Council of Industrial Boiler Owners
Technical Focus Group
Energy & Environmental Committee Meeting

Why Integrate Energy Storage Into a Behind-the-Meter CHP System?

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CEM ENGINEERING
COGENERATION & ENERGY MANAGEMENT

*Helping Our Clients Achieve Their **Energy** and **Environmental** Goals*

December 6, 2016

Overview

1) What Is Energy Storage?
2) Benefits of Energy Storage
3) Examples of Energy Storage
4) Typical Capacities
5) Integration with CHP
6) Case Study
7) Typical Business Case
8) Challenges Going Forward

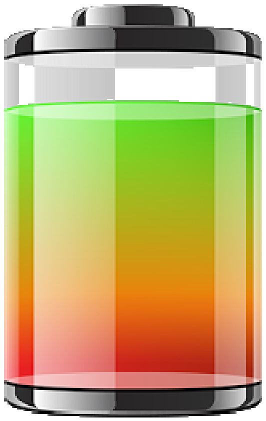
What is Energy Storage?

- Capturing and storing energy produced at one time to perform useful processes at a later time
- Involves converting energy from forms that are difficult to store to more conveniently or economically storable forms

- Stored energy can be used in the event of a power outage, voltage sag, or if a particular power source is unable to meet its demand

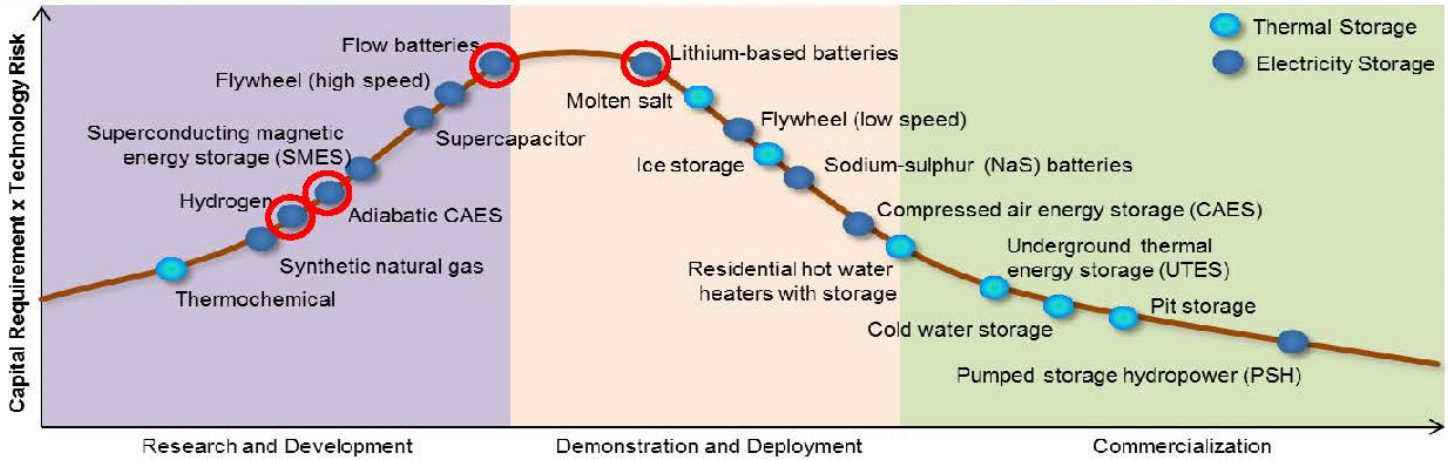
Types of Energy Storage Batteries

- **Flow Batteries**:
  - Stores energy in chemically reactive liquids, held in two tanks separate from the actual battery cell
  - System pumps the two liquids from the tanks into a cell where a chemical reaction releases electrons that supply power onto the grid



- **Solid State:**
  - lithium ion, nickel-cadmium, sodium sulfur
  - As the battery charges, chemical ions move through the electrolyte from the positive to the negative
  - From the negative to the positive electrode, as the battery discharges

Technology Evolution – 2013-2016



Technology:

- Li-ion have become the most installed new battery type (2012-2016)
- Cell costs have been decreasing, and are expected to continue:
  - Flow batteries ($680 → $350/kWh)
  - Li-ion ($550 → $200/kWh)
- Fully Installed costs are higher:
  - Inverter & interconnect ~$450/kW
  - BMS & control ~$325/kW
  - Installation & contingency ~$250/kW

Research and Development:

- University based research Networks
  - Future Energy Systems Research Institute (U of Alberta)
  - NSERC NEST Network (Ryerson)
  - UBC/Fraunhofer Clean Energy Partnership
- US DOE Energy Storage Program
- Energy Storage Integration Council (ESIC

