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ASIA PACIFIC FOUNDATION OF CANADA

FONDATION ASIE PACIFIQUE DU CANADA

MAXIMIZING CANADA'S NUCLEAR ENERGY OPPORTUNITY IN ASIA

PREPARED BY THE ASIA PACIFIC FOUNDATION OF CANADA

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ABOUT THE ASIA PACIFIC FOUNDATION OF CANADA

The Asia Pacific Foundation of Canada (APF Canada) is a not-for-profit organization focused on Canada's relations with Asia. Our mission is to be Canada's catalyst for engagement with Asia and Asia's bridge to Canada. A leader in research and analysis on Canada-Asia relations for over 30 years, APF Canada partners with government, business leaders, academics, and opinion makers in Canada and across the Asia Pacific region to offer clear, specific, and actionable policy advice. Established by an Act of Parliament in 1984, APF Canada's thematic priorities include: promoting trade, investment, and innovation; mobilizing energy assets; building skills and competencies; and understanding Asia now. Visit APF Canada at www.asiapacific.ca

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GLOSSARY

AECL: Atomic Energy of Canada Limited

AERB: Atomic Energy Regulatory Board (India)

ASEAN: Association of Southeast Asian Nations

ASEANTOM: ASEAN Network of Regulatory Bodies on Atomic Energy

CNL: Canadian Nuclear Laboratories

CNSC: Canadian Nuclear Safety Commission

COG: CANDU Owners Group Inc.

DAE: Department of Atomic Energy (India)

HTGR: high temperature gas-cooled reactor

IAEA: International Atomic Energy Agency

IEA: International Energy Agency

INDC: Intended Nationally Determined Contribution

NEA: National Energy Administration (China)

NPCIL: Nuclear Power Corporation of India Limited

PHWR: pressurized heavy water reactor

SCWR: supercritical water-cooled reactor

SME: small and medium-sized enterprise

SMR: small modular reactor

tU: tonne of uranium

WANO: World Association of Nuclear Operators

EXECUTIVE SUMMARY

The global nuclear energy industry is at a crossroads as demand for nuclear energy shifts from North America and Europe to developing Asia. On December 2, 2015, the Asia Pacific Foundation of Canada (APF Canada) convened the *Maximizing Canada's Nuclear Energy Opportunity in Asia* workshop in Toronto to assess the opportunities and challenges facing Canada as it seeks to adjust to this more Asia-focused nuclear energy landscape.

Speakers stressed that nuclear energy has never been more relevant. Countries across Asia face the dual challenge of securing large amounts of energy to develop economically while also reducing carbon emissions that contribute to climate change. Canada has an excellent opportunity to collaborate with Asian countries on nuclear energy technology and services that can achieve these dual objectives safely and economically.

However, workshop participants noted that the nuclear energy landscape is increasingly competitive, especially as many Asian countries are now leaders in nuclear energy technology in their own right. As a result, Canadian nuclear energy technology companies, federal and provincial governments and research institutions need to carefully evaluate where they can add value in competitive Asian markets.

Participants noted that the rapid development of nuclear energy in India and China in particular presents commercial and research opportunities for Canadian companies and research institutions. The following were identified as areas in which Canada has strong synergies with these countries:

- Uranium sales and investment in uranium extraction
- Collaboration on pressurized heavy water technology/R&D
- Small modular reactors (SMRs)
- Collaboration on third market opportunities
- Medical isotopes

In addition to abundant commercial and research synergies, Canada and countries in Asia can work together to further public acceptance or "social licence" for nuclear energy and to enhance nuclear safety across the Asia Pacific. Key areas of collaboration include the following:

- Capacity building and management education on leadership and nuclear safety
- Bilateral and multilateral regulatory lesson sharing
- Emergency response and preparedness mechanism benchmarking
- Implementation of technology for furthering nuclear safety
- Best practices for community engagement on siting nuclear waste storage facilities and for communicating to the public about safe operations and decommissioning of nuclear power plants

While Canada has many strengths to offer countries in Asia, barriers remain on both the demand and supply sides. On the demand side, India and China have highly self-sufficient and low-cost supply chains, making it difficult for foreign companies to compete for business. Some Canadian companies are concerned about the intellectual property risk associated with conducting business in Asian markets. Furthermore, many Canadian companies are opting not to enter the Indian market due to a lack of clarity regarding India's *Civil Nuclear Liability for Nuclear Damage Act*, which may open suppliers to nuclear power plants to unlimited liability in the case of a nuclear accident.

On the supply side, participants recognized that Canada's expertise in pressurized heavy water reactor (PHWR) technology applies only to a small fraction of reactors worldwide. Furthermore, many of the companies in Canada's nuclear energy supply chain are small and medium enterprises (SMEs) that often do not have the financial or human resources to explore Asian markets.

