Electricity meets ingenuity

2016 Annual Report

Ryerson University

Centre for Urban Energy
Faculty of Engineering
& Architectural Science

"In all that it does, the Centre for Urban Energy is at the forefront of enhancing our reputation as a global urban innovation university. By building great partnerships to harness Ryerson's strengths in education and applied research, it is shaping the future with sustainable solutions to urban energy challenges."

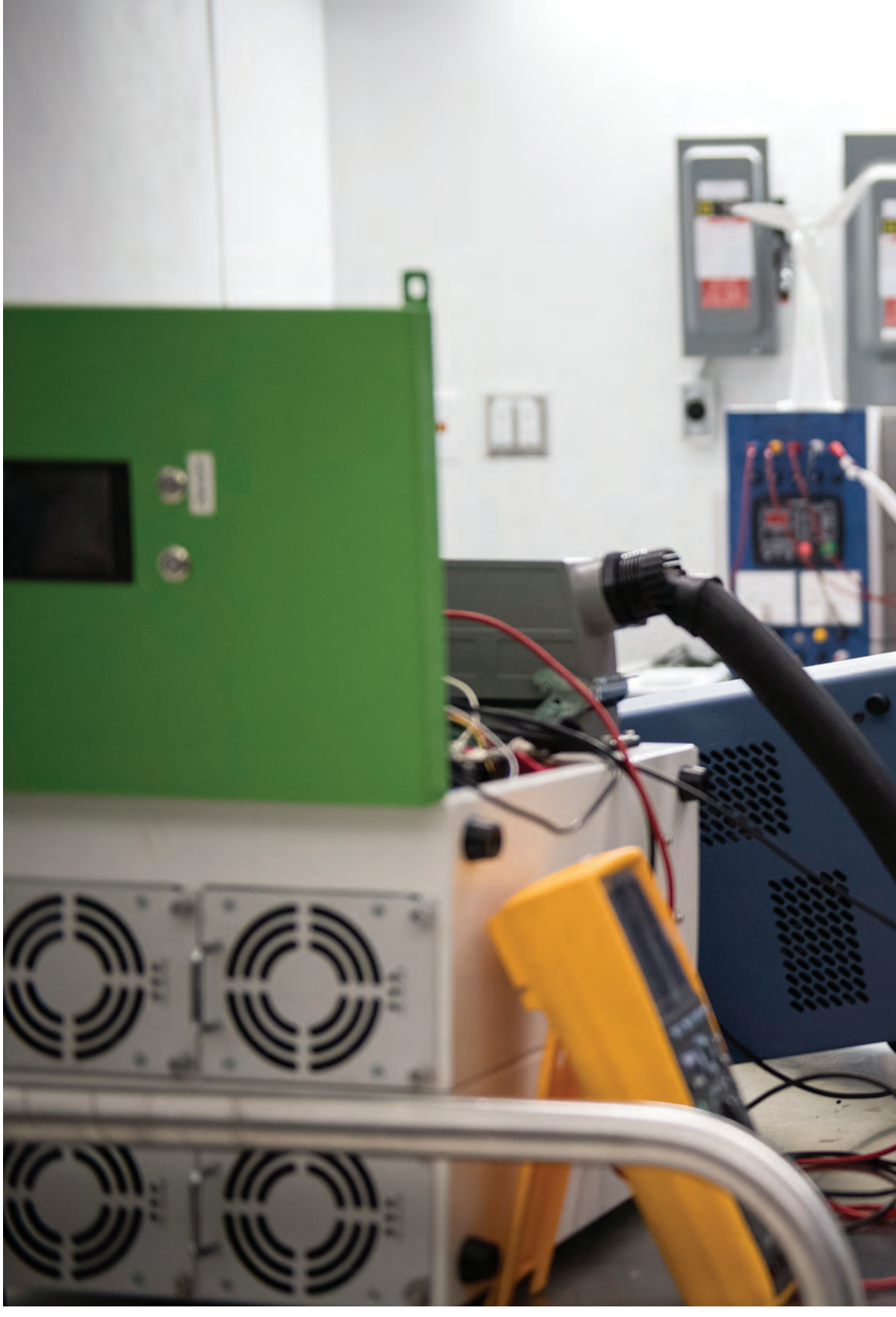
— **Mohamed Lachemi**
President and Vice-Chancellor, Ryerson University

Vision:

To be a world-class research and innovation centre dedicated to solving urban energy challenges.

Mission:

- Build academic, public and private sector partnerships.
- Conduct research, development and demonstration, leading to commercialization.
- Create the next generation of energy entrepreneurs.
- Encourage multidisciplinary and collaborative approaches.
- Provide scholarship and learning opportunities.



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Work with us

The Centre for Urban Energy (CUE) at Ryerson University is an academic-industry partnership that is exploring and developing sustainable solutions to urban energy challenges such as the advancement of smart grid technologies, energy policy and regulatory issues, storage, electric vehicles, net-zero homes and renewables.