OECD/IEA 2014 Technology Roadmap – Energy Storage, IEA Publishing/

Benefits of Energy Storage

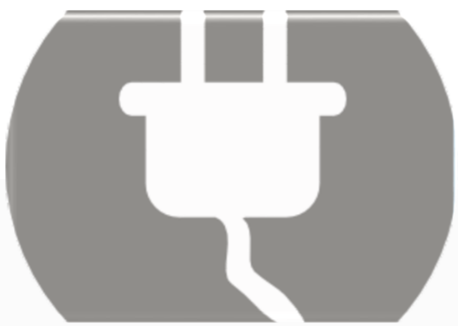

Reduced Shutdown


Reduced Re-Starts

Blackstart

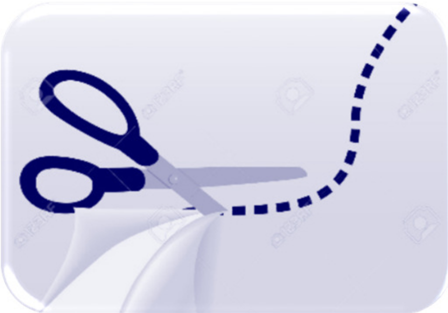

Turbine Load Levelling


Peak Shaving


UPS


Silent Operation

Benefits of Energy Storage

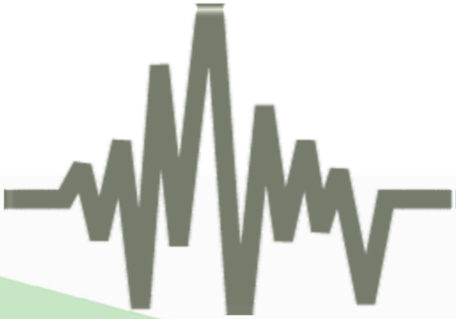


Islanded Mode

Zero Import

Increased Fuel Efficiency

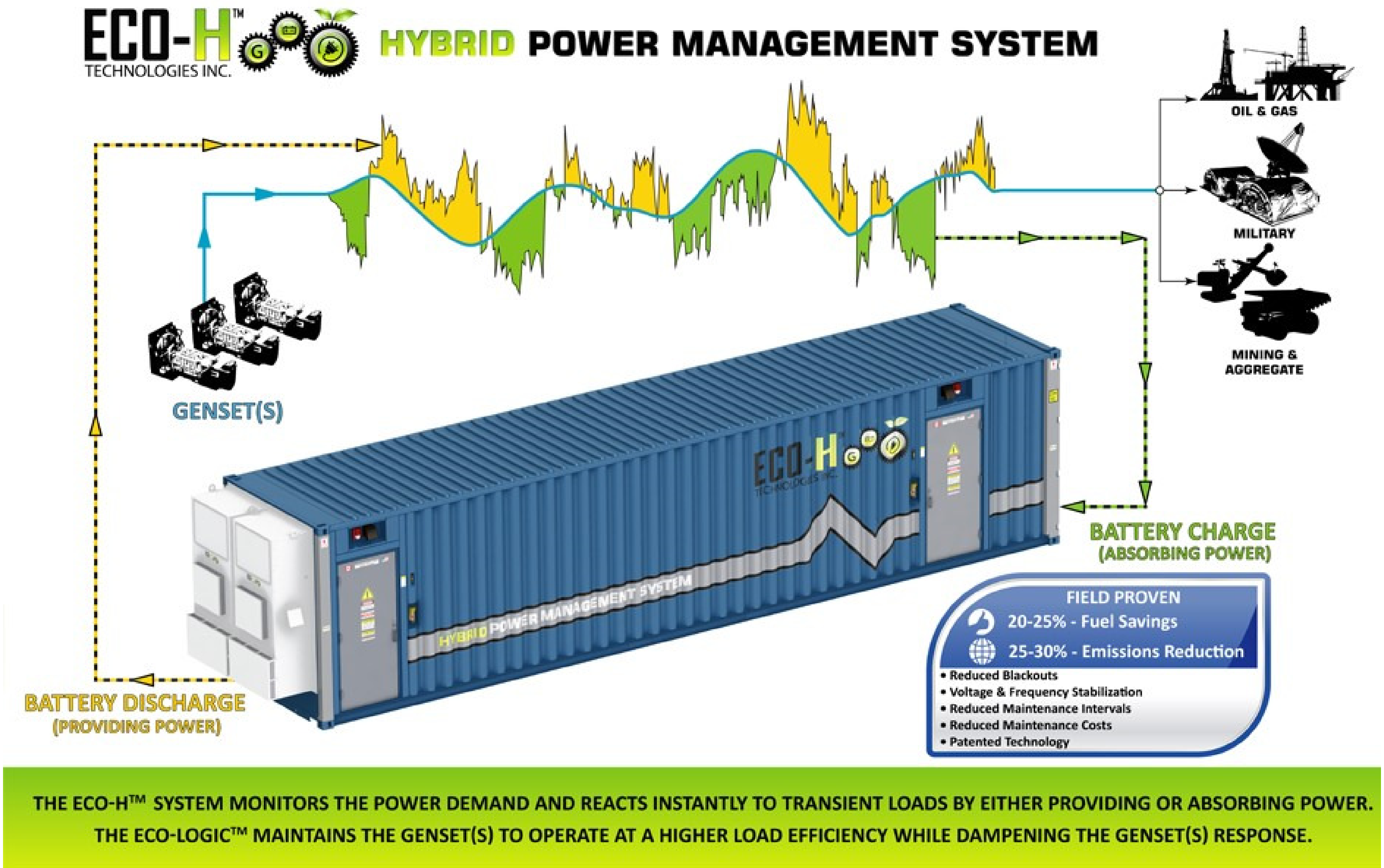
Emission Reduction

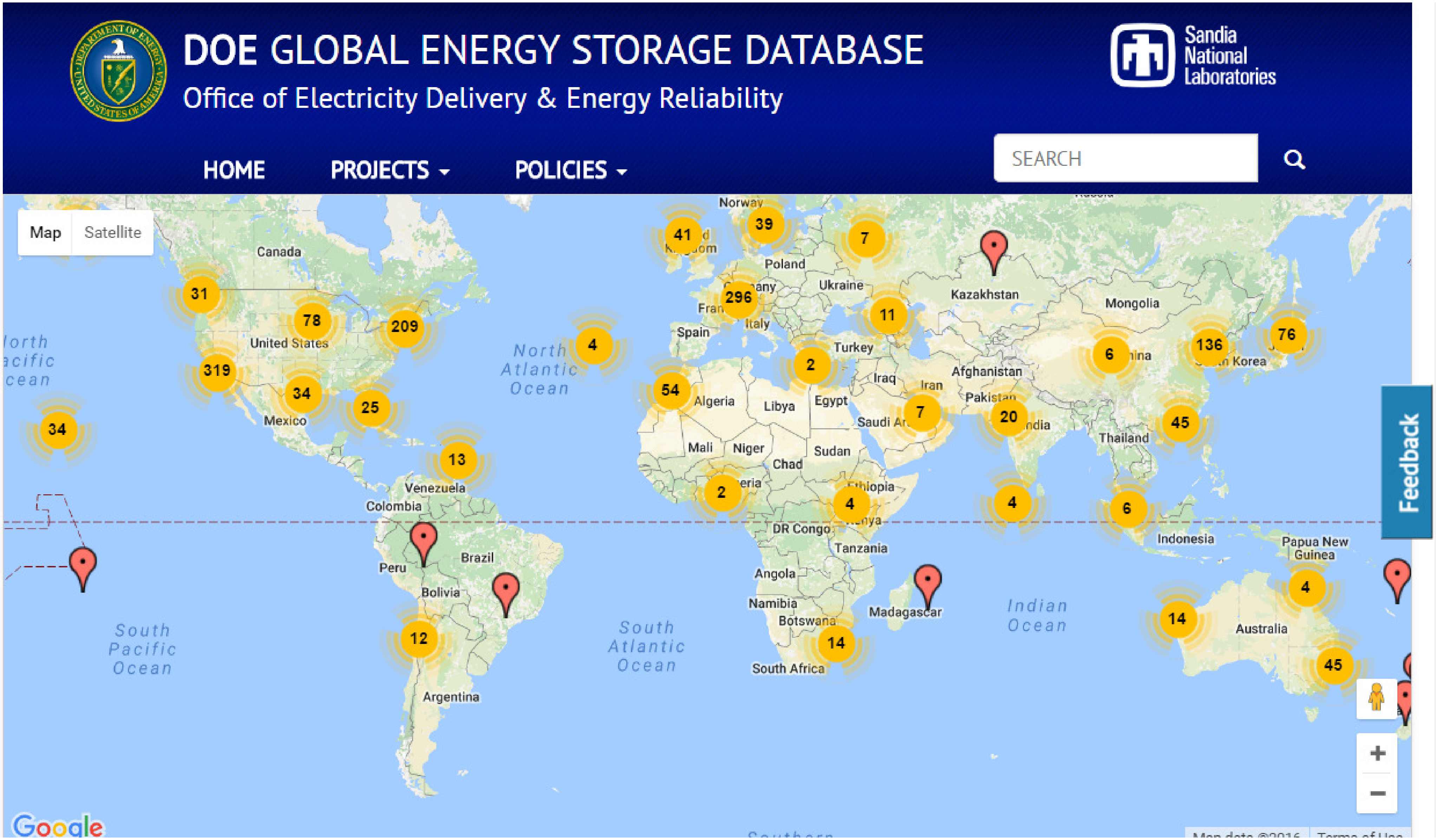


Stabilized Frequency

Reduced Maintenance

Stabilized Voltage


ECO-H™
TECHNOLOGIES INC.
HYBRID POWER MANAGEMENT SYSTEM
OIL & GAS
MILITARY
MINING & AGGREGATE
GENSET(S)
BATTERY CHARGE
(ABSORBING POWER)
BATTERY DISCHARGE
(PROVIDING POWER)
HYBRID POWER MANAGEMENT SYSTEM
FIELD PROVEN
20-25% - Fuel Savings
25-30% - Emissions Reduction
• Reduced Blackouts
• Voltage & Frequency Stabilization
• Reduced Maintenance Intervals
• Reduced Maintenance Costs
• Patented Technology
THE ECO-H™ SYSTEM MONITORS THE POWER DEMAND AND REACTS INSTANTLY TO TRANSIENT LOADS BY EITHER PROVIDING OR ABSORBING POWER.
THE ECO-LOGIC™ MAINTAINS THE GENSET(S) TO OPERATE AT A HIGHER LOAD EFFICIENCY WHILE DAMPENING THE GENSET(S) RESPONSE.


DOE GLOBAL ENERGY STORAGE DATABASE
Office of Electricity Delivery & Energy Reliability
Sandia National Laboratories
HOME
PROJECTS
