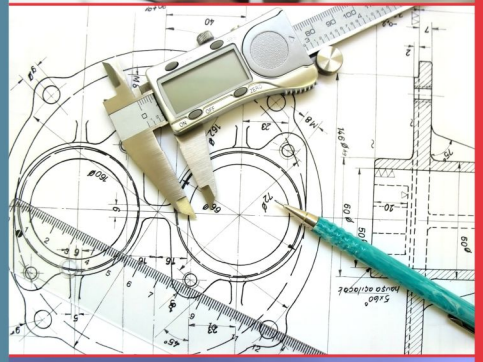

Challenges Facing Nuclear Energy After Fukushima

Energy Policy Presentation

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

OSPE Energy Task Force

January 2015

ONTARIO SOCIETY OF PROFESSIONAL ENGINEERS

Challenges Facing Nuclear Energy After Fukushima

Outline of Presentation

- Data Sources
- Challenges
- Impact of Natural Gas Prices
- Impact of Interest Rates
- Impact of Load Following
- Impact of Wind Turbines
- Public Concerns About Used Fuel Management
- Public Concerns About Accident Releases
- Cost and Schedule Over-Runs
- Large Capital Requirements
- Summary

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.
- Electricity production cost data was obtained from Ontario 2013 FIT rates and the *Projected Costs of Generating Electricity, 2010 Edition*, Organization for Economic Co-operation and Development, median case with carbon tax removed.
- You can download OSPE energy policy documents and this slide presentation at:

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

Challenges Facing Nuclear Energy After Fukushima

Challenges

- Multi-unit common mode accident at Fukushima Dai-Ichi undermined the public's confidence in the nuclear industry.
- All 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.
- Very little money for nuclear R&D in North America

Impact of Natural Gas Prices

- Public concerns about coal CO_2 emissions & pollutants.
- Natural gas has 60% 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 at less than 3 $US per M BTU spot price in North America so the fueling cost is less than 4 cents/kWh.
- New gas-fired generation is currently cheaper than new nuclear generation.

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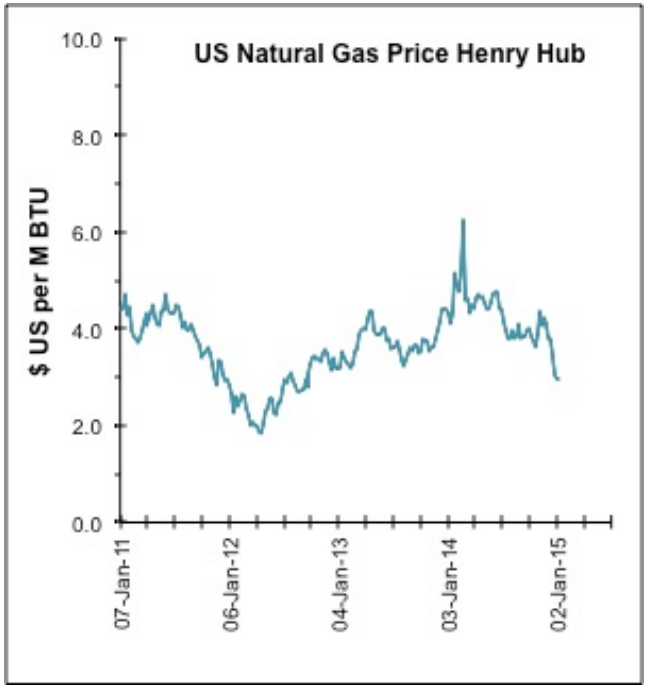
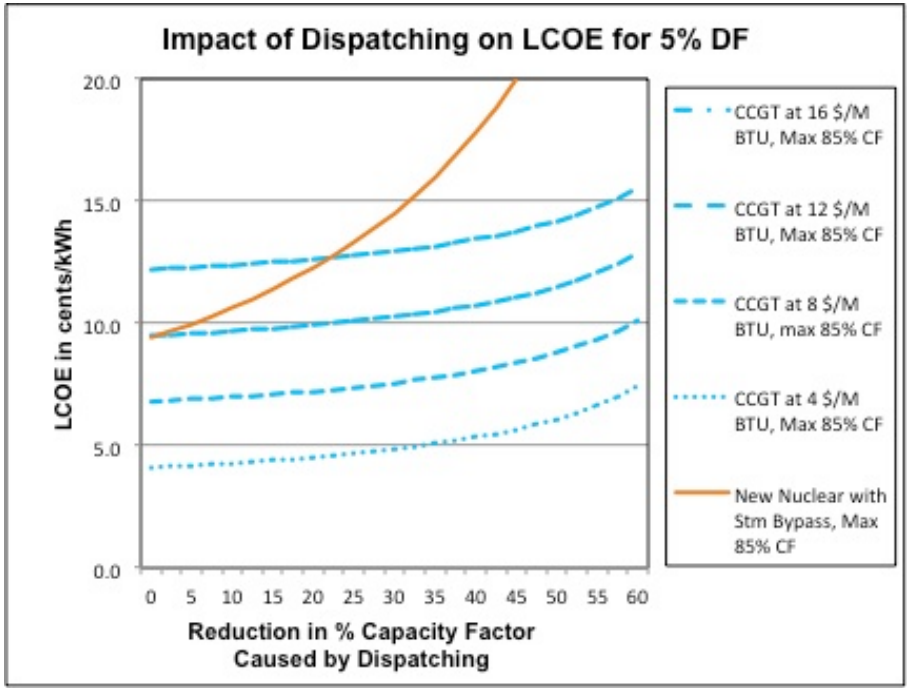
Impact of Natural Gas Prices





