The Flexibility Challenge

Energy Systems Integration for Low-Carbon Futures

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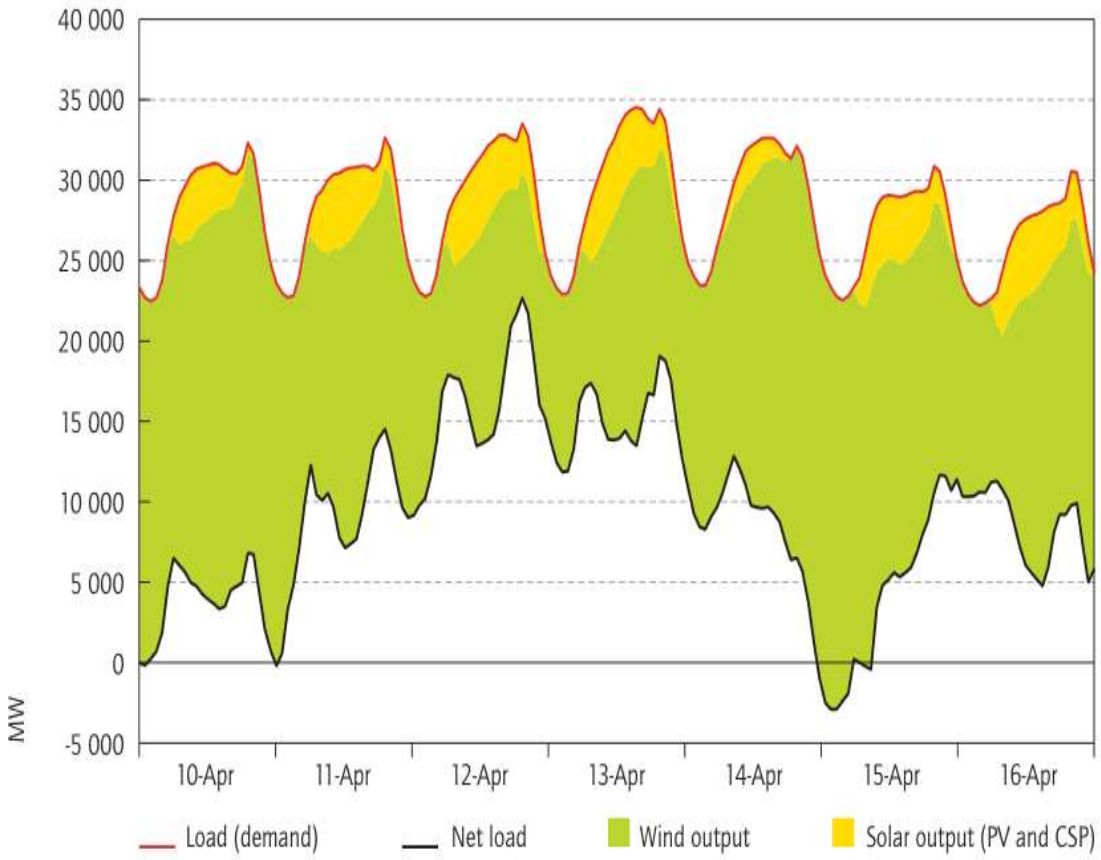
Power & energy system decarbonization

- Electricity is the energy carrier *par excellence* for decarbonized energy systems
  - Increasing demand as fossil fuels are replaced by electricity
    - Transport, industrial processes, space heating, etc.
    - Increased dependency on having a resilient electric power supply infrastructure
  - Supply-side decarbonization via integration of low-carbon energy sources
    - Wind, solar, marine, biomass, hydro, etc., distributed geographically
    - Phasing out of traditional generation assets
- The Laws of physics are still here
  - Need for *energy system integration*