POLICIES
SEARCH
Map
Satellite
Feedback
Canada
United States
Mexico
North Atlantic Ocean
South Pacific Ocean
South Atlantic Ocean
Indian Ocean
Venezuela
Colombia
Peru
Brazil
Bolivia
Argentina
Norway
Poland
Ukraine
Spain
Italy
Turkey
Algeria
Libya
Egypt
Iraq
Iran
Mali
Niger
Chad
Sudan
DR Congo
Tanzania
Angola
Namibia
Botswana
South Africa
Madagascar
Kazakhstan
Mongolia
Afghanistan
Thailand
Indonesia
Papua New Guinea
Australia
31
78
209
319
34
25
34
4
13
12
41
39
7
296
11
2
54
7
2
4
14
20
4
6
6
136
76
45
14
4
45
Google

Examples of Energy Storage

Ryerson University – Centre for Urban Energy (600 kW.h)

- Academic-industry partnership with Ryerson University, Hydro One, Toronto Hydro and IESO to test a homegrown battery system in downtown Toronto. The project's goal is to demonstrate how off-peak electricity can be stored to help improve grid performance during outages, fix power quality issues, and mitigate capacity constraints on the grid.

- The battery system is connected to Ryerson's Centre for Urban Energy located in the Merchandise building (a mixed-use facility) and can provide up to 600kWh of electricity.

Examples of Energy Storage

Stem – 1.3 MW Indoor Energy Storage System

- Mixed-use corporate complex with 2.1 million square feet of space, owned by LBA Realty.

- The battery system will be the largest indoor energy storage system in the U.S.