There are many ways for utilities and industry to partner with CUE in 2017:

- Commission a research project and let us help address your most pressing business challenges.
- Test and develop prototypes and products in the one-of-a-kind Schneider Electric Smart Grid Laboratory.
- Train highly skilled personnel to use new technologies or your existing assets at a fraction of the regular cost.
- Develop your workforce by hosting a customized executive energy education course.
- Sponsor a white paper.
- Become a guest lecturer for one of our professional development programs.
- Mentor a young energy entrepreneur in our Clean Energy Zone.
- Name one of our state-of-the-art laboratories.
- Support student research awards and internships.
- Participate in our conferences, roundtables and events.

To learn more, please contact us at 416-979-5000, ext. 2974 or cueinfo@ryerson.ca.

"We need to ensure that experts in all sectors can work together to create low-cost, low-carbon, made-in-Canada technologies that can be exported around the world. Imagination, ingenuity and thinking big is how we solved the largest societal challenges in the past."

— Jessie Ma
IESO Distinguished Research Fellow

Thank you to our supporters

Founding sponsors

Sponsors

Collaborators

Message from our academic director

According to NASA and the National Oceanic and Atmospheric Administration (NOAA), 2016 was the hottest year ever recorded. It was the third time in as many years that this record has been broken. It is clear that our climate is changing, and changing even more rapidly than many scientists first thought. Finding ways to solve – or adapt – to the climate crisis is an urgent task. Another megatrend reshaping our world is urbanization. 2016 census data shows that 82 per cent of Canadians now live in metropolitan areas. Providing them with reliable electricity is becoming increasingly complex.

Here at CUE, we focus on these challenges every day, looking at cost-effective, practical and low-carbon ways to power our cities and help our communities flourish. The good news is that solutions are within reach.

In addition to policies and initiatives that tackle climate change, aging infrastructure, greater consumer choices and the declining costs of renewable technology have all combined to create a once-in-a-generation paradigm shift within the electrical utility industry. The grid of tomorrow will look fundamentally different. It will be smarter, more flexible and more resilient. It will integrate distributed local, small-scale renewable power generation and harness energy storage technologies. Utilities can thrive in this new world, but research, development and innovation is imperative. That's where CUE comes in. Our industry-driven research, led by researchers in state-of-the-art facilities and applied to real-world scenarios, is unique in Canada.

2016 has been a productive year. CUE worked with Toronto Hydro to pilot two new energy storage solutions suitable for the unique challenges of an urban environment: a 600 kWh utility-scale unit and 15 kWh pole-top battery. The results from both are promising. Also in 2016, federal Science Minister Kirsty Duncan unveiled the Natural Sciences and Engineering Research Council of Canada (NSERC) Energy Storage Technology Network at CUE. Better known as NESTNet, the network provides a crucial platform for industry partners such as IBM and Siemens to work with local distribution companies, government partners and eminent researchers from 15 universities across the country to help make Canada a world leader in energy storage and benefit wider society.

The Schneider Electric Smart Grid Laboratory is a collaborative research facility for the demonstration of new technologies and products that will revolutionize the electricity system. In 2016, we worked on an asset planning project with PowerStream (now Alectra) in the lab. Together with the Independent Electricity System Operator (IESO), through its Conservation Fund, we also completed research papers devoted to electricity, water and gas conservation, and the integration of urban and energy planning.

Of course, as part of a career-minded university, CUE remains committed to training a new, highly skilled workforce and producing energy entrepreneurs. With this in mind, our provincially approved Postgraduate Certificate in Energy Management and Innovation was launched in 2016. Our Clean Energy Zone incubator continues to showcase some exciting energy-related startups that you will be hearing a lot more about in the future.

CUE's extensive capabilities are only as broad as the talented people who fill our labs. With that in mind, I'd like to thank our 65 staff and faculty members, researchers and students for their dedication, creativity and ingenuity. Special thanks must also go to Karen Ho-Cespedes, Matthew Kerry and Lalitha Subramanian, who are responsible for the smooth running of the centre.

Our work continues. Please join us in transforming our energy system.

Bala Venkatesh

Academic Director, Centre for Urban Energy

Professor, Electrical and Computer Engineering

Ryerson University

Six years of progress

2010

Ryerson University announces the creation of CUE with $7 million in support from our founding sponsors: Hydro One, the Ontario Power Authority (now part of the IESO) and Toronto Hydro.

2011

CUE opens its doors at 147 Dalhousie St. for the first time. Professor Bala Venkatesh is appointed as the centre's academic director. Sixteen industry-driven research projects led by Ryerson faculty get underway. CUE also establishes a partnership with Anna University in Chennai, India to develop a joint centre for research and collaboration in urban energy.

2012

CUE develops the Postgraduate Certificate in Energy Management and Innovation with Ryerson's G. Raymond Chang School of Continuing Education to help address the projected shortage of workers in the electricity industry. CUE launches the iCUE (now Clean Energy Zone), Canada's first business incubator and accelerator devoted to energy-focused startups.

2013

The Ontario Ministry of Energy and Schneider Electric announce funding to build a smart grid laboratory at CUE, the first of its kind in a university setting anywhere in Canada.

2014

In the aftermath of the December 2013 ice storm, CUE holds a roundtable discussion and releases a major report on lessons from the event, including recommendations on how utilities, policy makers and communities can prepare for extreme weather events in the future.

2015

NSERC awards CUE with a grant worth close to $5 million over five years to create a research network focused on energy storage.

