CNA Quantitative Research:

Why Renewable Energy Needs Nuclear

July 2019

Summary

In the real world, no amount of renewable energy could meet ***even current*** electrical demand by itself, let alone additional new demand.

Storage could help, on a huge scale and at vast expense. This won't happen.

When renewable energy falls short, which is inevitable, something else will be needed to fill in, and that something else strongly favours gas.

Therefore, renewable energy by itself is ***NOT*** how Canada will decarbonize.

Nuclear energy is the available and proven way to get off fossil fuels.

Current power demand vs. wind/solar supply

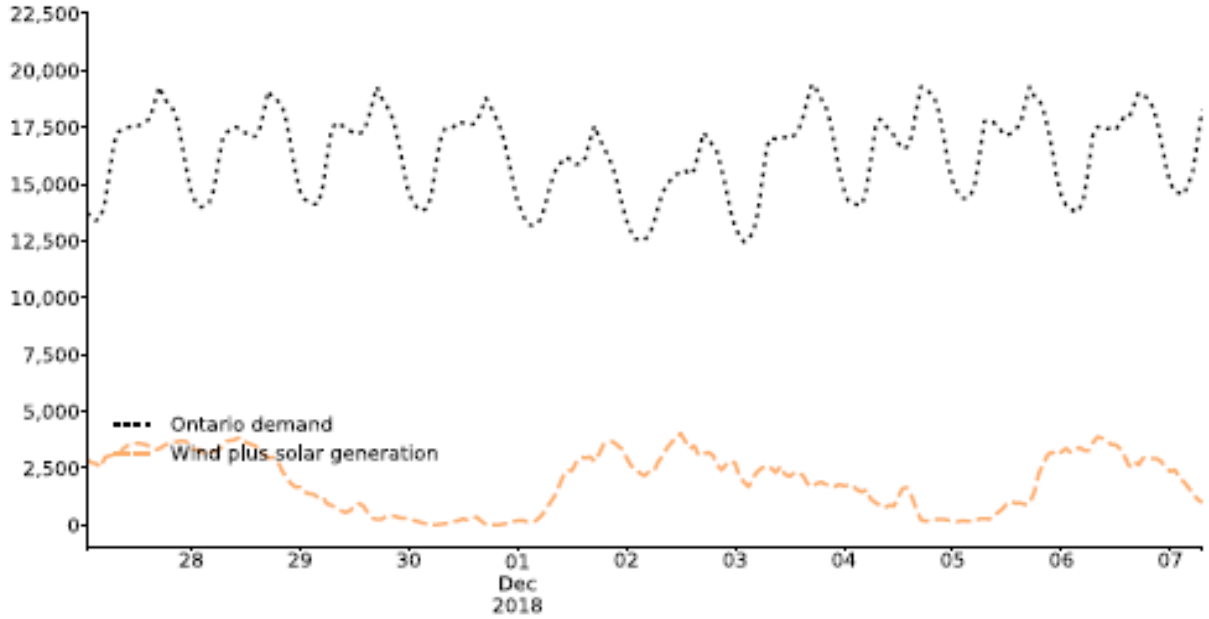
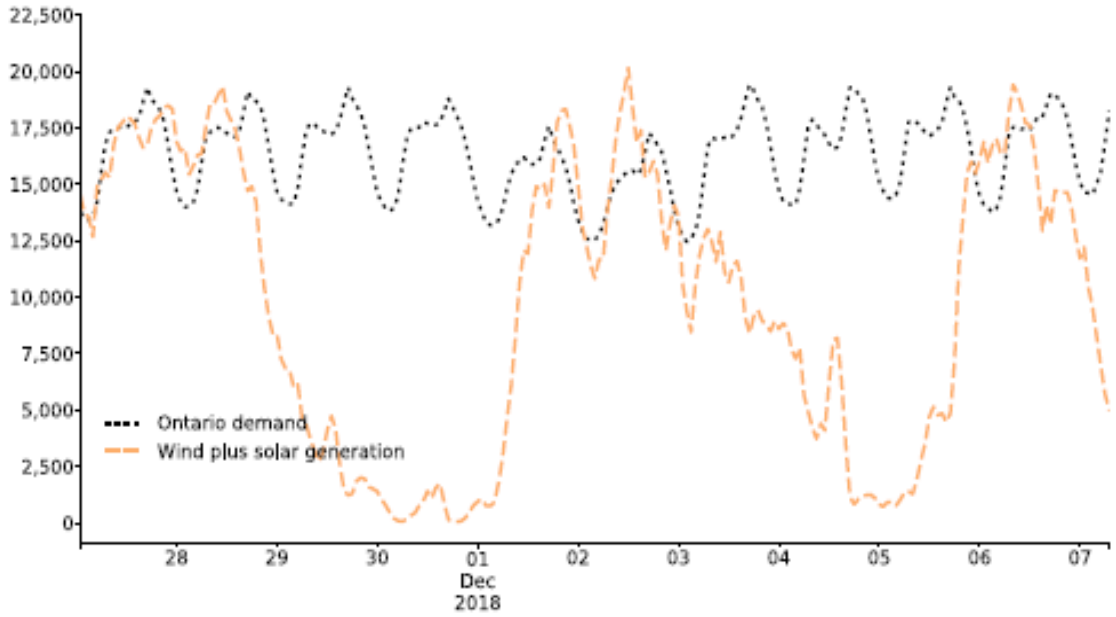


Fig. 1.1: Ontario electricity demand and actual wind/solar generation, megawatt hours, Nov 27–Dec 7 2018. Click to view file in Dropbox.

Here's the gap
between what we need

and what wind and solar generate **now**

What if we had 5X more renewable power?



Ontario would have very **poor match between supply and demand**.

On a few days, for a while, there would be too much electricity -- while most nights, and **sometimes for days on end, there would be much too little** renewable electricity to meet demand.

We would really need about a 9x (not 5x) **expansion** of renewables – with corresponding **backlash from landowners**/ratepayers/voters.

So what? Won't we have battery storage?

One of the largest battery packs in existence is Tesla's Moss Landing, in California.

It can deliver up to 182.5 megawatts for four hours. Then it **needs to be recharged, at the same rate and for the same duration,** to be full.

Ontario would need about 25 such batteries. The capital cost would be roughly $125 bn – around 36% of Ontario's current provincial debt!

But aren't battery costs declining?