To maximize Canada-Asia cooperation on nuclear energy, participants noted that Canadian federal and provincial governments, together with industry, need to define what they want to achieve through engagement with Asian countries on nuclear energy, not simply respond to the needs of Asian countries. Canada should embed its approach to cooperation within the broader context of its climate agenda, and economic and political interests.

A full set of recommendations for government and industry on how to maximize Canada's nuclear energy opportunity in Asia can be found in Section VIII of this report.

INTRODUCTION

As highlighted at the 2015 UN Climate Conference in Paris, the impetus for reducing carbon emissions has never been greater. A number of countries in Asia, especially India and China, are looking to nuclear energy as a way to meet growing energy demand while also reducing their carbon footprints.

In contrast, North America and Europe are reducing the role of nuclear energy in their plans due to flat energy demand growth projections and public opposition. Of the total nuclear energy generation capacity under construction, only 20 percent is located in North America and Europe.[1]

Within Canada, 18 of the country's 19 operating reactors are located in the province of Ontario. The province has approved refurbishment of 10 of these reactors,[2] but construction of new nuclear reactors has been delayed under the Long-Term Energy Plan, perhaps indefinitely.[3]

On December 2, 2015, the Asia Pacific Foundation of Canada (APF Canada) convened a workshop in Toronto to assess the opportunities and challenges facing Canada as it seeks to adjust to a new reality in which the demand for nuclear energy is shifting from North America and Europe to Asia. The content of this report reflects the workshop proceedings, as well as interviews from a wide range of participants in the Canada-Asia nuclear energy relationship.[4]

The key question for policy makers and the Canadian public is: does Canada's nuclear energy relationship with countries in Asia matter? The answer is "yes" for a number of reasons.

- **Economics**: Canada's nuclear energy industry currently creates 30,000 direct and 30,000 indirect jobs and is estimated to provide $1.5 billion in provincial and federal taxes.[5] The industry needs to access new market opportunities in Asia to ensure its future financial health.
- **R&D collaboration**: Canada has more than 70 years of experience in nuclear energy technology, while many countries in Asia, such as Japan, South Korea, India and China, are either well-established or emerging leaders in nuclear energy technology. Canada can bolster its R&D industry through research partnerships with Asian countries.

- **Government-to-government relations**: The way Canada handles issues related to nuclear energy and non-proliferation can impact our other political objectives abroad. This was demonstrated by the chill in the Canada-India relationship when Canada ceased nuclear energy cooperation with India in the 1970s over issues related to non-proliferation.

- **Commitment to nuclear safety**: As India and China increase their use of nuclear energy to both meet large-scale energy demand and reduce carbon emissions, attention must be paid to nuclear safety. Canada can partner in the provision of technology and expertise in this area.

Canada already engages extensively in Asia on nuclear energy through a number of institutions and mechanisms. This paper focuses on commercial and research opportunities in India and China for Canadian research institutions and nuclear energy technology and services companies. It then shifts focus to discuss how Canada can deepen engagement on social licence and nuclear safety in South Korea, Japan and across Asia.

Ontario's Pickering Nuclear Generating Station

DRIVERS OF NUCLEAR ENERGY GROWTH IN INDIA AND CHINA

India and China are fast growing economies, with large populations. As a result, they consume large amounts of electricity, which is mostly generated from coal. Though nuclear energy has expanded rapidly in each country, it still makes up less than 5 percent of the electricity mix (Figures 1 and 2). China currently has 33 reactors in operation, with a total capacity of approximately 28 gigawatts.[6] India currently has 21 nuclear reactors in operation, with an installed capacity of 5.78 gigawatts.[7] This places China and India fifth and seventh globally in terms of number of reactors.[8]

