Centre for Urban Energy
Ryerson University

Bala Venkatesh, PhD, PEng
Professor and Director

3,000
43,000
100+
### NEST Network on Energy Storage

**Canadian Energy Storage: $8.5 million**

<table>
<thead>
<tr>
<th>University</th>
<th>Professors</th>
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<tr>
<td>Dalhousie</td>
<td>Swan</td>
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<tr>
<td>Memorial</td>
<td>Iqbal</td>
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<tr>
<td>Polytechnique</td>
<td>Anjos, Gendreau, Savard</td>
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<tr>
<td>Ryerson</td>
<td>Venkatesh, Wu, Xu, Yazdani</td>
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<tr>
<td>Simon Fraser</td>
<td>Bahrami</td>
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<tr>
<td>Alberta</td>
<td>Kumar, Mertiny, Gallart</td>
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<td>Calgary</td>
<td>Zareipour</td>
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<td>New Brunswick</td>
<td>Chang, Saleh</td>
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<td>UOIT</td>
<td>Sood</td>
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<td>Ottawa</td>
<td>Tezel</td>
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<td>Saskatchewan</td>
<td>Karki</td>
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<td>Toronto</td>
<td>Iravani</td>
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<td>Waterloo</td>
<td>Canizares, Bhattacharya, Rowlands, Salama</td>
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<td>Windsor</td>
<td>Carriveau, Ting</td>
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<td>York</td>
<td>Winfield</td>
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<thead>
<tr>
<th>Utilities, Agencies, and Companies</th>
<th>Universities</th>
<th>Sponsors</th>
<th>Professors</th>
<th>Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ind. Electricity System Operator (Ontario)</td>
<td>National Research Council of Canada</td>
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<tr>
<td>Ontario Ministry of Energy</td>
<td>Advanced Energy Centre</td>
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<td>PowerStream Inc.</td>
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<td>eCAMION</td>
<td>Smart Grid Canada</td>
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<td>Hydrostor</td>
<td>Hydro-Québec</td>
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<td>Kylowave Inc.</td>
<td>Veridian Connections</td>
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<td>Temporal Power</td>
<td>Siemens Canada</td>
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<td>NRStor</td>
<td>BOMA Toronto</td>
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<td>Schneider Electric Canada</td>
<td>Cowessess First Nation</td>
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<td>Opus One Solutions</td>
<td>Natural Resources Canada</td>
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<td>Oshawa Power and Utilities Corporation</td>
<td>Wind Energy Institute of Canada</td>
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<td>TÜV SÜD Canada</td>
<td>Toronto Hydro</td>
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# Introduction to Ryerson Centre for Urban Energy

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<th>Founded:</th>
<th>Year 2010</th>
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<tr>
<td>Seed Funding:</td>
<td>$7 Million</td>
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| Founding Sponsors: | Hydro One  
|                | IESO  
|                | Toronto Hydro |

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<tr>
<th>Funding</th>
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<tr>
<td>Students</td>
<td>50+</td>
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<tr>
<td>Faculty</td>
<td>20+</td>
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Founded: Year 2010  
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Funding: $25 M  
Projects: 15+  
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Disclaimer:
All representations including boundaries are approximate. For actual details, please refer to appropriate authorities.

North American Power Systems
Introduction – Regions

Ontario is 4 times the size of the UK
Population of Ontario is a fifth of the UK
North American Power Systems
Introduction – Ontario, Canada

DEMAND

19,676 MW
Current Hour's Demand at 11:00 p.m. EST

Projected Demand at 1:00 a.m. EDT
18,075 MW

Today's Projected Peak at 5:00 p.m. EST
23,245 MW

Summer Record Peak Aug 1, 2006
27,005 MW
SUPPLY

Hourly Output by Fuel Type at 10:00 p.m. EST

- Nuclear: 11,092 MW
- Hydro: 3,756 MW
- Gas: 5,568 MW
- Wind: 126 MW
- Solar: 0 MW
- Biofuel: 85 MW

Hourly Imports: 1,476 MW
Hourly Exports: 1,092 MW
Generator Availability at Peak: 25,049 MW at 5:00 p.m. EST

PRICE

4.17 ¢/kWh
Current Hourly Price at 11:00 p.m. EST

Hourly Ontario Energy Price ($/MWh)

Projected vs. Actual

Average Weighted Price for July: 2.34¢/kWh
Global Adjustment for June: 9.55¢/kWh

EMBEDDED GENERATION

Installed capacity of wind and solar generation connected to local distribution systems.
Centre for Urban Energy – Research
Flywheel Energy Storage

- Magnetic Levitation
- Steel Rotor
- Vacuum
- Motor/Generator
- Cooling System
Flywheel improves power quality on Tillsonburg feeder
IESO procures the ancillary service of frequency regulation, a signal every 20 secs. Ontario requires 150 MW capacity.

Temporal Power specified a 10-flywheel system utilizing its 250 kW flywheels, providing a +/- 2.5 MW nameplate capacity.

The site, located in a small industrial park in the Town of Minto, approximately 2 hours north of Toronto [44 kV line, 2014].
Centre for Urban Energy – Research

Flywheel Energy Storage – Frequency Regulation
Centre for Urban Energy – Research
Urban Grid-Connected Battery Energy Storage

Electrovaya Battery Project
(1.2 MWh, 370 kW)

4-Wire
600 V
Three-Phase

2010 to 2016

$8.5+ Million
Centre for Urban Energy – Research

Urban Grid-Connected Battery Energy Storage

Electrovaya Battery Project
(1.2 MWh, 370 kW)

2010 to 2014
Build, Factory Testing and Installation
Centre for Urban Energy – Research
Urban Grid-Connected Battery Energy Storage

Merchandise Building

CUE

Legend:
- Fiber
- Ethernet
- 600V, 3 Ph
- DC signal

Electrical Room

13.8 kV Bus

13.8 kV Transformer

600 V Switchboard

Data switch

Frank Natale Lane way

Parking Lot

136 Dundas Street East

Concrete pad

Battery System

Legend:
- Fiber
- Ethernet
- 600V, 3 Ph
- DC signal

Merchandise Building

CUE

PC with SCADA

PC with SCADA

SCADA server

HISTORY server

Data switch

Electrical Room

13.8 kV Bus

13.8 kV Transformer

600 V Switchboard

Data switch

Frank Natale Lane way

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Battery System

Legend:
- Fiber
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Centre for Urban Energy – Research
Urban Grid-Connected Battery Energy Storage

Electrovaya Battery Project
(1.2 MWh, 370 kW)

Developed Test Plan
(2012 – 2013)
With Hydro One and EPRI

2012 to 2014
Developed Economic Models – Frequency Regulation and Ramping
Electrovaya Battery Project
(1.2 MWh, 370 kW)

2015 - 2016
Installation and On-Site testing
Centre for Urban Energy – Research

Pole Mount Energy Storage

- Substation
- HV Bus
- LV Bus
- Feeders
- Regulator

Electric Cars overload distribution equipment

Load Forecasting
Optimizing ES Unit

- Mechanical Design
- Electrical Design
- 3-wire (Split Phase) 15 kVA, 1 Hour (240 V, 60 Hz)

24 Hours
Load w/o ES
Load with ES
Centre for Urban Energy – Research
Pole Mount Energy Storage

Installed: August 2016
$15,000
Distribution upgrade
Deferral
Thank You.
Energy Storage
Ice Storage
Energy Shift (kWh)

Peak Load Reduction (kW)

Peak Demand Reduction and Energy Arbitrage benefits – as measured in Ryerson Demo