Natural Resources Canada | Ressources naturelles Canada

Small Modular Reactors in Canada: From Roadmap to Action Plan

Jean-Philippe Davignon, First Secretary (Energy and Environment)

Presentation to the 15th Research Association of HTGR Plant (RAHP) Annual Symposium | January, 18, 2021

Canada

Outline

- **Context**
  - *A Canadian Perspective on Energy*
- **Our Process**
  - *NRCan convened Canada's SMR Roadmap*
- **Our Progress**
  - *Canada's SMR Action Plan and Premiers' MOU*

CONTEXT

A Canadian Perspective on Energy

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

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

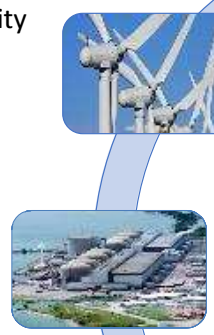
Energy efficiency
- Saved Canadians $38B in energy costs in 2015
- Avoided 95 Mt of GHG emissions

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

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

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

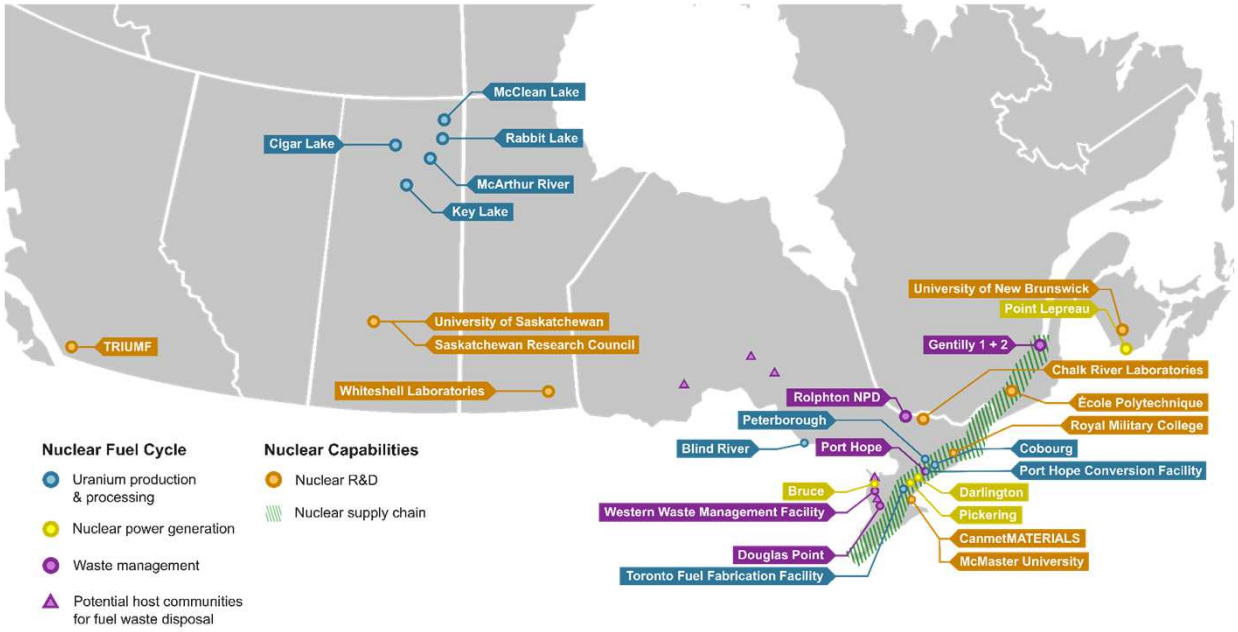


Nuclear
- 2nd in uranium production
- Tier 1 Nuclear Nation
- Own nuclear reactor technology (CANDU)

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

Nuclear energy is a pan-Canadian industry with a complete supply chain…

- Nuclear power **generates 15% of Canada's electricity**, including approximately 60% in Ontario and 38% in New Brunswick
  - Nuclear energy displaces over 50 megatonnes of greenhouse gas emissions every year across Canada, as compared to coal or natural gas
- **Nuclear power stations** operate in Ontario and New Brunswick
- **Mining, refining, and fuel fabrication** in Saskatchewan and Ontario
- **Research reactors** in Ontario and Quebec



… and is a strategic asset for Canada.

