, is in press. They also created the NEST section of the SEI website and are collaborating closely with Project 4.6 and an SSHRC Funded Partnership Development Project on community energy planning. Outcomes (cumulative): 2 journal papers and one book chapter, 6 working papers, 7 workshops/webinars organized/presented, 1 newspaper op-ed, multiple blog entries, marksw.blog.yorku.ca/blog.

Project Leader

Mark Winfield, York University

Highly Qualified Personnel (Year 3)

Shahab Shokrzadeh (Postdoctoral fellow)
Adam Jones (MES)
Adlar Gross (MES)
Amanda Gelfant (MES)
Scott Harbinson (CEKAP Funded) (MES)
Susan Wyse (CEKAP Funded) (MES)
Cristian Hurtado (MES)
Nathan Lev (MES/JD)

Collaborators

Ian Rowlands, University of Waterloo
Amit Kumar, University of Alberta
Rajesh Karki, University of Saskatchewan

PROJECT THEMES AND HIGHLIGHTS
NSERC ENERGY STORAGE TECHNOLOGY NETWORK

Project 4.6

Social Acceptance of ES Systems

Project Description

The main objective of this project is to explain why some ES technologies have been, and will continue to be, in turn, "supported," "accepted" or "rejected" by communities.

Progress

The project team has continued its work investigating various aspects related to social acceptance of energy storage technologies. Building upon the foundational work in concepts, theories, literature reviews and general approaches (e.g. public engagement), more recent work has focused upon particular case studies with detailed primary research. Results are being published on the project website (to view working papers and blogs, see uwaterloo.ca/social-acceptance-of-energy-storage-systems) and in international journals. Outcomes (cumulative): 3 journal papers, 2 conference papers, 3 working papers, 1 database, 5 blog entries.

Project Leader

Ian Rowlands, University of Waterloo

Collaborators

Mark Winfield, York University
Bala Venkatesh, Ryerson University
Miguel Anjos, Polytechnique Montréal

Highly Qualified Personnel (Year 3)

James Gaede (Postdoctoral fellow)
Dane Labonte (PhD)
Danielle Lavergne-Giroux (MES)
Sara Ganowski (MES)
Ines Havet (PhD)

Mark Winfield, Project 4.6 leader, facilitating the energy storage design challenge during NESTNet Week.

Events

NESTNet hosts a series of events and programming throughout the year to benefit its members, provide them with networking and learning opportunities, and promote collaboration between researchers. Key events in our calendar include winter schools, which are held in various locations across Canada between January and April, and NESTNet Week, which comprises a summer school, technical conference and industry conference hosted annually in Toronto.

53
Number of NESTNet events (through year 3)

1,068
Number of event participants (through year 3)

Winter School

by Kiki Cekota and Omair Sandhu

NESTNet's theme-based winter schools took place this year in February and March in three provinces: Quebec, Ontario and Nova Scotia. The winter schools gave NESTNet students the opportunity to learn more about each other's research projects.

Themes 1 and 4
In this first year of jointly held winter school, presentations for Themes 1 and 4 took place at the Auberge Gouverneur Shawinigan Convention Centre, Quebec from February 22-23, 2018.

Jocelyn Millette and his research team at Hydro-Québec also participated in the winter school activities by presenting their projects to the group as well as providing a tour of the Shawinigan branch of IREQ, Hydro-Québec's research institute. Presentation topics ranged from the examination of federal and provincial energy storage policy frameworks to thermal energy storage and flywheel testing for grid-scale energy storage.

Top: Theme 2 winter school with project leaders and guest speakers at Dalhousie University.

Bottom: Theme 1 and 4 winter school in Shawinigan, Que. with Hydro-Québec researchers.

Theme 2

Theme 2's winter school was held at Dalhousie University in Halifax from April 9-10, 2018. Presentation topics included battery-enabled EV fast charging systems, repurposing EV batteries for grid storage, and coordinated operation of multiple storage units and technologies. Invited speakers included Jill Searle of Nova Scotia Power and Denis Burkov of eCAMION.

