Lessons Learned from Conventional Renewal Generation for SMRs: An Emerging Carbon-Free Application

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ONTARIO POWER GENERATION

Outline

OPGs experience with the EA for a diverse fuel mix, to improve Green House Gas Emissions and contribute to climate change

- OPG- who we are
- Nuclear's role in Climate Change
- Hydro /Solar EA s
- SMRs
- Environmental Impact Professionals have a unique opportunity to act as change agents using the EA process to promote improvements to climate change
- Small Modular Reactors offer unique benefits to help reduce green house gas emissions
- Benefits of diverse energy mix to achieve green house gas reductions

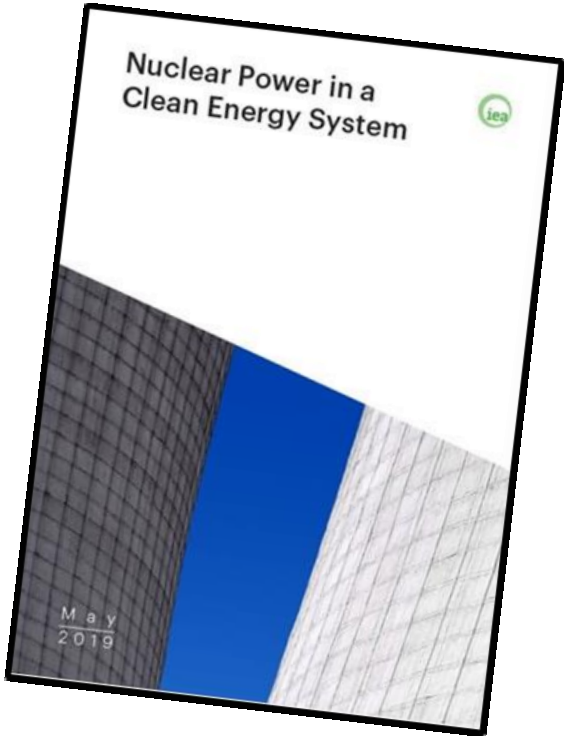
The Challenge Before Us

- Need to bridge the gap between:

  Increasing worldwide demand for energy and needs of countries with great poverty

  and

  Urgency to manage environmental impacts and achieve climate change goals



- No single energy solution; clean, reliable nuclear energy must be part of the mix to enable renewables

- International Energy Agency report May 2019

  "***A sharp decline in nuclear in advanced economies would mean a substantial increase in investment needs for other forms of power generation… Around USD 1.6 trillion in additional investment would be required in the electricity sector in advanced economies from 2018 to 2040.***"