Typical Capacities

(Assuming 1 MW_e of Total Power)

Description	Power Transient Management	Peak Demand and Power Transient Management	Peak Demand and Power Transient Management
Battery Design Energy @ Beginning of Life (kW.h)	160.5	2,142	2,562
Usable Energy @ Beginning of Life (kW.h)	151	2,014	2,408
Depth of Discharge Range	65% - 85%	5% - 95%	5% - 95%
Total Battery Racks (Populated of Total Racks)	6 of 6	46 of 55	55 of 55

Why Integrate Storage Into CHP?

1) **Quality** of remaining power purchased can fluctuate.

2) **Cost** of remaining power purchased can remain very high.

3) Pressure to reduce natural gas use/CO_2

4) Prime movers cannot always electrically load follow perfectly, in the islanded mode.

5) Not all CHP systems have blackstart capability

Case Study: Campbell Company of Canada

- 85 Years in Canada
- Plant Opened: August 1931
- Total Plant : 550,000 sq. ft.
- Annual Volume: 12.5 Million Adjusted Cases
- Human Resources: 400 non-union and 147 office
- Two-thirds of Campbell Canada’s ingredients (fresh carrots, potatoes, and mushrooms) come from within three hours drive of our plant
- Sole Campbell Plant in Canada producing **canned** products
- First Campbell Plant in North America producing **Aseptic** carton product

4.8 MW CHP System:
Online Since December 2015!

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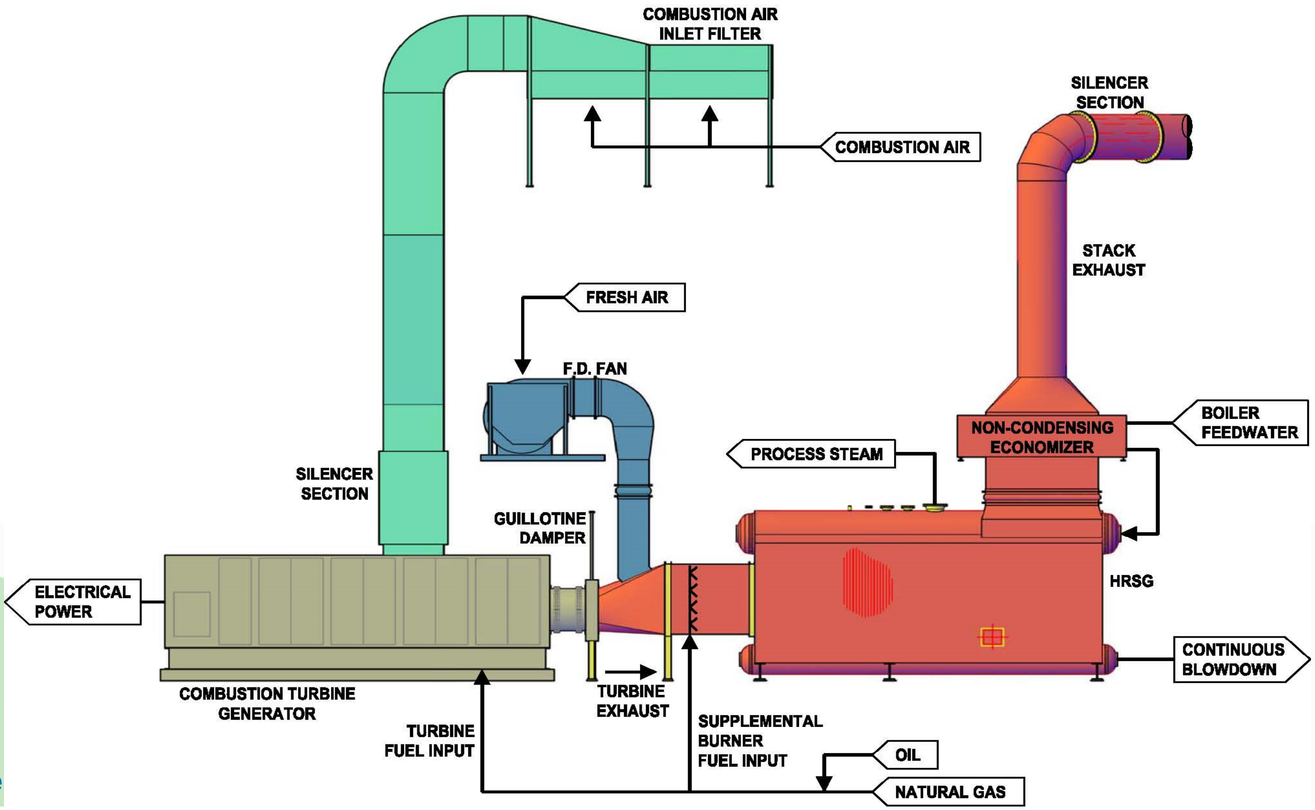
Outputs

- GTG Up to 4.8 MW power. HRSG 28,000 lbs/hr steam@165 psi from exhaust heat and up to 90,000 lbs/hr of Steam



Project will produce 92% of annual electricity and 93% of annual steam. Annually, Toronto will utilize approximately 40% more natural gas, but the generated electricity will have a net reduction of GHG emissions by approximately ***9,300 tonnes CO_{2e}.***