Fundamental shifts in operation and planning – the challenges

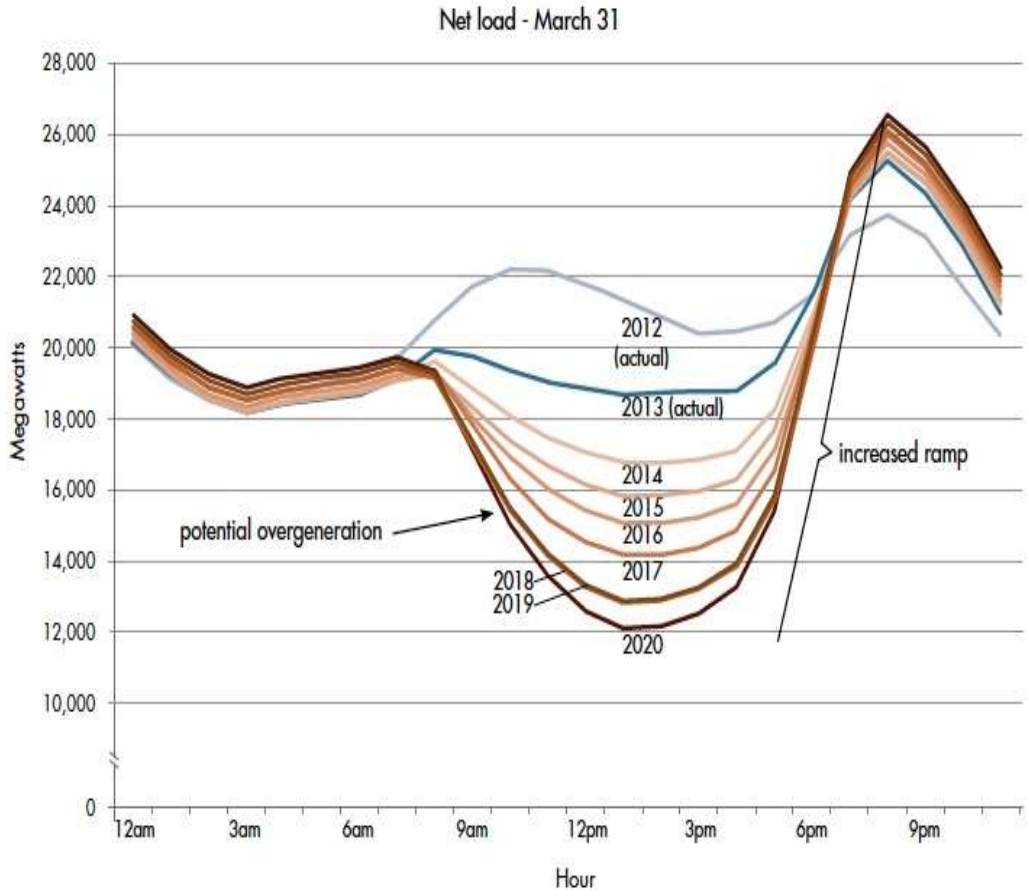
- Lower controllability
  - Phasing out of dispatchable generation assets, while integrating non- (or partially) dispatchable renewable generation
- Lower observability
  - Geographical dispersion of new generation all the way down to low-voltage distribution (e.g., behind-the-meter solar PV)
- Greater/different types of uncertainty
  - From outage-driven system planning to generation variability-driven planning
- Reliability paramount as electricity plays significant role in the economy

Fundamental shifts in operation and planning – the challenges



Source: International Energy Agency, 2011

Fundamental shifts in operation and planning – the challenges



Source: California Independent System Operator, 2013

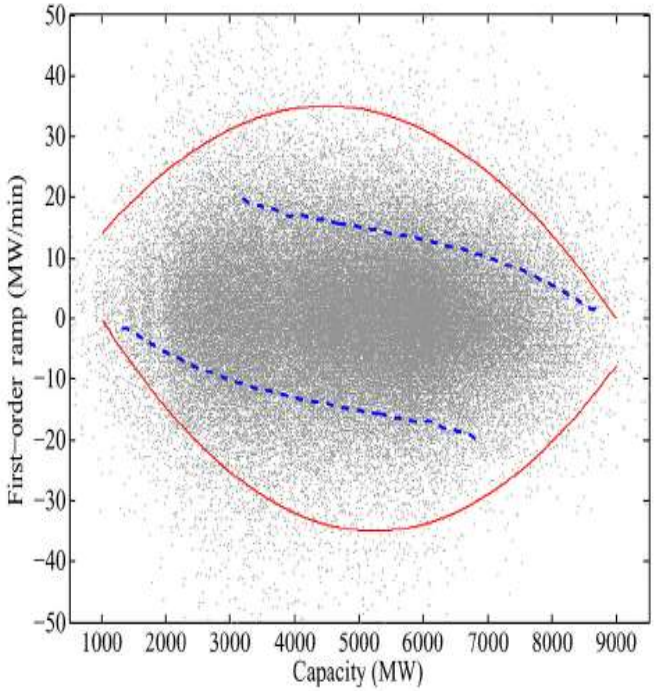
Fundamental shifts in operation and planning – the challenges

