Ontario's Electrical Grid – Getting to Zero CO_2 Emissions

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Terminology and Acknowledgement

- Grid – the IESO managed resources only
- Emissions – CO_2 emissions only
- Normal operating period emissions, not life cycle emissions
- Not including emergencies and contingencies
- Not including export support to adjoining grids
- The generation and customer demand data was obtained from the IESO website (http://www.ieso.ca)
- Electricity production cost data was obtained from the *Projected Costs of Generating Electricity, 2010 Edition*, Organization for Economic Co-operation and Development.
- CO_2 Emission data was obtained from the Natural Resources Canada, website, RETScreen Clean Energy Project Analysis Software, http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/eng/software_tools/retscreen.html

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Is a Zero CO_2 Emission Grid A Realistic Goal ?

- in 2010, 79% of the 142 TWh of electrical energy in the IESO managed grid came from zero CO_2 emitting generation resources:
  - Nuclear: 55%
  - Hydraulic: 20%
  - Other Renewables - wind, solar, bio-energy: 4%
- in 2010, CO_2 emissions were about:
  - 973 g/kWh for coal
  - 398 g/kWh for gas
  - 134 g/kWh for the overall IESO administered electrical grid
- the 2010 Ontario Long Term Energy Plan calls for 92% of electricity to come from zero CO_2 emitting sources by 2030
- today we will look at how to get that extra 8% ?

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Is a Zero CO_2 Emission Grid A Realistic Goal ?

- to see the difficulties involved you need to look at the electrical demand profile over the whole year
- spring and autumn are low demand periods
- evenings and weekends are low demand periods
- hot summer days create the highest demand
- let's look at the highest and lowest demand days

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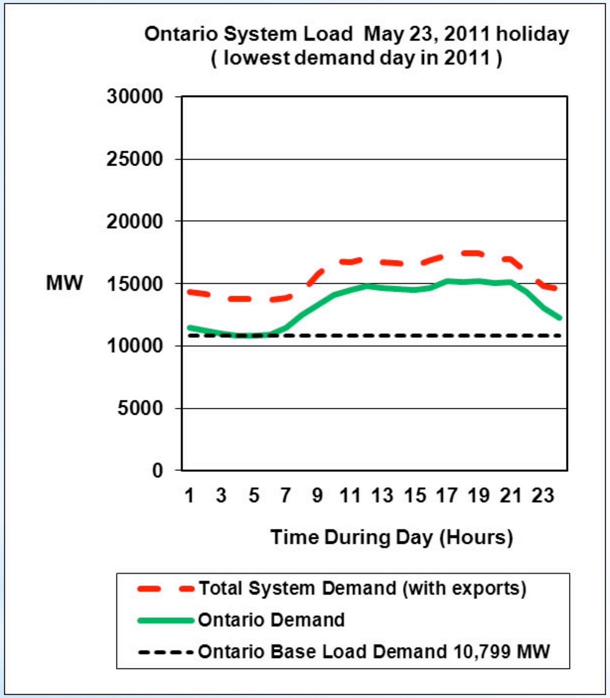
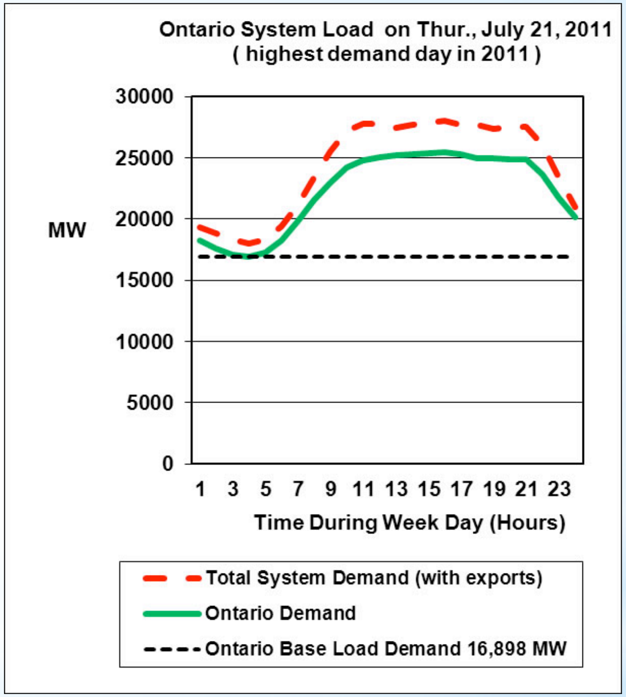
Highest and Lowest Demand Days in 2011