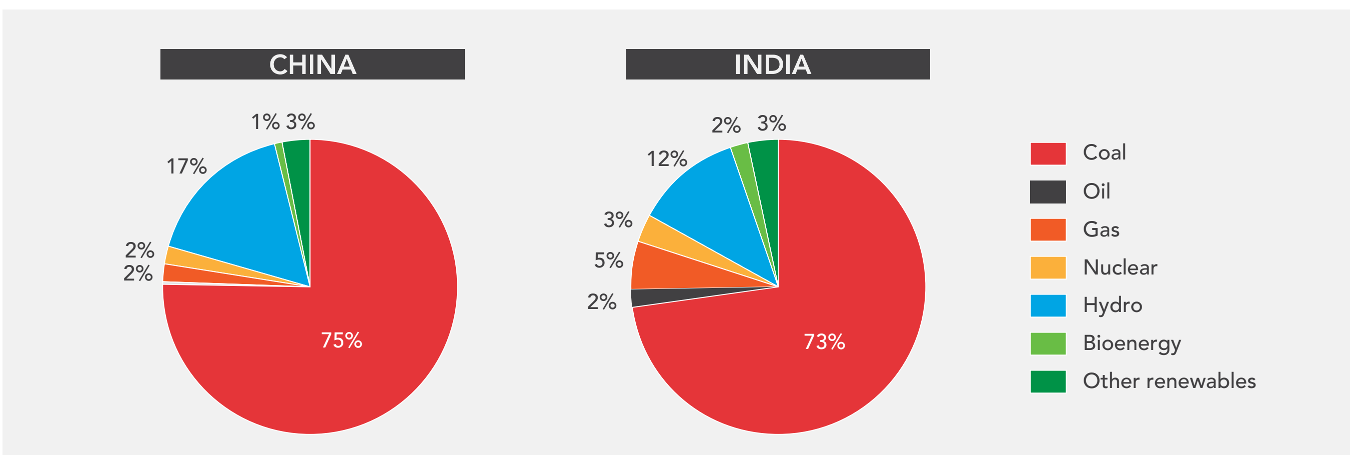


Figure 1. Electricity generation by source in India and China, 2013[9]

However, nuclear energy will play a much larger role in the energy mixes of both countries in the future, as they are implementing large-scale increases in nuclear power generation capacity. India currently has six reactors under construction that will generate an additional 4.3 gigawatts.[10] India aims to have a total installed capacity of 63 gigawatts by 2032, an approximately 10-fold increase from current capacity.[11]

China's nuclear expansion goals are particulary extensive, and the country is now the driver of growth in the nuclear energy industry. China currently has 22 reactors under construction (one third of the global total) with a total capacity of 26.7 gigawatts.[12] According to the *13th Five Year Plan*, nuclear power capacity will approximately double from current capacity to reach 58 gigawatts, with at least 30 gigawatts under construction, by 2020.[13]

China's and India's plans for nuclear energy expansion are driven by a number of factors, including the following:

- **Increasing primary energy and electricity demand**

India and China are expanding nuclear energy to meet large increases in demand for electricity. Under the central scenario in its *World Energy Outlook 2015*, the International Energy Agency (IEA) estimates that electricity demand in India will more than double in the next 25 years, due to high economic growth, urbanization and industrial demand.[14] In the case of China, slowing electricity demand growth rates will still translate into substantial absolute demand growth (Figure 3).[15]

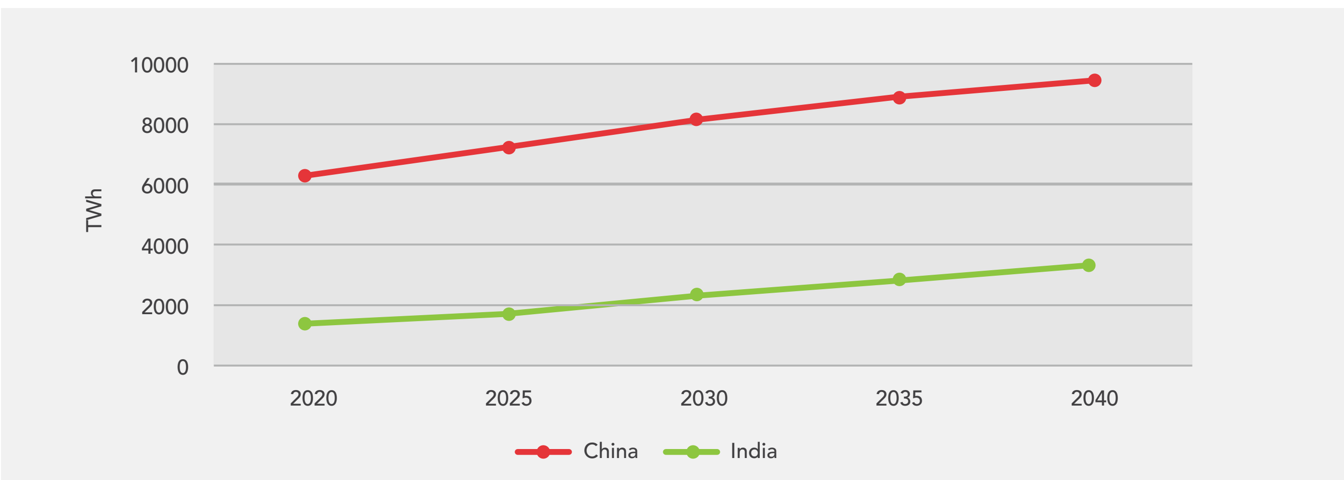


Figure 2. Electricity demand forecast for China and India, 2020–2040[16]

- **Energy security defined as energy self-sufficiency**

Government policy in India and China explicitly aims to increase energy security by reducing import dependence for fossil fuels. India and China rely heavily on imports for oil supply and for one third of natural gas consumption. Nuclear energy acts as an alternative to increasing use of coal and imports of natural gas to meet growing electricity demand.