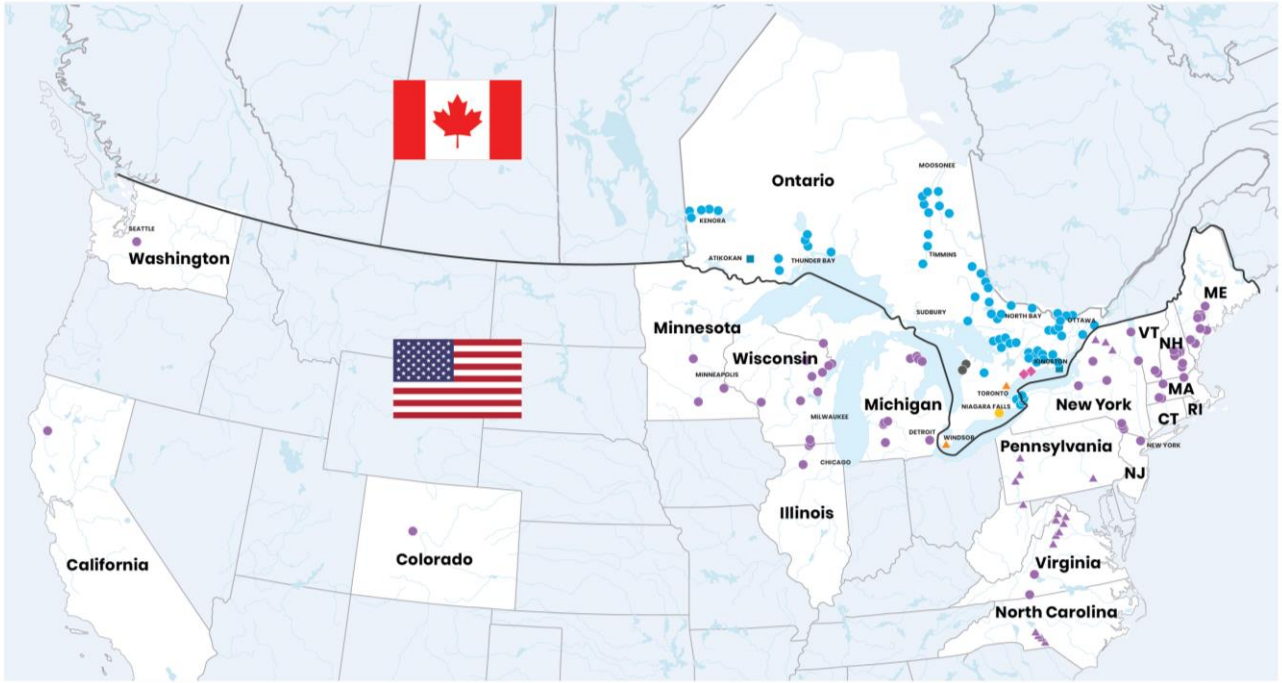
The Canadian Perspective

- Nuclear enables Canada to achieve environmental, climate change, social and economic goals
  - Nuclear = 15% of electricity generation in Canada; 60% in Ontario
  - A key reason Ontario no longer uses coal

- Clean, greenhouse gas-free, reliable energy
- Reduces reliance on fossil fuels (diesel, coal)
  - Climate change goals will require provinces to reduce/eliminate coal
- Complements well with existing energy mix, enables renewables
- Opportunity to support on and off-grid energy needs through advanced, adaptable technologies (like small modular reactors)

50 years of safe, nuclear generation in Canada:
expertise and technical depth, existing supply chain, infrastructure

Ontario Power Generation



2 **Nuclear** Stations

2 Leased **Nuclear** Stations

2 **Thermal** Stations

2 Co-Owned **Gas-Fired** Stations*

1 **Solar** Facility

66 **Canada Hydroelectric** Stations

65 **U.S. Eagle Creek RE Hydroelectric** Stations

19 **U.S. Cube Hydro Hydroelectric** Stations

16,295
Megawatts
In-service generating capacity

90% +
Free
Of smog and carbon emissions

40%
Average
Lower cost than power from other generators

9,300 +
Skilled
Employees supporting Ontario's economy

Or this one?

OPG – Who We Are

- Ontario's largest clean energy generator - over 16,000 MWe installed capacity; more than 9,000 employees
- Produces about half of the electricity used in the province of Ontario
- Clean energy portfolio includes: hydro, nuclear, solar, with gas plants for peaking, enabling renewables and further electrification
- More than 90% of generation is free of carbon emissions
- In 2014, OPG closed Ontario's last coal plant; coal closure is the largest single action to combat climate change in the world to date
- A century of experience in hydroelectric generation; 50 years of safe and reliable nuclear power

Environmental Assessments-Hydro

Completed

- Wawaitin
- Sandy Falls
- Lower Sturgeon
- Hound Chute
- Mattagami Lake Da
- Peter Sutherland(New Post Creek)
- Lower Mattagami- Kipling, Harmon, Smoke Falls

In construction:

- Ranney

EA Underway

- Calabogie and Coniston

Environmental Assessment

Gull Bay Micro-grid

- Gull Bay First Nation's Reserve (2 ½ hr north of Thunder Bay
- First of its kind in Canada
- Micro grid provided 40% of the community's electricity needs (35,817kWh)
- Operated in diesel off mode for 28 of the 31 days in August (total of 232 hours)
- Equates to reducing diesel use by approximately 9450 liters for the month of Aug.
- reducing emissions by 31 Tonnes CO2eq. (for the month of August)

Environmental Assessment

Nanticoke Solar:

- 44 MW
- In-service March 2019
- Number of panels ~192,000
- Footprint 260 acres.

Environmental Assessment

Ranney Falls

- A state-of-the-art new generating station with a new 10MW horizontal Eco-Bulb unit (G3), having sluicing operation capacity of 120m^3/s
- A state-of-the-art remotely operated new spillway with a discharge capacity of total station flow of 172m3/s
- Expanded forebay and tailrace channels, accommodating the G3 & spillway operations
- Expanded switchyard, accommodating new unit connecting to the 44kV distribution line
- Rehabilitation of the existing Forebay Intake structures
- Decommissioning of the existing G3 substation

Environmental Assessment

Ranney Falls

Canada's SMR Roadmap

- *"A Call for Action: A Canadian Roadmap for Small Modular Reactors"*
- Collaborative report developed by industry representatives, utilities, all level of governments
- Outlines potential applications, framework for SMR deployment in Canada
- Released November 2018; just the start of the conversation

> *"...Canada is uniquely positioned to lead the world on SMRs. We have experienced nuclear power plant operators— leaders such as New Brunswick Power, Ontario Power Generation, and Bruce Power — who have the know-how needed."*
>
> Honourable Amarjeet Sohi, Canada's Minister of Natural Resources, Nov 2018

Potential Applications in Canada

1. On-grid power

(150 to 300 MWe)

Competitive option for replacement of coal-fired generation

2. Heavy industry

(10 to 80 MWe)

SMRs could reduce mine energy costs by 20-60%

3. Remote communities

(1 to 10 MWe)

Longer-term market; over 70K communities internationally

What are Small Modular Reactors (SMRs)?