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

ECONOMIC

- **$17B** to the economy; **76,000 total 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, 36% in NB. **30 CANDU reactors** around the world – 5% of global installed capacity.

GEOPOLITICAL

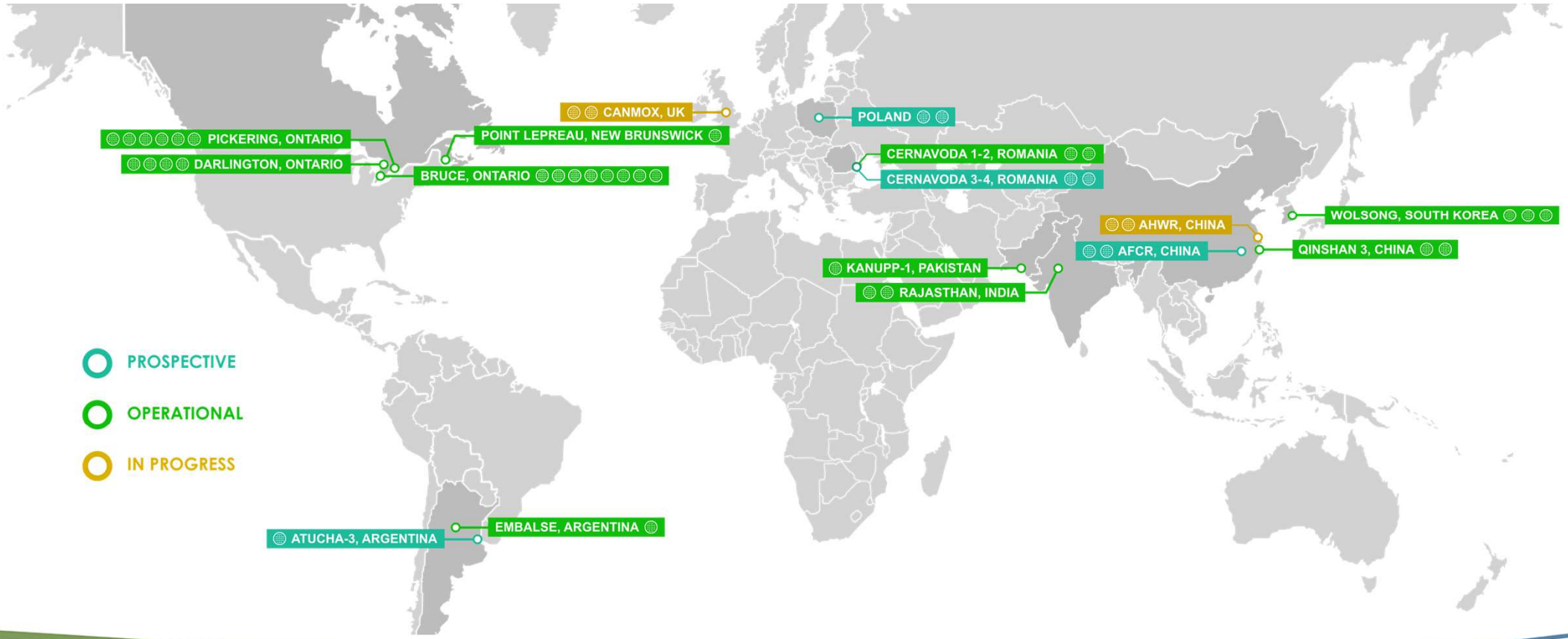
- **Beachhead for strategic international engagement**: bilaterally and multilaterally.
- **Leadership in nuclear energy innovation**, bolstered by $1.2B to revitalize Chalk River, gives us influence at **nuclear security tables**.

SOCIAL AND ENVIRONMENT

- **Canada supplies 50% of world's supply of Cobalt-60**, used for the sterilization of single-use medical equipment**.**
- **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.

