The Challenges Facing Nuclear Energy After Fukushima

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Data Sources

- The Ontario 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, median case with carbon tax tax removed.

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Introduction

- Multi-unit common mode accident at Fukushima Dai-Ichi undermined the public's confidence in the nuclear industry.
- 43 of 54 Japanese reactors have been shutdown pending installation of safety upgrades.
- Germany and Switzerland – are planning to retire their nuclear plants.
- China has slowed down its nuclear build program.
- USA projects are having difficulty getting funding.

Challenges

- Natural gas prices – why that is important
- Potential rise in interest rates
- Growing fleet of wind turbines
- Limited maneuvering capability/cost of dispatching
- Limited grid blackout restoration capability

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Challenges (cont'd)

- No permanent repository for spent fuel
- Public safety concerns
- Cost and schedule over-runs
- Very large capital requirements

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Natural Gas Prices – Why that is Important

- public concerns about CO_2 emissions - the alternate fuels are natural gas and nuclear for large scale dependable energy supply.
- natural gas has 50% less CO_2 emissions than coal.
- nuclear has zero CO_2 emissions but you have to accept the challenges inherent in nuclear energy.
- Natural gas is currently very cheap in North America at less than $3 per MBTU and less than $4 at the burner face yielding a fueling cost of less than 3 cents/kWhr.
- new gas-fired generation is currently more competitive than new nuclear generation to replace coal generation.

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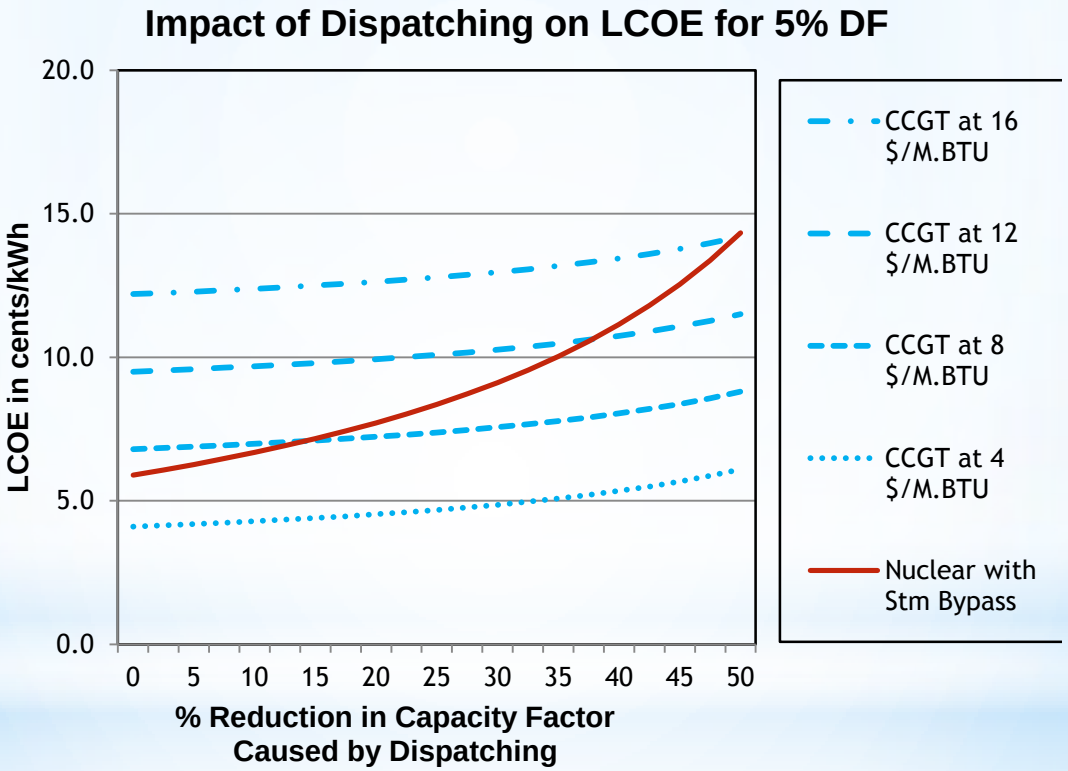
Natural Gas Prices – Why that is Important



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Potential Rise in Interest Rates

- Currently 30 yr government bonds are under 3%.
- 5% discount rate is being used to evaluate projects.
- nuclear projects are costly (4-6B$/GW) and have an extended construction schedule (10–15 yrs).
- Long term interest rates have a major impact on levelized cost of electricity (LCOE) for nuclear.
- a 10% discount rate will increase LCOE about 70% for nuclear but only about 20% for gas fired plants.

