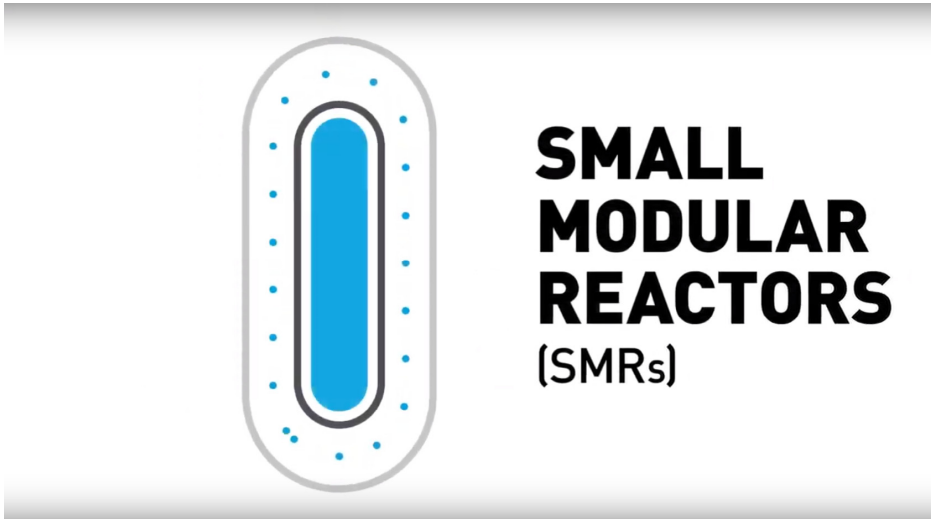

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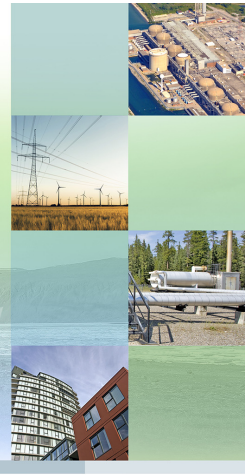
Nuclear Energy & Small Modular Reactors

Jean-Philippe Davignon
Embassy of Canada to Japan, Government of Canada

Association of Atomic Energy of Japan (AESJ) Annual Meeting
March 21, 2019 ▪ Ibaraki University, Japan



Canada

Outline

1. **Context**
   - *A Canadian Perspective on Energy*
2. **Nuclear Energy in Canada**
   - *A Strategic Asset*
3. **Small Modular Reactors (SMRs)**
   - *Canada's SMR Roadmap*

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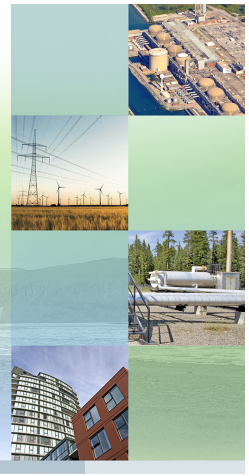
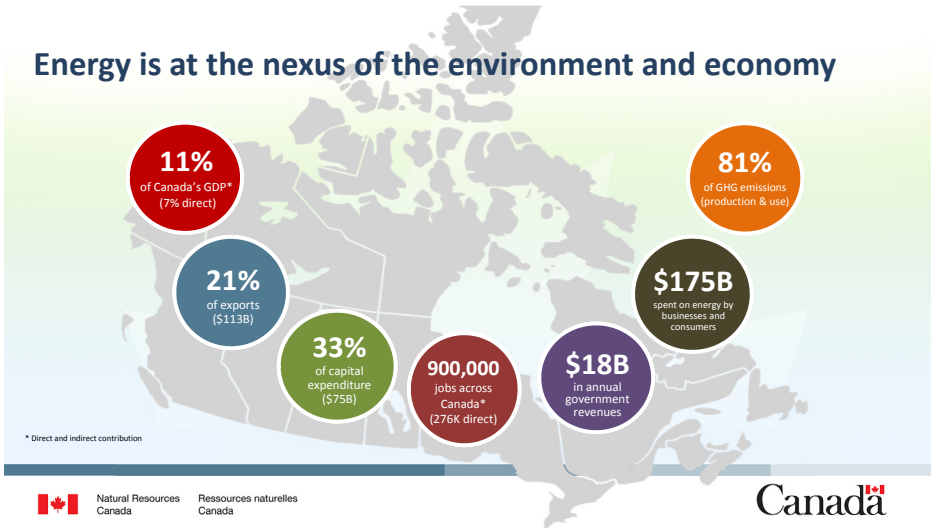
A Canadian Perspective on Energy