Theme 3

The University of Waterloo hosted Theme 3's winter school on March 8, 2018. Presentation topics included grid energy storage in Ontario, evaluating the benefits of energy storage for distribution networks, energy storage device protection and optimal planning of energy storage facilities in transmission systems. Daniel Sohm of Independent Electricity System Operator (IESO), Steven Wenyang Shi of National Research Council Canada, and Ahmed Awad of Natural Resources Canada, also presented to the group.

Outlook

This year's NESTNet winter school sessions were both informative and engaging with 77 participants attending across all themes. In future sessions, we plan to build on this year's success by visiting local distribution centre research labs not unlike that of IREQ's Shawinigan branch. Next year entails a joint winter school with Themes 2 and 4, similar to that of Themes 1 and 4 in 2018.

Theme 3 winter school at the University of Waterloo.

Canada-U.K. Workshop

Trans-Atlantic Conversations on Energy Storage

by Ian Rowlands

I participated in the Canada-U.K. Energy Storage for Utility Applications Roundtable at Ryerson University's Centre for Urban Energy on September 21, 2017. Supported by NESTNet and the British Consulate-General Toronto, this meeting brought together more than 25 energy professionals from government, industry, research and other communities on both sides of the Atlantic to share experiences, cross-fertilize ideas, and explore potential future collaborative work.

It was a pleasure to participate. Indeed, I felt "in my element," for so many of my worlds appeared to collide in the small meeting room – my research interests (social and other policy strategies to empower advanced energy technologies for the achievement of sustainable energy), my administrative activities (international collaboration in higher education), and my binational character (transformative experiences in both Canada and the U.K.). The day's verdict? "Immensely enjoyable," "insightful" and "invigorating" are three words that seem apt. Indeed, three more "i-words" also spring to mind: "inter-jurisdictional," "international" and "intercultural."

With that context, let me flag five things the day got me thinking about.

1. International discussions can often require a translator. Even though everyone at the roundtable was speaking English, it soon became clear that specialized terminology differs in the two countries. For example, a DNO in England is actually an LDC in Ontario and so on. Analysts have to enter inter-jurisdictional conversations with open minds, ready to learn the language of the other.

2. As is often the case with comparative studies, there is great opportunity for mutual learning when different international experiences are shared and contrasted. In my own recent work, I had already seen how the U.K.'s thinking about "smart grids and vulnerable households" could offer insights to Ontarians. This roundtable revealed a variety of examples where one jurisdiction's experience with an advanced energy issue might be able to help the other – England and Wales's thinking about the pros and cons of energy sector restructuring might offer insights into corporatization and privatization debates here; Canada's experience with smart metres (in various provinces) might offer lessons for forthcoming policy initiatives in the United Kingdom.

3. On both sides of the Atlantic, many of us are driven by similar motivations – largely these can be captured by the sentiment, "sustainable energy provision for societal well-being." Details may differ – Canada's framing on smart grids, for instance, has taken many forms; our British friends noted the "energy trilemma" (a phrase often associated with the work of the World Energy Council) – but aspirations are largely pointing us all in the same direction.

Thus, all in all, the day was a great success, and I offer my congratulations to the organizers! ... And what a timely reminder it was that multiple perspectives – include those that flow across jurisdictions, borders, and cultures – can generate new insights and new ways to make progress. I look forward to continued collaboration!

Canada-U.K. roundtable discussion between NESTNet members and U.K. governmental agencies at the Centre for Urban Energy at Ryerson University.

4. Moreover, an understanding that progress can be accelerated by partnerships – across disciplines, across sectors, across the public/private/civil society boundaries and so on – seemed to permeate the room. But perhaps that that is virtually a given when you find professionals willing to give up valuable working time to "get out of their silo" and explore ways forward by working with others.

