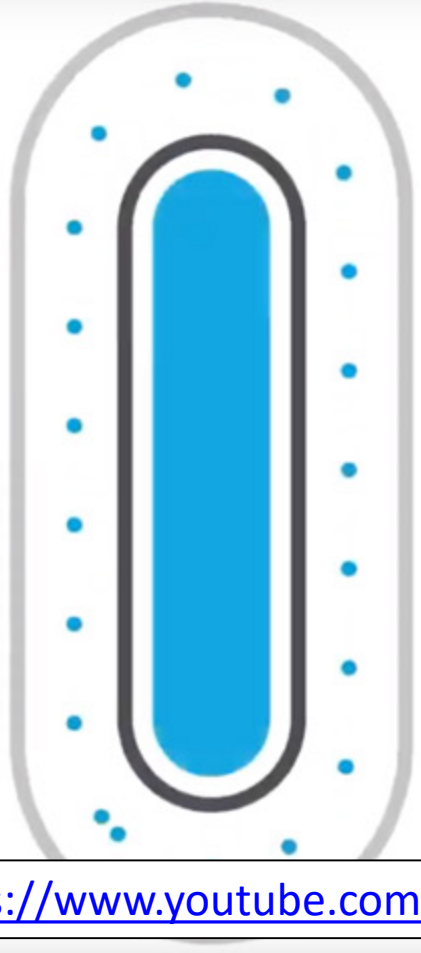

SMALL MODULAR REACTORS (SMRs)

https://www.youtube.com/watch?v=wsfrYpfmpWI

Natural Resources Canada | Ressources naturelles Canada

Small Modular Reactors for Mining




Diane Cameron | Director, Nuclear Energy Division
Natural Resources Canada, Government of Canada

Saskatchewan Mining Supply Chain Forum
April 4, 2019 ▪ Saskatoon, Saskatchewan

Canada

Outline

1. Nuclear Energy in Canada

2. Canada's Nuclear Energy Supply Chain

3. Small Modular Reactors (SMRs)

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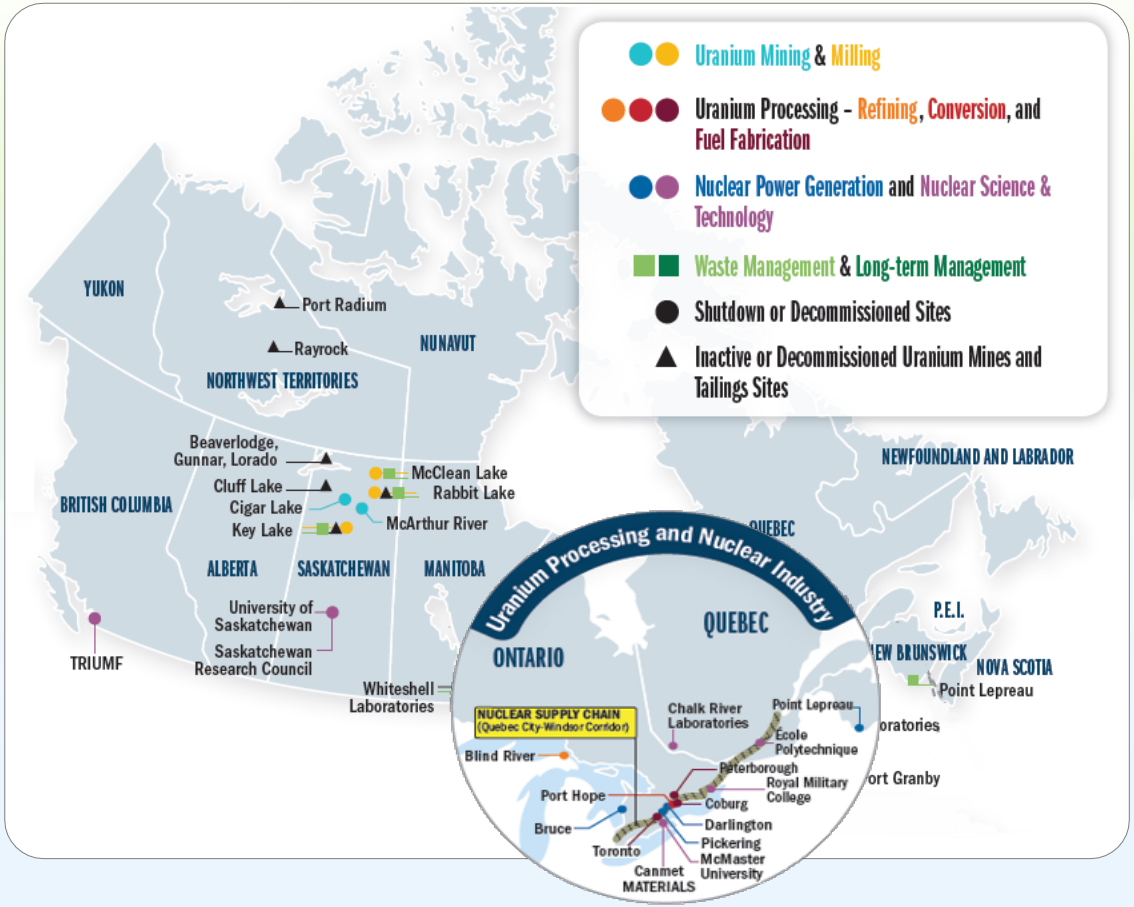
Nuclear Energy in Canada

