

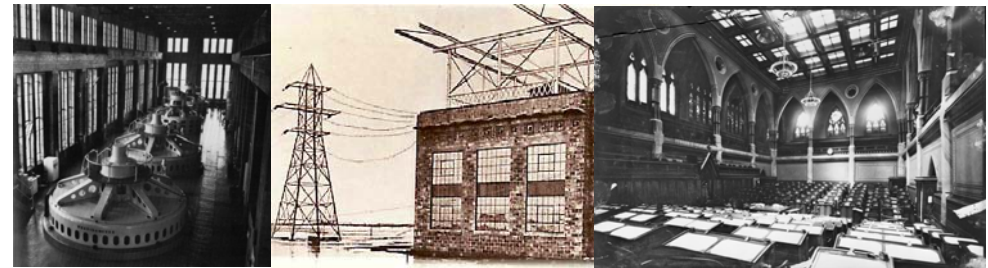
Transition in Power Systems

- Smart Grid and Renewable Energy

- Introduction to electrical power industry
- New developments in power systems
 - Distributed generation & renewable energy
 - Smart grid

Power Industry – Early Days

- At the beginning of electric power industry 130 years ago, generators were small and services were local
- The Parliament Building was lit by electric lamps in 1884 – early adopter of new technology



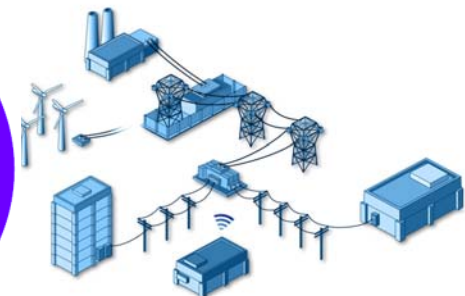
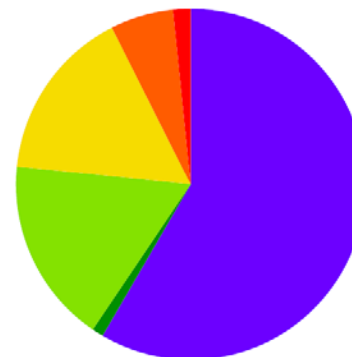
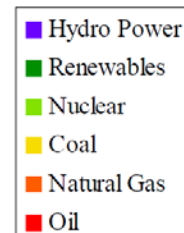
Power Industry – Yesterday

- Larger generators, longer distances and higher voltages - rapid expansion of “electrification”
- Power systems - a sophisticated, reliable, vertically integrated, man-made network



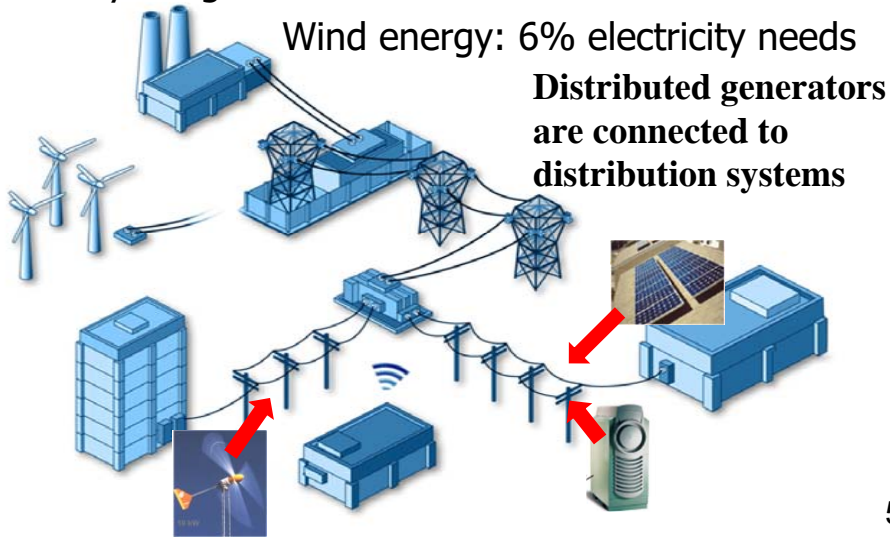
Power Industry - Today

- Generation, transmission, distribution and consumption
- ~25% of Canadian energy consumption, 22% greenhouse gas (GHG) in Canada
- Industry in transition: more players, GHG reduction, expectation for return on investment, new technologies



Power Industry in Transition

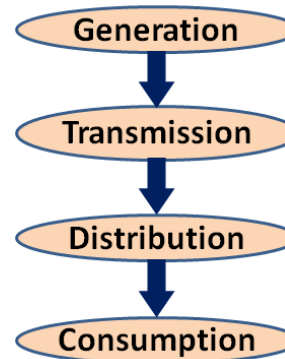
- More small, renewable energy based generators
- Vertically integrated network → Mesh network