5. The time is certainly ripe for increased Canada-U.K. international collaboration on advanced energy issues. From the bottom-up, it builds upon the various cultural, business, academic, and other links that exist between the two countries. And, from the top-down, the two prime ministers emerged from meetings in Ottawa earlier this month signaling their commitment to closer cooperation. Of course, each country has its own set of international relations to manage, but many forces are now encouraging them to explore their common interests. (And it was wonderful to hear comments from Kevin McGurgan, British Consul-General in Toronto at the roundtable.)

Mission to the U.K.

by Ian Rowlands

Internationalizing research has come to be seen to be critical. It takes the best minds from around the world – each bringing their own insights, wisdom and experiences – to tackle the world's most pressing problems and its most exciting opportunities. Increasingly, collaborative, transnational research is vital to knowledge breakthroughs.

To help to internationalize the NESTNet, a team of six travelled to the United Kingdom in March 2018 to interact with researchers, technicians, businesspeople and government representatives on energy storage issues.

The U.K. was a logical location for this first NESTNet international mission for a variety of reasons. First, energy storage is a key part of the British government's agenda going forward – it is central to the "clean growth" theme, which is one of four "grand challenges" guiding industrial strategy in the country.

Second, Canada and the U.K. have committed to strengthened cooperation in the fields of science, technology, innovation and entrepreneurship. "Sustainability, renewable energy and clean technologies" is one of the six priority areas that have been identified.

And third, the two countries have a long history of political, cultural and economic interaction, let alone the educational connections that exist. Sixteen of the world's top 100 universities are in the U.K.

Mission membership represented all four NESTNet themes:

Theme 1
Bala Venkatesh (Ryerson University)

Theme 2
Dr. Lukas Swan (Dalhousie University)

Theme 3
Mariano Arriaga (University of Waterloo)
Bala Venkatesh (Ryerson University)

Theme 4
Kankar Bhattacharya (University of Waterloo)
Ian Rowlands (University of Waterloo)

Network manager Karen Ho-Cespedes was also part of the mission. Venkatesh, as project principal investigator, often represented the project as a whole during discussions, and Ian Rowlands also supported the "internationalization" theme of the mission, drawing upon his day-job experience at the University of Waterloo as associate vice-president, international, and his own familiarity with the U.K.

The mission itinerary was built around participation in the U.K. Energy Storage Conference. Mission members enjoyed interacting with more than 250 participants at this conference. The depth of discussion and the range of topics presented were particularly impressive. Side meetings during the conference served to enrich the discussions even further, as did engagement with the broader Newcastle energy ecosystem.

Bookended on either side of the conference were business days in two of the U.K.'s major cities.

On Monday, the mission's members had a series of meetings in London, discussing Canadian and U.K. developments with the Department for Business, Energy & Industrial Strategy, the Energy Networks Association (the industry association representing transmission and distribution network operators in the U.K.), and the Energy Futures Lab at Imperial College London, one of the world's leading research centres. Colleagues at the High Commission of Canada in the U.K. were extremely helpful in facilitating much of this activity.

And on Friday, a series of meetings in Glasgow, Scotland were held, at which discussion on similar issues took place, but the particularly Scottish angle on challenges and opportunities was also highlighted. Interactions with Scottish Development International, Scottish Enterprise, and the Energy Technology Partnership provided a very useful range of perspectives; a site visit to the Power Networks Demonstration Centre was another highlight. The British Consulate-General Toronto was key in catalyzing this day's agenda.

Follow-up on many leads is now underway. Indeed, that is one of the elements that is most critical to the eventual success of any mission. Having scanned a broad landscape, the task is then to identify those areas that make most sense to pursue. An execution strategy subsequently needs to be developed. It is certainly the case that this particular mission revealed many promising candidates for further attention.

Additionally, development of the network's broader internationalization strategy is also well underway. This will be a topic of discussion at the 2018 NESTNet Week, and another report of that discussion follows.

NESTNet delegation at Scotland's Power Networks Demonstration Centre.