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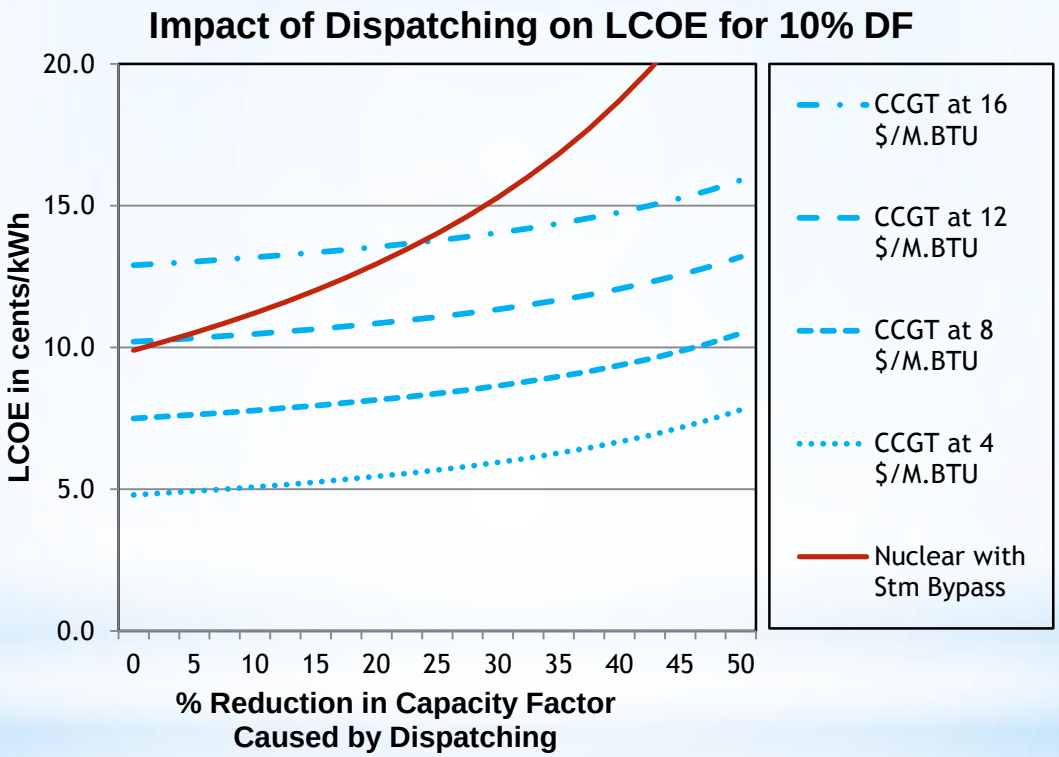