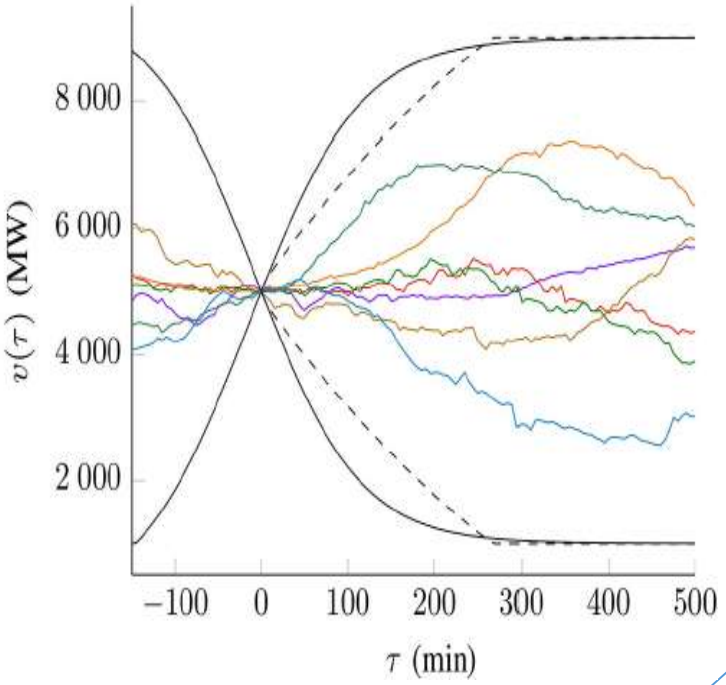
- Handling these challenges require great ***flexibility***
  - *The ability of a power system to alter its electricity production and consumption, in response to changing conditions, expected or otherwise*
  - Sources of flexibility
    - Generating assets – primary source
    - Consumers – space heating & cooling, sanitary water heating
    - Energy storage – batteries, thermal media
    - Networks – as conduits for flexibility
    - Institutions – markets, policies, system integration
  - How can we plan for flexibility?

The flexibility challenge – three fundamental elements

- I. Flexibility requirement characterization
  - What? How much? Where? When?
- II. Flexibility resource characterization
  - Energy, power and ramping limitations, other inflexibilities
  - Cost of flexibility provision
- III. Matching flexibility requirements with available flexibility resources
  - Cost-benefit analysis trading off now against later decisions
  - How to do this in the long run & flexibility business models remain open questions

Flexibility requirement characterization & integrated scheduling

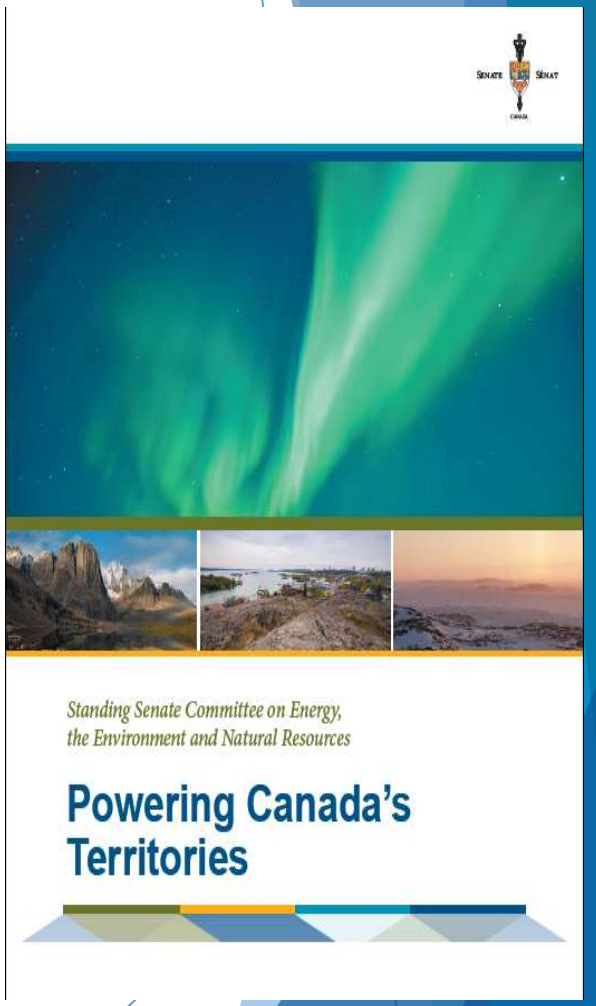




Source: Nosair & Bouffard, 2016

Canada's Northern communities: An opportunity to shine

- Displacing diesel through flexible operations
  - Techniques for more efficient use of generating assets through energy storage and consumer-side flexibility
  - Leveraging couplings with renewables
- System design techniques for remote microgrids
  - Finding best technological mix given economic, environmental and resiliency objectives and constraints



Thank you

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