NESTNet Week

by Kiki Cekota

Day one: Summer school

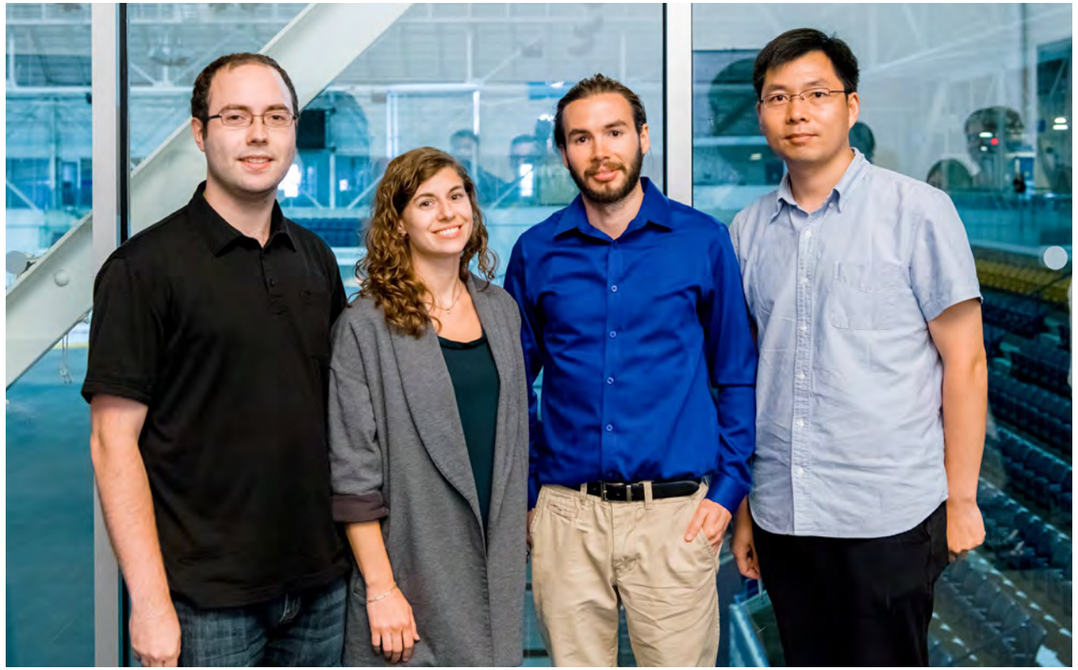
Kicking off NESTNet Week on June 18, this year's summer school brought together students and postdoctoral fellows from across Canada to collaborate on a unique energy storage design challenge to be presented to a judging panel at the day's end.

The day opened with remarks from, academic director of the Centre for Urban Energy (CUE), academic director Bala Venkatesh, and a presentation about intellectual property by Ryerson's applied research and innovation advisor, Suraj Shah.

Mark Winfield, a professor at York University and facilitator for the day, set the stage for the challenge, where the goal was to "design innovative solutions to present-day or near-future challenges in the energy sector." Attendees were strategically assigned to one of five teams, with each team having representatives from across the different universities and diverse themes of the network.

Teams raced against the clock to complete the challenge before taking a short walk to CUE, where they pitched their ideas to a panel of expert judges: Carter Li, CEO of SWTCH, Warren Navarro, cofounder of Actual Energy Solutions, Geoff Osborne, a manager at NRStor, and Marcelo Sarkis, a senior patent agent at Prima IP.

Team 2 at the energy storage design challenge during NESTNet Week.



Winners of the energy storage design challenge, (from left to right), Christian Richard (University of New Brunswick), Valérie Provost (Polytechnique Montréal), Chris White (Dalhousie University) and Yong Shi (University of New Brunswick). Not pictured: Reza Vatani (Ryerson University).

Chris White, a PhD candidate at Dalhousie University said that "the design challenge involved some mayhem along the way, but it was a lot of fun."

"Getting to know our teammates from different universities with different skill sets, we had to collectively bring our expertise together," White said. "A big part of it was about regulation and policy, which I don't have a lot of experience with, but my teammate did. So it worked out well."