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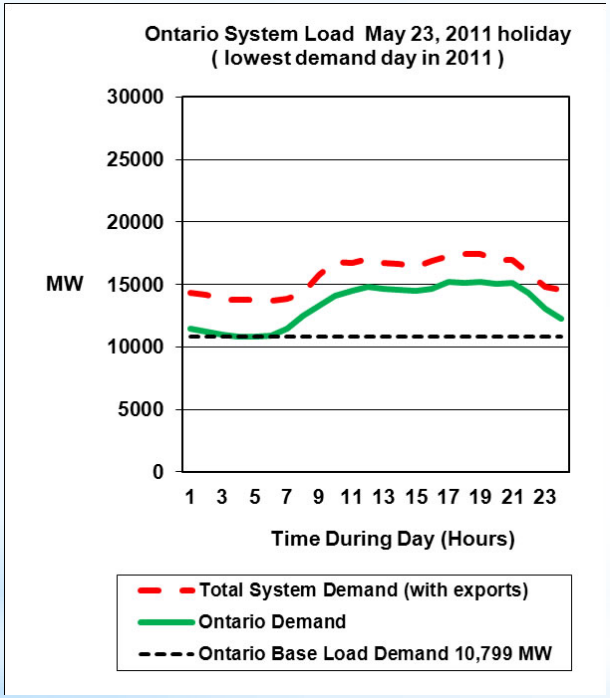
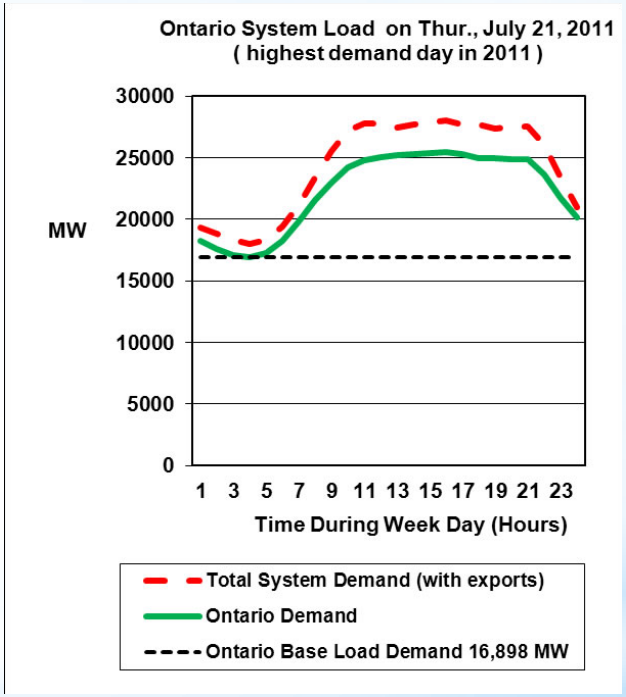
Ontario's Highest/Lowest Demand Days in 2011





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Growing Fleet of Wind Turbines

- Ontario will add 7,500 MW of wind turbines by 2018.
- Wind competes with nuclear for customer load at night.
- Independent Electricity System operator (IESO) plans to dispatch (maneuver) wind turbines down at night to allow existing nuclear plants to keep running.
- Dispatching wind turbines down is the lowest cost option if both wind and nuclear plants are already built.
- Wind generation has been overbuilt in Ontario - we spill water some nights. Ontario has not installed storage to prevent spill.
- The existing wind turbines will impact what can economically be built in the future.

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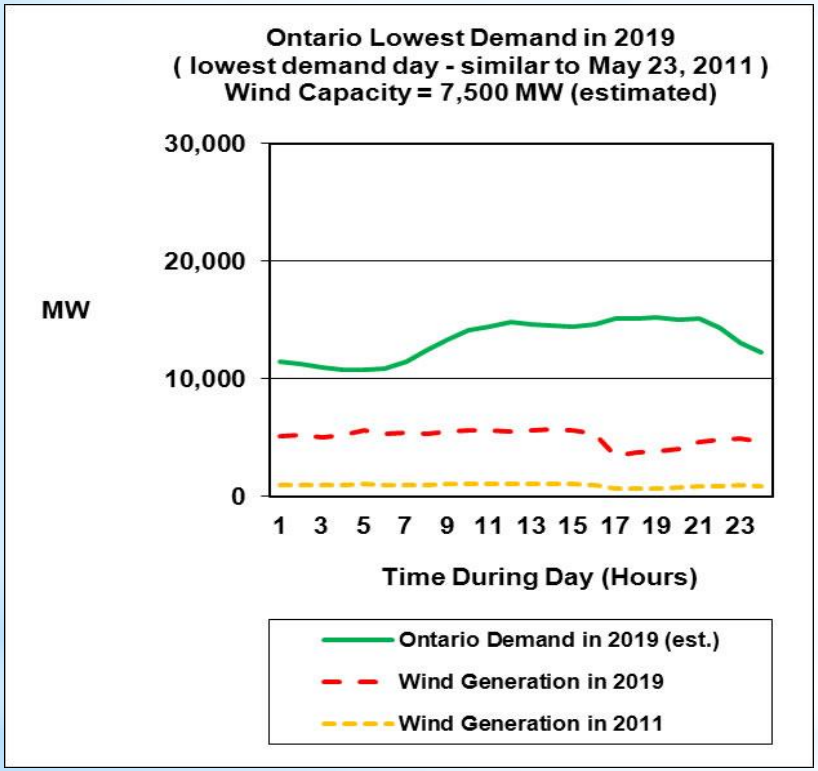

