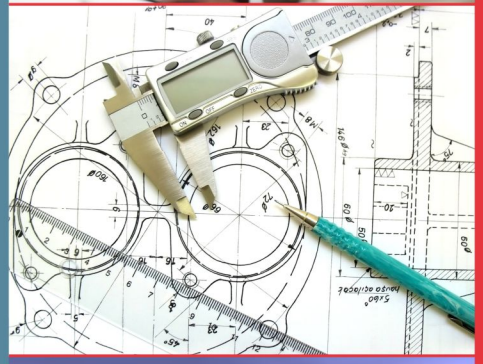


Ontario's Electricity Dilemma -

Achieving Low Emissions at Reasonable Electricity Rates

Energy Policy Presentation

This presentation can be downloaded at:
http://www.ospe.on.ca/?page=pres_lib#peo

OSPE Energy Task Force

April 2015

ONTARIO SOCIETY OF PROFESSIONAL ENGINEERS

Outline of Presentation

- Data Sources
- Original Goals for Electricity System Transformation
- Technology Limitations
- Unexpected Surprises
- Ontario's Electricity Demand
- The Cost Impact of Curtailing Generation Output
- Why Are Electricity Prices Rising So Fast in Ontario ?
- Why Will Emissions Double as We Add Wind and Solar Plants ?
- What Can We Do to Mitigate Increases in Rates and Emissions ?
- What Are the Enabling Policies and Technologies That We Need ?
- Summary
- Q&A period.

Data Sources for Today's Presentation

- The Ontario generation (except for solar) and customer demand data was obtained from the IESO website (http://www.ieso.ca). Detailed analysis was done in 2011 but load data for 2010 to 2014 has not changed much.
- Solar flux data comes from the Canadian Weather for Energy Calculations (CWEC) dataset for Toronto, Environment Canada. Solar generation output simulations were produced courtesy of CarbonFree Technology using PVsyst simulation software.
- Electricity production cost data was obtained from the 2013 Feed-In-Tariff (FIT) rates for wind and ground based solar and from the *Projected Costs of Generating Electricity, 2010 Edition*, Organization for Economic Co-operation and Development, median case with carbon tax removed for natural gas.
- If you are interested in the other energy related seminars or to download this presentation, please visit OSPE's website at:

  http://www.ospe.on.ca/?page=pres_lib#peo

Original Goals for Electricity System Transformation

- Reduce CO_2 emissions from power plants:
  - Phase out coal plants and build new efficient CCGT gas plants.
  - Restart 4 nuclear units at Bruce A and 2 units at Pickering A.
  - Add wind, solar, bio-energy and small hydro generation.
  - Refurbish nuclear units as they reach end of design life.
- Create new green energy sector jobs:
  - FIT program to accelerate deployment of renewables.
  - Create 50,000 jobs in new green sector.
- Keep transformation costs within 1% per year in additional costs:
  - Install smart meters with Time-of-Use (TOU) rates.
  - Encourage peak reduction and load flattening.

Original Goals for Electricity System Transformation

- A careful engineering analysis and grid simulation would have shown that the policy goals could not have been economically accomplished because:
  - Backup generation is required for wind and solar. Consequently wind and solar are displacement energy sources.
  - The total value of displacement sources to the consumer is only the economic value of the displaced fuel. For hydroelectric and nuclear it's 0.5 cents/kWh. For natural gas it's 4 cents/kWh plus a carbon reduction benefit of 1 cent/kWh for each $30 per ton CO_2 of environmental costs.
  - The policy to eliminate coal in Ontario reduced the carbon reduction benefit of wind and solar by 2.5x because gas is cleaner than coal.
- Let's look at some of the engineering challenges we now face to mitigate future increases in electricity rates and emissions.