2016

CUE launches a Professional Master's Diploma (PMDip) in Energy and Innovation intended to provide participants with the knowledge and skills required to function in the fast-growing and rapidly changing Canadian energy sector.

By the numbers

Priorities

Research

Testing

Education

Innovation

Focus areas

Climate change / Conservation / Demand management / Efficiency / Electric vehicles / Microgrids / Electricity planning / Net-zero buildings / Policy and regulation / Renewables / Smart grids / Storage / Transmission and distribution

Applied research projects

64
Total

33
Completed

31
In progress

Supporters

21
Industry and government sponsors

24
Industry and academic collaborators

Funding

$26.2M
Since 2010

$1.7M
In 2016

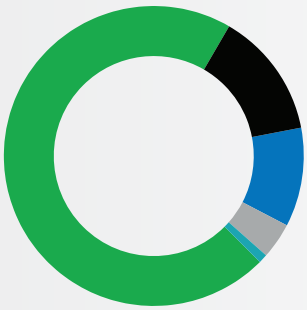
Funding breakdown

53% Industry

34% Government

13% Academic

Funding distribution



70.9% Applied research

13.6% Research fellows

11.3% Operations

3.7% Student awards

0.5% Innovation

People

6 Staff

6 Principal investigators

7 Research fellows

7 Postdoctoral fellows

28 Student researchers

11 Student interns

Education

11

Enrolled in Professional Master's Diploma in Energy and Innovation

41

Enrolled in Postgraduate Certificate in Energy Management and Innovation

Innovation

14 Current Clean Energy Zone startups

13 Clean Energy Zone graduated enterprises

38 Jobs created

11 Applications received in 2016

101 Zone learners

Events and outreach in 2016

31 Tours (representing 19 countries)

17 Speaking engagements

1 Government announcement

3 Student awards ceremonies

2 Conferences hosted

21 External events

2 Open houses

3 Seminars

3 Student info sessions

3 Workshops

2017 advisory board

Chair

Chris Evans

Interim Provost and Vice President Academic

Ryerson University

Tom Chapman

Senior Manager, Market Development

IESO

Thomas Duever

Dean, Faculty of Engineering and Architectural Science

Ryerson University

Evelyn Lundhild

Manager, Market Transformation, Conservation and Corporate Relations

IESO

Juan Macias

President, Canada and Senior Vice-President Energy, United States

Schneider Electric

Dino Priore

Executive Vice-President and Chief Engineering and Construction Officer

Toronto Hydro

Neetika Sathe

Director, Emerging Technologies

Alectra Energy Solutions

Hari Subramaniam

President

Carousel Development

Bala Venkatesh

Academic Director, Centre for Urban Energy and Professor, Electrical and Computer Engineering

Ryerson University

People

Administration

Bala Venkatesh
Academic Director

Lily Arase
Departmental Assistant

Denis Arseneault
Administrative Coordinator

Karen Ho-Cespedes
Manager, Research Projects

Matthew Kerry
Marketing and Communications Manager

Lalitha Subramanian
Project Manager

Principal investigators

Ling Guan
Magdy Salama
Vijay Sood
Bin Wu
David Xu
Amirnaser Yazdani

Fellows

Sean Conway
Jessie Ma
Bhanu Opathella
Omid Alizadeh
Mohamed Awadallah
Zhijian Fang
Pratap Revuru
Bob Singh
Hari Subramaniam
Zhiming He
Santhi Karthikeyan
Peng Yu
Gary Thompson
Huafeng Xiao

Student researchers

Amr Adel
Afarin Amirirad
Jahangir Afsharian
Nima Alibabaei
Gouri Rani Barai
Ayman Elkasrawy
Benjamin Fischer
Aditi Garg
Romulus Gheorghe
Nastaran Hajia
Gareth Higgins
Kaveh Khorramnejad
Kamran Masteri Farahani
Shiva Motamedi
Venkatesh Muthusamy
Isuru Pasan Dasanayake
Md Mizanur Rahman
Ragulan Rajenthiran
Frances Okoye
Pallavi Roy
Michael Santorelli
Harmanjot Singh Sandhu
Shriram Shukla
Stacy Sun
Randy Tan
Ryan Tan
Qiang Wei
Shuo Yu

Student interns

Hugo Almeida
Maleeha Alvi
Sara Azimi
Kiki Cekota
Nashmin Harun
Dara Jarallah
Jordan MacDonald
Guilherme Mateus Franke
Carolinne Magalhaes
Jonathan Nikodem
Johnny Tan

Talent

Our eminent faculty members, distinguished research fellows and world-class researchers have a wealth of academic, business and government experience and CUE is privileged to draw on this diverse, multidisciplinary and highly qualified talent pool to tackle projects related to our urban electrical systems on behalf of our sponsors. Our team's unique skills and technical capabilities include:

Power systems – technical studies

- Steady state analysis, short circuit analysis, transient analysis, operational optimization, asset optimization and planning, voltage stability, capacity markets, power quality.
- Economic, environmental and social studies.
- Conservation and demand management.
- Load forecasting and intelligent system applications.
- Microgrids.
- SCADA systems.

Power systems – policy

- Energy policy, communications and government relations.