Canada

Energy is at the nexus of the environment and economy



* Direct and indirect contribution

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Canada

Canada is a global energy leader with world-class assets and expertise…

Hydro
- 2nd largest hydro producer
- 59% of Canadian electricity

Renewables (e.g. wind, solar)
- 9th in wind power capacity
- 10-fold growth in solar capacity since 2010
- 8th in liquid biofuels

Energy efficiency
- Saved Canadians $38B in energy costs in 2015
- Avoided 95 Mt of GHG emissions

Nuclear
- 2nd in uranium production
- Tier 1 Nuclear Nation
- Own nuclear reactor technology (CANDU)

Crude oil
- 4th largest producer
- 3rd largest proved reserves

Energy innovation
- $2.2B invested in energy RD&D
- 56,000 employed in clean energy
- 1st in G20 on potential for new clean tech start-ups

Environmental performance
- From 2000-2016, emissions per unit of energy decreased 13%
- Oil sands emissions per barrel have decreased 29% in the same period

Natural gas
- 4th largest producer
- $7B net exports
- Cleanest LNG in the World

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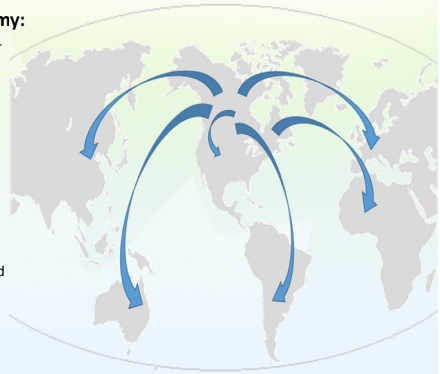
Canada

…and a key player in an integrated global energy market.

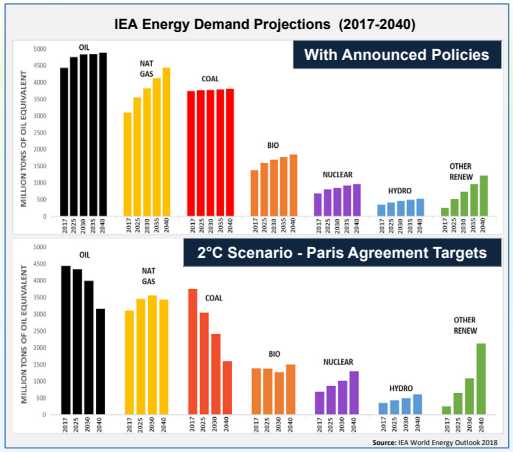
- ✓ **Free trade with considerable share of global economy:**
  - Free trade with countries having combined GDP over US $50T
  - CUSMA, CETA, CPTPP, bilateral free trade agreements
  - Engaging with China and India
- ✓ **Proximity to high-demand energy markets**
  - Asia from West Coast
  - Europe from East Coast
  - Integrated North American network
- ✓ **A leading exporter**
  - In the top five for exports of electricity, uranium, crude oil and natural gas
  - Energy exports worth over $100 billion annually



Committed to strong international partnerships and engagement.

The global energy landscape is changing

- **Growth in energy demand is shifting from OECD countries**
  - India, China, South East Asia are leading growth
- **Decisions around the world will determine which pathway is taken**
  - In the IEA's Sustainable Development Scenario, **to meet Paris Agreement commitments**:
    1. Oil and coal use decline, but fossil fuels remain a large part of the mix
    2. Renewables increase by a factor of four
    3. Nuclear energy generation nearly doubles by 2040



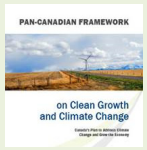
Canada is charting a long-term path toward a low-carbon future

Generation Energy

Four pathways and a pathfinding relationship with Indigenous peoples, to get to a low-carbon future:

- **Wasting less energy** to help Canadians save money and reduce emissions
- **Switching to clean power** and investing in electrification
- **Using more renewable fuels** for use in transportation, industry, and residential sectors
- Innovating to become a world-leading producer of **cleaner oil and gas**

Pan-Canadian Framework



Supported by significant federal investments through:

- Low Carbon Economy Fund **($2B)**
- Green Infrastructure bilateral agreements **($9.2B)**
- Canada Infrastructure Bank **($35B, with $5B** earmarked for green infrastructure)
- Strategic Innovation Fund **($2B)**
- Nuclear innovation **($1.2B)**
- Clean Growth programming **($200M)**

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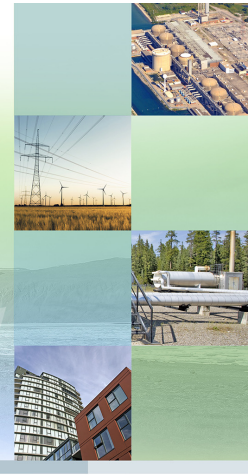
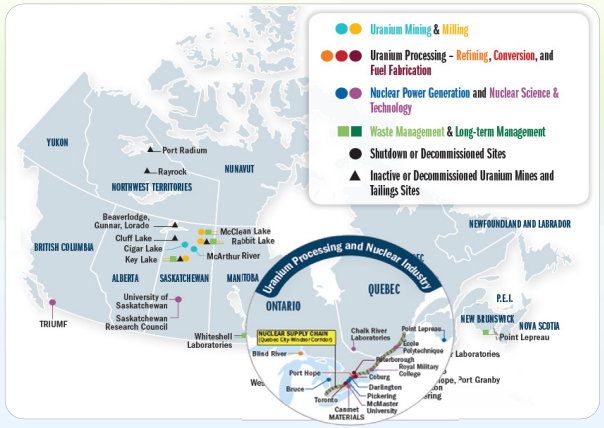
Nuclear Energy in Canada



Canada

Canada's nuclear sector has a pan-Canadian footprint and complete supply chain



… and a strategic asset for Canada.

For 60 years, Canada has leveraged its nuclear leadership for significant strategic, economic, and scientific benefit.

ECONOMIC

- **$6B** to the economy; **30,000 direct jobs**. **$26B investments** to refurbish Ontario's fleet.
- **$1.4B uranium exports** annually; powers **1 in 17 American homes**.
- 19 home-grown CANDU reactors for **15% of Canada's electricity** – 60% in ON, 33% in NB. **30 CANDU reactors** around the world – 5% of global installed capacity.

GEOPOLITICAL

- **Beachhead for strategic international engagement**: bilaterally (US, China, India) and multilaterally (International Atomic Energy Agency, Nuclear Energy Agency).
- **Leadership in nuclear energy innovation**, bolstered by $1.2B to revitalize Chalk River, gives us influence at **nuclear security tables**.

SOCIAL AND ENVIRONMENT

- **2nd largest source of non-emitting electricity in Canada**, offsetting 50M+ tonnes of CO_2.
- Waste management framework is **seen as the gold standard** internationally.

Canada's expertise and supply chain are world-class — *but what's next for nuclear in Canada?*

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Canada

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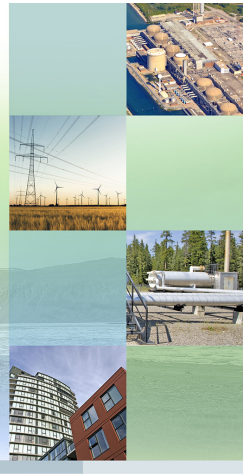
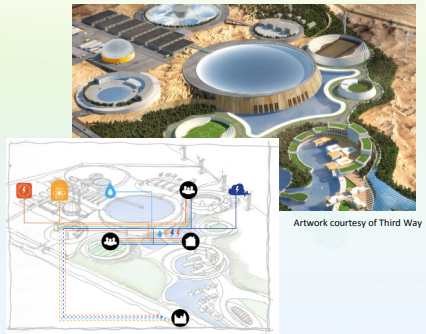
Small Modular Reactors



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.

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Small modular reactors are nuclear *re-imagined*...