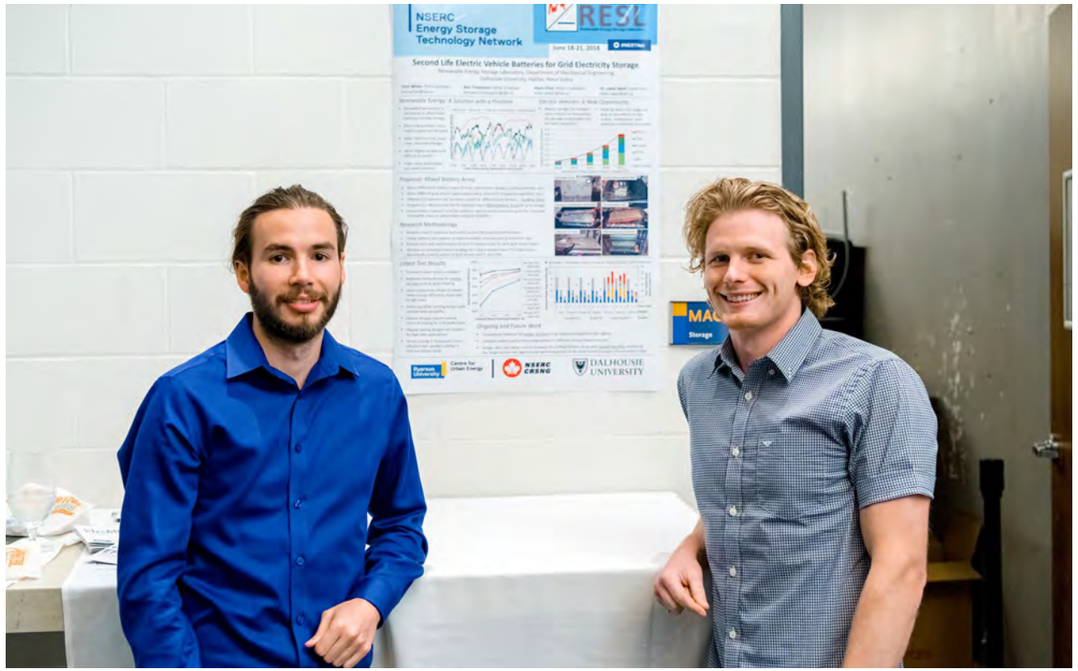
White was part of the winning team for the design challenge, and also won the poster contest, staged as part of day three's technical conference, along with Mark Elliott, a master of applied science candidate at Dalhousie University.

Days two and three: Technical conference

June 19 and 20 were dedicated to an overview of the progress that has been made this past year on the 24 projects contained within the four NESTNet research themes of energy storage technologies, power electronic converters, power systems integration, and economics and policy.

Jennifer MacInnis, senior legal counsel and senior director of applied research and commercialization at Ryerson, who acts as chair of NESTNet's commercialization and outreach committee, got proceedings underway.

One of the conference highlights was a presentation from Jacqueline Edge, energy storage research manager at Imperial College London's Energy Futures Lab, who shared her perspective on energy storage research in the U.K.



Winners of the poster session, Chris White, (left), and Mark Elliot of Dalhousie University

"In terms of grid-scale installations in the U.K., we have two liquid air energy storage installations, which is a very new and promising technology," Edge said. "There's also one pumped thermal project, looking specifically at electricity provision, not heat."

Those in the audience benefited enormously from the knowledge being shared.

"The presentations were really engaging. The technical information being presented was very informative of what's happening right now," said Xavier St-Onge, a graduate student from the University of New Brunswick. "Research-wise, it's always nice getting different perspectives on energy problems. In New Brunswick, we don't have issues with power generation; we have issues with the environment interfering with power distribution. It's good to see other sides of the problem," he said.

Ian Rowlands, a professor at the University of Waterloo and internationalization leader of NESTNet, said that the progress project leaders have made in the past year is impressive.