Heat Recovery Steam Generator

Gas Turbine Generator

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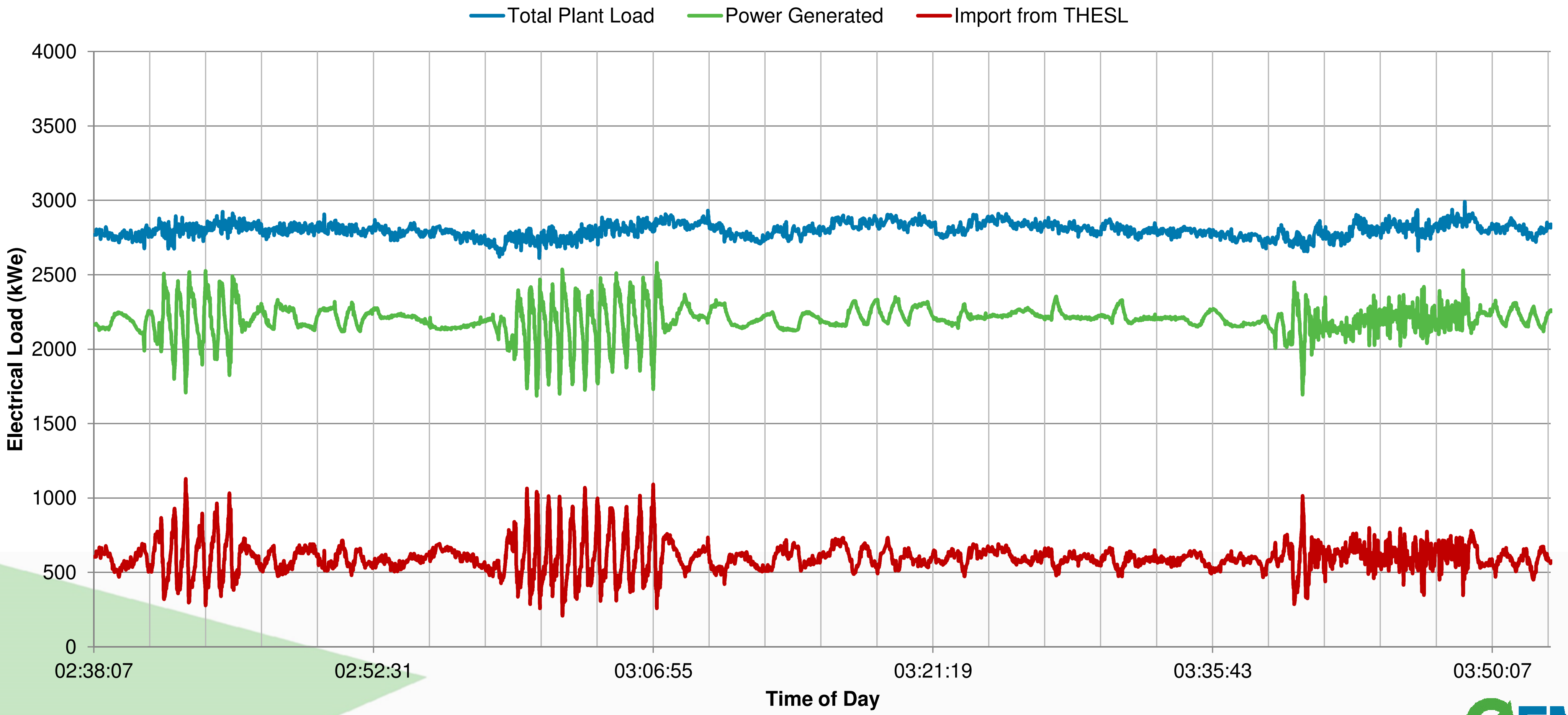
Problem

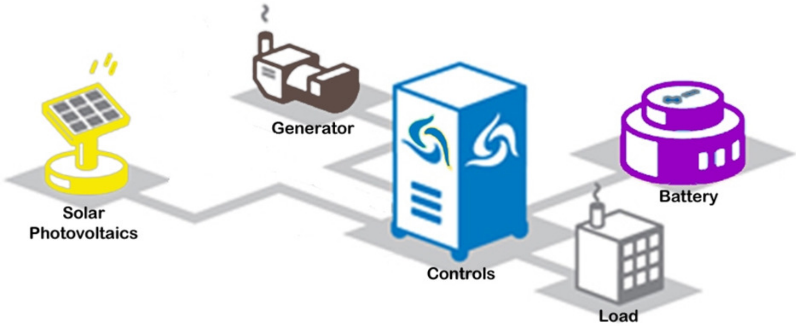
- The CHP system has been operating for about one year.
- Frequent power blips from electrical LDC (roughly 1 every 3 weeks)
- Cost of remaining power purchased (200 kW_e – 300 kW_e) very high (roughly 35¢ CAD/kW.h)
- Cost of lost production is crazy
- Plant losing new product/volume due to power blips

1-Second Interval Data



Proposed Project

- 1 MW/2 MW.h battery storage
  - Lithium ion (LG)
  - Containerized
- Islanded from the electrical grid (that is, microgrid)