- Smaller in size than a traditional reactor; based on the same science
    - Use fission to create heat energy
    - Both use uranium fuel (SMRs – enriched; CANDU - natural uranium)
- Range from community scale (< 1 MW) to utility scale (~300 MW)
    - Some are scalable (modular) up to about 1000 MW
- Based on technology that has existed around the world for 50+ years
    - 1950s – US Atomic Energy Commission
    - 1960s/70s – Chalk River Nuclear Power Demonstration, McMaster university, Royal Military College
    - Internationally in marine vessels (submarines, aircraft carriers, icebreakers)

Range from <1MW to ~300 MW
For comparison: Pickering Nuclear - 515 MWe per unit;
Darlington Nuclear: 885 MWe per unit

Why SMRs? Proposed Advantages

- Safety:
  - Enhanced safety features (passive safety)
  - Increased safety margins
  - Some designs underground, enhancing security
- Simpler:
  - Modular designs
  - Reduced project schedules
  - Fleet-based approach to control cost and project schedule
- Adaptable:
  - Load-following source of electricity (match load to demand) *[important one!!]*
  - "Scale-to-fit" approach (modules can be added)
  - Generate heat for uses beyond just electricity
- Environment:
  - Clean energy producing no smog or greenhouse gas emissions
  - Some technologies claim ability to burn-up used nuclear fuel (reduce waste volume)
- Cheaper:
  - Lower up-front capital investment
  - Economies of modularity
  - Lower staffing profile
  - Factory constructed
  - Economies of scale (standardization of design, construction and operation)
- Enabler for other energy sources:
  - Can be integrated with other forms of energy (hybrid nuclear-renewables)
  - Produce clean fuel for battery charging or hydrogen for transportation

Environmental Assessments
Lessons Learned

- A planning tool to ensure adverse impacts from a project are identified, avoided, mitigated and managed
- Iterative Process
- Increasing importance for more than the traditional science relating to air, water land
- Consultation with Indigenous communities and stakeholders increasingly important
    - First nation participation
        - partnerships
        - field work ;
        - TEK
- Increasing post EA monitoring and reporting
- EA and Construction permits –two sides of the approvals coin

Lessons Learned

Renewables versus SMR

Aspect	Renewable	smr
Diversified fuel mix	X	X
Small scale	Can be both	Can be both
Flexible scalable	X	X
Minimize footprint	range large to small	X
Reuse of existing infrastructure	X	X
Regulatory oversight	medium	Same as large nuclear very complex
Number of regulators	Several	Few but intense
Proponent driven	Can be both	Federal Driven CNSC
Indigenous Consultation	X	X

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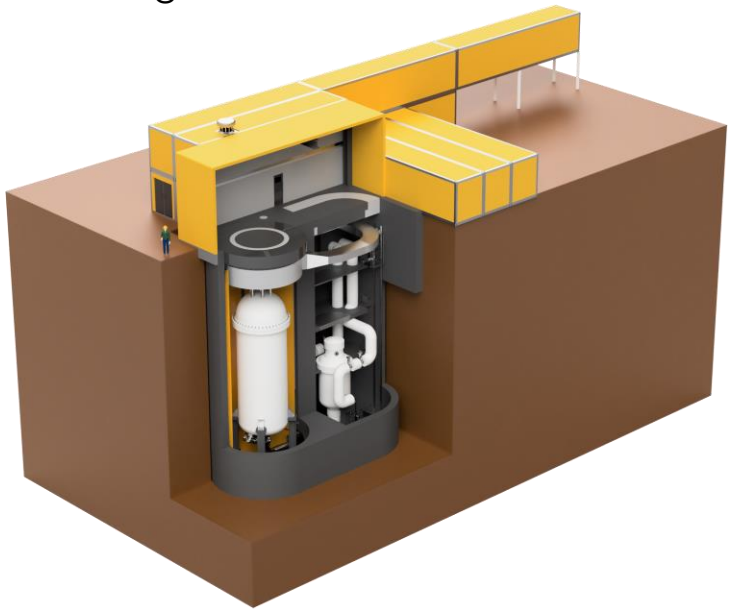
Additional info