Technology Limitations

- **Hydroelectric** is clean but:
  - Large land areas are required.
  - Most economic sites in Ontario have been developed.
  - Output flexibility requires much larger storage ponds.
  - Impacted by climate change (affects capacity factor).
- **Wind** is clean but:
  - Impacts negatively on natural views and quiet enjoyment of property near turbines.
  - Output is intermittent - backup generation/storage is needed.
  - Capacity factor is low (30%) so more transmission required.
  - 40% of energy arrives when load demand is low - low energy value.
  - Total integration costs are high (100% wind means 2x retail price).

Technology Limitations

- **Solar** is clean but:
  - Produces most of its energy mid-day, none at night.
  - Output is intermittent so backup generation/storage needed.
  - Capacity factor is very low (15%) so more transmission required.
  - Total integration costs are very high (100% solar means 6x retail price).
- **Nuclear** is clean but:
  - Produces long term nuclear waste.
  - Safe but public concerns regarding accidents and nuclear waste.
  - Output is not very flexible.
  - Total integration costs are moderate (100% nuclear means 1.5x retail price).

Technology Limitations

- **Natural Gas** is the cheapest energy source today but:
  - Natural gas price is very volatile.
  - Future LNG facilities will drive natural gas price higher.
  - Emits 40% of CO_2 emissions of a coal plant (about 400 grams CO_2 per kWh).
  - Public health concerns regarding fine soot and NOx emissions especially at lower load levels.
  - Output is not flexible in lower 40% of load range (CCGT plants).
  - Integration costs are low (100% natural gas means the same retail price).
- **Bio-Energy** is clean with post combustion filters but:
  - Insufficient bio-energy fuel to meet all of our electrical energy needs.
  - Public concerns regarding odors and emissions.
  - Output is not very flexible – often tied to local facility needs not the grid.
  - Total integration costs are moderate (100% bio-energy means 1.5x retail price).