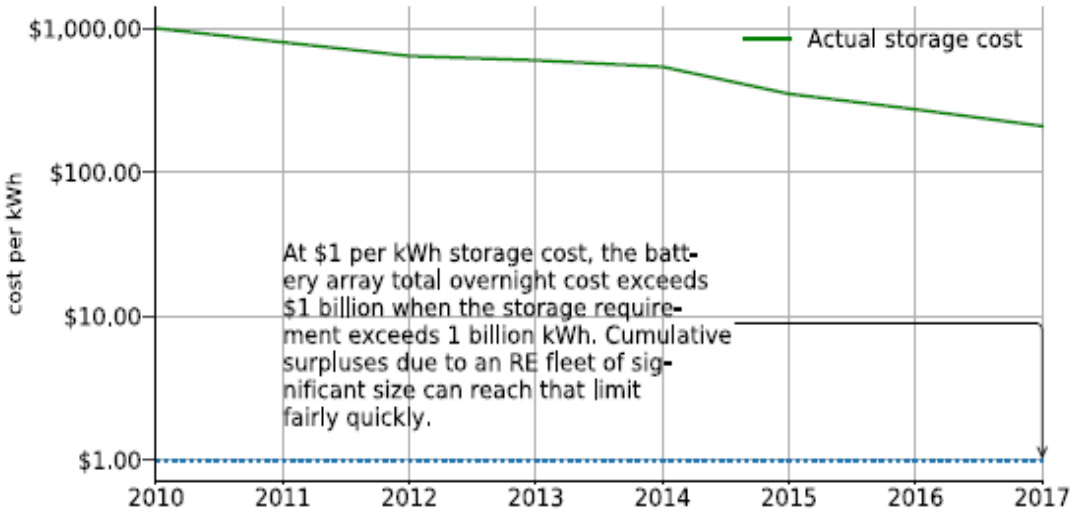


Fig. 1.13: Battery storage per-kWh cost declined a bit more than a half order of magnitude 2010–2017 (source: Deloitte & *Bloomberg*). Click to view file in Dropbox.

Yes, they are – but this rate of **cost reduction will have to continue for perhaps 2-3 more orders of magnitude**.

This is questionable. Batteries aren't like microchips or software – rather, they are **materials-intensive, heavy industrial products**, with physical costs. **Current prices already reflect over a century of research and development**.

Even if deep cost reductions were coming, **we can't delay investing for decades. We are already part-way in.**

There often won't be time to recharge!

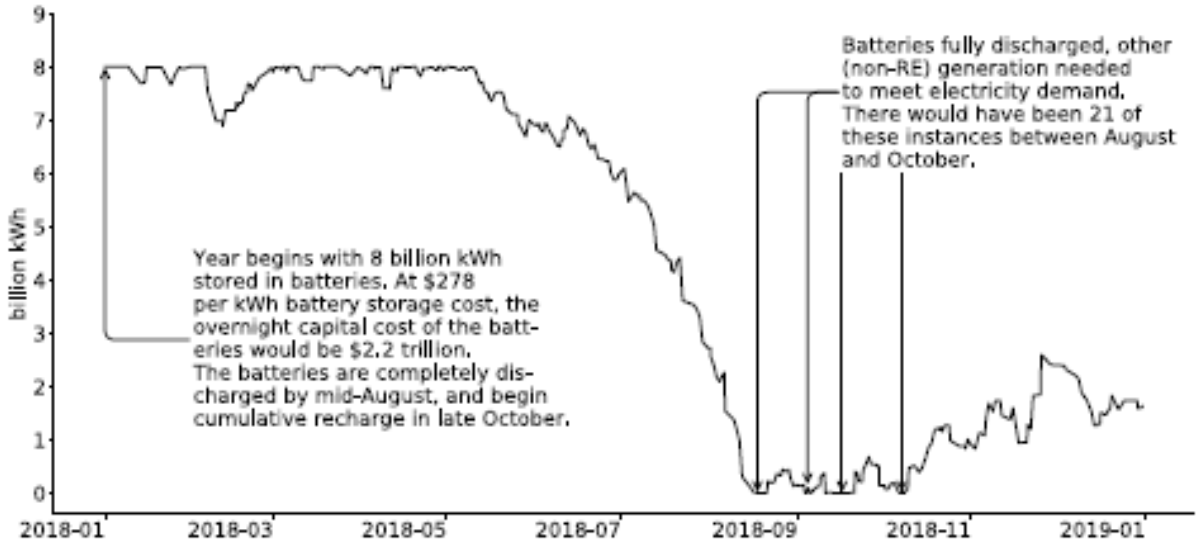


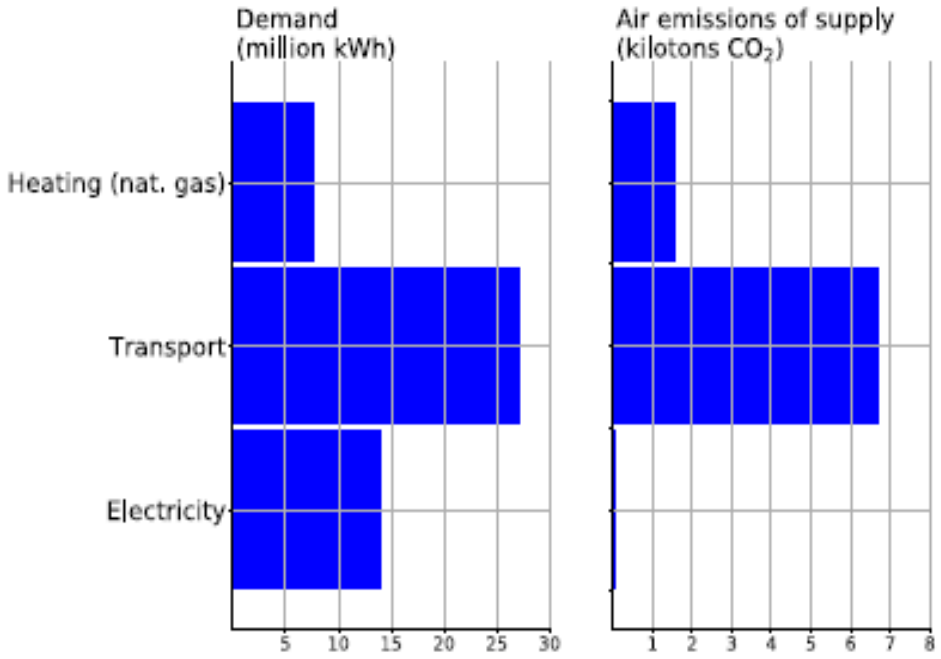
Fig. 1.15: Available battery-stored energy at the beginning of each shortfall-surplus cycle, Ontario electricity, 2018. Click to view file in Dropbox.

Charging batteries takes time – it **requires hours or days during which there is surplus** renewable generation.

Periods when batteries need charging sometimes won't coincide with long enough periods of surplus renewable power.

In Ontario, **discharge will tend to exceed recharge between August and October** – leaving batteries dead in the late fall.

And electricity isn't nearly the hard part



In Ontario, **transport uses twice as much energy as electric power** – and is vastly higher-emitting.

Heat is a substantial energy need, even at 6 am in June (seen here) – and enormous in winter.

Renewables would somehow have to be harnessed to supply all transport and all building heat – **a far greater expansion than 5x or 9x**.