CANDU Around the World



Nuclear Innovation: Clean Energy Future (NICE Future) → Highlights from the 10th Clean Energy Ministerial

CEM10/MI-4 VANCOUVER

Record representation in Vancouver:

- ✓ 2500+ CEM participants
- ✓ 200+ nuclear sector participants
- ✓ 15% of Innovation Showcase
- ✓ 15 civil society organizations
- ✓ 14 SMR developers
- ✓ 5+ side events featuring nuclear energy
- ✓ 4 leading nuclear operators (OPG, Bruce Power, NB Power, Exelon)
- ✓ 5 nuclear sector industry associations from around the world (CNA, OCNI, NEI, USNIC, WNA)

Two CEM side events focused on nuclear energy, plus inclusion of nuclear in several other side events.

Events emphasized the important role of nuclear energy globally, as well as Canada's status as a "Tier 1" nuclear nation and a leader in nuclear innovation.

Release of *Breakthroughs*: Nuclear innovation in a clean energy system

A "top 10" book featuring short vignettes on examples of short-term nuclear innovation.

Canadian Premiere of "The New Fire"

A documentary film on SMRs, by Canadian Emmy-award winning film-maker David Schumacher.

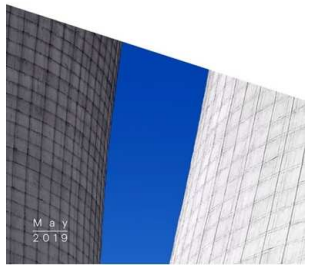
FNC FLEXIBLE NUCLEAR CAMPAIGN FOR NUCLEAR-RENEWABLES INTEGRATION
A CAMPAIGN OF THE CLEAN ENERGY MINISTERIAL

Launch of the *Flexible Nuclear Campaign*

Civil society groups, with support from Canada, the UK and the US, launched a campaign to understand the benefits of nuclear-renewables integration. The Campaign's first report is available here: https://www.nice-future.org/

IEA Report: Nuclear is needed for climate change goals

- Special report on the need for nuclear in global climate policies
  - Launched at the 10th Clean Energy Ministerial in May 2019 by IEA Executive Director Fatih Birol
  - First IEA report on nuclear in 20 years



- Key findings:
  - **Nuclear plant retirements will significantly constrain global efforts to meet Paris targets**
  - Investments in nuclear energy life extensions and new builds make it **cheaper and easier to meet Paris targets**
  - **Not investing in nuclear energy increases risk of failure** to meet targets
  - It will cost an estimated **US$1.6 trillion less to meet targets with nuclear** than without

Bottom Line: IEA recommends including nuclear energy in climate policies and programs, and recommends strong support for nuclear energy, including SMRs

Flexible Nuclear Campaign (Canada, Japan, UK, US) → Technical Report

- First technical report to compile existing research on flexible nuclear operation, launched at the 11th Clean Energy Minister in September 2020.
- Highlights how nuclear energy can effectively integrate into current and future clean energy systems.
- **Key findings:**
  - There is an existing body of knowledge and community of practice that enables flexible operation of the current fleet of nuclear plants;
  - Innovation can increase the flexibility of existing nuclear reactors to produce both clean electricity and nonelectric products; and
  - Advanced reactors, will present even more opportunities for flexibility in nuclear systems.
- Includes contributions from leading research institutions and organizations, including from Japan: Agency for Natural Resources and Energy, Ministry of Economy, Trade, and Industry of Japan, Japan Atomic Energy Agency, Japan Atomic Industrial Forum and Tokyo Institute of Technology