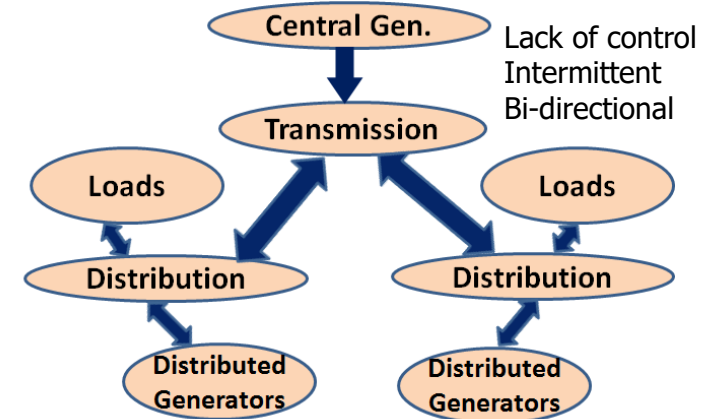
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Vertically Integrated Systems → Mesh-Networked Systems

Established:

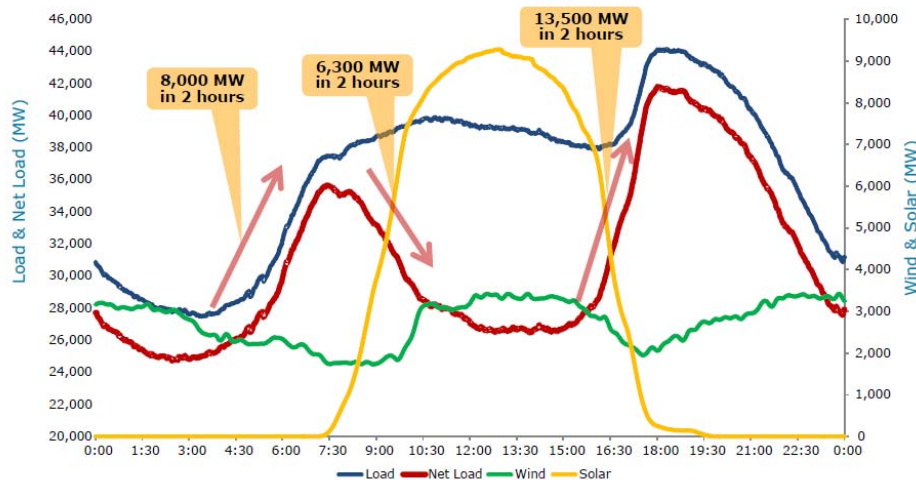


In development:



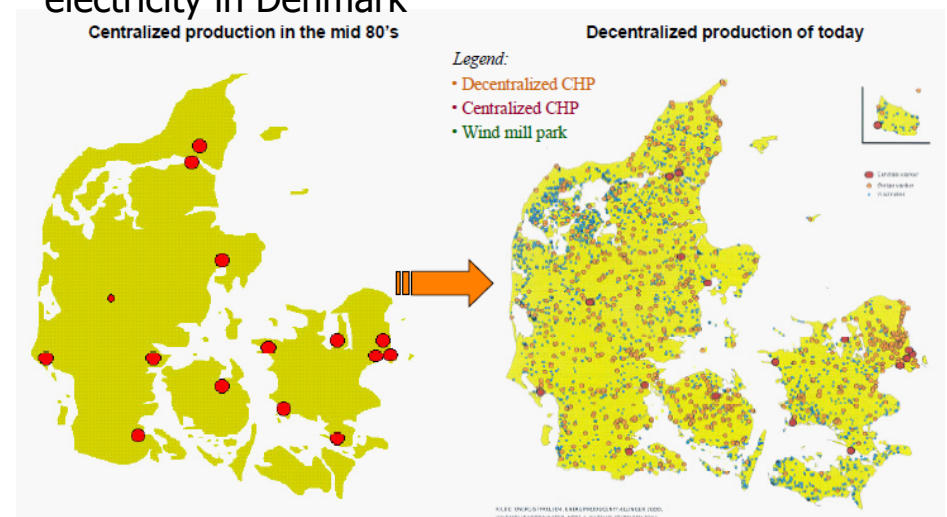
Impact of Renewable Energy

- CA (USA): Solar → Valley at noon, high ramp rate



Increased Distributed Generation

- Distributed generation provides about 45% of electricity in Denmark

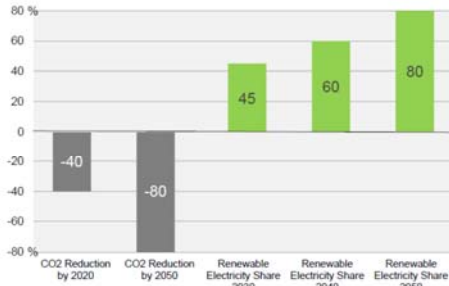
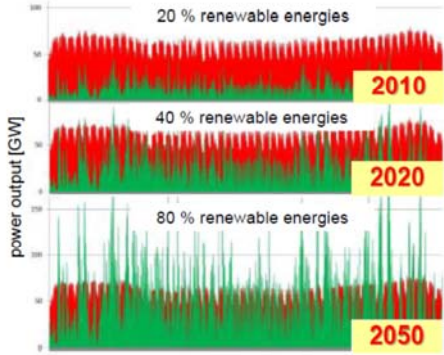


Analogy: large computers <> personal computers

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Germany Climate Change Target

How to balance the system?