Renewable energy is land-intensive

To meet Ontario's current electrical demand would require 9 times the province's current renewable capacity. That means about:

- 39,000 new MW of wind turbines and 21,000 new MW of solar.
- Over **10,000 square kilometers of land**, just for the wind turbines

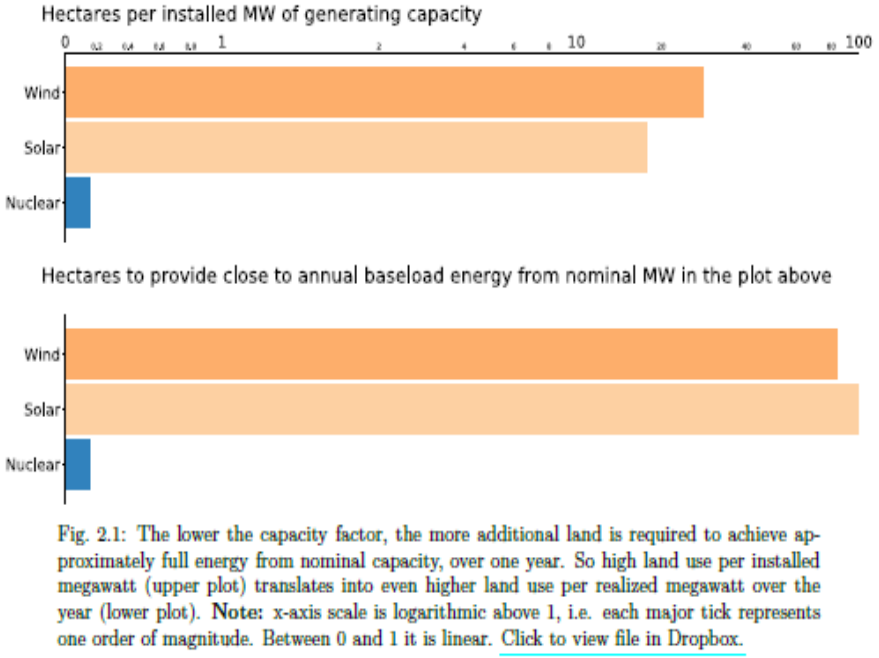


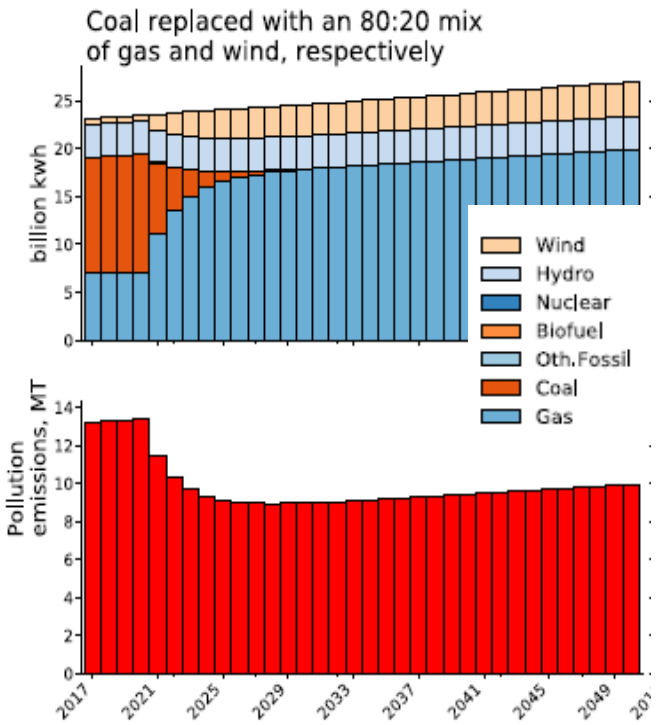
Fig. 2.1: The lower the capacity factor, the more additional land is required to achieve approximately full energy from nominal capacity, over one year. So high land use per installed megawatt (upper plot) translates into even higher land use per realized megawatt over the year (lower plot). **Note:** x-axis scale is logarithmic above 1, i.e. each major tick represents one order of magnitude. Between 0 and 1 it is linear. Click to view file in Dropbox.

All energy has lifecycle costs

That same 9x expansion of Ontario's renewables would also need:

- **2,000 km of new power transmission line**
- **21 million tonnes** of additional construction/manufacturing materials
- The **battery storage** (28 Moss Landing facilities) would weigh **166,000 tonnes** – more than twice the total used nuclear fuel in Canada now
- All this **would have to be replaced** every 20-25 years.

Example: Phasing out coal in Saskatchewan



- Saskatchewan's coal-burning power plants will reach the end of their lives in the 2020s.

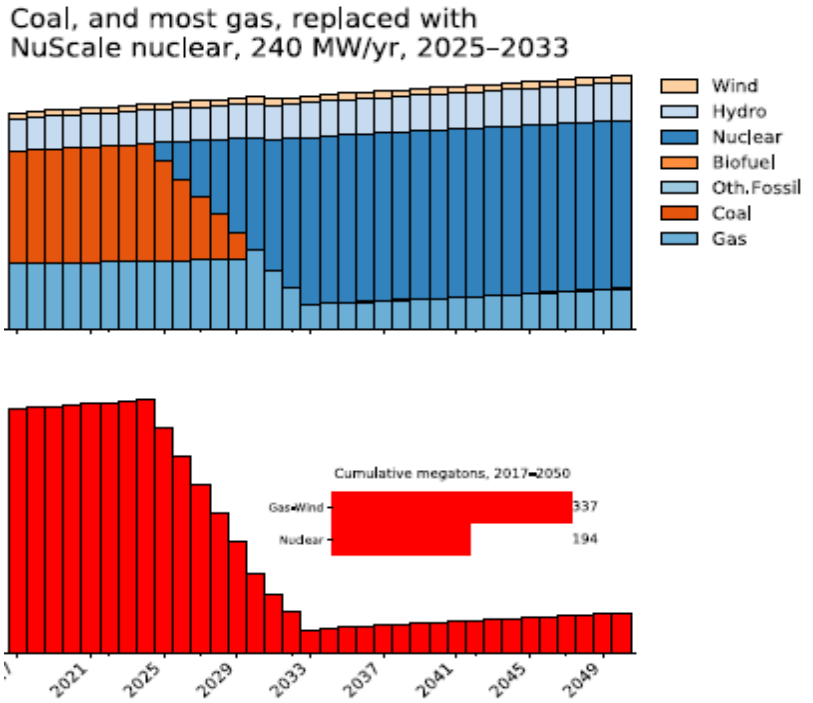
- Wind in Saskatchewan is intermittent. Wind turbines on average produce about 20% of their maximum generating capacity.
- In low-wind periods, remaining demand must be met with gas-fired generation.
- This results in about an 80:20 gas/wind mix.
- **More renewables means sharper irregularity and unpredictability** in power supply – and so, **more gas capacity idling in the background** to fill the gaps.

- Emissions fall somewhat when coal is phased out – but **the province still has a high-emitting electricity system**.