Power electronics

- Analysis, development, prototyping of drives, power conversion systems for renewables, energy storage, microgrids, industrial applications and aerospace.

Product development

- Development and integration of new technologies and prototypes, including renewables, microgrids, microturbines and energy storage.

Power systems testing

- Products, services and software for electric utilities can be tested at several levels and scales from a few volts and watts to several kilovolts and megawatts.

Power engineering education

- Instruction for executives, mature students and graduates.

Electricity industry asset management

- Business risks, leadership and commitment, asset management planning, support requirements, performance evaluation and continuous improvement.

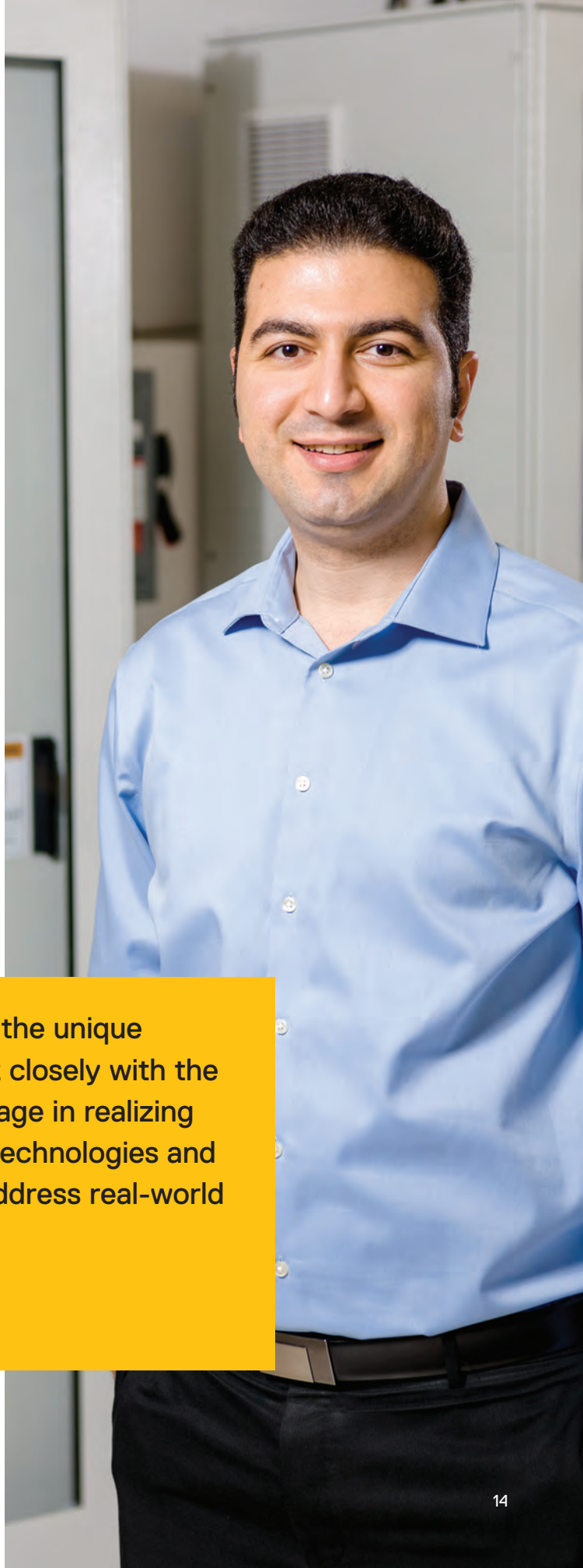
Business

- Business strategy development, risk management, asset analytics, regulatory approvals, corporate responsibility and stakeholder relations.

Research highlights

Energy storage implementation study for Sunnybrook Hospital

Canada is becoming an international leader in energy storage systems. Battery-based energy systems are one of the key parts of the storage landscape and can serve a wide range of applications across the electricity supply chain. In this study, CUE researchers worked with Toronto Hydro to address Sunnybrook Hospital's power quality issues and examined battery-based energy systems as potential solutions. Computer modelling evaluated various options for mitigating power quality issues, especially momentary voltage sags and power interruptions. A power conditioner employing a multi-megawatt battery system, installed at an available node ahead of the customer meter, was found as the most effective solution in mitigating the adverse impacts of momentary incidents at Sunnybrook Hospital.



"CUE has given me the unique opportunity to work closely with the utility sector to engage in realizing new and emerging technologies and novel solutions to address real-world problems."

— **Omid Alizadeh**
Postdoctoral Fellow

Capacity markets white paper

Ontario's electricity power system procures future generation capacity to maintain healthy investment in its system infrastructure. The power systems planning paradigm is changing to a capacity market model where generation facilities compete with each other.

Today, the environmental benefits of using energy storage for providing niche services in electric power systems, instead of power plants that emit greenhouse gasses, is evident. Hence there needs to be a systematic process of including energy storage products and services in capacity markets.

The capacity markets white paper, made possible through the financial support of the Independent Electricity System Operator, presents details of a capacity market auction model which is designed to consider energy storage. The model was tested with actual Ontario generation capacity data and a set of energy storage systems.