- **Nuclear technology industry to further economic growth and technological self-sufficiency**

Both India and China have identified nuclear technologies as an important contributor to their domestic economies and aim to continue developing domestic capabilities in this area. For example, in its intended nationally determined contribution (INDC) submission, India noted that it will continue to develop pressurized water reactor, integral pressurized water reactor, advanced heavy water reactor, and fast breeder reactor (FBR) technology.[17] China's *Energy Development Strategy Action Plan (2014-2020)* notes that the country will actively support nuclear energy R&D and the export of nuclear energy technology.[18]

- **Environmental and climate goals**

China and India see nuclear energy as providing a clean, non-carbon-emitting source of energy. Coal use in power generation in India and China is worsening air quality and generating greenhouse gases that contribute to climate change. Cities in India and China have consistently topped the rankings of the world's most polluted cities, as measured by concentration of PM2.5.[19] Beijing issued a "red alert" for air pollution in December 2015, while New Delhi reached a "hazardous" level of PM2.5 concentrations of 497 µg/m3 in November 2015.[20]

China is now the largest absolute emitter of greenhouse gases in the world, accounting for 25 percent of global emissions annually. India is the fourth-largest emitter in the world (6.6 percent of total in 2014).[21]

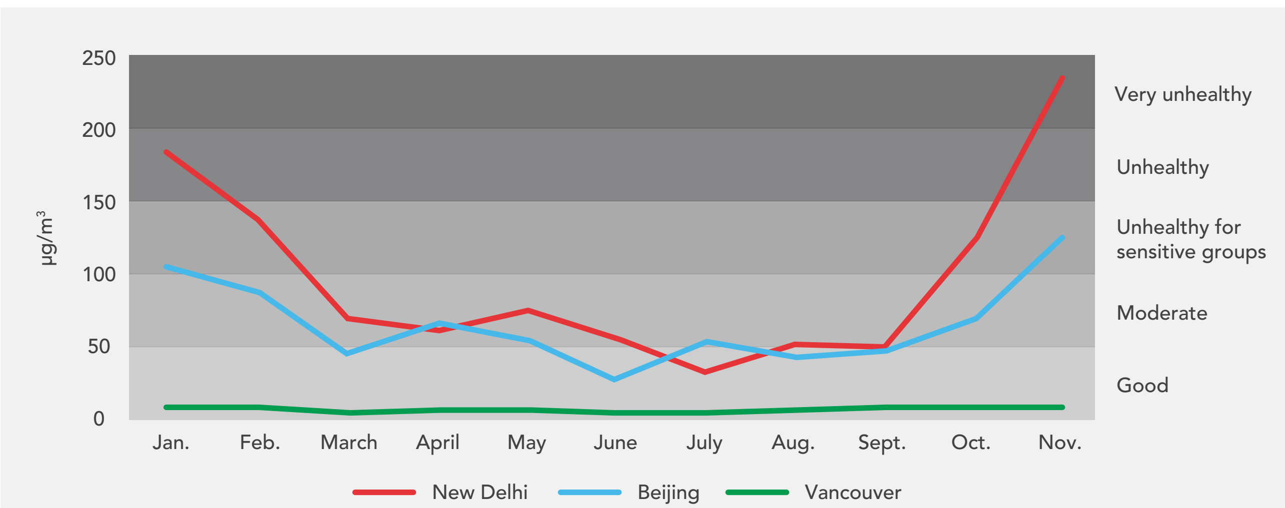


Figure 3. Average PM2.5 levels in Beijing, New Delhi and Vancouver, 2015[22]

India has committed to reducing the emissions intensity of its GDP by 20–25 percent over 2005 levels by 2020.[23] China has committed to a 40–45 percent reduction in emissions intensity by 2020 and a 60–65 percent reduction by 2030.[24] Nuclear energy is an explicit element of both countries' efforts to combat emissions, and targets for nuclear energy growth were included in each country's INDC submitted in advance of the UN climate conference in Paris. In November 2014, in a joint announcement with the U.S. on climate change and clean energy cooperation, China noted that expanding nuclear energy was part of its carbon emission reduction plans.[25]

NUCLEAR ENERGY DECISION MAKING IN INDIA AND CHINA

INDIA

Decision making around nuclear energy in India takes place at the highest levels of government and is almost entirely dominated by the public sector. The Department of Atomic Energy (DAE), headquartered in Mumbai, reports directly to the prime minister of India. The DAE is responsible for nuclear energy planning; development of nuclear power technology; applications of radiation technologies in agriculture, medicine and industry; and basic nuclear research. There are a number of other bodies with responsibility for nuclear energy in India, including:

- **The Atomic Energy Commission (AEC)** is the overseeing body of the DAE and oversees many aspects of the atomic energy sector such as promoting and organizing indigenous nuclear energy research and prospecting of atomic minerals in India.
- **Atomic Energy Regulatory Board (AERB)** was created in 1983 to manage regulatory and safety functions relating to atomic energy generation.
- **Nuclear Power Corporation of India Limited (NPCIL)** is a public sector company of India, responsible for the development of nuclear power plants. Other public sector corporations include Uranium Corporation of India Ltd. and Indian Rare Earths Ltd.
- **Nuclear laboratories,** including Bhabha Atomic Research Centre (BARC) in Mumbai; Indira Gandhi Centre for Atomic Research (IGCAR) in Kalpakkam; Centre for Advanced Technology (CAT) in Indore; Variable Energy Cyclotron Centre (VECC) in Kolkata; and Atomic Minerals Directorate for Exploration and Research (AMD) in Hyderabad.

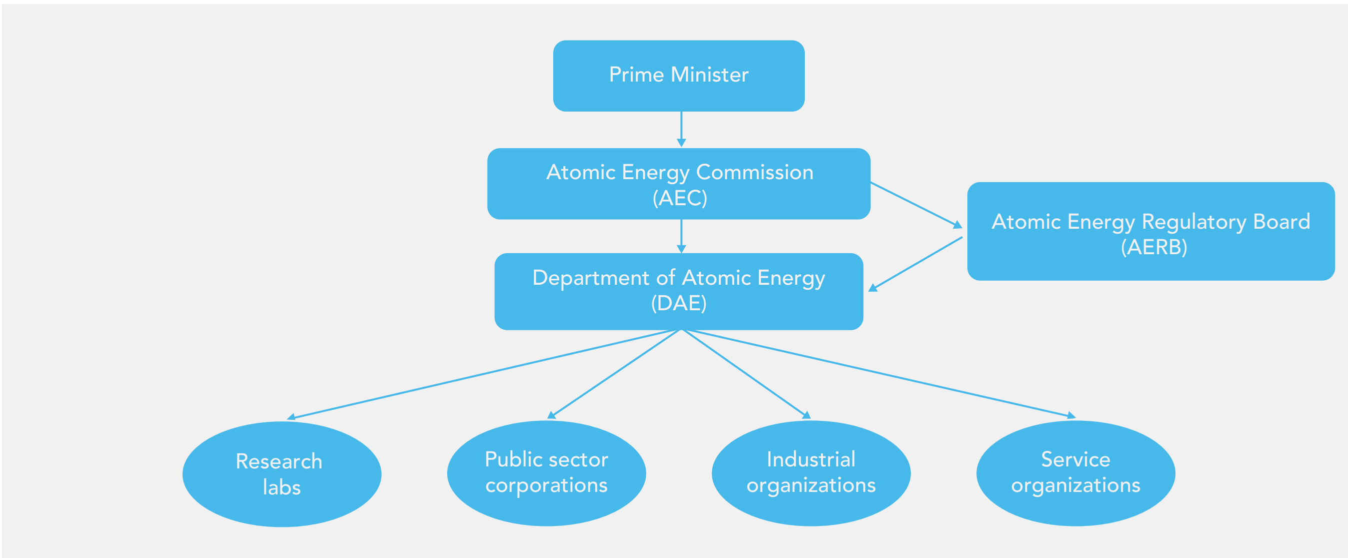


Figure 4. India's nuclear energy decision making structure[26]

The atomic energy sector in India is regulated by the *Atomic Energy Act* of 1962. In February 2015, the government amended the *Act* to allow NPCIL to form joint ventures with other public sector entities to build reactors and engage in other aspects of the fuel cycle.[27]

The Union Budget released in March 2016 allocates approximately Rs 117 billion to the Department of Atomic Energy,[28] an increase from Rs 109 billion allocated in the 2015 budget[29] and Rs 104.5 billion allocated in 2014.[30] In his budget speech, the Indian Minister of Finance noted that "government is drawing up a comprehensive plan, spanning the next 15 to 20 years, to augment the investment in nuclear power generation." Under the plan, up to Rs 30 billion per year, over and above currently committed funds, will be allocated to nuclear energy development for the next two decades.[31]

CHINA

In China, the State Council is the highest decision making body and ensures that policies are developed according to the principles of the People's Congress. There are a number of different ministries and agencies with responsibility for nuclear energy in China.

- **The China Atomic Energy Authority** is a ministry of the State Council and has primary responsibility for developing policies and regulations, programs and industry standards related to the civil nuclear energy industry.
- **The State-Owned Assets Supervision and Administration Commission** supervises all of China's nuclear power producers and develops plans for expanding nuclear energy.