Canada

Canada's nuclear sector has a pan-Canadian footprint



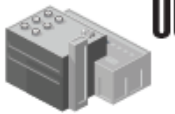
And a full-spectrum nuclear supply chain

1

20% of the world's production of uranium is mined and milled in northern **Saskatchewan.**

3

At Port Hope, Ontario, uranium trioxide is converted.



URANIUM TRIOXIDE UO_3

CONVERSION

URANIUM DIOXIDE UO_2

UF_6 URANIUM HEXAFLUORIDE

UO_2 is used to fuel **CANDU nuclear reactors.**

UF_6 is **exported for enrichment** and use in foreign light water reactors.

5

19 CANDU reactors at
4 nuclear power generating stations
7th globally in nuclear power capacity

CANDU REACTOR

CANADA'S ELECTRICITY — SUPPLYING **15%**

NEW BRUNSWICK (Point Lepreau)

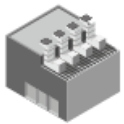
ONTARIO (Bruce, Pickering, Darlington)

supported by a stable domestic supply chain in southern Ontario and across Canada

URANIUM MINING AND MILLING → **REFINING AND CONVERSION** → **FUEL FABRICATION** → **NUCLEAR POWER GENERATION** → **WASTE MANAGMENT**

2

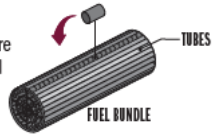
Yellowcake is refined at Blind River, Ontario, to produce uranium trioxide.

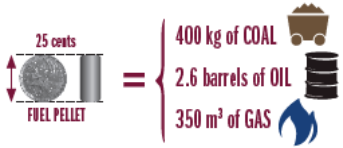


U_3O_8 YELLOWCAKE — REFINING → UO_3 URANIUM TRIOXIDE

4

At plants in southern Ontario, fuel pellets are loaded into tubes and assembled into fuel bundles for CANDU reactors.





6

Radioactive waste is produced throughout the nuclear fuel cycle and safely managed in licensed storage facilities:

High-level waste - Nuclear fuel waste **HLW**

Low and intermediate-level waste **L&ILW**

Uranium mine and mill tailings waste **UMMT**

Reinforced Concrete Containers

Initiatives underway for long-term management of radioactive waste include:

- Deep geologic repositories – suitable for all waste categories;
- Near-surface mounds – suitable for LLW and some ILW; and
- Tailings management facilities – specially designed for taillings.

All in keeping with internationally accepted approaches and best practices

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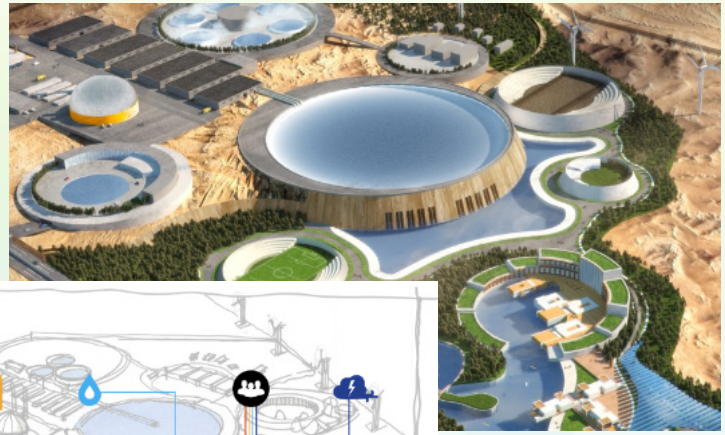
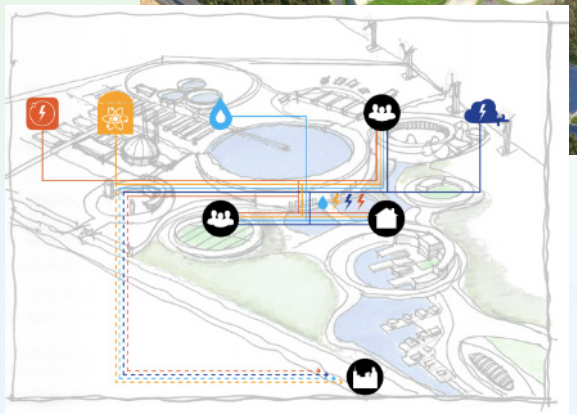
Small Modular Reactors

Canada

Markets are signalling demand for smaller, simpler, and "hybrid" nuclear technologies...