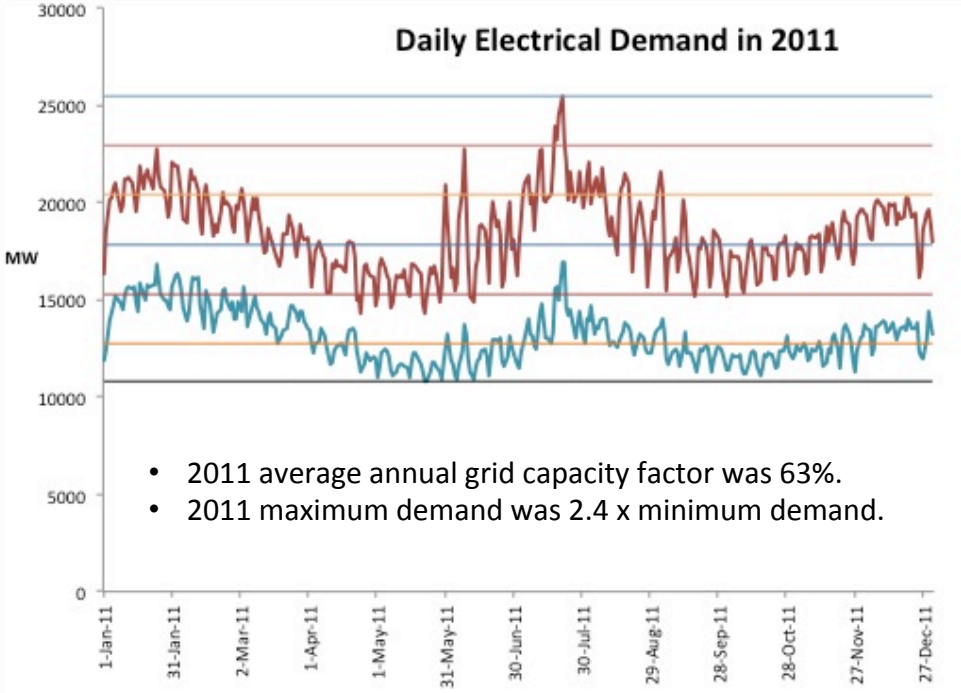
Unexpected Surprises

- Green energy costs (including integration costs) are higher than expected and not dropping as fast as in other jurisdictions.
- Demand is not rising as fast as planned when capacity commitments made.
- New gas plants not as flexible as coal plants. Higher integration costs and higher than expected emissions for wind/solar backup service.
- Refurbishing old plants 2x more expensive than expected - discovery work.
- Unfavorable WTO trade ruling means fewer jobs here in Ontario.
- Smart meters did not flatten nor reduce peak loads to the extent anticipated due to ineffective TOU price plan (see 2014 Auditor General of Ontario report and 2011 OSPE smart meter submission to the OEB).
- Recession in 2008-09 created surplus generation capacity in North America and drove electricity market prices well below total cost of production. Global Adjustment (GA) rose rapidly. GA 2 to 3x greater than market price.

Ontario's Electricity Demand

- Ontario does not impose electrical demand management on consumers unless the grid is reaching its technical limits.
- Demand management is only done in accordance with agreed contracts with consumers. Few consumers subscribe to demand management contracts.
- Consumer demand varies widely by day and season.
- Flexibility in generation output is necessary to maintain grid stability.
- When flexible generation is lacking, curtailment (waste) rises to maintain grid stability especially with large amounts of renewables.

Ontario's Electricity Demand



- 2011 average annual grid capacity factor was 63%.
- 2011 maximum demand was 2.4 x minimum demand.

←**Peak load** is provided by:
- Solar
- Daytime wind
- Flexible nuclear
- Flexible hydraulic
- Flexible CHP, bio-energy
- Flexible natural gas

←**Base load** is provided by:
- Must run natural gas
- Must run hydraulic
- Must run nuclear
- Must run CHP, bio-energy
- Night time wind

Note: From 2010 to 2014 there has been no growth in energy demand in Ontario.

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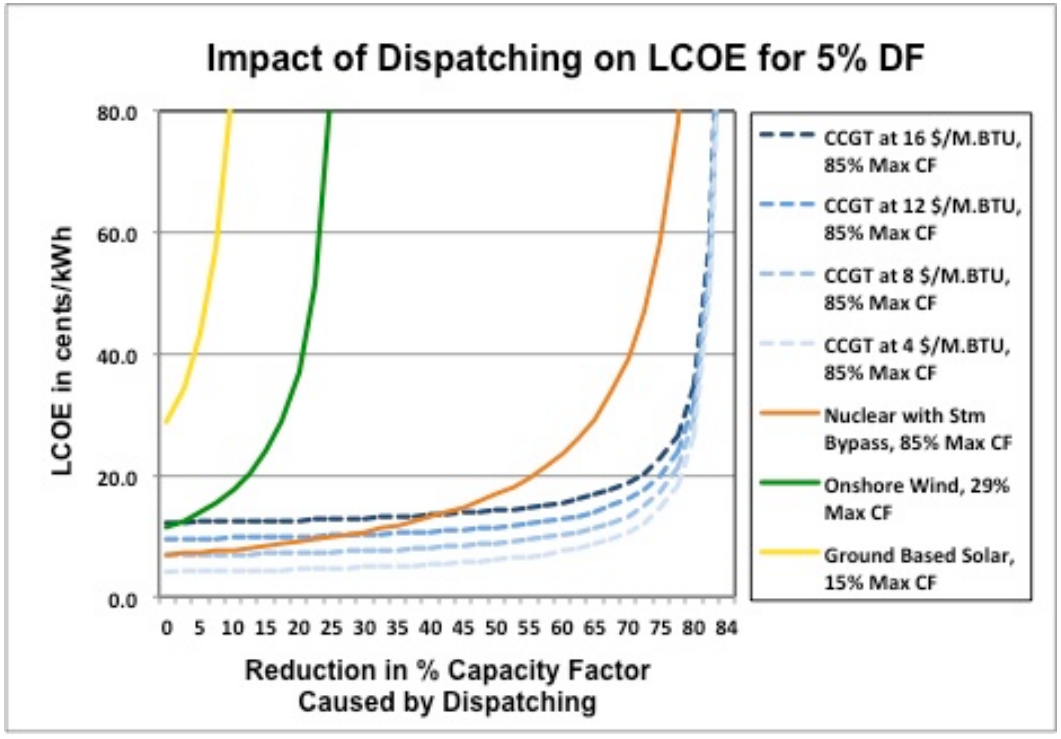
Cost Impact of Curtailing/Dispatching Generation