- **The National Development and Reform Commission** undertakes overall planning for China's energy strategy. The NDRC provides formal approval for new nuclear power plants.
- **The National Energy Administration** is a vice-ministry under the NDRC and works with the NDRC on a wide range of energy related responsibilities, including supervision of the power market and power production, as well as the administration of nuclear power.
- **The National Nuclear Safety Administration** is the nuclear energy regulator and is housed under the Ministry of Environmental Protection.
- **The Ministry of Science & Technology** is responsible for planning national research programs, including those for nuclear energy.

In addition to these ministries and agencies, there are two other entities under the State Council that make decisions on nuclear energy, acting almost as advisory and consulting agencies. These include:

- **The National Energy Commission (NEC)** studies and drafts the national energy development strategies, examines and discusses major issues on energy development, and coordinates major projects on domestic energy exploration and international cooperation.
- **The National Leading Group Dealing with Climate Change, Energy Conservation, and Emission Reduction (NLG)** works on major strategies, principles and solutions to address climate change. The NDRC runs the daily operation of the NLG.

In March 2016, the government released the *13th Five Year Plan* which reiterated China's commitment to build 58 gigawatts of nuclear energy generation capacity by 2020. The plan also includes targets to complete four AP1000 units, which were originally developed by Westinghouse, as well as to construct demonstration units for Hualong One, China's domestically developed reactor, and CAP1400, a reactor based on AP1000 and developed by the State Nuclear Power Technology Corporation in consultation with Westinghouse.[32]

According to media reports, the draft *13th Five Year Plan for the Power Sector* calls for RMB 500 billion (US$78 billion) for the construction of nuclear power plants using domestic technology and includes targets for six to eight new nuclear power facilities to be built annually over the five-year period.[33] This compares to average expenditure of approximately US$2 billion per annum in the 2000 to 2013 period, according to the IEA.[34]

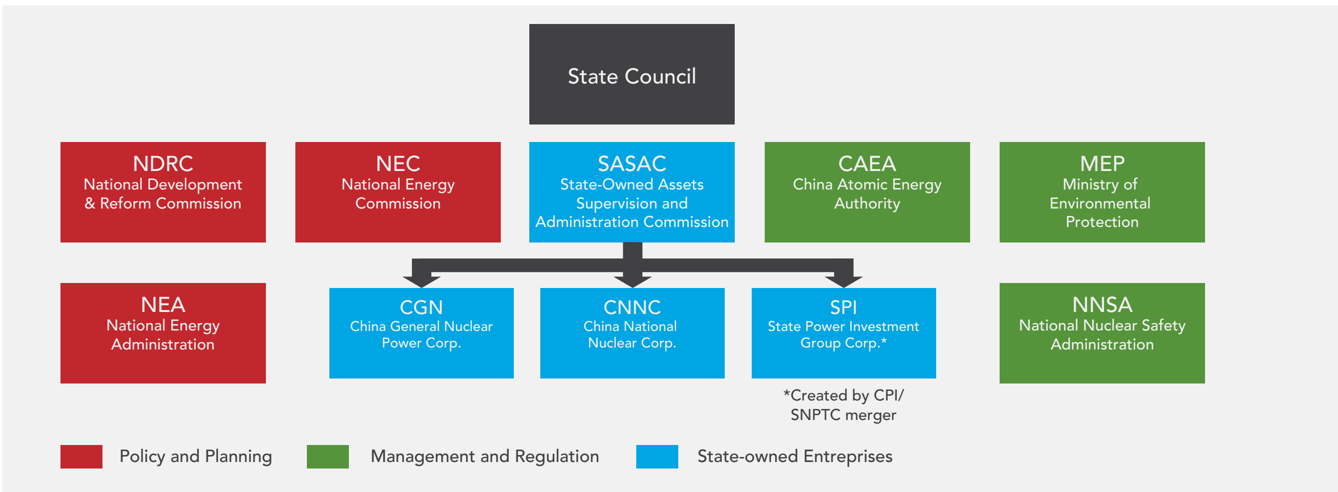


Figure 5. China's nuclear energy decision making structure[35]

THE POLITICAL DIMENSION OF CANADA-INDIA AND CANADA-CHINA NUCLEAR ENERGY COLLABORATION

In Canada's relationship with both China and India, nuclear energy often features prominently. For example, civil nuclear cooperation was featured in the Joint Statement between former Canadian Prime Minister Harper and Indian Prime Minister Modi, attesting to the political importance of the relationship at least on the Indian side.[36] As a result, the way that Canada handles issues related to non-proliferation and nuclear energy is important to the long-term health of Canada's relationships with both China and India.

However, Canada's relationships with India and China on nuclear energy have taken very different trajectories, impacting our current state of engagement on nuclear energy with each country.