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Canada

Canada's SMR Roadmap:

The focal point for developing Canada's SMR policy framework

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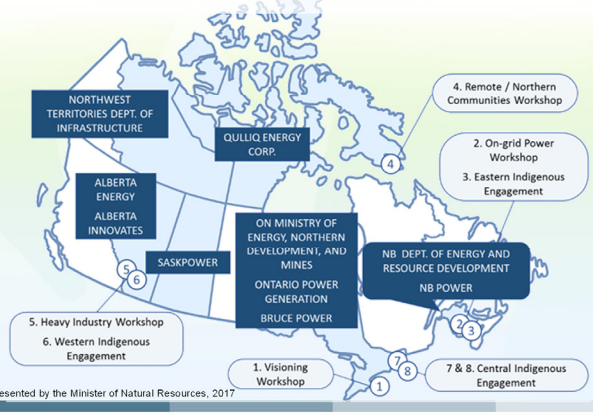
Canada

We took a national approach to engagement…

NRCan-convened, stakeholder-driven:

- ✓ **Nov 2017 – Sept 2018**
  - ➢ Extensive engagement
  - ➢ Analysis by experts
- ✓ **Collaborative, innovative leadership**
  - ➢ Provinces, Territories
  - ➢ Power Utilities
- ✓ **8 workshops across Canada**
  - ➢ 55 organizations
  - ➢ 10 sectors/subsectors
  - ➢ 180+ participants
- ✓ **5 expert working groups**
  - ➢ 18 organizations



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

Canada's SMR Roadmap:

Key Findings

BENEFITS FOR CANADA

We heard that SMRs are an innovation story with a range of potential benefits for Canada…

ECONOMIC

✓ **Thousands of jobs**	*…robust Canadian supply chain supporting high-skill labour force*
✓ **Centre of the export market**	*…Canadian power utilities leading the market as global SMR operators*
✓ **Cutting edge research**	*…CNL providing services as an international hub, helping to anchor the emerging high technology subsector in Canada*
✓ **Leadership in mining sector**	*…Canadian mining companies deploying SMRs in domestic operations, and leverage their networks to access export markets*

GEOPOLITICAL

✓**Policy expertise**	*…Canada as a Tier 1 SMR nation, with a strong international brand, strengthening Canada's position in international relations*
✓**Globally-recognized regulator**	*…CNSC as a standards-setter to influence international frameworks and enable export markets for technologies anchored in Canada*

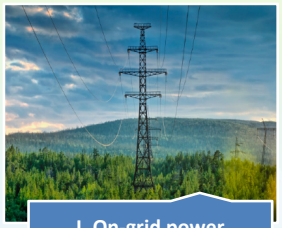
SOCIAL AND ENVIRONMENT

✓**Reduce GHG emissions**	*…deployment of SMRs in Canada across several markets, displacing GHG emissions and increasing energy security*
✓**Regional growth**	*…New Brunswick leading on specific advanced SMRs; Saskatchewan exporting uranium; Ontario providing advanced manufacturing to the world*
✓**Constructive partnerships**	*…Northern and Indigenous communities and SMR industry demonstrating engagement and partnership best practices*

Action now could lead to deployment and benefits for Canada by 2030.

ECONOMICS

There are three distinct markets for SMRs in Canada and the global export market



I. On-grid power (150 to 300 MWe)

II. On- and off-grid heavy industry (10 to 80 MWe)

III. Off-grid communities (1 to 10 MWe)

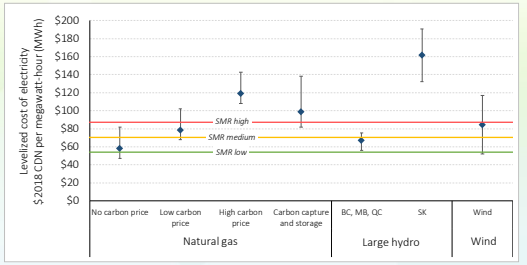
ECONOMICS

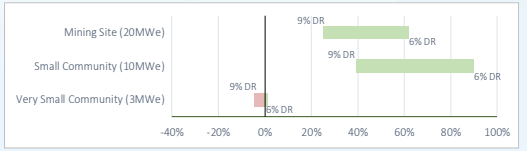
SMRs could be a competitive option in all three markets

I. On-grid power (150 to 300 MWe)
- SMRs are expected to be competitive with alternatives, including wind, large hydro and natural gas

II. On- and off-grid heavy industry (10 to 80 MWe)
- SMRs could reduce energy costs by 20-60% for off-grid mine sites

III. Off-grid communities (1 to 10 MWe)
- **Small communities (10 MWe):** a viable option for communities seeking a competitive, reliable alternative to diesel
- **Very small communities (3 MWe):** costs similar to incumbent technologies, and offer other advantages (e.g. energy security)





ECONOMICS

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**

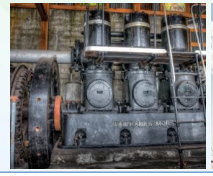
Bottom line: SMRs could conservatively yield **$5.3B in total value** between 2030 and 2040.