Abbreviations:

- **LCOE = the levelized cost of electricity = total lifetime costs divided by energy produced.**
- **DF = discount factor**
- **CCGT = Combined Cycle Gas Turbine**
- **M.BTU = Million British Thermal Units**
- **CF = Capacity Factor**

Note: Data is for existing plants. Wind and solar are shown using Ontario 2013 FIT rates.

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Why Are Electricity Rates Rising So Fast in Ontario ?

- There are 6 major drivers of rapidly rising rates in Ontario:
  - Incremental cost of wind/solar energy compared to displaced generation.
    - Over 1 B$ in 2014, rising to over 3 B$ in 2021
  - Loses for curtailment and exporting at very low price.
  - Conservation and demand management programs have reduced financial value during periods of excess capacity (2013 Long Term Energy Plan predicts excess capacity will persist from 2009 to 2019).
  - Higher costs for refurbishment of older plants.
  - Higher costs for power system upgrades to accommodate renewables and Bruce A restart.
- In the GTA area residential "energy" rates have risen about 70 to 90% in the 7 years since 2008 depending on when the utility switched you to TOU rates.

Why Are Electricity Rates Rising So Fast in Ontario ?

- Exports in 2014 averaged less than 4 cents/kWh.
- OEB estimated 2014 energy price for electricity inside Ontario was 8.9 cents/kWh.
- According to OEB estimates, the cost of electricity production was :

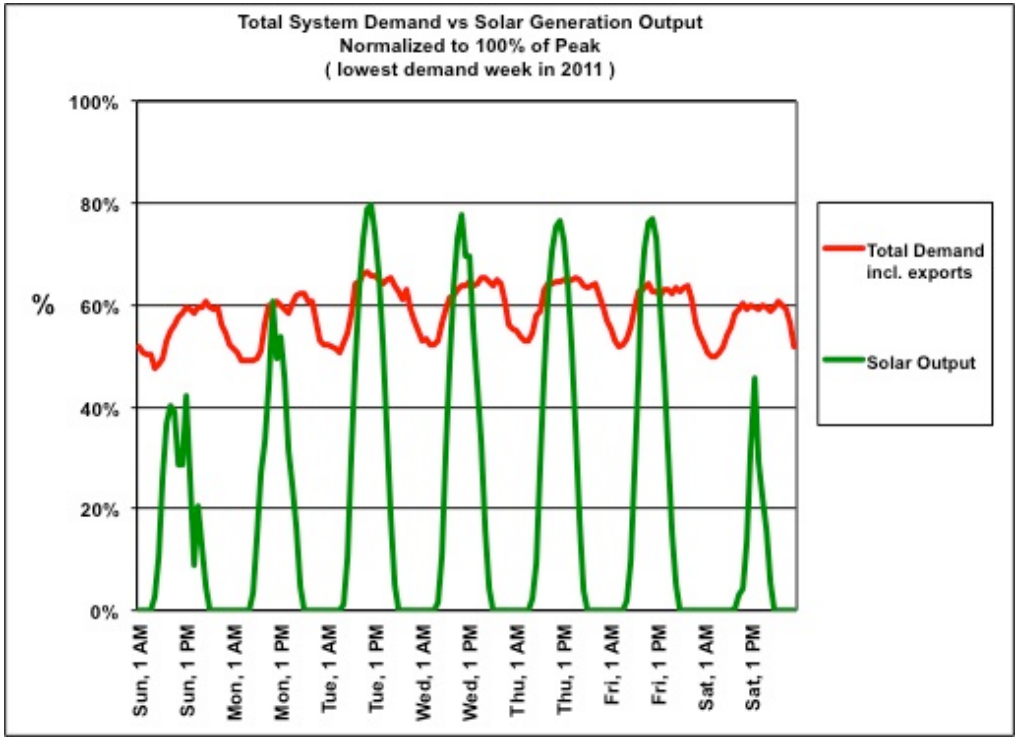
Nov – Apr 2013	May – Nov 2014	May – Nov 2015	Generation Type
4.8	5.1	5.6	Hydroelectric
6.0	5.9	6.6	Nuclear
12.0	12.3	12.5	Wind
12.6	12.9	21.1	Bio-energy
13.5	14.2	12.7	Natural Gas
48.9	47.6	47.3	Solar
7.2 / 10.9 / 12.9	7.5 / 11.2 / 13.5	8.0 / 12.2 / 16.1	TOU Rates