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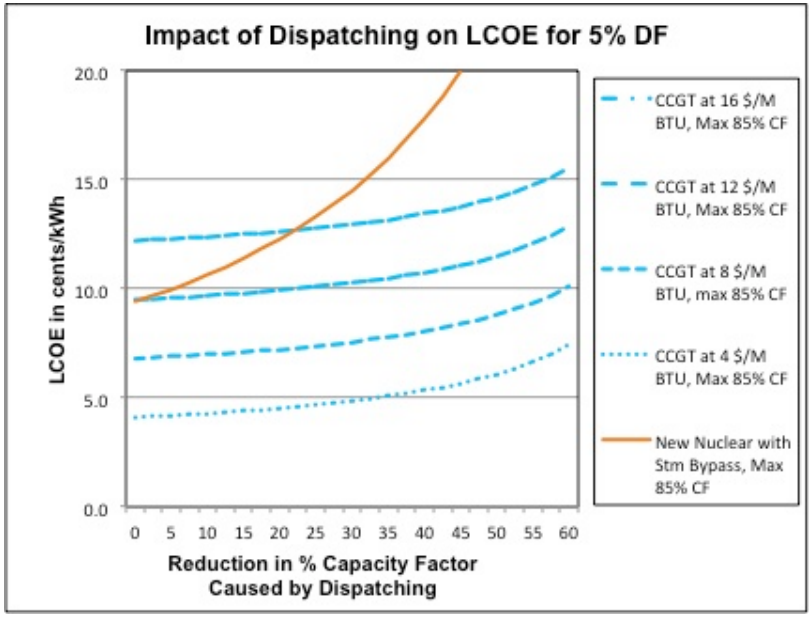
Challenges Facing Nuclear Energy After Fukushima

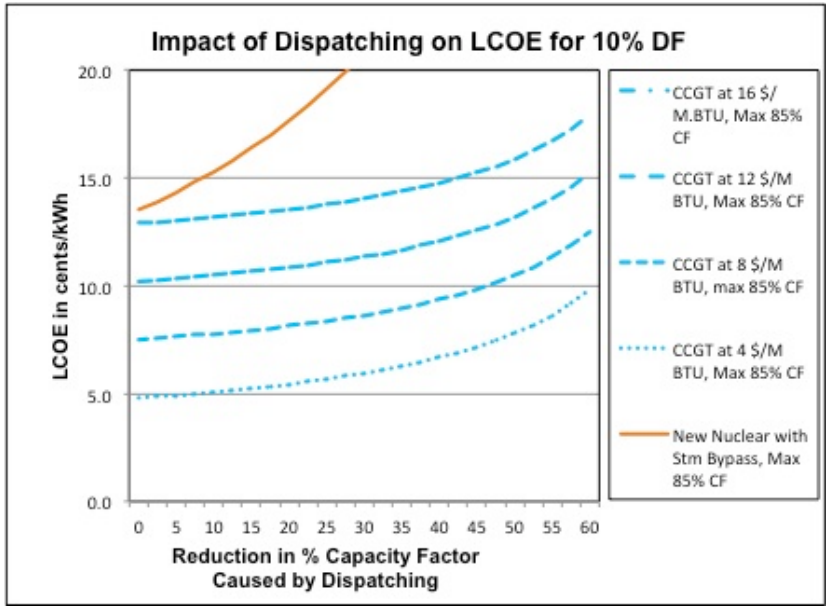
Impact of Interest Rates

- Currently 30 yr government bonds are 3 to 4 %.
- 5% discount rate is being used to evaluate projects.
- Nuclear projects are costly (6 to 7 B$/GW) and have a long construction schedule (5 to 10 years).
- Long term interest rates have a major impact on levelized cost of electricity (LCOE) for nuclear.
- A rise in interest rates will increase LCOE more for nuclear than for gas fired plant.