According to the base case results, even with the current prices, energy storage technologies can compete with conventional and intermittent generation capacity offers. Furthermore, the model can be used for selecting all types of future generation capacity requirements.

Asset planning for PowerStream (now Alectra)

Asset planning is an important task for utilities. They forecast demand and plan for assets to enable them to deliver electricity to meet their demand at the least annualized cost to customers. These costs include annualized cost of equipment, operations, maintenance and customer interruption.

Over the last decade, smart grid technologies, renewable energy sources and energy storage have become more commonplace among utilities. However, planning tools have typically only considered traditional utility assets such as lines and transformers and haven't included newer asset classes such as energy storage. Unless newer planning methods evolve, there can't be widespread adoption for these types of newer asset classes.

Recognizing this challenge, PowerStream (now Alectra), commissioned a project at CUE. This project entails considering a conventional asset planning algorithm and enhancing it to consider a newer asset class of energy storage. The result is a comprehensive asset planning tool that considers energy storage and renewables in addition to traditional assets such as lines and transformers.

This project offered a way to minimize investment costs comparing conventional assets, such as feeders and transformers with new technologies such as energy storage and renewables such as wind and solar. Projects like this one will ultimately help integrate more clean energy and help lower customer bills.

NSERC Energy Storage Technology Network

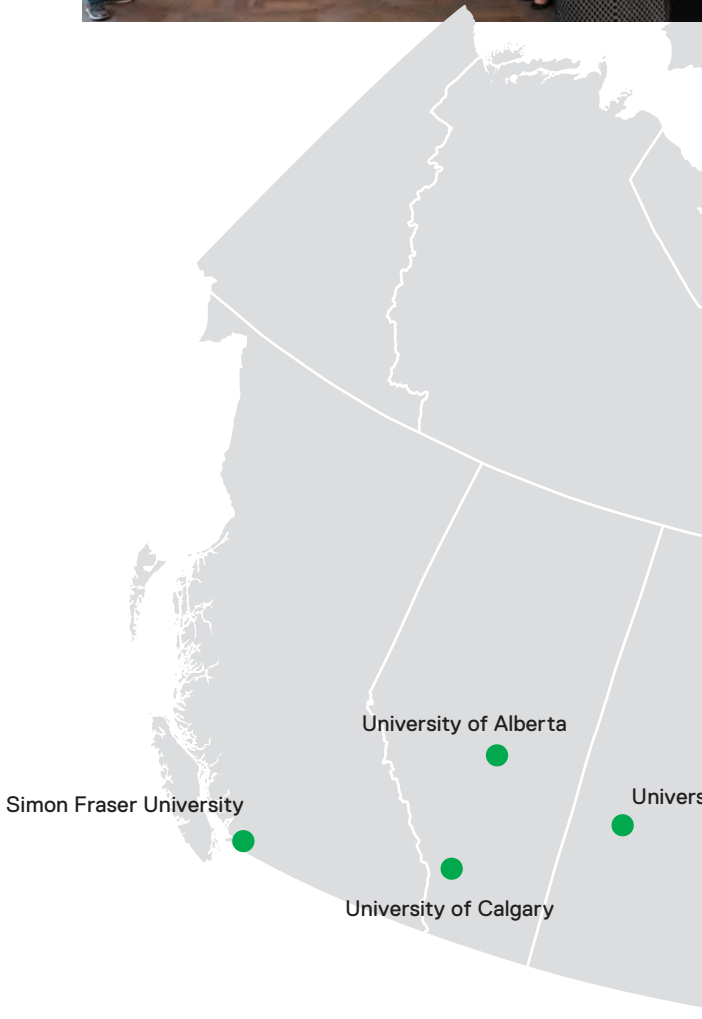
Ryerson University is proud to lead this five-year undertaking. With $5 million in funding, the NSERC Energy Storage Technology Network (NESTNet) is a pan-Canadian network consisting of 15 universities and 26 industry and government partners, all focused on the future of energy storage – an essential technology in Canada's transition to clean energy.

NESTNet collaboratively explores 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 energy storage 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 energy storage industry that is also competitive in the global marketplace.

NESTNet enjoyed a fruitful first year. We were pleased to host federal Science Minister Kirsty Duncan, and Mario Pinto, president of NSERC, to officially announce the formation of the network in March 2016.

We welcomed close to 200 researchers, academics, professionals and students to Ryerson University in June 2016 for a week of events including NESTNet's Annual Technical Conference and Summer School. The program culminated with Leading the Charge, an industry conference that provided a unique stage for manufacturers, utilities and customers to share their experiences. The IESO's CEO, Bruce Campbell, provided the keynote address.

NESTNet is also committed to training the next generation to power the future of Canadian energy storage. Through the first year of research, 72 highly qualified personnel worked with NESTNet's theme leaders, Handan Tezel, Liuchen Chang, Claudio Cañizares and Miguel Anjos.



Learn more at ryerson.ca/nestnet.