Note: Exporting is economically attractive if the market price is above the variable (fuel) cost of that energy and the plants are already built (sunk cost). However, we should not build new plants for the purpose of exporting energy if the market price is below the total cost of production.

Why Will Emissions Double as We Add Wind and Solar Plants ?

- Wind and Solar require flexible backup generation.
- Nuclear is too inflexible to backup renewables without expensive engineering changes to the reactors.
- Flexible electric storage is too expensive at the moment.
- Consequently natural gas provides the backup for wind and solar in North America.
- When you add wind and solar you are actually forced to reduce nuclear generation to make room for more natural gas generation to provide flexible backup.
- Ontario currently produces electricity at less than 40 grams of CO_2 emissions/kWh.
- Wind and solar with natural gas backup produces electricity at about 200 grams of CO_2 emissions/kWh. Therefore adding wind and solar to Ontario's grid drives CO_2 emissions higher. From 2016 to 2032 as Ontario phases out nuclear capacity to make room for wind and solar, CO_2 emissions will double (2013 LTEP data).
- In Ontario, with limited economic hydro and expensive storage, it is mathematically impossible to achieve low CO_2 emissions at reasonable electricity prices without nuclear generation.

Solar Production Profile – Typical Week



- To ensure a dependable supply of electricity with only solar generation, we need significant amounts of storage to fill in the gap between the two curves.
- We also need to capture enough solar energy above the red line to supply the customer demand when the sun is not shining.
- Alternatively we can fill in the gaps with natural gas backup generation.

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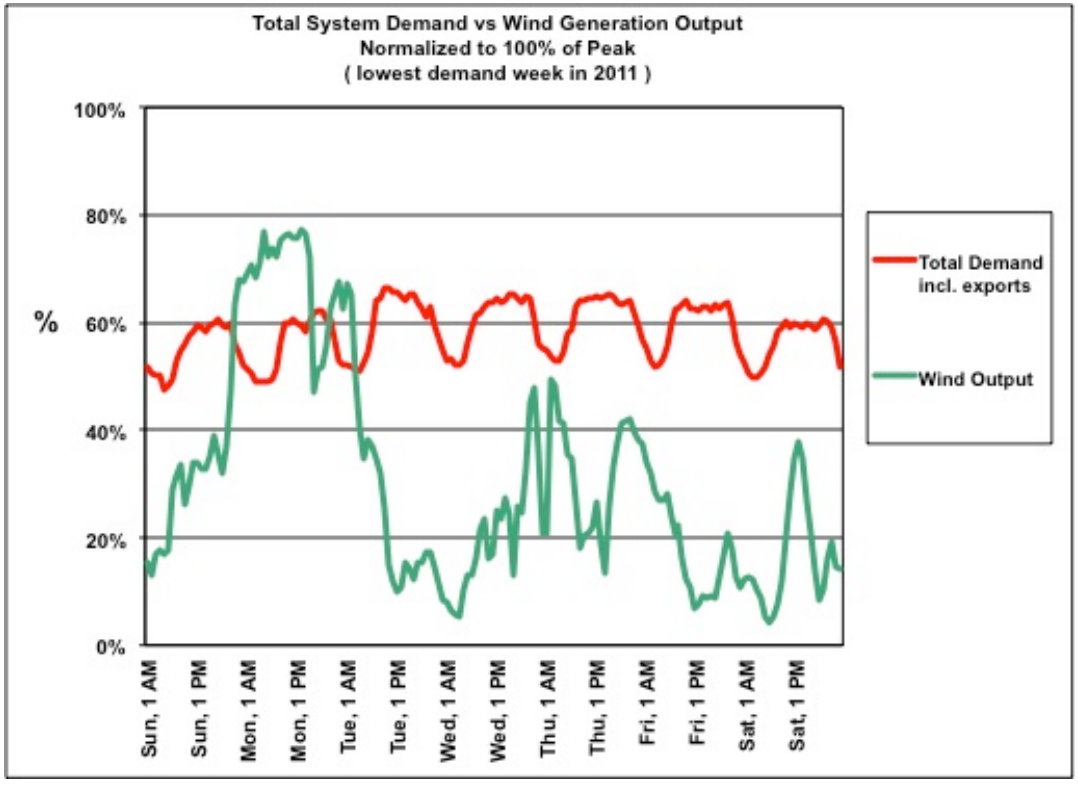
Wind Production Profile – Typical Week