Artwork courtesy of Third Way

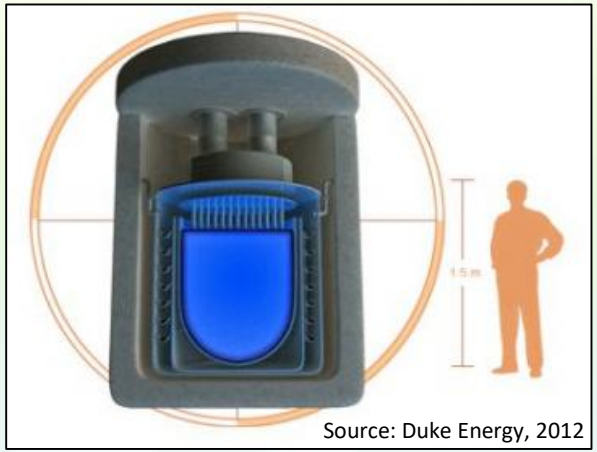
- Nuclear energy needed to meet climate change targets—IEA projects it **must double by 2040** to meet a 2 degree scenario.
- The **future of nuclear** is SMRs – smaller, simpler, safer and cheaper than full-scale nuclear power
- **New applications** for SMRs, such as load-following renewables, hybrid systems and energy parks
- **Fleet approach** – using the same design for several reactors – increases value proposition
- **Hybrid energy systems** integrate multiple energy sources to increase efficiency and allow for dynamic load-following
- **SMRs paired with variable renewables** could enable higher penetration of variables on a decentralized grid

...and industry is innovating.

What is a Small Modular Reactor?

Small

- Small in size and power output relative to conventional nuclear power reactors
- Some SMR designs are small enough to fit in a gymnasium, others are larger but still smaller than today's reactors



Source: Duke Energy, 2012

Modular

- Manufactured in factories and transported to site for lower capital costs as well as ease of installation, operation, and removal

Reactor

- SMRs use nuclear power, a non-emitting and efficient way to generate electricity
- Some SMR designs also provide district heating, heat for year-round greenhouses, desalination, and water purification
- Next generation SMR are designed for simplified ("passive") safety and proliferation resistance

Small modular reactors are nuclear *re-imagined*…

Data Centre

Remote Community

Industry

Catalyst for Clean Growth

There are three distinct markets for SMRs 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

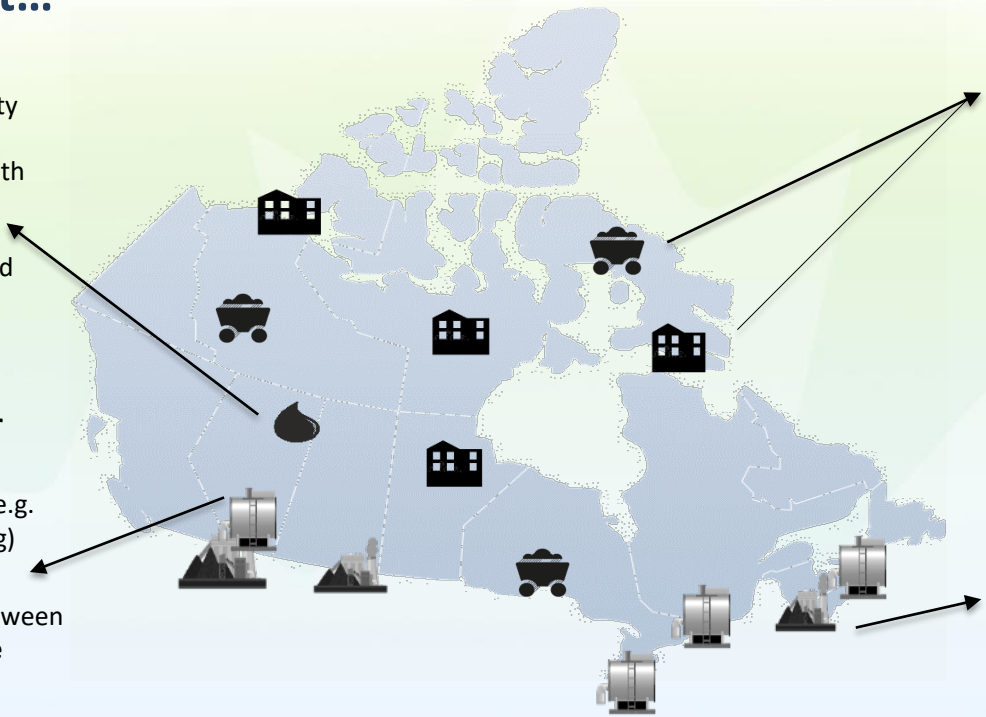
An SMR sub-sector is emerging in Canada, with an eye to a pan-Canadian domestic market…