Year one outputs:

72 Highly qualified personnel (HQP)

14 Journal articles

6 Conference papers

1 Patent

sity of Saskatchewan

Memorial University

University of New Brunswick

Dalhousie University

University of Ottawa

École Polytechnique de Montréal

University of Ontario Institute of Technology

University of Waterloo

Ryerson University
University of Toronto
York University

University of Windsor

Professional development

Postgraduate Certificate in Energy Management and Innovation

For every two people retiring in the energy industry today, there is only one available to replace them. Since the sector is rapidly growing, there are increasing opportunities for professionals to begin a successful career in the energy sector. This certificate program provides adult learners with an opportunity to acquire a level of knowledge and expertise that will permit them to contribute effectively to energy management, conservation, sustainability and public policy governing this regulated market. It also explores the exciting opportunities in this space through material on energy innovation, entrepreneurship and the challenges and opportunities in developing new energy technologies and businesses. The program was developed in cooperation with the G. Raymond Chang School of Continuing Education. Students can complete coursework in-class, online or in their workplace via the customized executive course.

Required courses are Energy Innovation and Entrepreneurship; Energy and the Public Policy Debate in Canada; Energy Conservation: Emerging Trends; and An Introduction to Smart Grid. Students then choose two electives.

Learn more at ryerson.ca/ce/energy.

Professional Master's Diploma in Energy and Innovation

Launched in 2016, the Professional Master's Diploma (PMDip) in Energy and Innovation exposes participants to the relevant knowledge and skills required to excel as corporate officers, administrators, technicians and in other leadership roles in the fast-growing and rapidly changing Canadian energy sector. In addition to providing diverse, meaningful and lucrative career experience to participants, the diploma program addresses the pressing need for individuals qualified in these areas within the public and private sectors. With the expertise gained from this program, students can also assume a variety of operational, administrative and managerial roles outside of energy companies, including becoming energy analysts, policy advisors and managers.

The program requires the completion of four core courses plus a final diploma project. The four core courses are: Smart Grids – Electricity, Petroleum and Infrastructure; Demand Management and Conservation; Energy Storage and Use; and Electricity Markets.

Learn more at ryerson.ca/graduate.

"Thanks to Ryerson for all the industry research that you provide your students. I can see how the knowledge I'm learning is setting me up for future success in my business."

— Kathleen Brown, Student

Student opportunities

Internships

At CUE, we recognize that young people will be the ones to solve the next generation of urban energy challenges, both at home and abroad. To help them kick-start their careers, CUE offers numerous opportunities for students from a variety of programs at Ryerson University to learn about the tremendous opportunities in our field. Since our inception, around 60 students have worked with us as interns and many have gone on to careers in the energy sector. And since urban energy challenges know no borders, we've extended our reach by welcoming students from around the world though programs such as Science without Borders. Two such students, from Brazil, are Carolinne Magalhaes and Hugo Almeida who worked at CUE during 2016. Carolinne is from Belo Horizonte and is studying Industrial Engineering at Universidade Federal de Minas Gerais. Hugo is from Rio de Janeiro and is studying Electrical Engineering at Universidade Veiga de Almeida. They reflect on their experience at CUE:

Carolinne: "Energy storage is a good approach to try to solve the reliability problem of alternatives like wind and solar. I liked that CUE doesn't only think about the technical aspects like how to build a battery, but also on conservation, policy and marketing. They focus on actual integration, with lots of fields working together, and not just on lab experiments."

Hugo: "I liked CUE because there were so many researchers working on wide-ranging projects with everyone working together: from very big initiatives like the Schneider Electric Smart Grid Lab to the small startups working on battery solutions for mobile phones."

Research awards

Our awards recognize Ryerson students who have shown excellence in a project related to energy. These projects serve as a great experiential learning tool as students are given the opportunity to solve real-world industry problems alongside experts in their chosen field. Each recipient receives an award of up to $5,000, made possible by our generous sponsors.

IESO Student Assistantship Awards

Summer 2016 recipients

Pallavi Roy	Environmental Applied Science and Management
Stacy Sun	Architectural Science
Afarin Amirirad	Mechanical Engineering
Shiva Motamedi	Mechanical Engineering
Amr Adel	Electrical Engineering
Ayman Elkasrawy	Electrical Engineering

Fall 2016 recipients

Frances Okoye	Civil Engineering
Venkatesh Muthusamy	Aerospace Engineering
Benjamin Fischer	Environmental Applied Science and Management
Nima Alibabaei	Mechanical Engineering
Amr Adel	Electrical Engineering
Ayman Elkasrawy	Electrical Engineering

Toronto Hydro Student Assistantship Awards

Fall 2016 recipients

Alex Mines	Business Management
Bobby Anand	Mechanical Engineering
Dara Jarallah	Business Management
Jordan MacDonald	Business Management

Enwave Energy Corporation Student Assistantship Awards

Summer 2016 recipients

Altamash Ahmad Baig	Mechanical and Industrial Engineering
Jamie Fine	Mechanical and Industrial Engineering
Ying Lam Law	Mechanical and Industrial Engineering
Ayman Elkasrawy	Electrical Engineering

Fall 2016 recipients

Amr Adel	Electrical Engineering
Hang Gao	Electrical and Computer Engineering
Hiep Nguyen	Mechanical and Industrial Engineering
Qiang Wei	Electrical and Computer Engineering

CLEAN ENERGY zone

Formed in November 2012 as the Innovation Centre for Urban Energy (iCUE), the new and improved Clean Energy Zone is an incubator and accelerator focused on urban energy within Ryerson's unique experiential "zone learning" ecosystem. Instead of a co-op term where students work for someone else, the Clean Energy Zone encourages entrepreneurship by providing opportunities for collaboration, support and mentorship. Our goal is to help students turn their ideas into viable commercial products, services and technologies for the energy sector, while providing environmental, social and economic value to Canadian society.