Challenges Facing Nuclear Energy After Fukushima

Impact of Interest Rates





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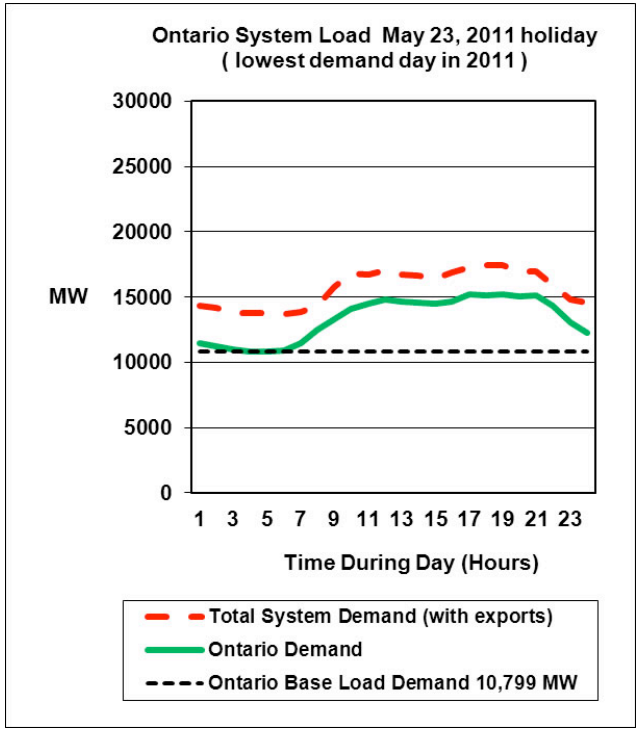
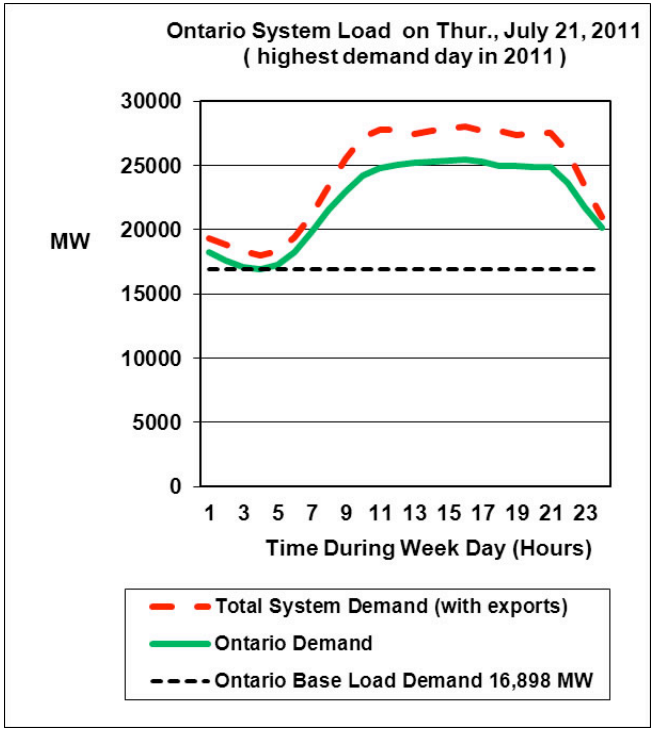
Impact of Load Following