Example: Phasing out coal in Saskatchewan

- **Nuclear power generation is about as low-emitting as wind – but with much less need for gas backup**.

- This solution is open to using wind and solar where they fit best, and **benefits the province with a low-emitting electricity system after coal is gone**.



The bottom line

- Non-hydro **renewables generate power very irregularly** over time.
- They require **large amounts of land**, and power transmission lines.
- Power **storage would be needed on vast scales**, for days or weeks.
- Both renewables and storage would require large amounts of materials that would need periodic replacement.
- All this has **economic costs and environmental impacts**.
- **Relying on wind and solar for most power is not environmentally sound**.
- Unless hydro is very abundant, **nuclear is the best option** to complement renewables **in a complete, clean, reliable power system**.

Quantitative research by Emissiontrak

Commissioned and presented by CNA

Thanks to Steve Aplin

Canadian Nuclear Energy:
Moving from Mainframe to Laptop

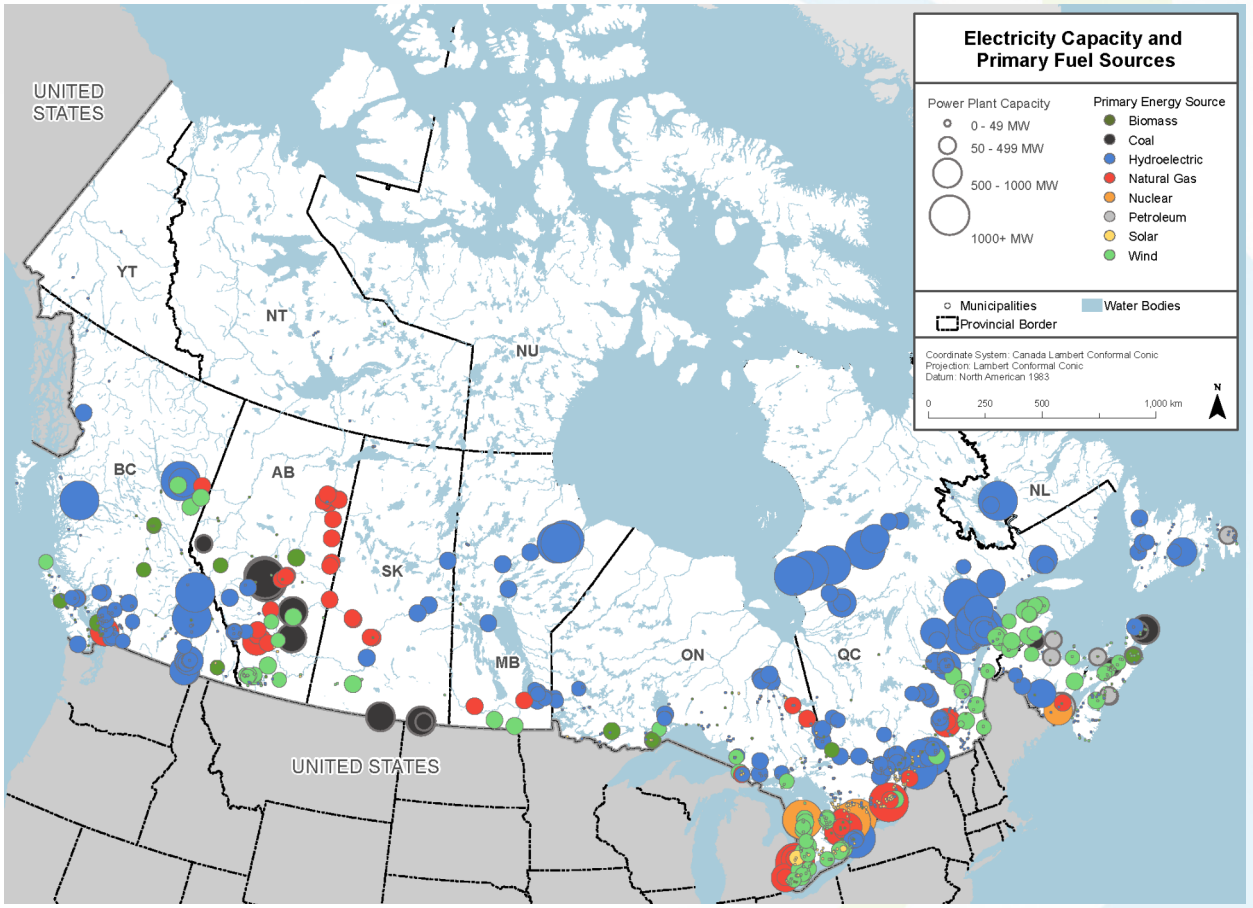
Living Without Oil – Part 2

Victoria, BC -- February 15, 2020

cna canadian nuclear association

Of Canada's 10 provinces:

- 4 are mostly hydro (BC, MB, QC, NL)
- 2 are mostly hydro + nuclear (ON, NB)
- 4 are fossil-reliant (AB, SK, NS, PE)
- Remaining hydro capacity is abundant, but remote
- Long-distance transmission lines have become harder to build



Challenges for wind & solar in Canada:

- Short, dark winter days
- Little wind in coldest and hottest periods
- Long power storage times
- Poor battery performance at low temperatures
- Huge heating demand

On the positive side:

- Hydro power's flexibility helps compensate for intermittency
- Abundant land, in some cases

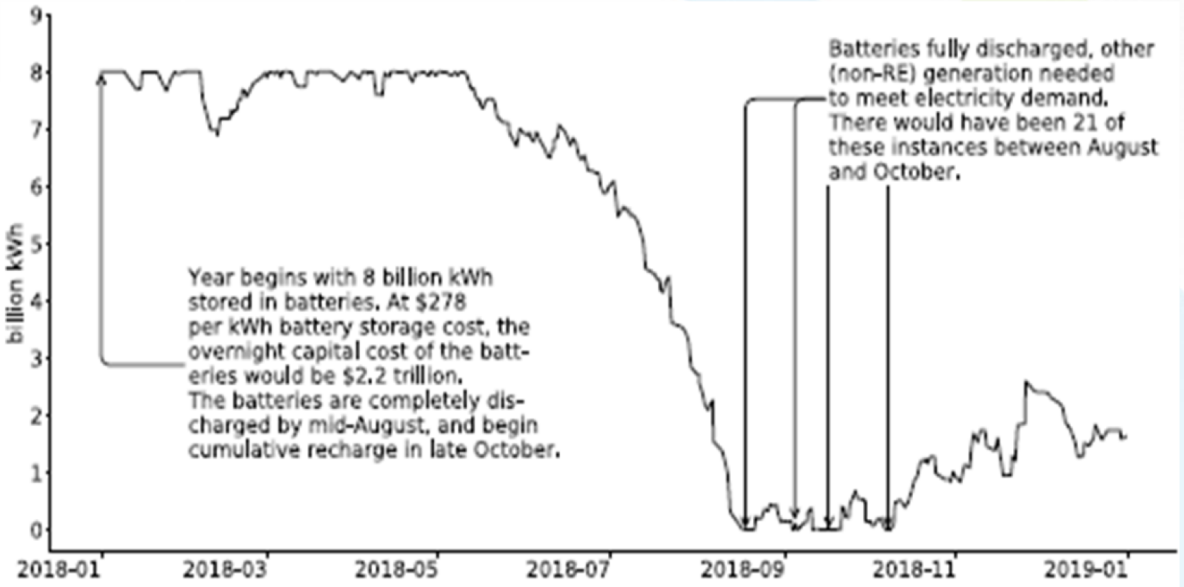
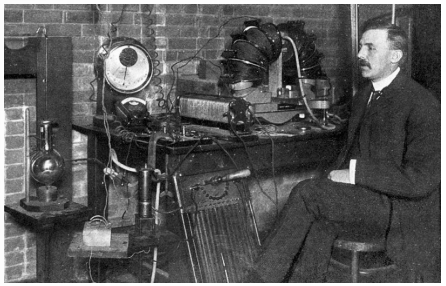