Current startups

Actual Energy Solutions

Argentum Electronics

Distributed Resources

Electrefy

Elocity

Innovit

PawCharge

Peak Power Energy

Plug'n Drive

Screaming Power

Smartto Media

SolarTop

Tap the Grid

VAVETek

Graduated enterprises

2nd Lot

CaribShare Biogas

DanTeb Enterprises

EnergySavers

En-Tire Savings

I-EMS Group

InDee

Heliolytics

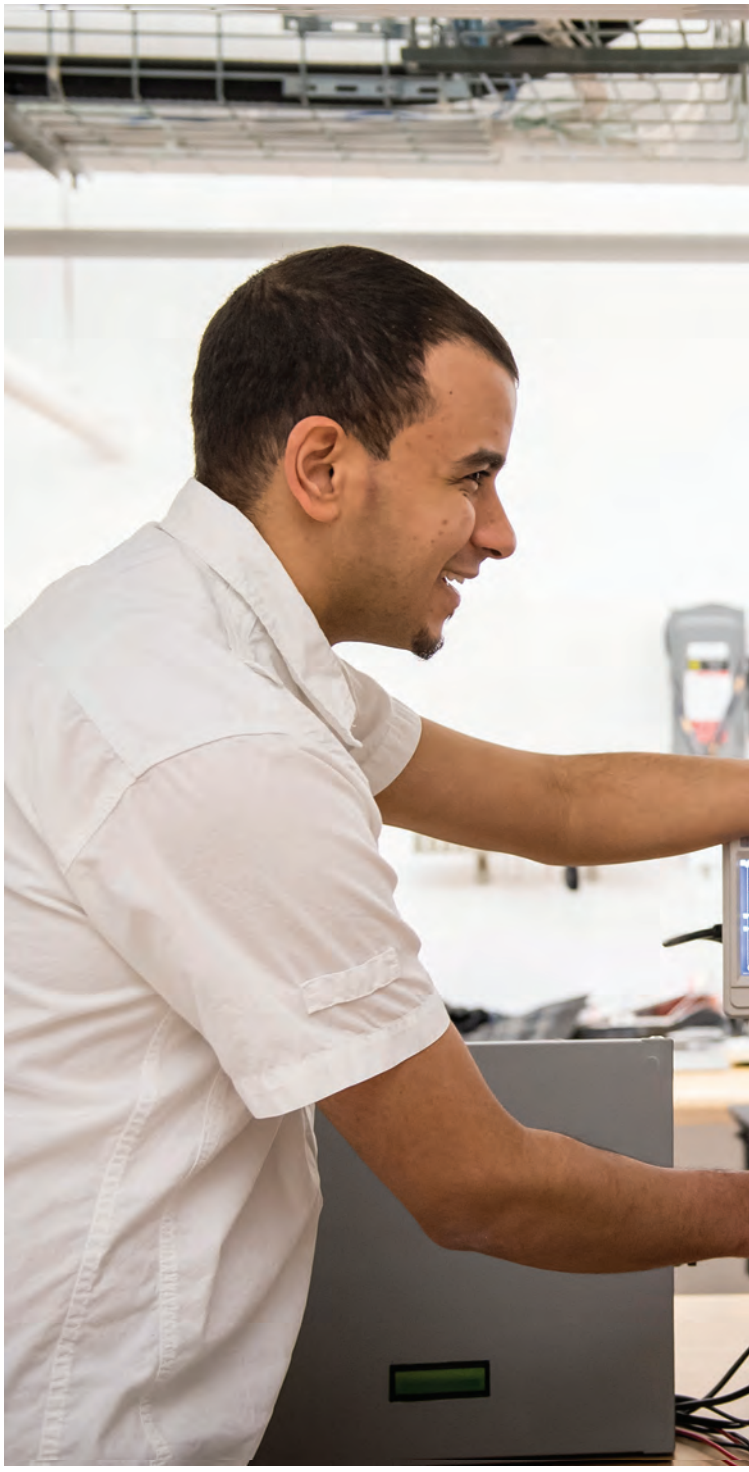
Lightning Shard

My Green Neighbour

PowerCost Monitor

Rigel Scientific Research

Truly Local



Argentum Electronics: A solar success story

Bolis Ibrahim and fellow Electrical Engineering student Oleh Zhyhinas are the founders of Argentum Electronics, a solar energy startup. The company develops smart power electronics and charge controllers for the solar industry, with the aim of promoting clean energy and making solar power more affordable and efficient.