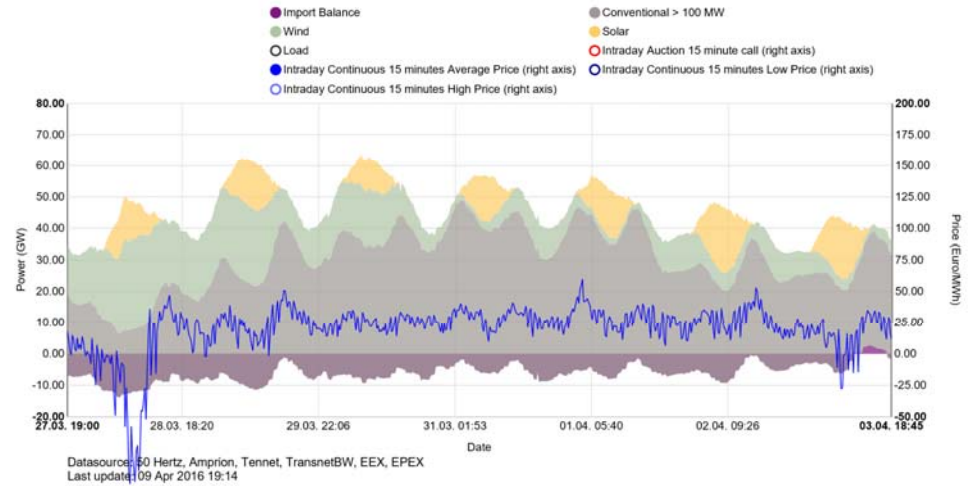


With rising contribution of volatile renewable energy sources, flexibility becomes a core capability for the electricity system

**Need storage.
Need new resources.**

red: German electricity consumption 2010 green: wind & solar power generation

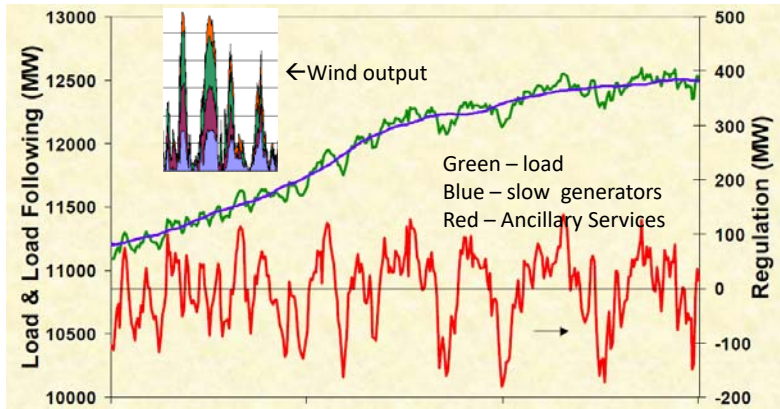
Negative Prices



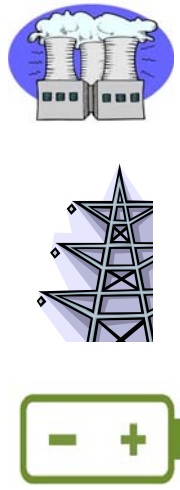
Datasources: E.ON Hertz, Amprion, Tennet, TransnetBW, EEX, EPEX
Last update: 09 Apr 2016 19:14

New Challenges in Power Systems

- Additional flexible system resources – where are they from??