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Our Challenges

- Nuclear has limited maneuvering capability
- Hydraulic has limited maneuvering capability
- Hydraulic has limited storage capability
- Solar is not available at night and on over-cast days
- Wind is not dependable and needs a backup
- Renewable bio-energy is limited by bio-waste volumes
- Seasonal storage is expensive (about 27 cents/kWh not including the cost of the primary energy source)

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Additional Challenges

- When we maneuver (dispatch) generating facilities their capacity factor drop and their cost per unit of energy output rises.
- Solar and wind are the most sensitive to dispatching
- Gas fired generation is the least sensitive to dispatching but it has significant CO_2 emissions of about 398 g/kWh at 45% thermal cycle efficiency

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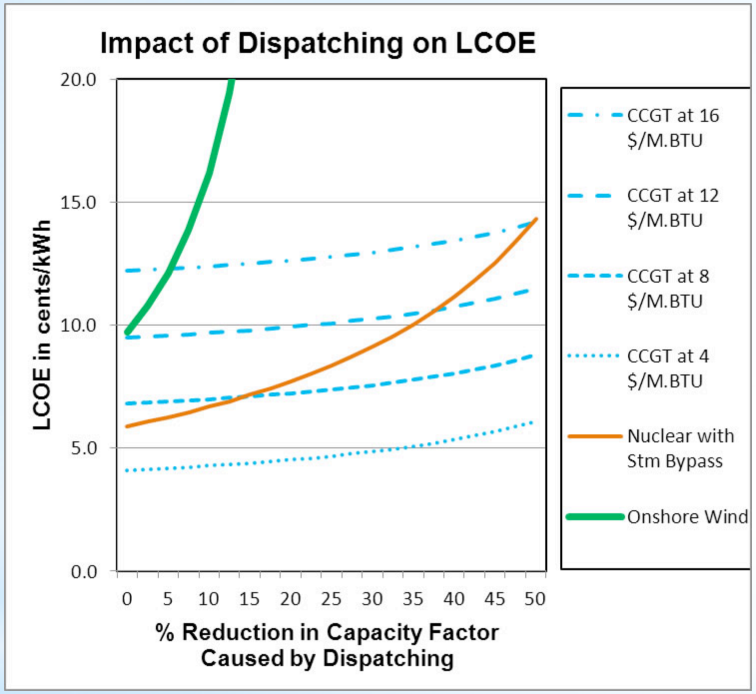
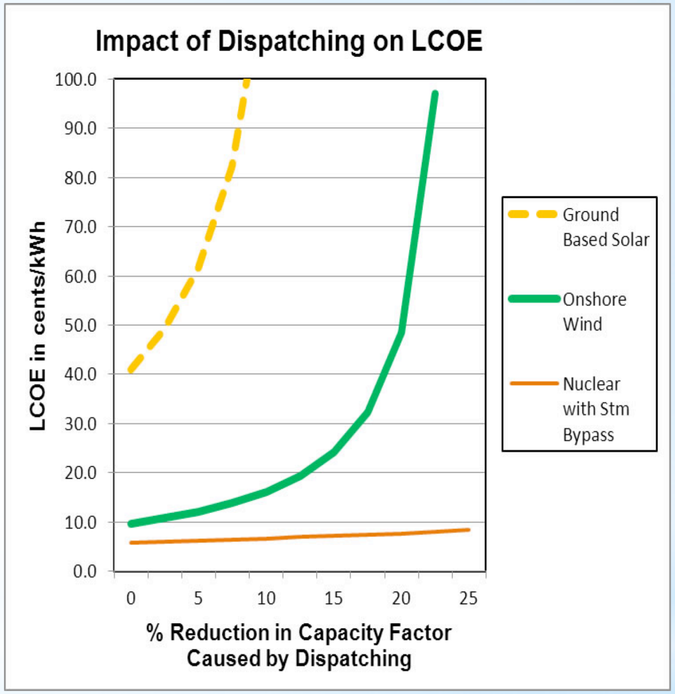
Impact of Dispatching on Levelized Cost of Electricity





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Strategies to Achieve Zero CO_2 Emissions

- Option A - More Renewables with Storage:
  - Nuclear operates as a base load resource
  - Storage is used to make solar and wind dependable so they can supply peak demand both daily and seasonally
  - Daily storage can be close to wind and solar plants
  - Seasonal storage is provided centrally at new pumped storage facilities
  - Maneuverable bio-energy reduces storage requirements
  - Gas generation is retained for emergencies and contingencies (outages, de-ratings, unexpected demand)