Oil sands

- Steam for SAGD and electricity for upgrading at **96 facilities**
- 210 MWe average size for both heat and power demands
- 5% replacement by SMRs between 2030 and 2040 could **provide $350-450M in value annually**

High-temperature steam for heavy industry

- 85 heavy industry locations (e.g. chemicals, petroleum refining)
- 25-50 MWe average size
- 5% replacement by SMRs between 2030 and 2040 could **provide $46M in value annually**



Remote communities and mines

- 79 remote communities in Canada with energy needs > 1 MWe
- SMRs replacing costly diesel and heating oil could **reduce energy costs to the territorial government**
- **The high cost of energy from diesel is a barrier. SMRs could facilitate and enable new mining developments**
- 24 current and potential off-grid mines

Replacing conventional coal-fired power:

- 29 units in Canada at 17 facilities
- 343 MWe average size
- 10% replacement by SMRs between 2030 and 2040 could **provide $469M in value annually**

Bottom line: SMRs could conservatively yield **$5.3B in total value** between 2030 and 2040.

Canada's Small Modular Reactor Roadmap

SMRs as a source of safe, clean, affordable energy — opening opportunities for a resilient, low-carbon future and capturing benefits for Canada and Canadians.

www.smrroadmap.ca

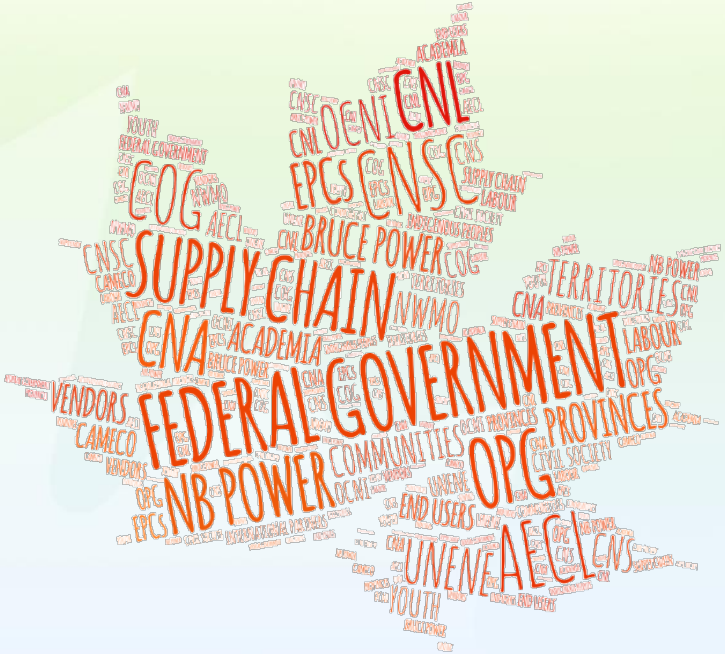
Government of Canada is taking action on key priorities for 2019…

- ✓ **Mining:** focused engagement with mining sector on end-user requirements, taking steps to foster strategic partnerships
- ✓ **Indigenous engagement**: preparing ongoing engagement strategies in partnership with Indigenous peoples
- ✓ **Global enabling frameworks**: active engagement and leadership in key fora (CEM, NEA, IAEA); validating size and pathways to global deployment
- ✓ **Strategic bilateral partnerships**: collaboration with other international leaders on SMRs (US, UK)
- ✓ **SMR demonstration:** project evaluation progressing across multiple markets (on-grid, off-grid, mining)

Partnerships will be key to success

Roadmap called for “**Team Canada**” to come together with concrete commitments for action.

The **Pan-Canadian supply chain** is an important partner.



Recommendations for action

The SMR Roadmap contained over **50 recommendations** for all essential enablers—

Including **two recommendations for the Canadian supply chain**.

Recommendations for the Canadian supply chain:

1. *Organization of Canadian Nuclear Industries (OCNI) should lead on a **transition strategy for retooling** the Canadian nuclear supply chain.*
2. *Industry should develop and **advance initiatives with a view to reducing SMR capital costs** (e.g., advanced manufacturing).*

OCNI is stepping up!

- Meet supply chain partners at OCNI's Advanced Manufacturing Seminar and Exhibit
- A direct follow-on to the Canadian SMR Roadmap

Thank you!


Canada