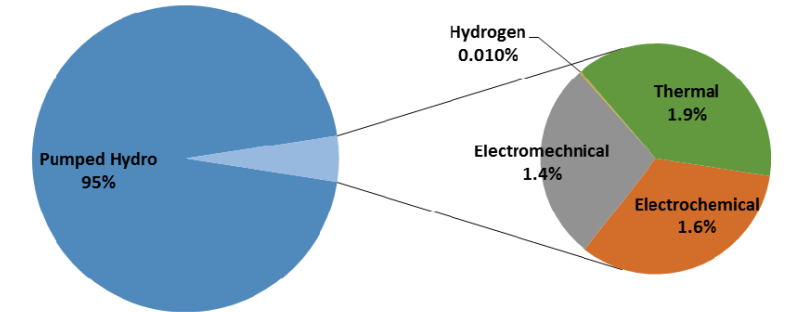


Courtesy of B. Kirby, Oak Ridge National Laboratory



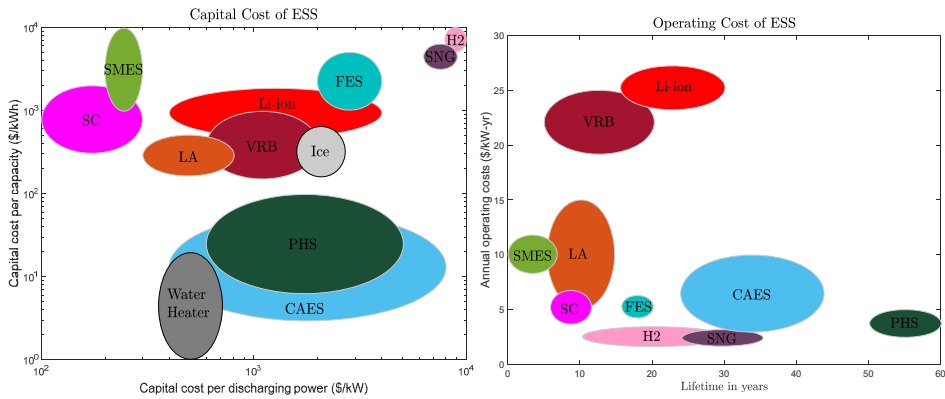
Utility Energy Storage Market - Developing Rapidly

Capacity Share of ESS Categories

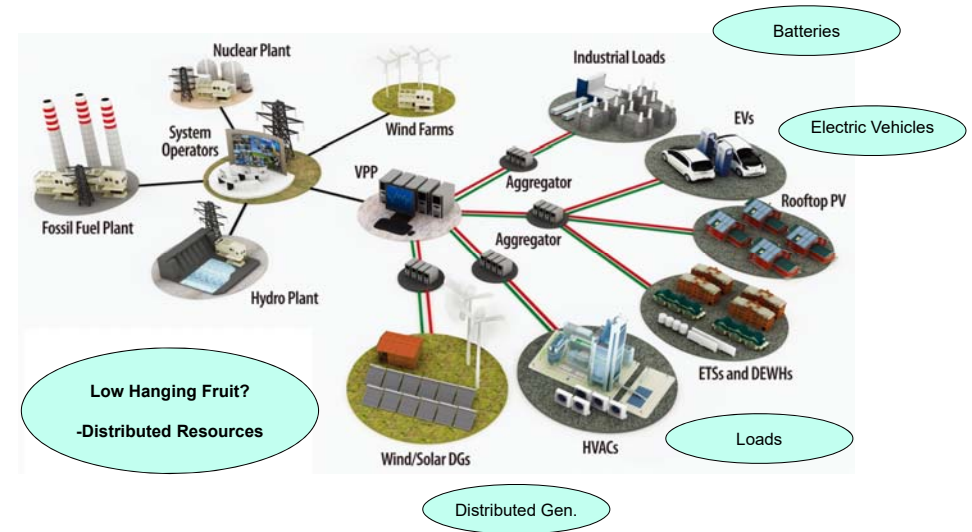


■ Pumped Hydro ■ Electrochemical ■ Electromechanical ■ Hydrogen ■ Liquid Air ■ Thermal

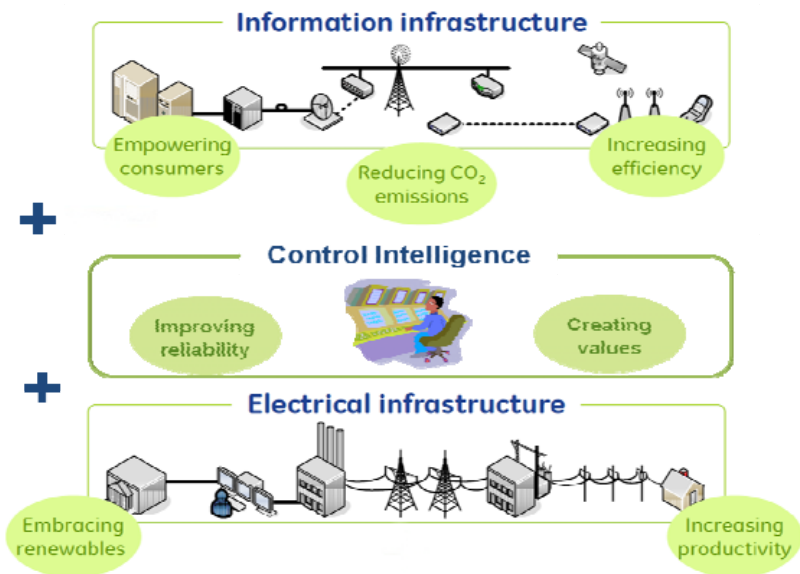
Storage Technologies are Still Expensive - Where is the low hanging fruit