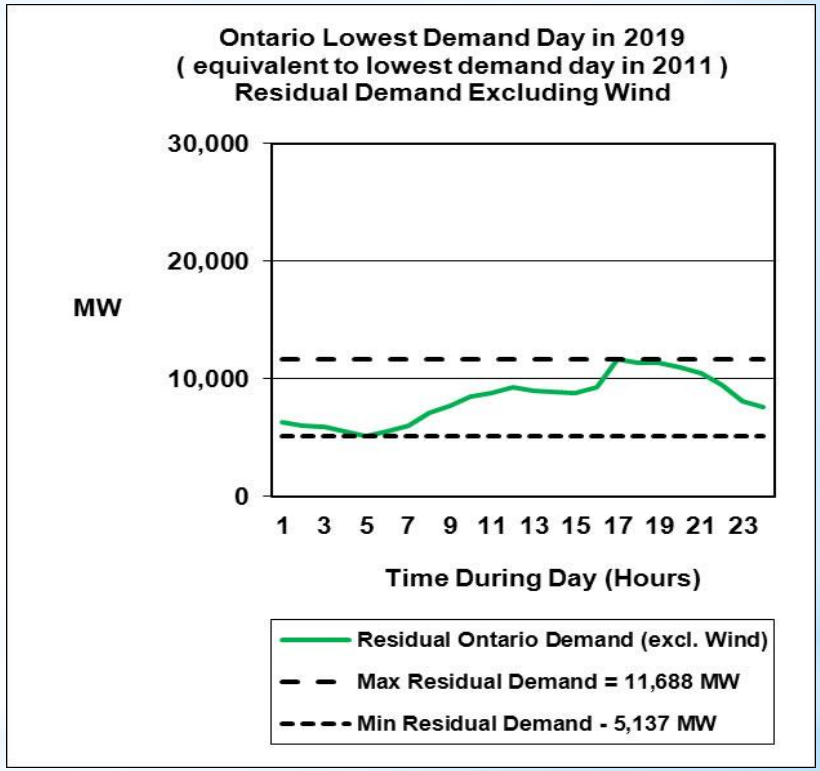

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Limited Maneuvering Capability/Cost of Dispatching

- Nuclear plants have limited maneuvering capability due to reactor physics. CANDU plants poison out for 3 days if they are shutdown.
- Steam bypass systems can be used to improve maneuverability but there is additional cost for the equipment and the nuclear fuel consumption.
- Due to their high capital cost, nuclear plants have a much steeper dispatch penalty than natural gas plants when they maneuver.
- Ontario will have surplus base-load generation (SBG) for many years if demand remains flat as it has done for the past several years.
- Until SBG is eliminated new nuclear and new gas plants will have to be dispatched or wind and solar plants paid to shutdown.
- If there is a significant amount of dispatching, natural gas can become more economical than nuclear, even with high gas prices at a 10% DF.

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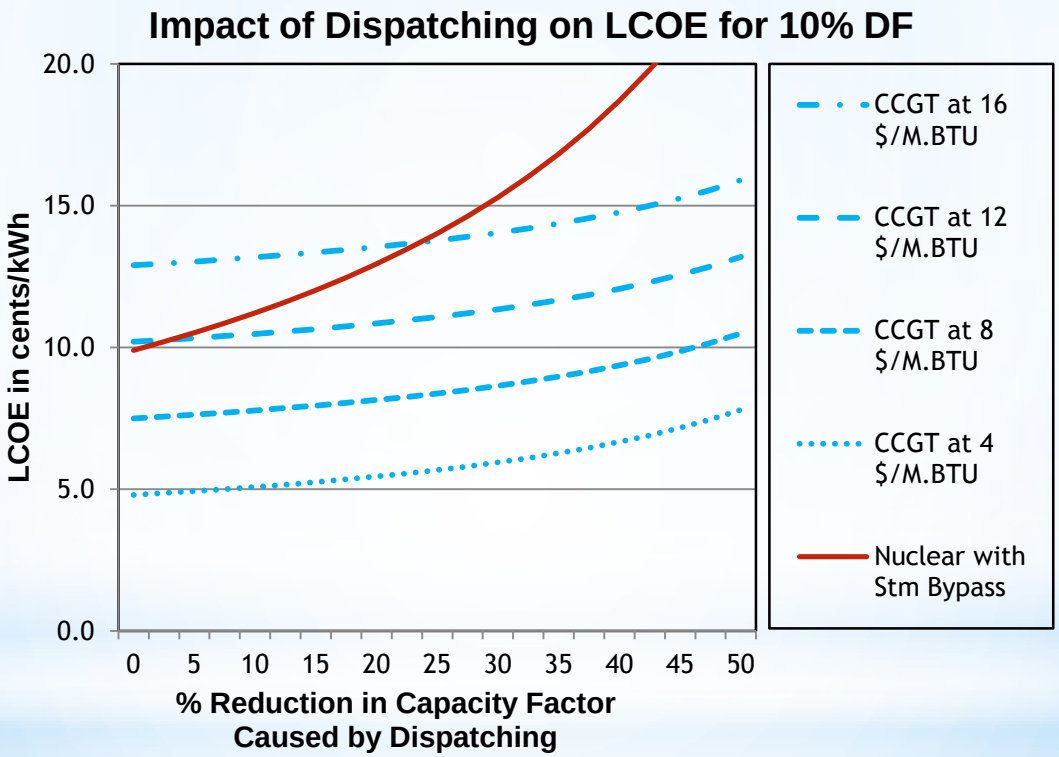