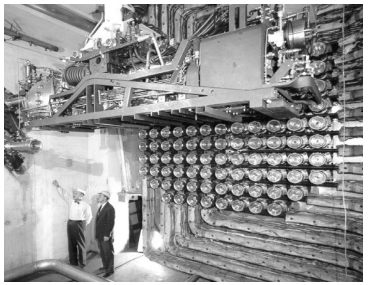
Fig. 1.15: Available battery-stored energy at the beginning of each shortfall-surplus cycle, Ontario electricity, 2018. Click to view file in Dropbox.

Even with generous assumptions, wind and solar would not keep batteries charged in fall/winter

Canada's Good at Nuclear



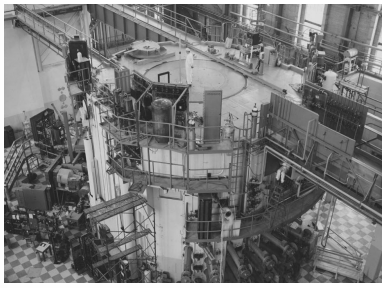
1905



1962

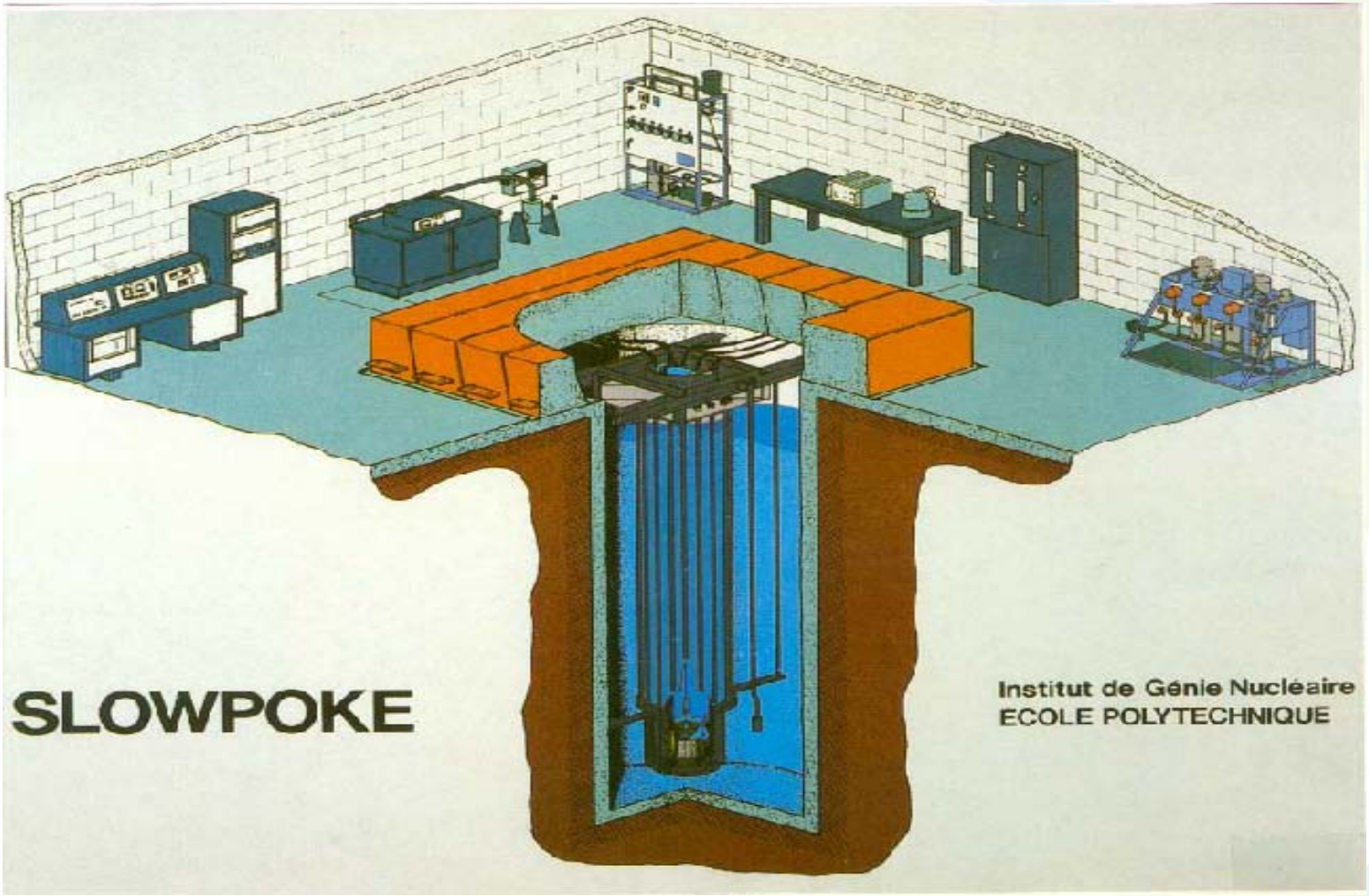
2019

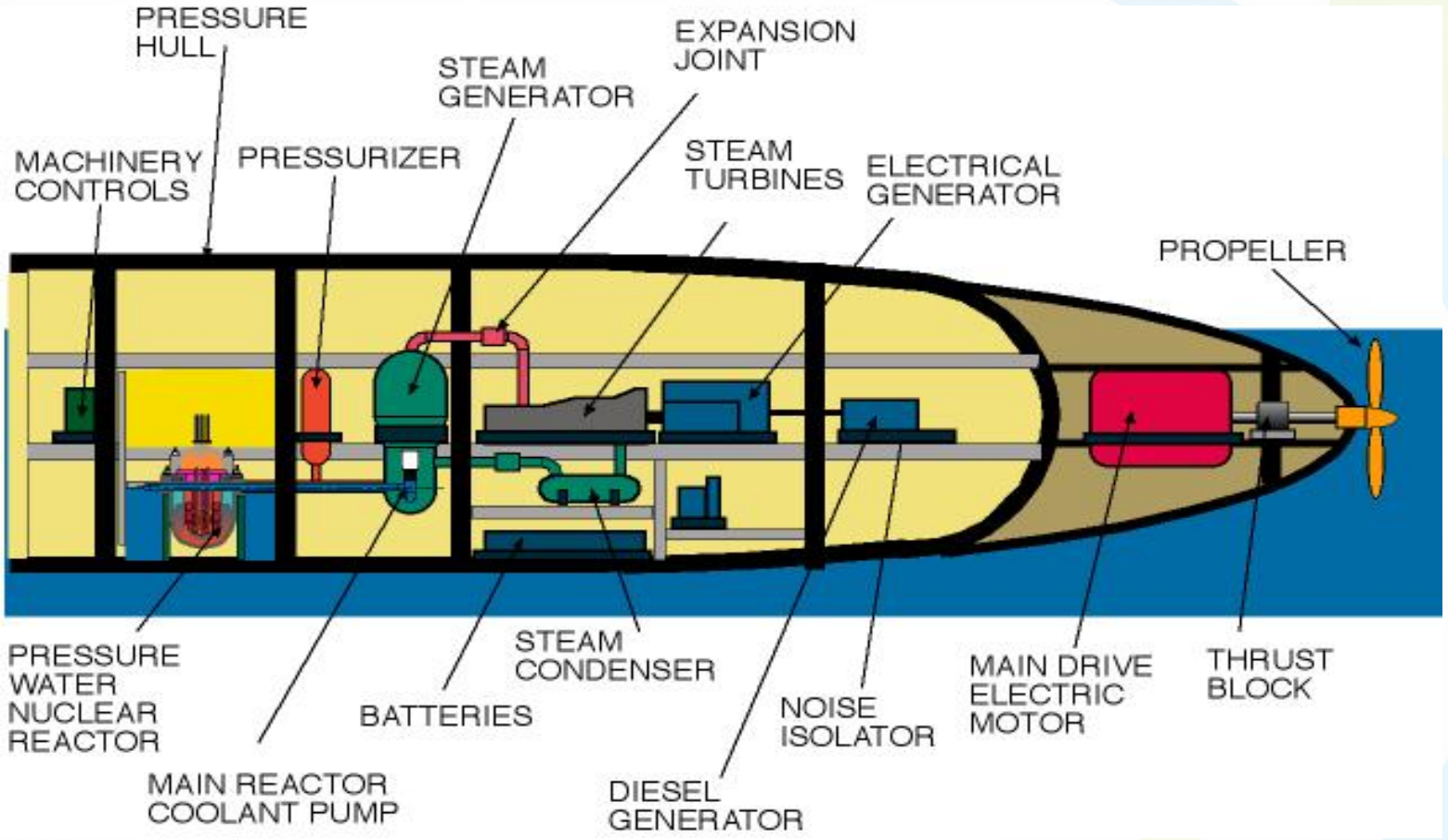