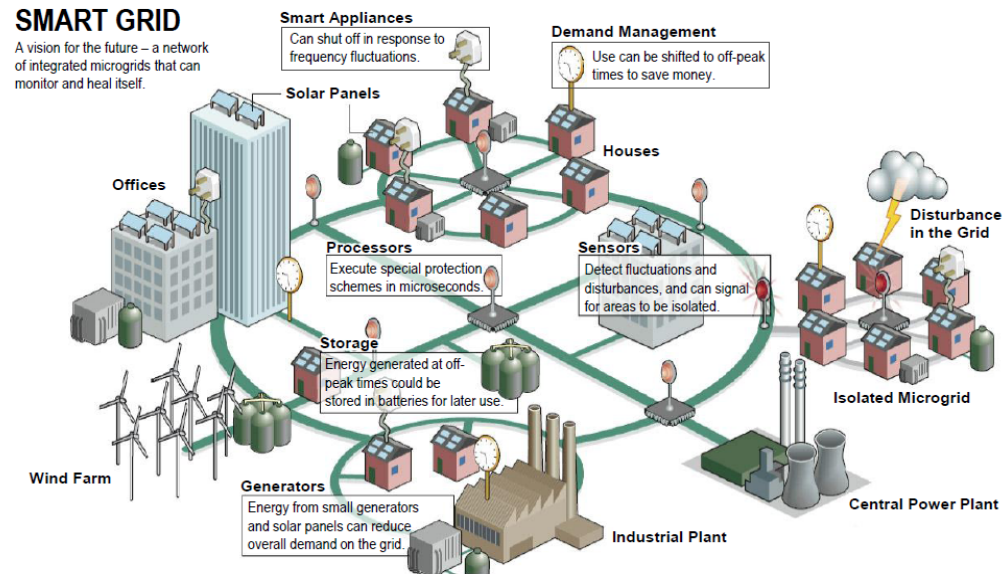
Alternative Energy Storage?



Smart Grid - Integrating Two Large Man-Made Infrastructures

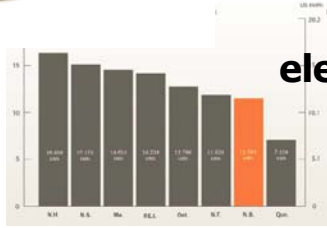
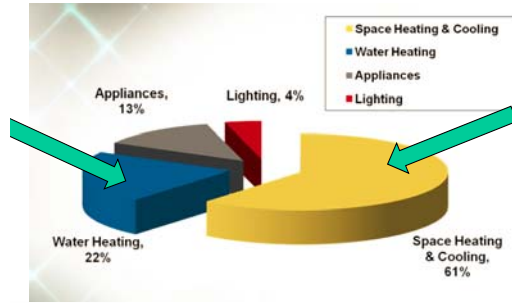
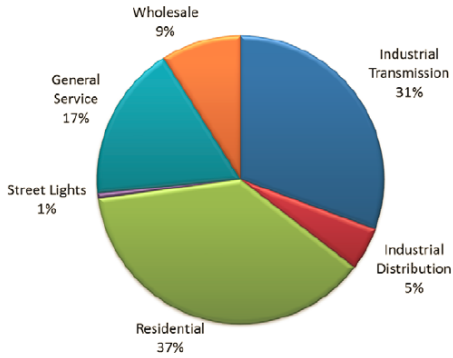


A New Electric Grid



“Upgrading the grid,” *Nature*, vol. 454, pp. 570-573, 30 July 2008.

Loads as Energy Storage Devices Similar to Dispatchable Generators?