- To ensure a dependable supply of electricity with only wind generation, we need significant amounts of storage to fill in the gap between the two curves.
- We also need to capture enough wind energy above the red line to supply the customer demand when the wind is not blowing.
- Alternatively we can fill in the gaps with natural gas backup generation.

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What Can We Do to Mitigate Increases in Rates and Emissions ?

- We need to minimize curtailment of high fixed cost plants we have already purchased like hydroelectric, nuclear, solar and wind facilities.
- We need to stop adding solar and wind for ideological reasons and focus on using them only when their economic and environmental contributions are positive.
- We need to identify flexible load that can be aligned with available energy production from intermittent sources (using smart grid devices).
- We need to utilize more of our low cost hydroelectric and nuclear base-load energy in Ontario and stop curtailing or exporting them at low market prices.
- We need to encourage consumers to flatten their load profile each day by using technology that can utilize inexpensive thermal storage in buildings & appliances.
- We can increase base-load demand by 2,000 MW and reduce peak load demand by 3,000 MW by flattening each day's load profile. The present value is 20 $B.

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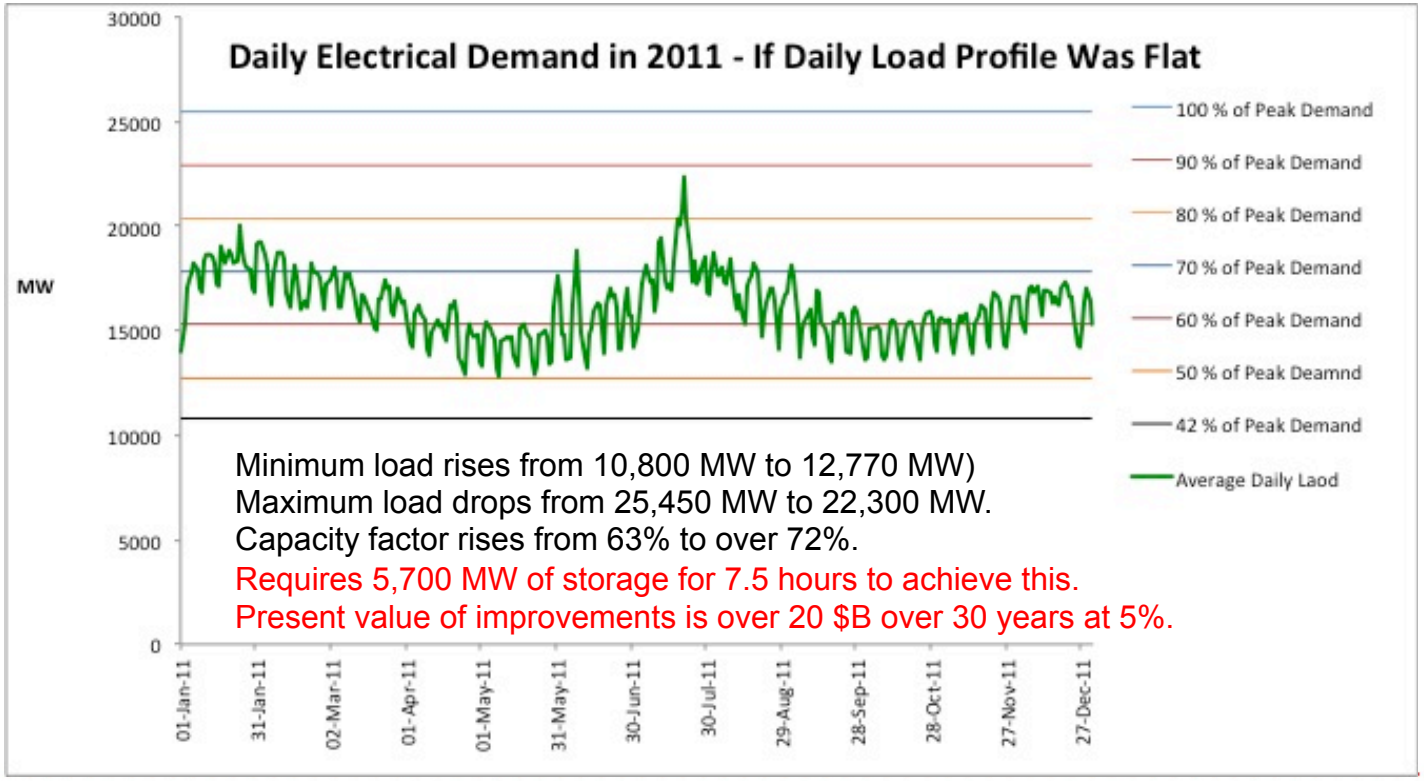
Benefits of a Flat Daily Load Profile (Ontario Example)



Minimum load rises from 10,800 MW to 12,770 MW)
Maximum load drops from 25,450 MW to 22,300 MW.
Capacity factor rises from 63% to over 72%.
Requires 5,700 MW of storage for 7.5 hours to achieve this.
Present value of improvements is over 20 $B over 30 years at 5%.

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What are the Enabling Policies and Technologies That We Need ?