"It's clear from the conversations we've had in this room over the past few days that these individuals have made a lot of significant achievements. Achievements in the work they've done have impacts for both research and society," he said.

The technical conference also encompassed a poster session that doubled as a networking opportunity for students, a welcome dinner where award recipients were announced, and AGMs for both NESTNet's board of directors and research steering committee.

Day four: Leading the Charge conference

A packed house gathered for NESTNet Week's final day, which was filled with distinguished speakers from different parts of the energy sector in Canada and the U.S., who provided a wide range of outlooks on energy storage.

The morning began with welcoming remarks from Neetika Sathe, vice president of Advanced Planning at Alectra Inc. and chair of NESTNet's board of directors, and Sean Conway, honorary fellow at CUE and public policy adviser at Gowling WLG. The first keynote of the day was from Scott Hoyte, managing director of distributed energy solutions at GE Power based in Atlanta, Ga.

"The grid is getting more and more diverse. We're seeing high renewable energy generation, we're seeing energy storage come into play with more distributed systems being able to localize solutions," Hoyte said.

Jill Powers, an infrastructure and regulatory policy manager at the California Independent System Operator based in Folsom, Calif. spoke about energy storage at the transmission and distribution level in the state.

"The California ISO is very much an independent organization, but we work closely with state regulators. Our key function is to use advanced technologies to balance supply and demand on a second-by-second basis, operate markets and do transmission planning," Powers explained.

Following her keynote, Powers said she found the conference informative.

"It's always great to learn about international collaboration and hear about what others are doing in this area of energy storage," she said. "I really appreciated the day and the ability to give some perspective on what's happening in California, and to hear what's happening throughout our country as well as internationally," Powers said.

Left to right: Sean Conway, Gowling WLG and Centre for Urban Energy Honorary Fellow; Jill Powers, California Independent System Operator; Scott Hoyte, GE Power; and Michael Maiello, Schneider Electric.

The stellar lineup of speakers and panelists also included:

Michael Maiello
Vice president of energy storage systems at Schneider Electric

Leonard Kula
COO and vice president of planning, acquisition and operations at the IESO

Jane Kearns
Senior advisor with MaRS Cleantech

Daniel McCormick
Vice president of sales at Constant Power Inc.

Matthew Sachs
COO of Peak Power

Hari Suthan
Chief strategic growth and policy officer at Opus One Solutions

Claudio Cañizares
Professor of electrical and computer engineering at the University of Waterloo

Liuchen Chang
Professor of electrical and computer engineering at the University of New Brunswick

F. Handan Tezel
Professor of chemical and biological engineering at the University of Ottawa

Ian Rowlands
Professor and associate vice-president, international at the University of Waterloo

As the week wrapped up, Lukas Swan, a professor at Dalhousie University, explained the importance of NESTNet.

"The energy market is shifting fast, and there are lots of new players being involved. It's important that everyone becomes educated as decisions are financially significant. NESTNet is educating that next round of people," he said.

NESTNet would like to thank everyone who contributed to a successful week of events marking year three of the network. The team is already looking forward to another year of collaboration among researchers, culminating in a discussion of progress at next year's fourth annual NESTNet Week.

Leonard Kula, Independent Electricity System Operator.

Key Dates for Year 4

Looking ahead to year four, some event dates are already set. Please mark your calendars!

September 24–28, 2018
International mission to the United States.

March 2019
International mission to Europe.

June 17–20, 2019
NESTNet Week in Toronto:

- **Monday, June 17**
  Summer school for students.
- **Tuesday, June 18–Wednesday, June 19**
  Technical Conference for all researchers (project leaders, collaborators and students), committee members and industry and government partners.
- **Thursday, June 20**
  Leading the Charge conference. This is a paid event with limited availability for members (project leaders, committee members) and a discounted rate for students.

NESTNet members during the 2018 technical conference.

To learn more, please visit **ryerson.ca/nestnet**

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