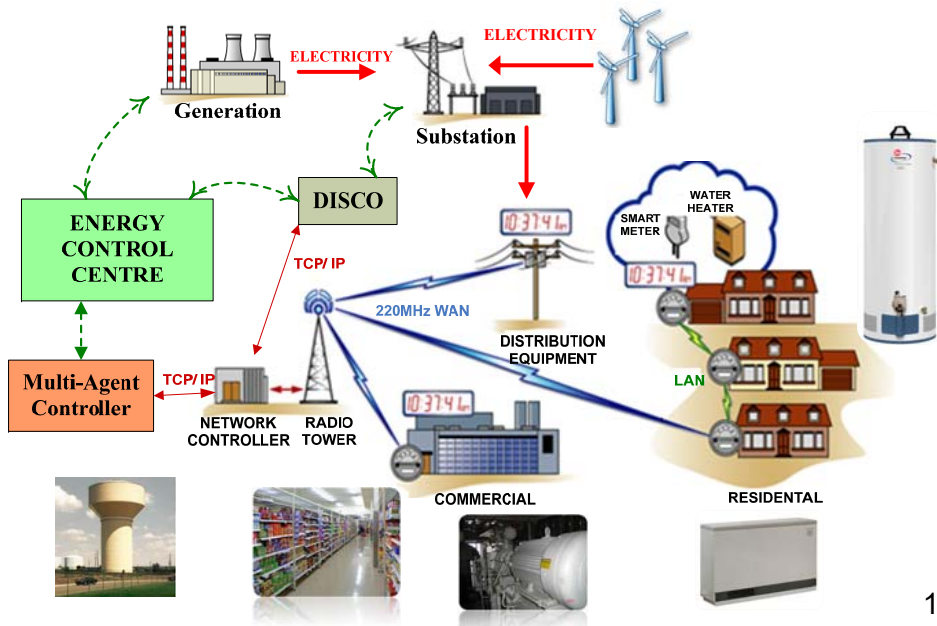


Typical household electricity usage in NB, Canada

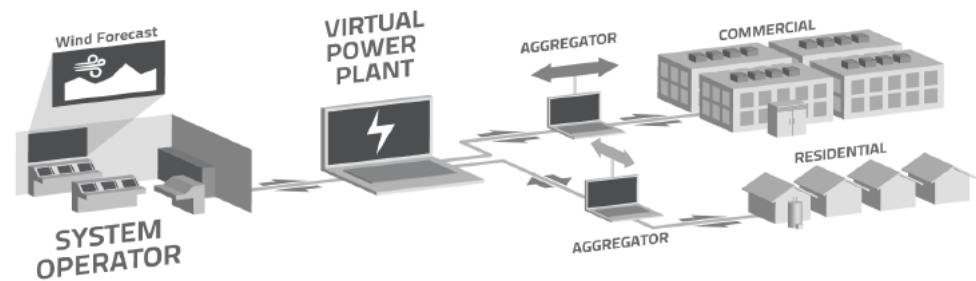
Shifting Power without Negative Impact to End Use – from Demand Response to Direct Load Control



Overall System Structure



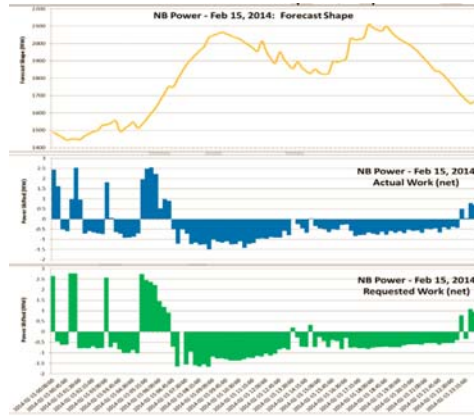
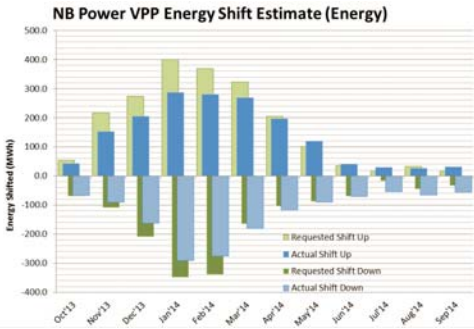
PowerShift System Structure



- System Operator – energy and service dispatch
- Virtual power plant – similar to a large controllable storage unit
- Load aggregators – groups of residential and commercial loads
- Customer loads (with storage capacity)
- Control, communication and management (tap into smart grid infrastructures)

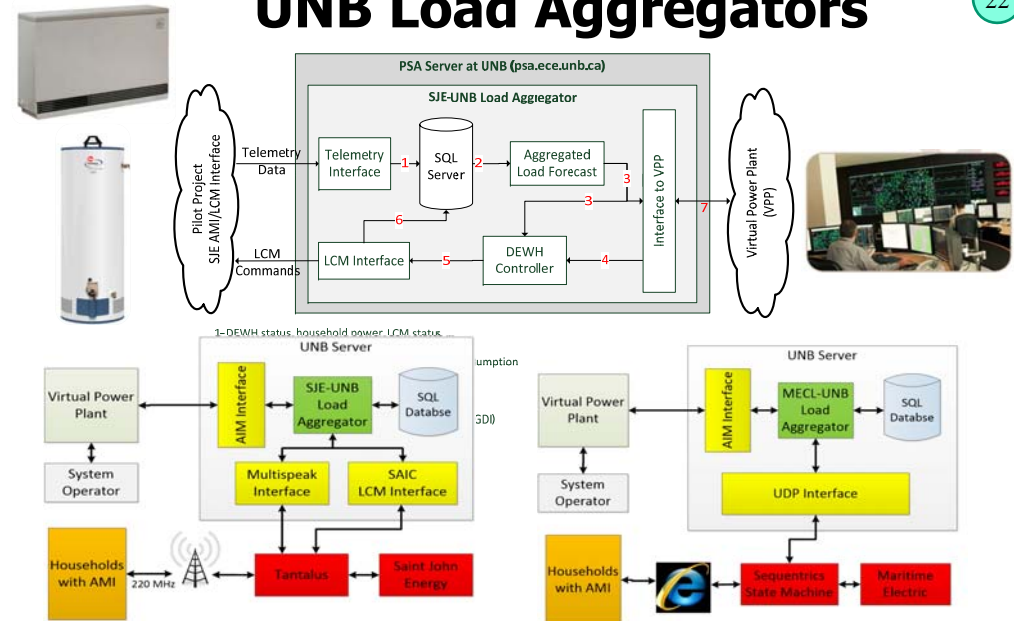
Virtual Power Plant (VPP)

- Optimize load profile based on system resources
 - Shifting load power without negative impact to end use