CANADA-INDIA RELATIONS

Canadian technological support was critical to the development of India's nuclear energy industry and as a result, India and Canada's nuclear reactors use similar pressurized heavy water reactor technology. However, Canada and a number of other countries ended bilateral nuclear co-operation with India in 1974 when India tested a nuclear weapon developed using technology derived from a Canadian reactor. As a result, Indian nuclear technology has largely developed over the last 40 years in isolation from the international community.

This confrontation over issues of nuclear non-proliferation negatively affected almost all aspects of the Canada-India relationship and hindered Canada's ability to further economic and political goals in both nuclear and non-nuclear sectors. As was noted at APF Canada's December 2 workshop, "Canada was not a priority for India even among second-tier strategic partners due mostly to the somewhat negative bilateral relationship we had for over 45 years. The very difficult nuclear relationship, compounded by the Air India disaster in 1985, created a level of distrust between our two countries that impacted almost everything we did." Tellingly, there was no bilateral visit by an Indian prime minister to Canada until Prime Minister Modi's visit in 2015.

India and Canada have now re-established commercial and regulatory cooperation. India and Canada signed a Nuclear Cooperation Agreement (NCA) in 2010 and subsequently completed administrative arrangements, opening the door for trade of controlled nuclear materials, equipment and technology to Indian facilities that are subject to International Atomic Energy Agency (IAEA) safeguards.[37] The countries have established a Joint Committee to ensure enactment of the agreement's provisions and to facilitate engagement between the nuclear energy industries in both countries.[38] The Canadian Nuclear Safety Commission and the Atomic Energy Regulatory Board (AERB) of India have also negotiated an agreement for regulatory cooperation for exchange of information on issues related to civil nuclear energy.[39]

However, the issue of non-proliferation still looms large in Canada-India nuclear energy relations. The existing Joint Committee structure, which is central to Canada-India engagement, will need to continue increasing emphasis on commercial and research collaboration. Workshop participants suggested that Canada and India may benefit from developing a Canada-India nuclear energy contact group to advise on the future development of the relationship. Canada could follow the U.S.-India contact group model.

CANADA-CHINA NUCLEAR RELATIONS

Canada has had a less challenging nuclear energy relationship with China than with India. In 1997, Canada concluded administrative arrangements for a nuclear cooperation agreement, which was a prerequisite for Atomic Energy of Canada Limited (AECL) to construct two CANDU reactors at China's Qinshan Nuclear Power Plant in the late 1990s. In 2012, Canada and China signed a supplementary protocol to allow for larger shipments of Canadian uranium to China.[40]

Canada and China have signed memorandums of understanding (MOUs) that set priorities for Canada-China cooperation in nuclear technology, regulatory affairs and uranium trade. In 2014, the two countries signed an MOU between Natural Resources Canada and China's National Energy Administration to advance collaboration in the field of civilian nuclear energy including development of advanced fuel reactors and exports to third markets. Each year, the two parties create a work plan to execute priorities under the MOU.[41] The Canadian Nuclear Safety Commission and China's National Nuclear Safety Administration plan to negotiate a memorandum of understanding for cooperation and exchange of information on nuclear regulatory matters.[42]

OPPORTUNITIES FOR CANADA-INDIA AND CANADA-CHINA COMMERCIAL AND RESEARCH COLLABORATION

Canada's engagement with India and China needs to be mutually beneficial, meeting the commercial and political needs of all parties. Some priority areas are already under discussion or being implemented through annual MOUs or Joint Committee discussions.

Participants at APF Canada's December 2 workshop as well as interviewees identified areas where Canada has strong commercial and research synergies with China and India in the nuclear energy sector, such as uranium sales; pressurized heavy water reactor (PHWR) technology and R&D; SMRs and non-PHWR technology; third-market opportunities for nuclear technology and services; and medical isotopes.

URANIUM SALES AND INBOUND INVESTMENT

The sale of uranium is an area where Canada has very clear synergies with both India and China. Neither India nor China produces sufficient uranium to meet domestic demand, making these countries net uranium importers. China produces about 1,450 tU per year and plans to expand capacity to 3,250 tU per year.[43] However, this production falls short of China's current demand of 6,072 tU[44] and projected demand of 12,000 tU in 2020.

India requires approximately 1,077 tU annually, but the World Nuclear Association estimates that India produces less than half that amount (around 400 tU a year).[45] India plans to have 12 new reactors running by 2020, consuming an extra 1,500 tU per year.[46]

Conversely, Canada is the second-largest uranium producer in the world. In 2014, Canada was China's third-largest source of uranium. However, Canadian uranium represented only 10 percent of China's overall uranium imports, suggesting potential room for expansion of Canadian exports.[47]

In 2014, Kazakhstan was by far China's largest source of uranium, supplying 70 percent of total imports, followed by Uzbekistan at around 10 percent.[48] Kazakhstan's dominance in the Chinese markets is likely to continue into the future, a result of its large annual uranium production and close proximity to China. China also aims to strengthen relationships with Central Asian states for geopolitical reasons.