1947

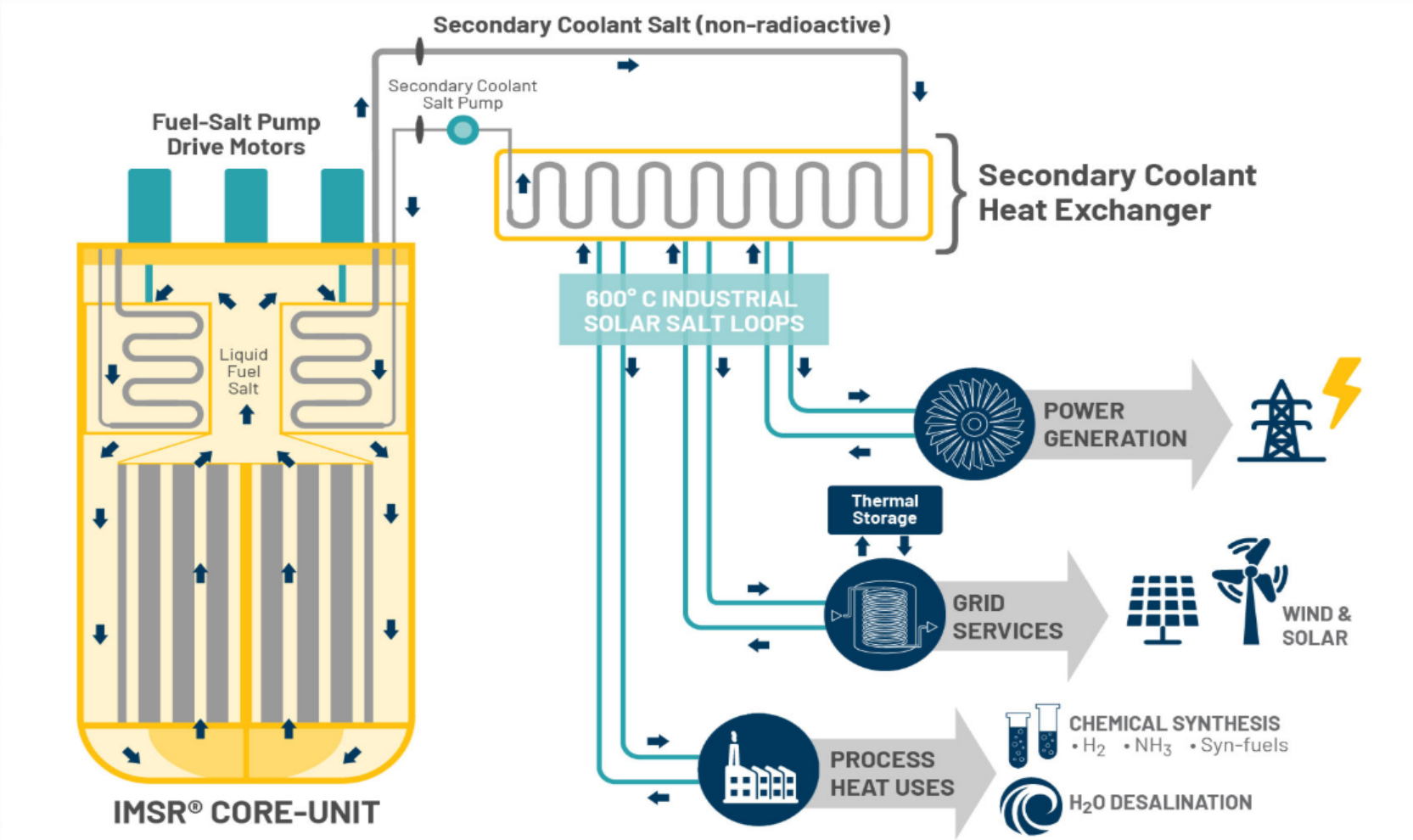


1996

Reactors sold to six countries incl. China, South Korea & India


SLOWPOKE
Institut de Génie Nucléaire
ECOLE POLYTECHNIQUE


PRESSURE HULL
EXPANSION JOINT
STEAM GENERATOR
MACHINERY CONTROLS
PRESSURIZER
STEAM TURBINES
ELECTRICAL GENERATOR
PROPELLER
PRESSURE WATER NUCLEAR REACTOR
STEAM CONDENSER
BATTERIES
NOISE ISOLATOR
MAIN DRIVE ELECTRIC MOTOR
THRUST BLOCK
MAIN REACTOR COOLANT PUMP
DIESEL GENERATOR