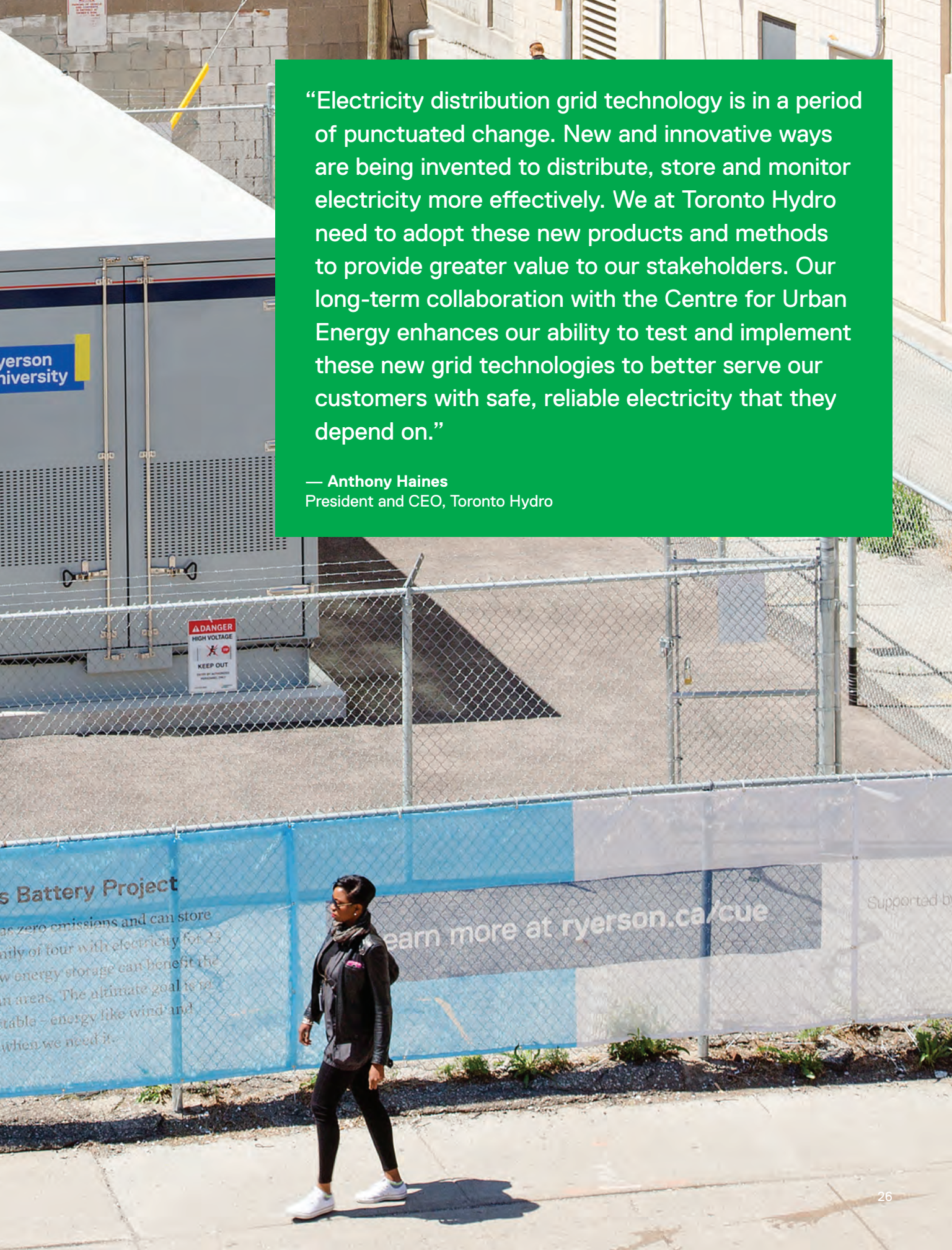
The two students are already winning awards. Their startup won the David McFadden Energy Entrepreneur Challenge at the OCE Discovery event, beating four other student teams from Ontario universities for a prize of $25,000. This added to their earlier financial support from the Norman Esch Engineering Innovation and Entrepreneurship Awards – Argentum Electronics won all three stages of Esch funding, helping them develop their idea.

The common perception is that solar panels are plugged in directly to the devices they're providing power for, but there are many power electronics on the path of electricity. Argentum Electronics is working on a solar charge controller to extract more power from the solar panels, and to provide customers the most energy out of the solar panels. "It's competitive efficiency at a much lower price," says Oleh. "Our goal from the very beginning was to promote clean air and clean energy."

So far, the team has developed a working prototype, which they plan to eventually commercialize. "Not everything that runs on a computer simulation is viable in real life – a lot of the stuff we were dealing with were ideal components," says Bolis. "So we started working on this to realize a physical model – a lot of prototyping. It was a good learning experience."

"I like being in the Ryerson ecosystem," says Bolis. "There are always high-profile individuals from the power industry rolling through, and there are always potential investors."


4MY NATIVES ONLY
We're helping to build a more reliable, resilient and cleaner grid for our future
Ryerson University's



"Electricity distribution grid technology is in a period of punctuated change. New and innovative ways are being invented to distribute, store and monitor electricity more effectively. We at Toronto Hydro need to adopt these new products and methods to provide greater value to our stakeholders. Our long-term collaboration with the Centre for Urban Energy enhances our ability to test and implement these new grid technologies to better serve our customers with safe, reliable electricity that they depend on."

— **Anthony Haines**
President and CEO, Toronto Hydro

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Ryerson University

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