Flexible Nuclear Energy for Clean Energy Systems

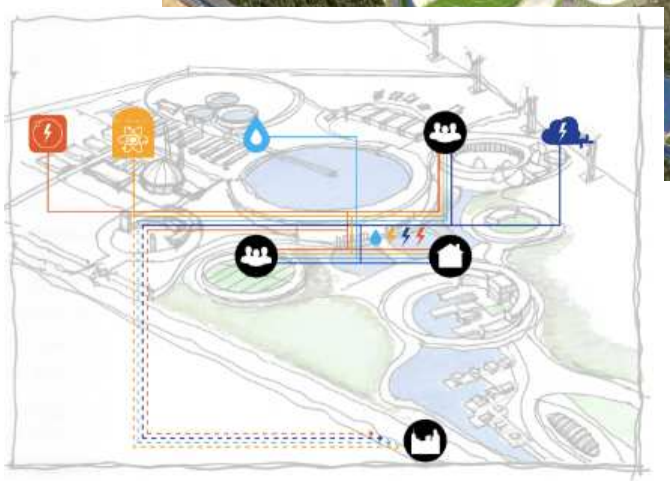
FNC FLEXIBLE NUCLEAR CAMPAIGN FOR NUCLEAR-RENEWABLES INTEGRATION
A CAMPAIGN OF THE CLEAN ENERGY MINISTERIAL

CEM12/MI-6 CHILE 2021

Our Process

NRCan convened Canada's SMR Roadmap

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



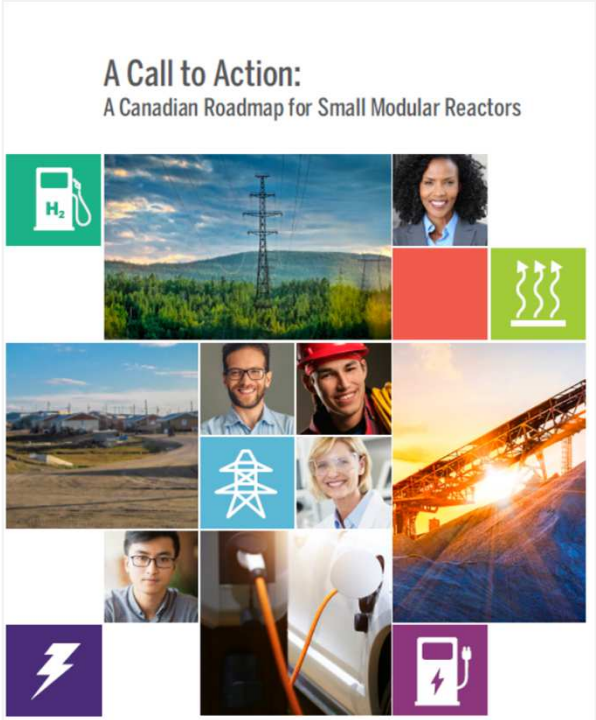
Artwork courtesy of Third Way

- 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.

Canada's SMR Roadmap – The focal point for developing Canada's SMR Policy Framework

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

The Government of Canada co-created the SMR Roadmap with sub-nationals and Team Canada

Northern and Indigenous Communities

AECL

SaskPower Powering the future

Natural Resources Canada

Ressources naturelles Canada

Regulatory

Waste

Bruce Power Innovation at work

Qulliq Energy Corporation
Société d'énergie Qulliq
Qulliq Alruyaktuqtunik Ikumatjutiit

Technology

District Heating

CNSC CCSN

ONTARIO POWER GENERATION

Alberta Energy

Ontario MINISTRY OF ENERGY

nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Supply Chain

Énergie NB Power

ALBERTA INNOVATES

Manufacturing

Next Generation

Canadian Nuclear Laboratories
Laboratoires Nucléaires Canadiens

New Nouveau Brunswick CANADA

Government of Northwest Territories Department of Infrastructure

COG

Heat

Mining

ORGANIZATION OF CANADIAN NUCLEAR INDUSTRIES OCNI Clean Energy for a Low Carbon Economy

cna canadian nuclear association

Steam

Non-Power applications

Heavy Industry

Oil Sands

On-Grid

Off-Grid

Co-Generation

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 by 2030.

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

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**

SMRs could yield up to **$19B in total economic impact** between 2030-2040, creating over **6,000 new jobs annually** across the country.

A potential game-changer for climate change and energy security

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**

HEAT AND POWER FOR MINES

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

REMOTE ISLAND NATIONS AND OFF-GRID COMMUNITIES

- Large potential in over 70k communities
- **$30B/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 to exceed $150-300B per year by 2040.