Strategies to Achieve Zero CO_2 Emissions

- Option A - More Renewables with Storage:
  - Wind operates at its full 25% design capacity factor
  - Solar operates at its full 15% design capacity factor
  - An additional 5,500 MW of wind turbines to fill storage and 5,500 MW of peak capacity storage would be required to meet summer peak demand and displace gas for the low growth planning scenario (150 TWh in 2030)
  - Storage (a blend of daily and seasonal) is assumed to cost 2.5x the cost of wind turbines
  - Electrical energy price component of rates will rise **31%**

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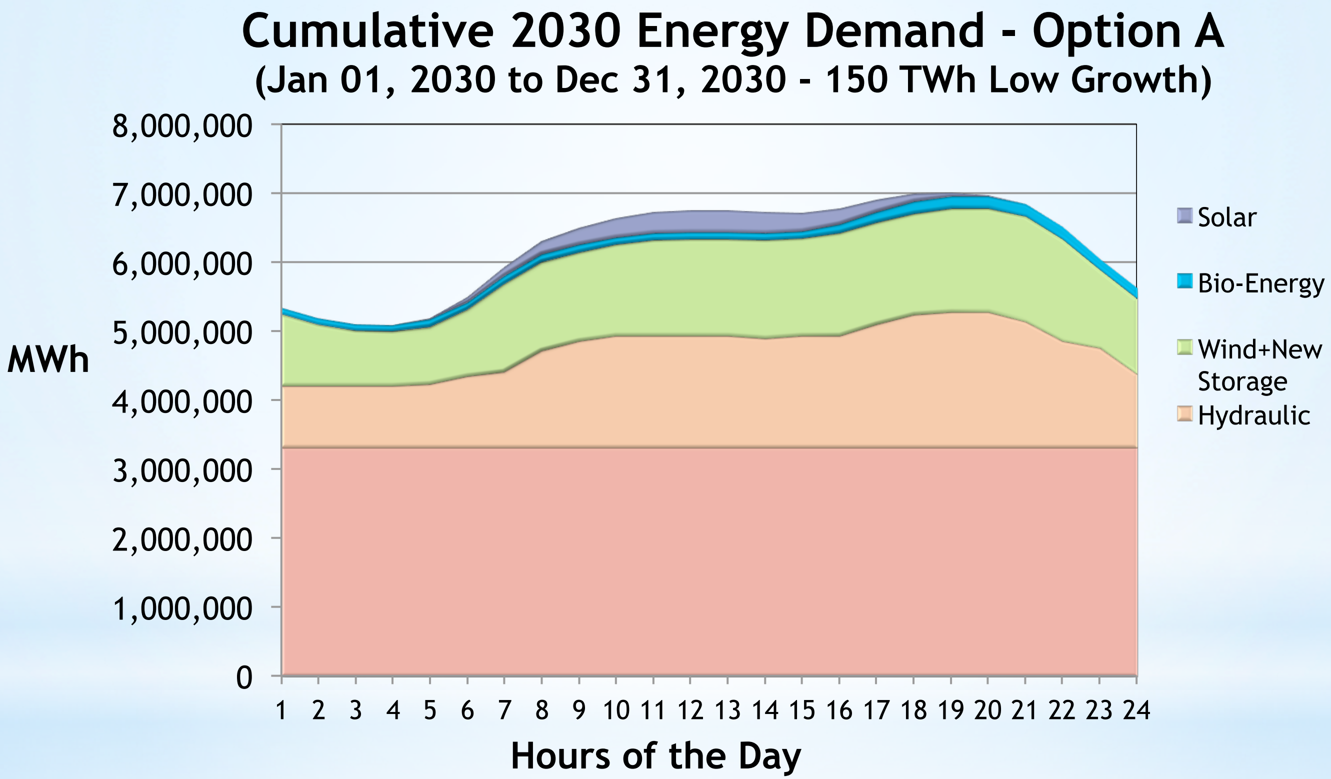
Strategies to Achieve Zero CO_2 Emissions



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Strategies to Achieve Zero CO_2 Emissions

- Option B – More Maneuverable Nuclear Electrical Output
  - An additional 5,000 MW of nuclear capacity would be required to meet summer peak demand and displace gas for the low growth planning scenario (150 TWh in 2030)
  - Nuclear would load cycle at night and weekends
  - Hydraulic, bio-energy and nuclear would back up wind/solar
  - Gas generation is retained for emergencies and contingencies (outages, de-ratings, unexpected demand)
  - Wind operates at its full 25% design capacity factor
  - Solar operates at its full 15% design capacity factor