Secondary Coolant Salt (non-radioactive)
Secondary Coolant Salt Pump
Fuel-Salt Pump Drive Motors
Secondary Coolant Heat Exchanger
600° C INDUSTRIAL SOLAR SALT LOOPS
Liquid Fuel Salt
POWER GENERATION
Thermal Storage
GRID SERVICES
WIND & SOLAR
CHEMICAL SYNTHESIS
• H_2 • NH_3 • Syn-fuels
PROCESS HEAT USES
H_2O DESALINATION
IMSR® CORE-UNIT

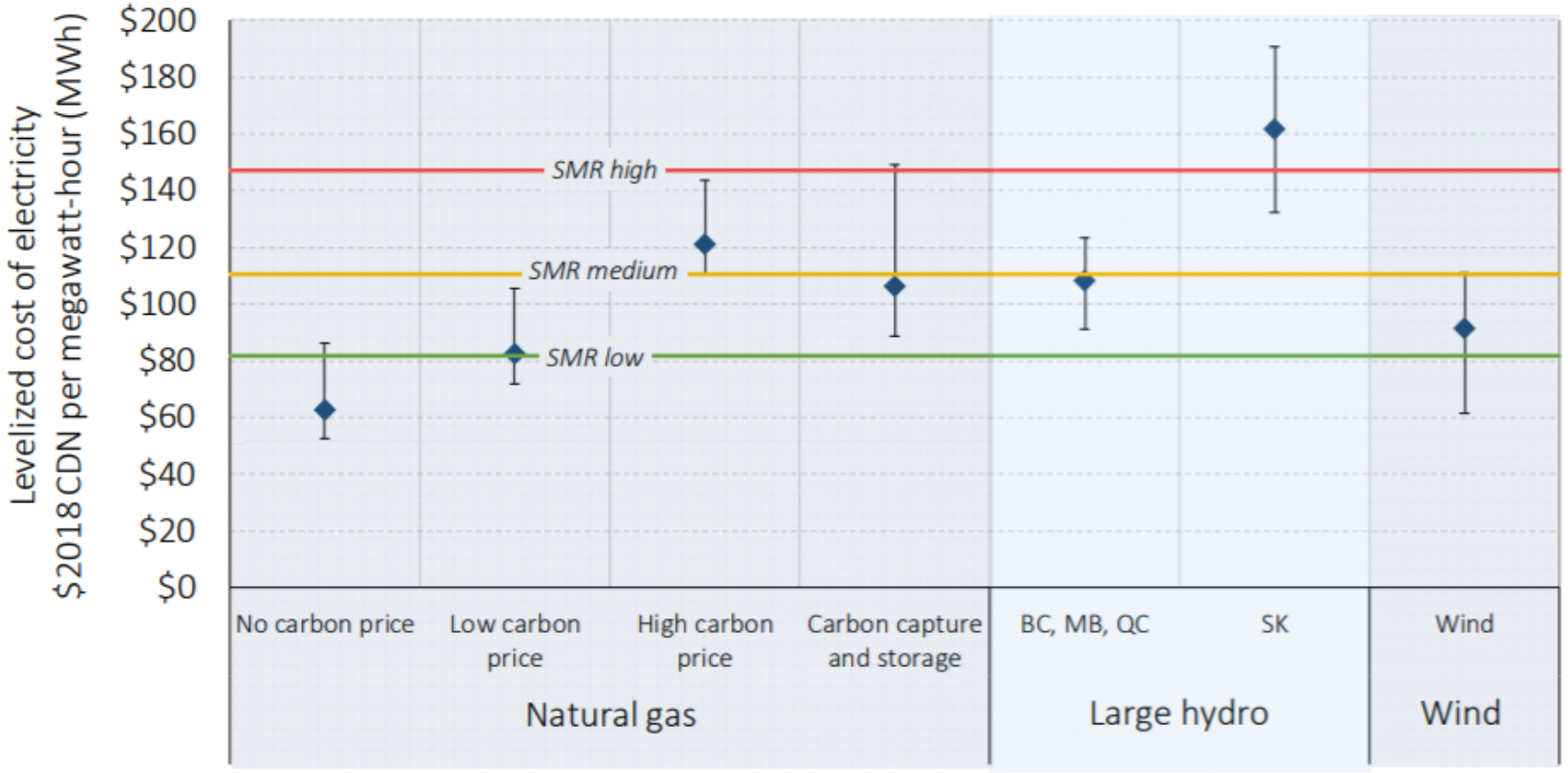


Figure 2. Comparison of levelized cost of electricity from on-grid SMRs with other options: Worst case (9% discount rate, less innovative technology)

Multiple Canadian Markets for Small Reactors

1. **On-grid** – likeliest on existing, licensed nuclear sites, or replacing coal-fired units in coal-mining towns
2. **Mining** – electricity (+ heat?) for remote but rich mining sites
3. **Process heat** – e.g. melting bitumen from the oilsands
4. **Remote communities** – electricity (+ heat?) for hundreds of isolated towns now depending on diesel

It’s not ALL about the machine

Suppose you wanted all the benefits of current air transport: Global commerce, vacations, family re-connections, just-in-time deliveries…

Would you get them **just by making the best airplane?**

What about…

- Marketing
- Ticketing
- Crews
- Training
- Runways
- Terminals
- Transport links
- Public acceptance
- Financing/insurance
- Safety regulation
- Security systems
- Air traffic control
- Customers
- Parking
- Fuel
- Water
- Food
- Waste

Why a National SMR Roadmap Project?

Canadians have many **needs that SMRs can help address**

- Electricity
- Cleaner local air
- Heat
- Reduced GHGs
- Clean resource extraction
- Energy security
- Quality of life

BUT…

Deploying SMRs in Canada would **require some wide-ranging conversations**

- Engaging early with **provincial governments** and electric utilities
- Engaging early with **Indigenous people** and local communities
- Assessing the **regulatory** framework's suitability for SMRs
- Learning about, and **selecting, SMR technology** (e.g. proven vs. advanced)
- Market size, **business models, ownership structure, financing** options, liability, etc
- **International partners, supply chain options**, local benefits, fuel & waste issues

Who are we?

Contributing **organizations**:

- Federal government
- 3 sub-federal governments
- 1 innovation agency
- 5 electrical utilities
- 1 industry association

Other **participants**:

- Indigenous people
- Mining & oil industry reps
- Nuclear experts
- Academics
- Local government reps

What did we do?