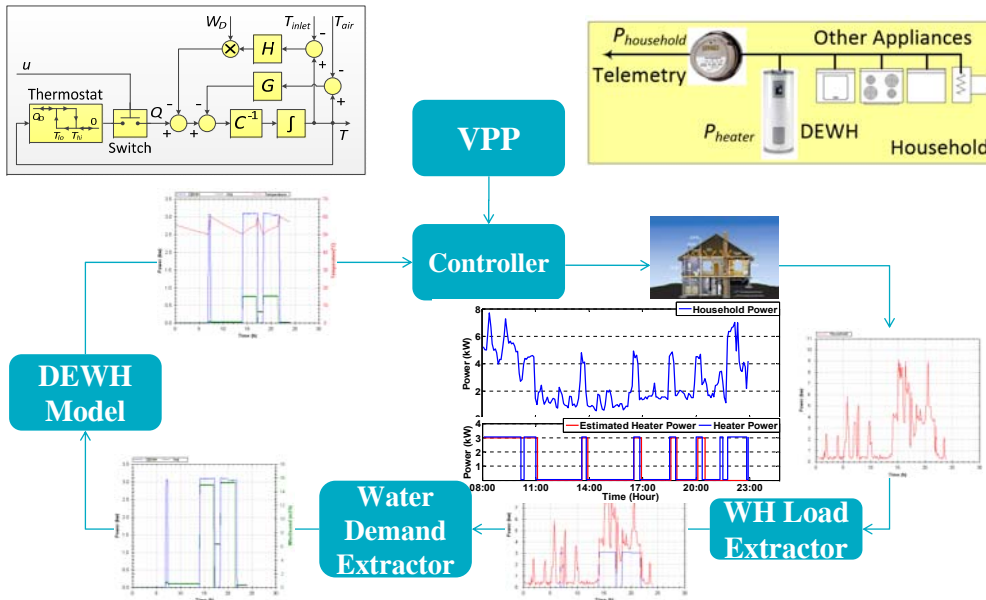
- Real-time power system operation
 - Ancillary services (eg 10-minute reserve)

UNB Load Aggregators

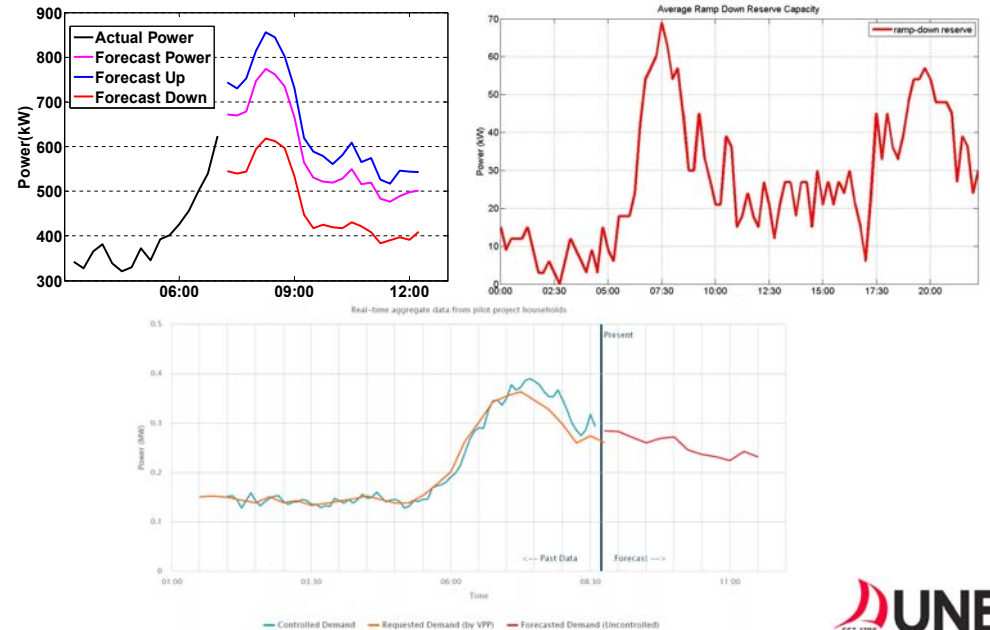


- Fully utilize existing smart grid infrastructures

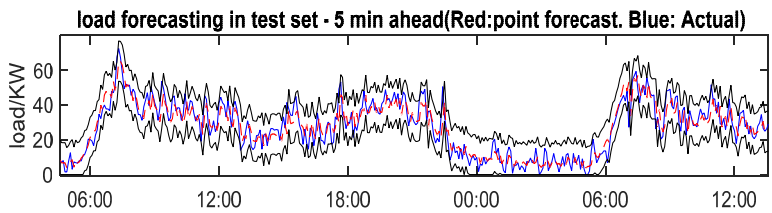
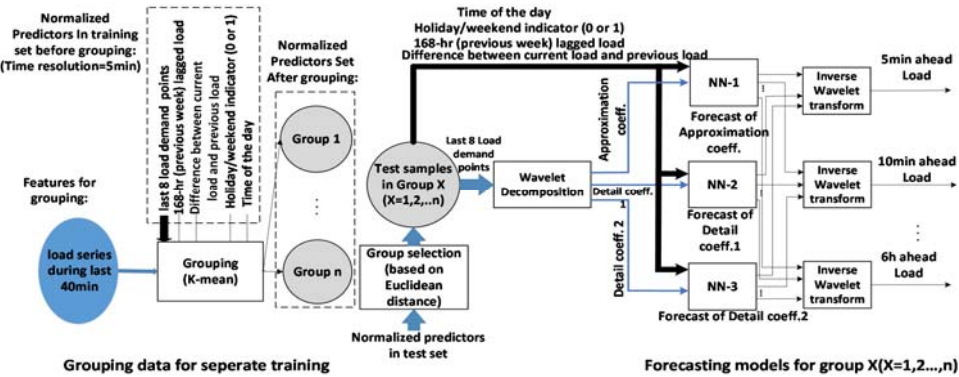
Modeling, Forecast & Control