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Limited Grid Blackout Restoration Capability

- Following a grid blackout, rapid restoration requires units with sufficient MW, MVAR, and automatic voltage regulator and governor response speeds to pick up radial transmission lines and customer load.
- IESO target for blackout restoration is 8 hrs.
- 2003 blackout did not meet this target due to the loss of too many nuclear units and non-participation of 4 surviving nuclear units in the early restoration activities.
- Grid must rely on large hydraulic and gas fired plants with black start capability to restore the grid following a blackout.

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No permanent repository for spent fuel

- No current permanent repository for spent fuel.
- Nuclear Waste Management Organization (NWMO) is working with Canadian communities to locate a long term repository but it is many years away from becoming an operating facility.
- Public concern about spent fuel hazards and its very long life time.

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Public Safety Concerns

- Complexity and human error:
  - Three Mile Island – poor design and operator errors
  - Chernobyl – poor design and operator errors
  - Fukushima Dai-Ichi – poor design and operator errors
- Robustness – poor tolerance to design/operator errors
- Terrorism – tolerance to concerted attack
- Proliferation – nuclear material diversion
- Widespread contamination following an accident
- Leaks during normal operation
- Public demands very low risk from high impact plants

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* The Challenges Facing Nuclear Energy After Fukushima

Cost and Schedule Over-Runs

- New designs result in technical and licensing risks
- Finland – Olkiluoto Unit 3 – 1600 MW EPR-PWR
  - construction problems and design issues
  - original plan: 3.0 B€, in-service 2009
  - current plan: 5.7 B€, in-service 2013
- France – Flamanville Unit 3: 1600 MW EPR-PWR
  - construction problems and design issues
  - original plan: 3.3 B€, in-service 2012
  - current plan: 6.0 B€, in-service 2016
- better experience for China's 1100 MW AP1000 PWR on both cost and schedule

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Large Capital Requirements

- Large capital investment (4-6 B$/GW) and prolonged schedule for a large unit are effectively a bet-the-company project.
- High indirect construction costs for 1 unit on 1 site. Multi-units on one site increases financial commitment and risk.
- Governments are reluctant to backstop project risk.
- Private sector doesn't want to finance multi-B$ projects with technical and licensing risk without government financial guarantees.
- Costs may go higher after completion of the Fukushima Dai-Ichi accident investigations/analysis and resulting safety upgrades.
- Small modular reactor concepts (40 MW – 200 MW) promise improved safety, lower costs, shorter schedule, better quality assurance (factory assembly) and lower financial risk (smaller incremental investments) but are many years away from commercial operation.

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Summary/Conclusions

- nuclear industry has a number of challenges to overcome before a nuclear renaissance can be realized.
- small modular rectors that promise improved safety and lower financial risk are still at the concept stage and many years away from commercial operation.
- nuclear industry needs to better educate the public on the risks and benefits of nuclear power.
- nuclear industry needs to be more vigilant about maintaining high quality standards for design and construction work so schedules and costs can be better controlled.
- Nuclear industry needs to re-examine economies of scale in light of major cost and schedule over-runs on large projects. Smaller may be cheaper in the case of nuclear power.

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