6 one-day **sessions** in 4 regions:

- Visioning
- Indigenous engagement (2)
- On-grid applications
- Remote communities
- Heavy industry

5 working group **studies**:

- Indigenous & public engagement
- Technology
- Regulatory readiness
- Economics & finance
- Waste & decommissioning

So what does it say?

- **SMRs are** real and **happening now**
- **Canada has what it takes** to apply SMRs successfully toward our low-carbon energy needs
- There are many SMR technologies
- **Fleets of similar units** can control costs
- More Indigenous engagement is needed
- The waste management system works
- The domestic market potential is there

See for yourself at www.smrroadmap.ca

What's Happening Now?

Canadian Nuclear Laboratories (government owned nuclear labs)

- Preparing to host a number of demonstration SMRs
- Four proponents are in the process

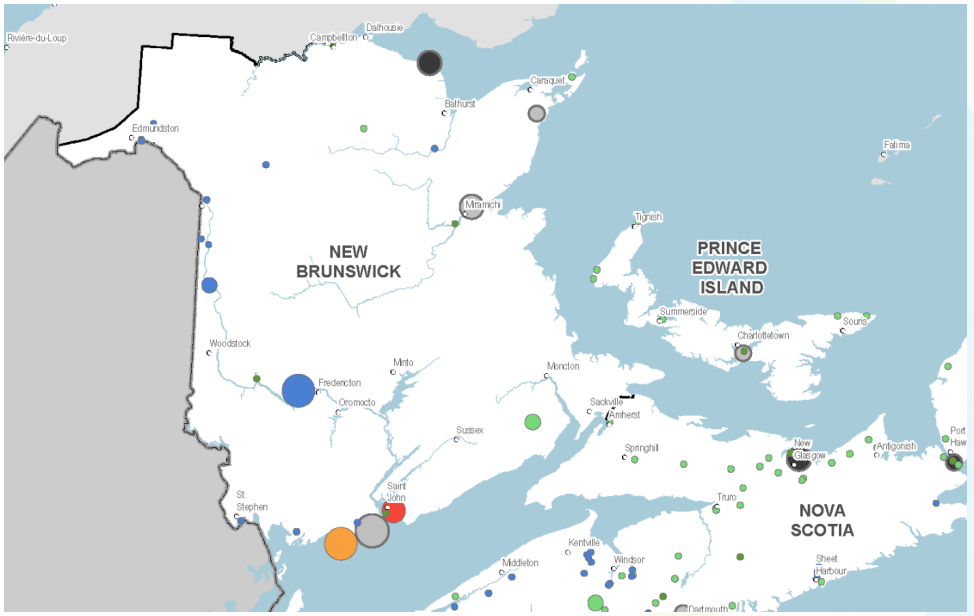
www.cnl.ca

What's Happening Now?

Province of New Brunswick

- Already a regional energy hub that hosts a nuclear power plant plus oil, gas and hydroelectric facilities. Exports energy to Maine & two other provinces

- Committed C$10M to an advanced SMR research cluster; two SMR developers are investing $5M each in the province



www.nbpower.com

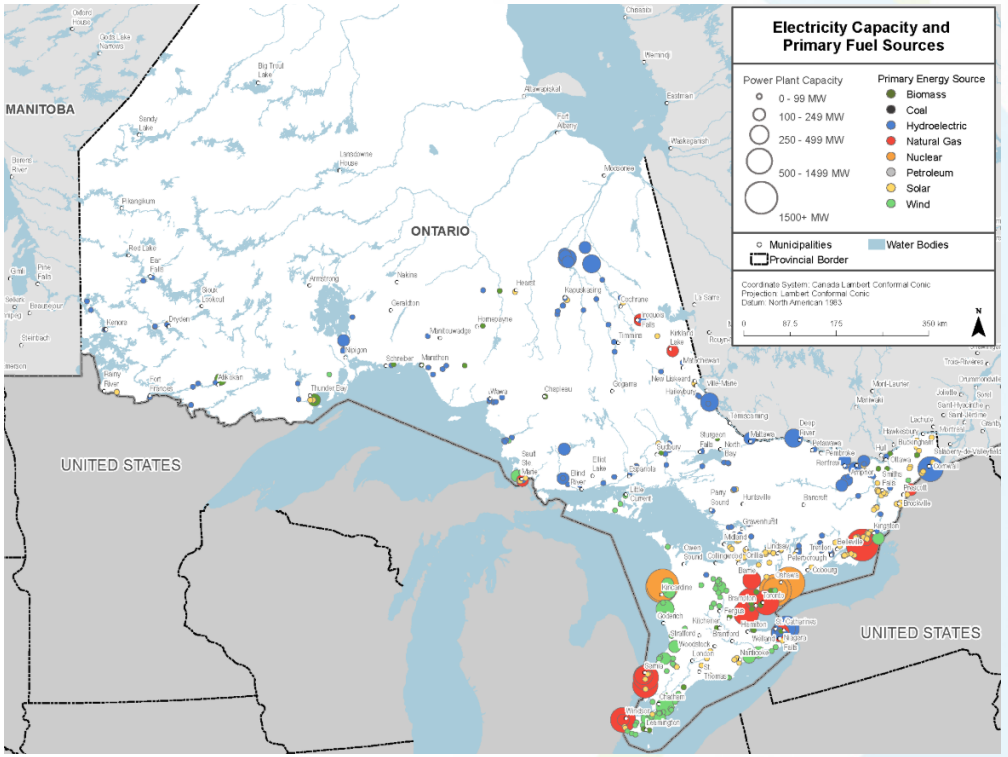
What's Happening Now?

Province of Ontario

- Provincial utility is a partner in one of the proposals to build a demonstration SMR at Canadian Nuclear Laboratories
- Has a licensed nuclear plant site that is near-ready for additional units and has strong local support

www.opg.com

www.globalfirstpower.com



Provincial Collaboration

December 1, 2020: Premiers of ON, NB and SK agree (with AB likely to join soon)

"To collaborate on the development and deployment of innovative, versatile and scalable nuclear reactors, known as Small Modular Reactors (SMRs), right here in Canada.

SMRs could generate clean and low-cost energy for both on-grid and off-grid communities, connect more remote and rural areas of our province, and benefit energy-intensive industries, including the mining and manufacturing sectors. It could also drive economic growth and export opportunities as these technologies are further adopted across the country and around the world.

Our governments support a collaborative approach to reducing emissions and growing the economy in a way that meets the specific needs and economic priorities of each province."

Roadmap Follow-up

Roadmap has many detailed recommendations for many different players. Now Canada's nuclear industry is:

- Obtaining players' reactions to these challenges
- Prioritizing the actions
- Convene discussions
- Monitor and report progress
- Creating a renewed SMR Secretariat, and obtaining resources for the next phases of work
- Working toward a pan-Canadian, multi-stakeholder Action Plan

Thank You

John Stewart

stewartj@cna.ca

www.smrroadmap.ca