Aggregated DEWHs (pilot)

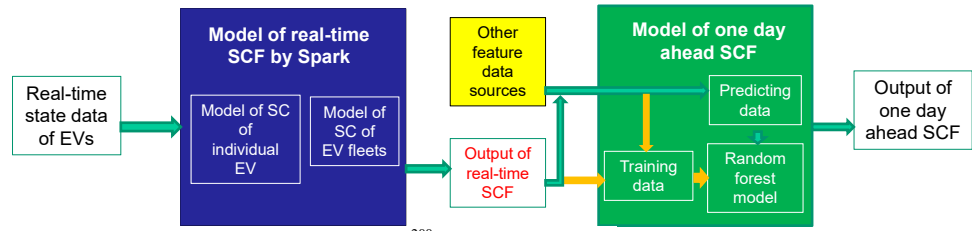


Aggregator Load Forecast

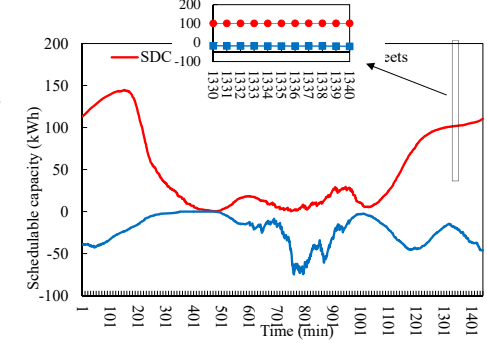


EVs as Energy Storage Devices

Schedulable capacity forecasting (SCF)



1000 EVs: a mix of buses, taxis & cars



Emera's Strategic Focus

Barbados



- Population of nearly 300,000
- 166 square miles
- Supportive Government and receptive and engaged public
- Donor and Multilateral Lending agencies are very engaged
- 15th highest population density in world
- 6th highest road density in world
- GDP per capita approximately equal to Thailand and Costa Rica (\$16K/person)

Transformation of Barbados Electricity Market and Economy

Carbon Free = Renewable Energy + Electrification
(Replacement of vehicle fuels with electricity)

Barbados to be 100% Clean Energy by 2045

Barbados to be 100% Electrified by 2045

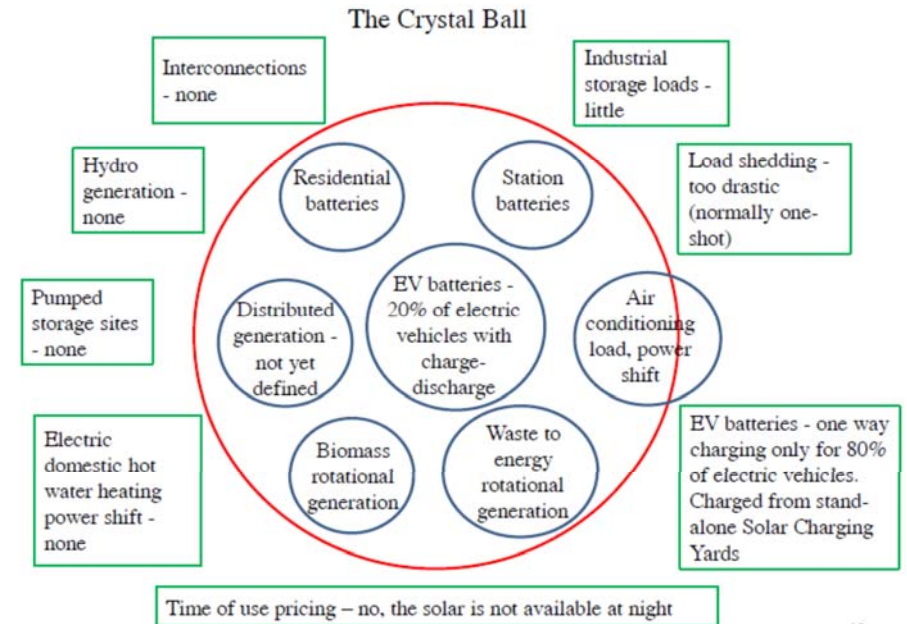
Economics

Jobs

Customer Choice



Technical Solutions for Barbados



Summary

- Electric grid in transition:
 - Penetration of distributed renewable generators
 - Structural change to a mesh-networked system
- Smart grid technologies as an enabler:
 - Transformation of power systems
 - Technology for innovation and economic benefits
- Opportunities for Canada to take the leadership
 - Innovative technologies
 - Full scale installations – economic development