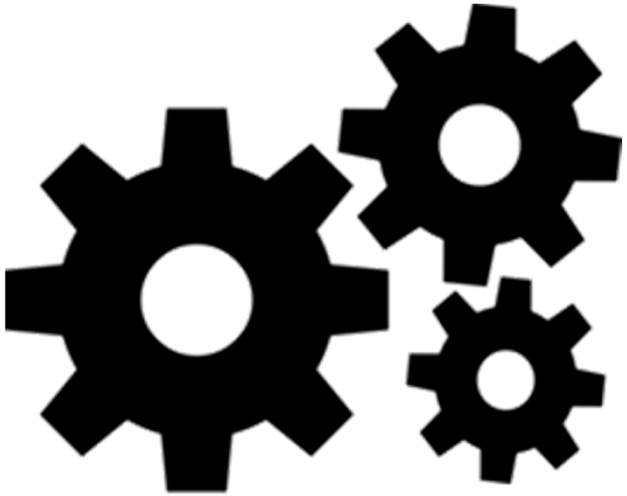
Canada is uniquely positioned to lead

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

1. Regulatory	An independent, world-renowned nuclear regulator open to innovation;
2. Sites	Historic leadership in S&T with suitable sites for demonstration with facilities and expertise;
3. Operators	Several experienced nuclear operators ready to partner;
4. Financing	A mix of public and private financing;
5. Supply Chain	A full-spectrum supply chain including strong engineering, procurement and construction firms and Indigenous businesses ramped up from the $26 billion refurbishments in Ontario, and soon to be looking for new projects;
6. Demand	A strong brand internationally; favourable markets and economics; significant interest for mining; community support and public confidence; and
7. Indigenous Partnerships	Meaningful, two-way engagement and opportunities for benefits-sharing.

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
- The Project List under the *Impact Assessment Act* includes enabling thresholds for SMRs
- Some additional refinements are underway to improve efficiencies



Enabling frameworks are ready for SMR deployment in Canada.

Canada's Energy Advantage: A central hub for global trade…

Preferential Market Access to 2/3 of the Global Economy:

14 trade agreements

51 countries

1.5 billion consumers

$52 trillion USD combined GDP

$2 billion government investment for trade corridors

Source: Global Affairs Canada, Trade and Investment Update 2019

USMCA

A new agreement that protects North America's supply chains

CPTPP

Reaching key Asia-Pacific markets

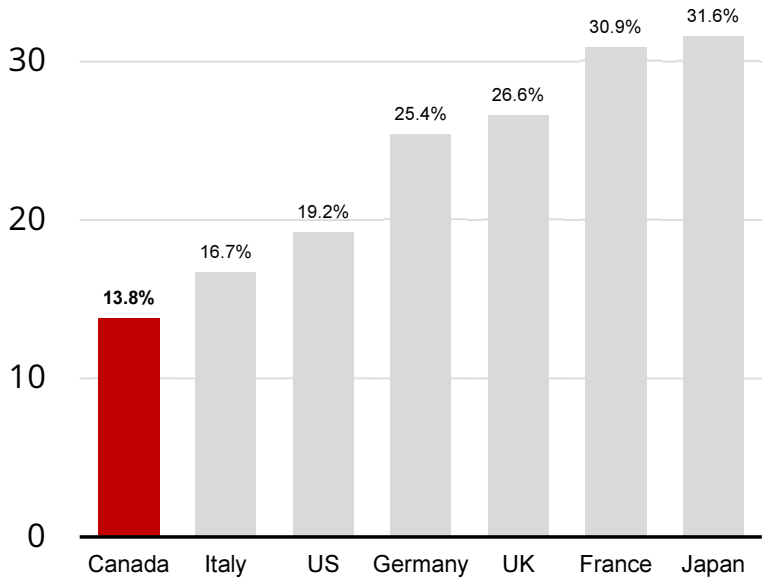
CETA

Access to Europe with a focus on sustainable sourcing and supply

A sound investment climate...