- 500 kW of solar PV panels
- 8 electric vehicle recharging stations

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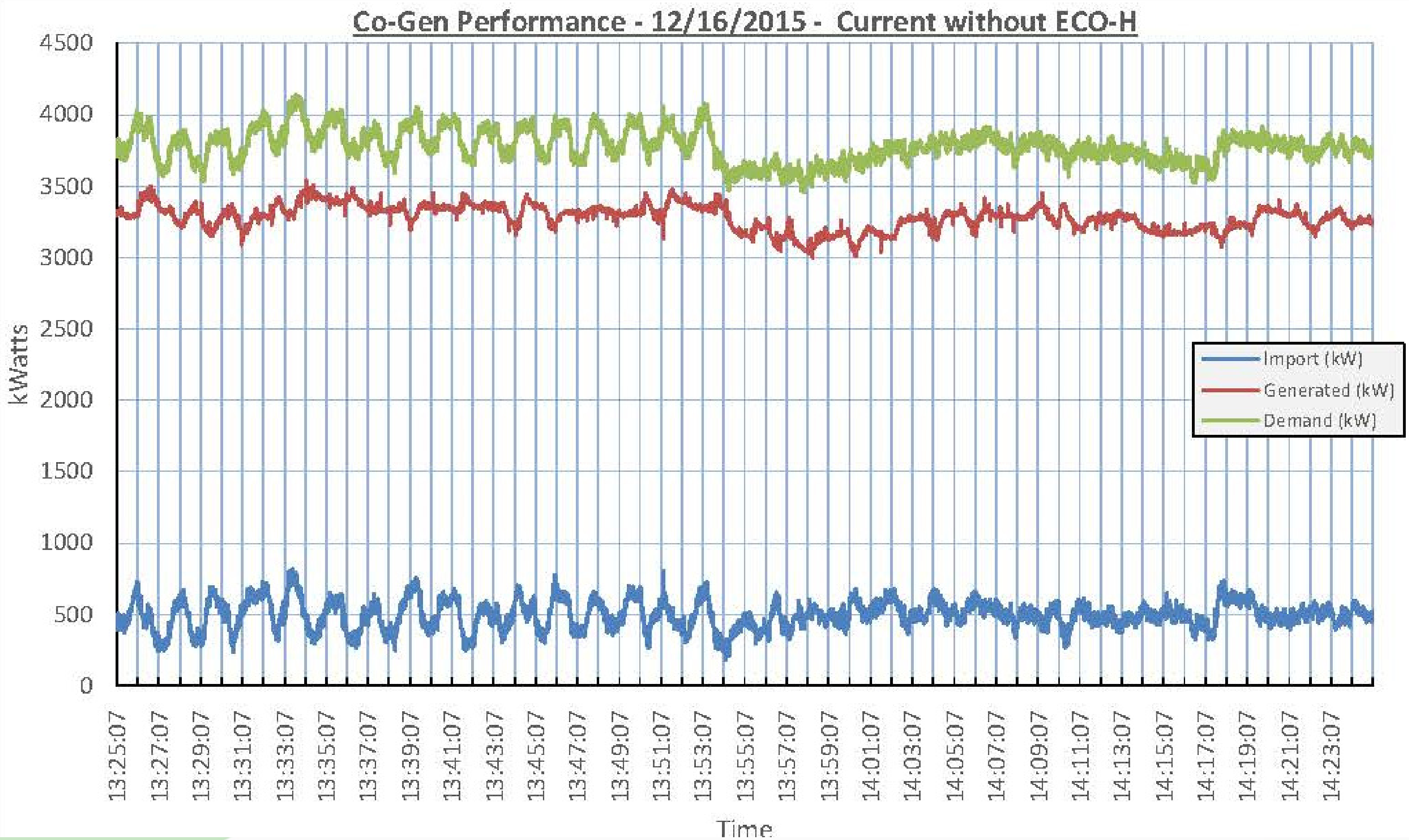
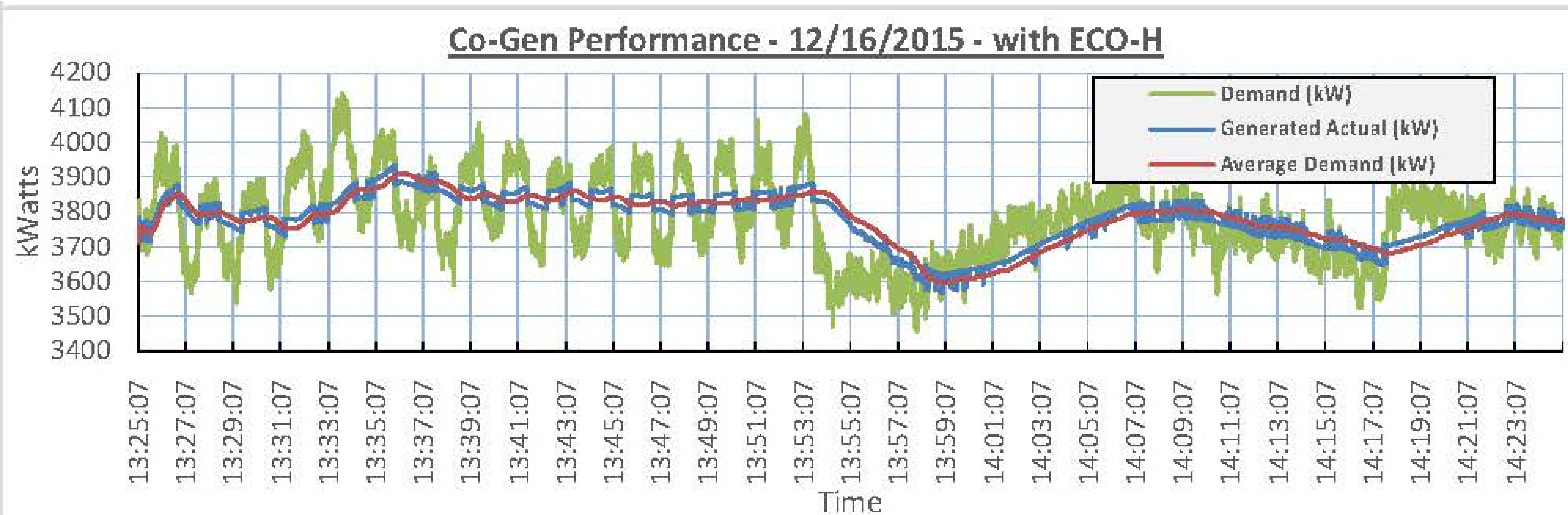
Proposed Storage Project (Cont'd)

Description	Peak Demand and Power Transient Management
Battery Design Energy @ Beginning of Life (kW.h)	2,142
Usable Energy @ Beginning of Life (kW.h)	2,014
Depth of Discharge Range	5% - 95%
Total Battery Racks (Populated of Total Racks)	46 of 55