ECONOMICS

…and an immense global SMR opportunity driven by climate change mitigation and energy security imperatives.

Replace coal-fired power generation
- SMRs can further transition the power sector away from coal
- Even in a 2-degree scenario IEA projects 1100 GWe
- Potential market **over $100B/year**

Remote island nations and off-grid communities
- Large potential in over 70k communities
- **$30B/year market**



Heat and power for mines
- SMRs powering of new mines between now and 2040 could yield total global value of **$3.5B/year market**

Steam for heavy industry
- Potentially **$12B per year global market**. Joint project from Idaho NL and NREL identified 850 facilities where SMRs could provide steam for US heavy industry.

Bottom Line: Estimated global value of $150B per year by 2040.

TECHNOLOGY

There are real project options for Canada

- Projects that meet end-user needs are **ready to move forward** in Canada
- There are many technologies with **different risks and rewards**, across all three markets
- Canada is **well-positioned to lead** and capture value

10+ working with the CNSC on pre-licensing vendor design reviews

5+ working with CNL on its siting process

2+ working with NB Power

2+ working with OPG and Bruce Power

Applications submitted through ISED's Strategic Innovation Fund

ENABLING FRAMEWORKS

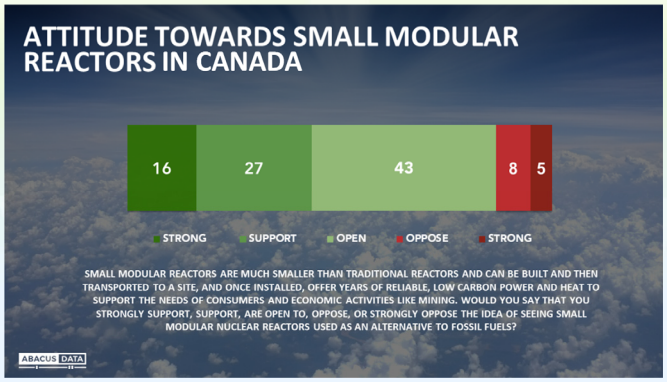
Canada's enabling frameworks are sound and flexible

- Line-by-line review of 150+ pieces of federal, provincial and territorial legislation and regulations, applicable codes and standards
- Frameworks are sound for safety and security, emergency response, nuclear liability, and waste management
- Some refinements are underway to improve efficiencies

Enabling frameworks are ready for SMR deployment in Canada.

PUBLIC CONFIDENCE

Recent public opinion research finds openness to SMRs in Canada



INDIGENOUS ENGAGEMENT

Indigenous engagement on SMRs

- Diversity of backgrounds, views, interests and drivers – **some are open to SMRs, others are not**
- Important historical legacy and strong **need for respect and building trust**
- Indigenous engagement began under the SMR Roadmap – **ongoing engagement will be important**
- Priorities on **building constructive relationships**, including business partnerships and economic development
- Environmental stewardship and long-term effects are priorities – applying a **"seven generations lens"**

Canada's SMR Roadmap:

The Road Ahead

We are 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)

…to leverage Canada's SMR advantage

Beyond technical feasibility, there are six key conditions for success—and **Canada has what it will take to succeed:**

1. **Regulatory:** Independent regulator, open to innovation
2. **Sites:** Leadership in S&T and sites for demonstration
3. **Operators:** Experienced nuclear operators ready to partner
4. **Financing:** Mix of public and private financing
5. **Supply chain:** Full-spectrum supply chain ramped up
6. **Demand:** A strong brand internationally; favourable markets and economics; significant interest for mining

Canada is uniquely positioned to lead.

Effective partnerships are key to success

Domestic – *Team Canada*

- SMR Roadmap called for "Team Canada" to come together with concrete commitments for action
- Government of Canada committed to a team approach bringing together key enablers, leveraging respective roles, resources and responsibilities

CEM10/MI-4 VANCOUVER

International – *Clean Energy Ministerial (CEM)*

- Canada is hosting the **Clean Energy Ministerial** (May 26-29, 2019) in Vancouver
- Canada is hosting the **Generation IV International Forum** on the margins of CEM
- **Bringing nuclear to the clean energy conversation**