SMR at Canadian Nuclear Laboratories

- OPG engaged with Global First Power proposal for SMR commercial demonstration unit at Chalk River
  - Proposed 15-MWt (approx 5 MWe) high-temperature gas reactor
- First submission to advance to Phase 3 of CNL's review process
- Application submitted to CNSC for Licence to Prepare Site; first-ever SMR regulatory application in Canada
- Environmental Assessment has begun
  - Indigenous and stakeholder engagement
  - Environmental and technical studies
- A model for future SMR support for heavy industry

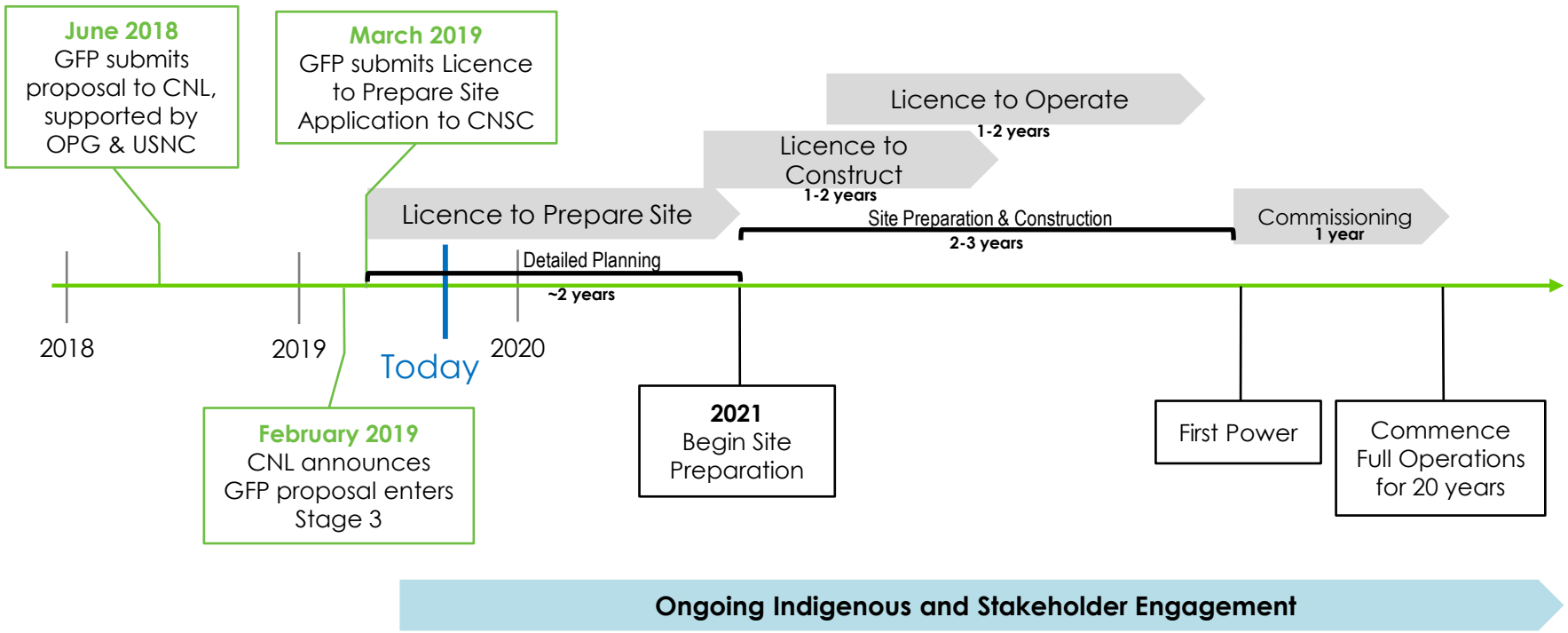


Micro Modular Reactor™ Technology

- Designed by Ultra Safe Nuclear Corporation (USNC)
- Designed for heavy industry or remote communities (does not require grid connection)
- Generates high quality heat; to generate electricity or other heat applications
- Advanced safety systems are inherently built into design
- No requirement for electrical power or water to operate safely or shut down reactor
- Constructed, commissioned and tested off-site; assembled on site
- Minimal operations and maintenance requirements
- Scalable/modular – modules can be combined for different sites/energy needs

Project Activities & Milestones

(Planning Purposes Only)



Project Goals

- Demonstrate the benefit of SMRs as part of the solution to achieve climate change and environmental goals
- Demonstrates the value of SMRs as a cost-effective option to help solve energy challenges for heavy industry
- Support confidence in:
  - Project business model
  - Commercial model for potential market
  - Licensing and regulatory precedent
  - Technology
  - Project delivery including cost, schedule and operational performance
  - Long-term cost of power
- Potential launch pad for export opportunities
- Ultimately, enables future projects