Co-Gen Performance - 12/16/2015 - Current without ECO-H
4500
4000
3500
3000
2500
2000
1500
1000
500
0
kWatts
Import (kW)
Generated (kW)
Demand (kW)
13:25:07
13:27:07
13:29:07
13:31:07
13:33:07
13:35:07
13:37:07
13:39:07
13:41:07
13:43:07
13:45:07
13:47:07
13:49:07
13:51:07
13:53:07
13:55:07
13:57:07
13:59:07
14:01:07
14:03:07
14:05:07
14:07:07
14:09:07
14:11:07
14:13:07
14:15:07
14:17:07
14:19:07
14:21:07
14:23:07
Time


Co-Gen Performance - 12/16/2015 - with ECO-H
kWatts
4200
4100
4000
3900
3800
3700
3600
3500
3400
Demand (kW)
Generated Actual (kW)
Average Demand (kW)
13:25:07
13:27:07
13:29:07
13:31:07
13:33:07
13:35:07
13:37:07
13:39:07
13:41:07
13:43:07
13:45:07
13:47:07
13:49:07
13:51:07
13:53:07
13:55:07
13:57:07
13:59:07
14:01:07
14:03:07
14:05:07
14:07:07
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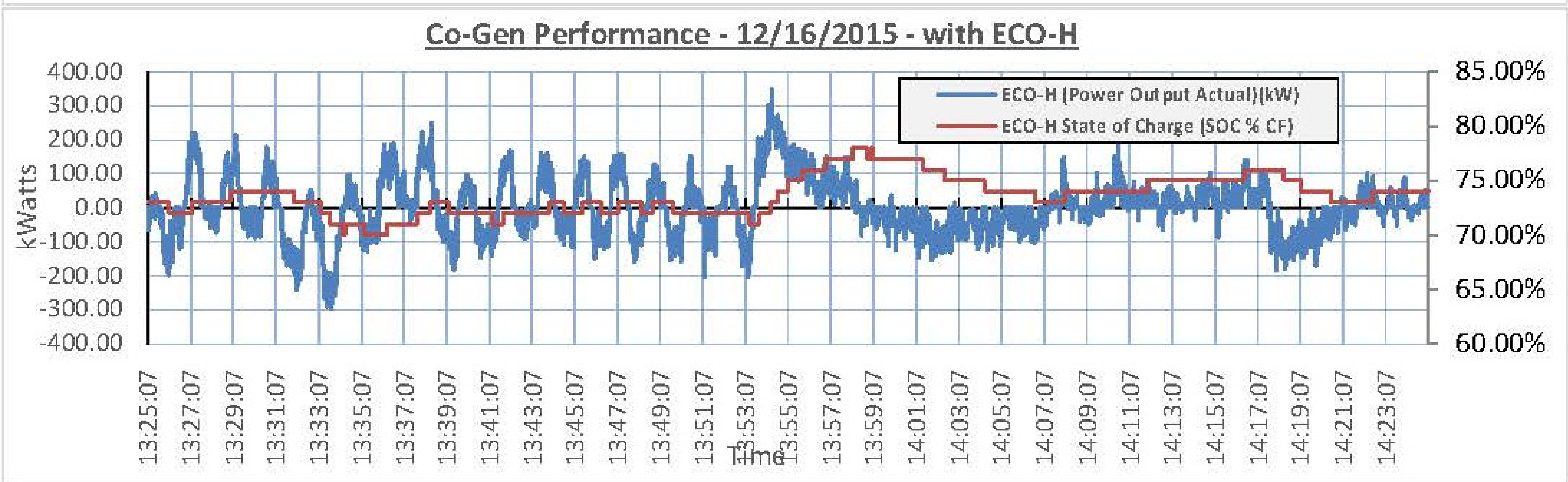
14:13:07
14:15:07
14:17:07
14:19:07
14:21:07
14:23:07
Time