- Canada's banking system ranked 2nd in the world and soundest in the G7
- Lowest business costs in the G7
- First in the G7 and 8th out of 126 countries for ease of investor protection
- Ranked 2nd in the G20 and 5th overall in Forbes' latest 153-country annual study, *The Best Countries for Business*
- Strong intellectual property regime
- Open and transparent government
- Most educated workforce in the world

MARGINAL EFFECTIVE TAX RATE ON NEW BUSINESS INVESTMENT, 2018



Our Progress

Canada's SMR Action Plan

Canada's SMR Action Plan (https://smractionplan.ca/)

- Canada's SMR Roadmap made over 50 recommendations, including that the federal government and partners finalize an SMR Action Plan.
  - In February 2020, Minister O'Regan announced plans to respond publicly:
    - *"To keep the momentum going, this fall, together with our partners from across the country, we will launch Canada's SMR Action Plan – outlining the progress and ongoing efforts across Canada to turn our Roadmap into reality."*

- In December 2020, the federal government launched the SMR Action Plan which features:
  - **Government of Canada chapter** – developed through a whole-of-government approach in partnership with all implicated departments and agencies, outlining federal support and linking to key priorities (e.g. climate, innovation)
  - **109 organizations submitted chapters**, including seven provincial and territorial governments (AB, SK, ON, NB, PEI, YT, NU), power utilities, civil society, industry (nuclear, hydrogen, renewables, mining, oil and gas), academia, and some Indigenous voices
  - Tracks 450 actions to support SMR demonstration and deployment, responding and exceeding Roadmap recommendations

CANADA'S SMR ACTION PLAN

Structure of the Action Plan

- Includes two key elements:

1. **Introductory Statement of Principles**
   - An overarching vision for SMRs in Canada and a shared intention to act
   - Informed by the SMR Roadmap and emerging priorities since the Roadmap
   - The introductory statement of principles will be drafted by NRCan with input from partners

2. **Participant Chapters with Actions and Plans**
   - Each chapter sets out the participant organization's actions and plans, including responses to the Roadmap's recommendations and other planned activities based on progress since the Roadmap
   - Chapters will be drafted by participant organizations and added to the Action Plan

- All essential enabling partners were invited to join the Action Plan, including governments, Indigenous peoples, utilities, industry, academia and civil society

SMR projects are moving forward in Canada

- In December 2019, the Premiers of **New Brunswick, Ontario and Saskatchewan** agreed to work together to commercialize and deploy SMRs.
  - **Alberta** announced its intent to join the agreement in August 2020.
- 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

12 working with the CNSC on pre-licensing vendor design reviews

Vendors working with CNL on its siting process

Vendors working with NB Power

Vendors working with OPG and Bruce Power

Applications submitted through ISED's Strategic Innovation Fund

Projects emerging along three parallel “streams”

Stream 1: *Near Term On-Grid SMRs in Ontario and Saskatchewan*

- Ontario and Saskatchewan pursuing higher-readiness SMRs for faster deployment
- Potential deployment in Ontario by late 2020s, and Saskatchewan by the early 2030s

Stream 2: *Next Generation On-Grid SMRs in New Brunswick*

- New Brunswick pursuing innovative next generation SMRs for its Point Lepreau site and the export market, that would include first-of-a-kind waste recycling technologies
- Potential deployment in the early 2030s

Stream 3: *Off-Grid SMRs for Mining*

- Mining companies signalling interest and carrying out feasibility studies for SMRs to replace diesel
- Licensing application and environmental assessment for demonstration by 2026

World-leading players are moving fast in Canada

Brookfield

SNC·LAVALIN

HOLTEC INTERNATIONAL

ARC ADVANCED REACTOR CONCEPTS, LLC

Westinghouse

TERRESTRIAL ENERGY

AECOM

eVinci™

BWXT

USNC ULTRA•SAFE•NUCLEAR

GLOBAL FIRST POWER

ROLLS ROYCE

HITACHI

urenco

moltex energy safer, cheaper, cleaner

UBATTERY Local Modular Energy

energy

LeadCold

STARCORE NUCLEAR

NUSCALE

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