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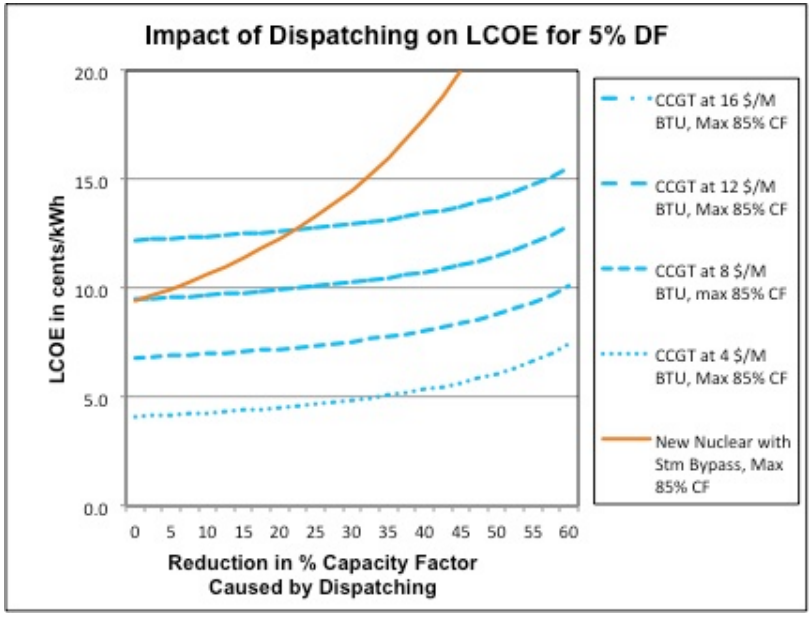
Challenges Facing Nuclear Energy After Fukushima

Impact of Load Following (Dispatching)



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

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Impact of Wind Turbines

- Ontario will add 7,500 MW of wind turbines by 2021. 1,700 MW installed in July 2013, 4,700 MW installed by end of 2014.
- Wind competes with nuclear for customer load at night.
- When demand is low at night the operator (IESO) dispatches (lowers the output of) flexible nuclear before wind turbines and then shuts down inflexible nuclear.
- More flexible nuclear will be needed to manage growing intermittent renewable output - impacts capacity factors.
- Ontario does not have storage to prevent energy loss.
- The size of the intermittent renewable portfolio (wind and solar) will impact the economics of nuclear.

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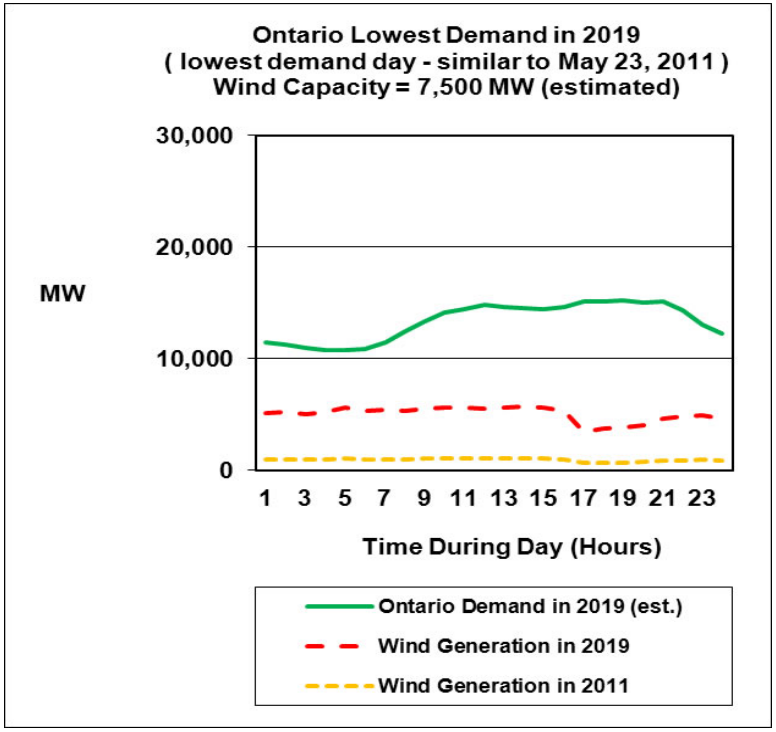
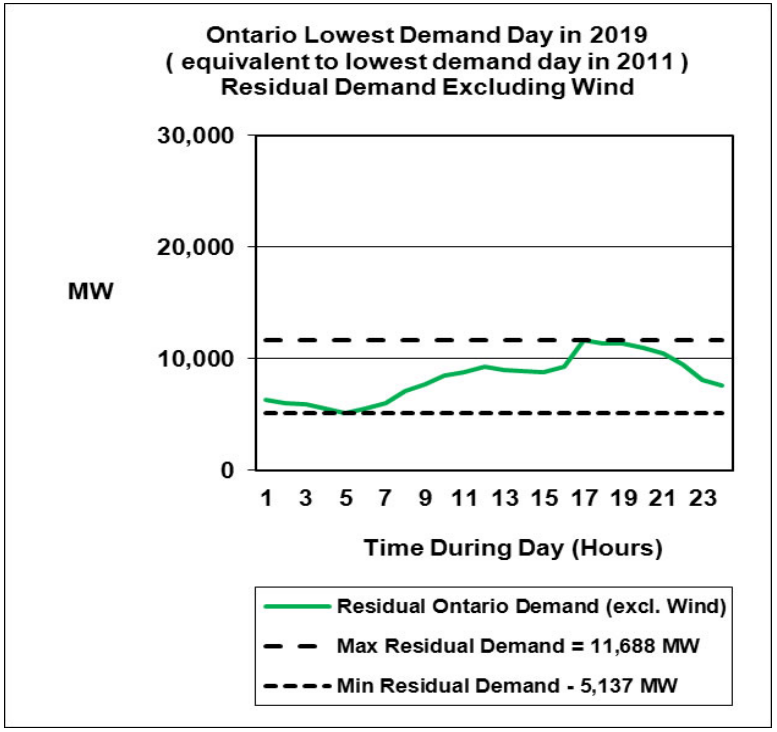
Impact of Wind Turbines