Strategies to Achieve Zero CO_2 Emissions

- Option B – More Maneuverable Nuclear Electrical Output
  - New nuclear assumed to cost 9 cents/kWh assuming a base load operation and 5% financial discount rate
  - Simulation analysis is required to get accurate costs because wind and solar generation vary day-to-day
  - We can get an approximate cost based on annual energy production and summer peak capacity requirements
  - Nuclear would operate at 14% lower capacity factor
  - Nuclear energy cost would rise approximately 29% and electrical energy price component of rates will rise 14%

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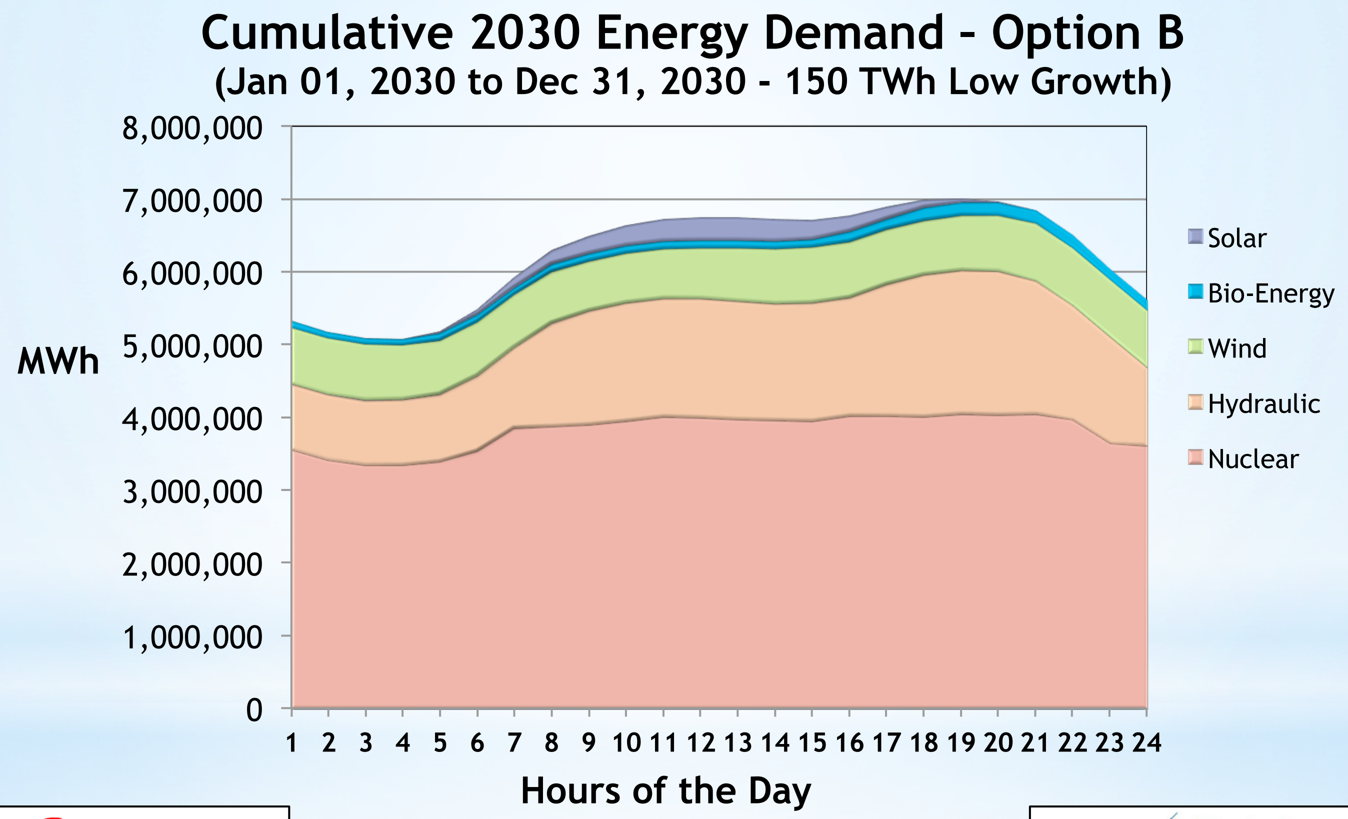
Strategies to Achieve Zero CO_2 Emissions



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Summary/Conclusions

- The phase out of coal generation in Ontario will reduce CO_2 emissions by about 59% for the electrical grid
- Further reductions in CO_2 emissions will require additional investments that will raise the electrical energy price component of rates a further:
  - 31% using storage and wind turbines (option A), or
  - 14% using nuclear maneuvering (option B)
- Detailed simulation and cost studies are required to obtain accurate cost estimates
- Nuclear maneuvering offers the lowest cost path to eliminate CO_2 emissions for grid electricity production
- Nuclear is also relatively immune to the impact of climate change if jurisdictions do not reduce emissions sufficiently

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