Co-Gen Performance - 12/16/2015 - with ECO-H
ECO-H (Power Output Actual)(kW)
ECO-H State of Charge (SOC % CF)
kWatts
400.00
300.00
200.00
100.00
0.00
-100.00
-200.00
-300.00
-400.00
85.00%
80.00%
75.00%
70.00%
65.00%
60.00%
13:25:07
13:27:07
13:29:07
13:31:07
13:33:07
13:35:07
13:37:07
13:39:07
13:41:07
13:43:07
13:45:07
13:47:07
13:49:07
13:51:07
13:53:07
13:55:07
13:57:07
13:59:07
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14:03:07
14:05:07
14:07:07
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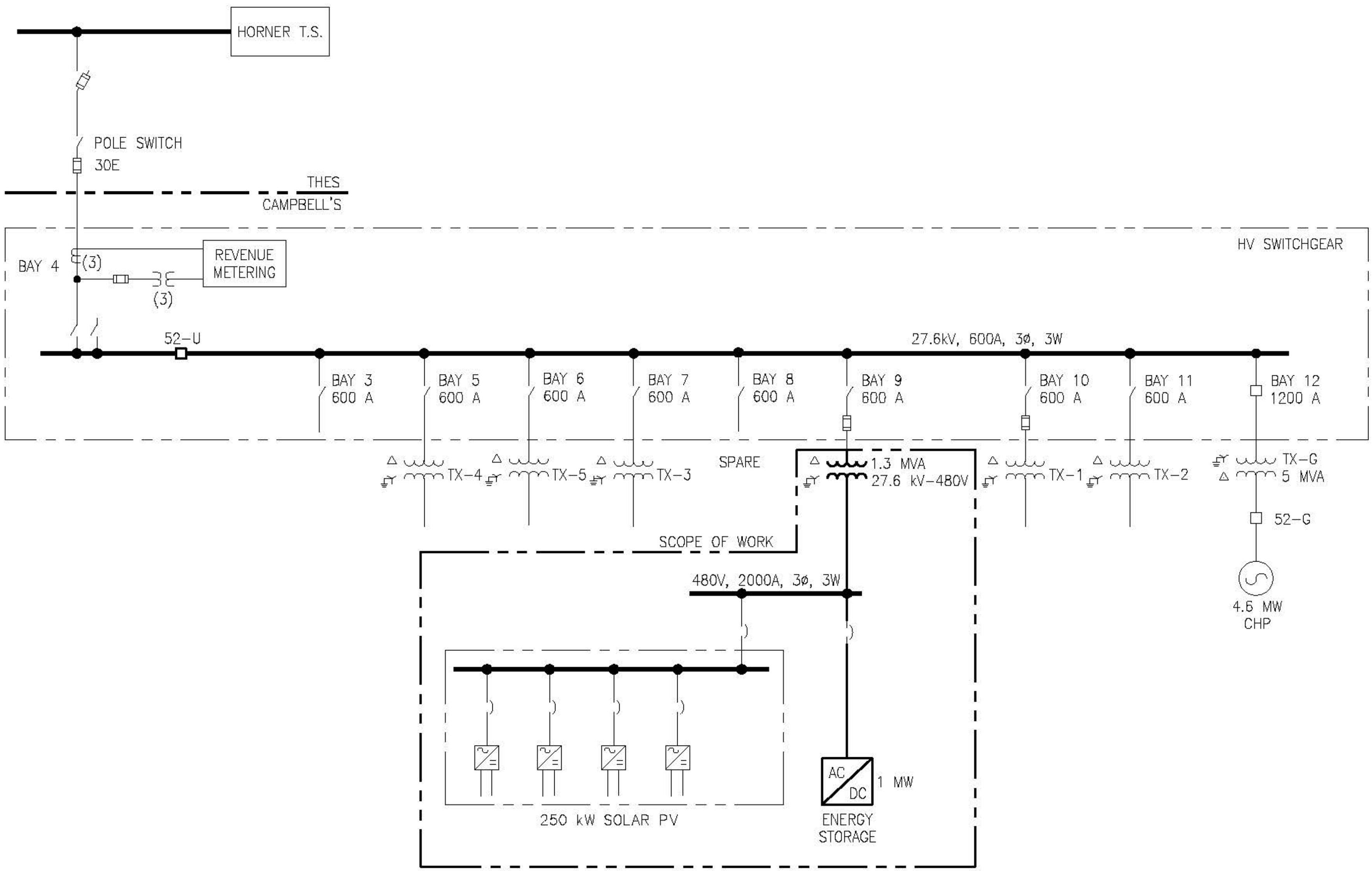
14:21:07
14:23:07
Time


HORNER T.S.
POLE SWITCH
30E
THES
CAMPBELL'S
HV SWITCHGEAR
BAY 4
(3)
REVENUE METERING
(3)
52-U
27.6kV, 600A, 3ø, 3W
BAY 3 600 A
BAY 5 600 A
BAY 6 600 A
BAY 7 600 A
BAY 8 600 A
BAY 9 600 A
BAY 10 600 A
BAY 11 600 A
BAY 12 1200 A
TX-4
TX-5
TX-3
SPARE
1.3 MVA
27.6 kV-480V
TX-1
TX-2
TX-G
5 MVA
52-G
4.6 MW
CHP
SCOPE OF WORK
480V, 2000A, 3ø, 3W
AC
DC
1 MW
ENERGY STORAGE
250 kW SOLAR PV

Approximate Capital Cost ($000's CAD)

Storage Capacity: 120 Minutes	
Main Equipment	3,930
Installation by Trades	680
Civil/Structural	130
Professional Services	850
Project Contingency (10%)	510
Approximate Capital Cost (Supply/Install)	**6,100**

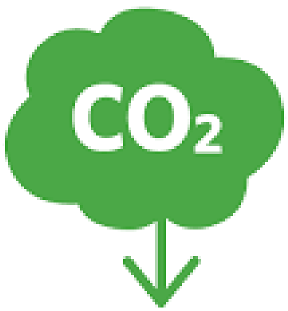
Typical Business Case ($000's CAD)

Storage Capacity: 120 Minutes	
Purchased Electricity Avoided (Per Year) 6,000 MW.h x $110/MW.h	660
Lost Production Avoided (Per Year) $50,000/occurrence x 12 occurrences/year	600
Value of CO2 Credits Generated 1,700 tonnes/yr x $30/tonne	50
Total Potential Cost Savings (Per Year)	1,310
Rough Net Capital Cost (After Grant)	3,050
Simple Payback	**2.3 years**

CO_2 Tonnes/Year Saved

- CO_2 Emissions Factor for Natural Gas: 0.059 tonne CO_2/mmBtu
- Gross FCP Heat Rate: 4,700 Btu/kW.h (HHV)
- Total Electricity Saved: 6,000 MW.h/year

- CO_2 Savings = 6,000 MW.h/year x 4,700 Btu/kW.h x 0.059 tonne CO_2/mmBtu
- **CO_2 Savings = 1,700 tonne CO_2/year**



What gaps still exist?

Competitiveness

- Total installed costs, including manufacturing and grid integration costs, must be less than the monetizable benefits of individual projects.

Industry Acceptance

- All stakeholders must have solid understanding of storage technology's benefits and risks relative to other options

Validated Reliability and Safety

- Sample performance data, standard testing protocols and validation tools must be readily available to a variety of stakeholders to ensure validated performance of new technology.

Equitable Regulatory Environment

- Any artificial barriers to the installation, and operation (including the sharing of benefits) must be identified and eliminated in order to reduce financing and project development risk

 U.S. Department of Energy "Grid Energy Storage", Dec 2013