Note: Dec 2013 Long Term Energy Plan delayed installing 7,500 MW of wind to end of 2021 from 2018.

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Public Concerns About Used Fuel Management

- No current permanent repository for used fuel.
- Nuclear Waste Management Organization (NWMO) is working with Canadian communities to locate a long term repository - many years away from becoming operational.
- Public concern about used fuel hazards and its very long life time.
- Used fuel reprocessing that would reduce radioactive waste volumes significantly is not permitted in Canada, USA and in many other countries – proliferation concerns.

Public Concerns About Accident Releases

- Statistically , nuclear has the lowest death & injury rate and lowest emission profile of any dependable energy source.
- Public concerns about technical complexity and human error:
  - Three Mile Island – poor I&C design and human errors.
  - Chernobyl – poor reactor design and human errors.
  - Fukushima Dai-Ichi – poor emergency power design and human errors.
- Public concerns about plant robustness – tolerance to design/human errors.
- Public concerns about terrorism – tolerance to concerted attack.
- Public concerns about proliferation – tolerance to nuclear material diversion.
- Public concerns about contamination following an accident.
- Public demands very low risk from high impact plants.

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: 8.5 B€, in-service 2018
- France – Flamanville Unit 3: 1600 MW EPR-PWR
  - construction problems and design issues
  - original plan: 3.3 B€, in-service 2012
  - current plan: 8.0 B€, in-service 2018
- Better experience in China - 1100 MW AP-1000 PWR, about 1 year and 20% over original plan.
- First AP-1000 in USA - about 1 year and 1 B$ over original $14 B plan for 2 units.

Challenges Facing Nuclear Energy After Fukushima

Large Capital Requirements

- Large capital investment (6-7 B$/GW) and long schedule for a large unit are effectively a “bet-the-company” project.
- High indirect construction costs for 1 unit on 1 site. Multi-units on one site increases financial commitment and corporate risk.
- Private sector doesn’t want to finance multi-B$ projects with technical and licensing risk without government financial guarantees.
- Governments are reluctant to backstop project risk.
- Costs may go higher after completion of the Fukushima Dai-Ichi accident investigations/analysis and resulting safety upgrades to cover “beyond design basis accidents”.

Challenges Facing Nuclear Energy After Fukushima

Large Capital Requirements

- Small Modular Reactor (SMR) concepts (40 MWe – 200 MWe):
  - Improved safety - some are passively safe.
  - Lower costs - mass production.
  - Shorter schedule - smaller units.
  - Better quality assurance - factory assembly and testing.
  - Lower financial risk - smaller incremental investments.
- But SMR's are many years away from commercial operation.

Challenges Facing Nuclear Energy After Fukushima

Summary

- Nuclear industry has a number of challenges to overcome before a nuclear renaissance can be realized – cheap natural gas is a major barrier to new nuclear capacity.
- Small modular reactors promise improved safety and lower financial risk but are many years away from commercial operation.
- Nuclear industry needs to better educate the public on the actual risks and benefits of nuclear power.
- Nuclear industry needs to re-examine economies of scale. Smaller may be cheaper in the case of nuclear power.

Questions ?

Notes:

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