- We can create a "voluntary" price plan that incentivizes consumers to flatten their load profile and let market forces (to save money) pull solutions and technology into the marketplace without separate government programs and subsidies.
- We would need to decide how much of the savings from improved grid operations would flow to the solution purchasers and how much will flow to all consumers.
- Market driven mechanisms are preferred to choosing specific solutions because they allow any technology to be developed (eg: thermal storage is much cheaper than electrical storage).
- Market driven mechanisms also allow optimum combinations among various solutions (eg: smart controllers, storage, equipment upgrades or fuel substitution to accomplish the load shifting). Government does not need to get involved.
- We should move non-production expenses out of the electricity price and move them to the tax base – helps industry be competitive with other jurisdictions.
- We should link wind and solar capacity to flexible load that can use them.

Summary

- A balanced energy mix with minimal amounts of storage and using natural gas for "peak-load" and "backup" requirements will result in the lowest electricity price.
- A electrical system that uses hydroelectric and/or nuclear for **all** its 'base-load" requirements will produce the lowest CO_2 emissions.
- Ideally, renewables (wind and solar) should be added only to the extent that grid flexibility and/or smart grid technology can align flexible customer load demand to fully utilize variable renewable output when it is available in real time.
- Installed capacity and customer demand that is more closely balanced will reduce curtailment and exports at a loss.
- A voluntary price plan that incentivizes consumers to make better use of the grid's assets will result in lower rates and lower emissions over time.
- Undertaking engineering analysis and simulation studies before policies are set, will help to ensure we have the lowest cost and emission grid achievable.

Questions ?

Notes:

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