While Kazakhstan is a major competitor for Canadian uranium companies, Canadian uranium producers have also found opportunities in mining uranium in Kazakhstan. For example, Cameco owns 60 percent of Kazakhstan's Inkai mine,[49] while Toronto-based Uranium One is a stakeholder in six mines.[50] Uranium from these mines supplies the Chinese market.

Canada's uranium export relationship with India is less developed than with China, due to the 40-year cessation of nuclear energy cooperation between the countries. In 2015, Cameco signed a deal to sell 2,730 tU to India through 2020 and delivered the first shipment in December 2015. This was the first large commercial outcome of the Canada-India nuclear cooperation agreement finalized in 2013.[51]

As was noted at APF Canada's December 2 workshop, achieving the first delivery of uranium to India took years of preparation, including high level commitment from the Government of Canada to get the nuclear cooperation agreement and administrative arrangements completed. Significant preparation and relationship building at the state-to-state level was necessary before negotiations could begin in earnest.

The process also highlighted the importance of company-to-company relationships in getting commercial deals done. One former president of Cameco was noted for making repeated trips to India to build connections before the nuclear cooperation agreement was even concluded. Workshop participants noted that state-to-state, company-to-company, and personal relationships will need to be nurtured and cultivated continuously in target markets to realize more uranium deals.

While most of the major barriers to accessing the Indian and Chinese markets have now been removed, participants at APF Canada's December 2 workshop noted that Canada still faces some challenges for expanding uranium exports to these countries. One challenge is the fact that most of China's fuel fabrication facilities are used for both military and civilian purposes and are not open to inspection by the IAEA. This limits Canada's export potential because companies cannot sell Canadian uranium for use in uninspected fabrication facilities. Some participants also noted that Australia may become a larger competitor in India, as Australia and India recently completed the administrative arrangements for a nuclear cooperation agreement.[52]

Another barrier to larger-scale uranium sales was identified within Canada itself. Canadian uranium producers require access to an efficient and effective transportation network—including road, rail and port facilities—to get their product to tidewater for export to Asian markets. Uranium mines in Canada are predominantly located in remove locations where rail and road infrastructure is less developed, and Canada's ports are already heavily used. Further development of infrastructure may be required if Canada is to export larger volumes of uranium to Asia.

Participants also pointed out that opportunities for collaboration between Canada, India and China with respect to uranium are not restricted to exports. China in particular has been looking to acquire international uranium assets in order to meet domestic demand. The head of China National Nuclear Corporation (CNNC) stated in media interviews that his company was seeking to purchase uranium extraction projects in Canada and elsewhere.[53] In January 2016, CGN Mining (owned by China General Nuclear Power Corp.) purchased just under 20 percent of Fission Uranium Corp., in the first direct investment by a Chinese company into a Canadian uranium firm.[54,55] At present, Canadian law requires a minimum of 51 percent Canadian ownership of producing uranium mines, unless an appropriate Canadian investor cannot be found.[56]

COLLABORATION ON PRESSURIZED HEAVY WATER TECHNOLOGY/R&D

Research and development in the area of pressurized heavy water nuclear reactor (PHWR) technology has been highlighted by India and China as a priority for cooperation with Canada. Pressurized heavy water reactors are one of many types of reactors and make up about 12 percent of nuclear reactors internationally.[57] They use heavy water as a moderator (which slows down the speed of neutrons to help generate a nuclear reaction) and as a coolant (which transports heat generated from the reaction to generate steam).

Canada is the design authority for CANDU pressurized heavy water reactor technology. All of Canada's 19 reactors are CANDU, and India has 18 PHWRs. While the majority of China's reactors are light water, CNNC purchased two CANDU reactors that were built at its Qinshan site in the late 1990s and early 2000s. Collaboration on PHWRs was highlighted in MOUs between Canada and both India and China and in the Joint Statement issued by Indian Prime Minister Modi and former Canadian Prime Minister Harper in 2015.[58]

APF Canada workshop participants and interviewees identified two categories of opportunity in the PHWR area: sustainable fuel cycles and reactor synergies, as well as life extension and other technologies.

SUSTAINABLE FUEL CYCLE AND REACTOR SYNERGIES

APF Canada workshop participants noted that Canada has strong expertise in nuclear fuel research and applications, especially for pressurized heavy water reactors. This has already been an area of collaboration between Canadian and Asian utilities and laboratories. For example, the CANDU Owners Group, an association of all the operators of CANDU reactors worldwide, recently coordinated a fuel design project in which operators and research laboratories from South Korea, Romania and Canada collaborated to develop an improved fuel bundle for CANDU reactors.[59]

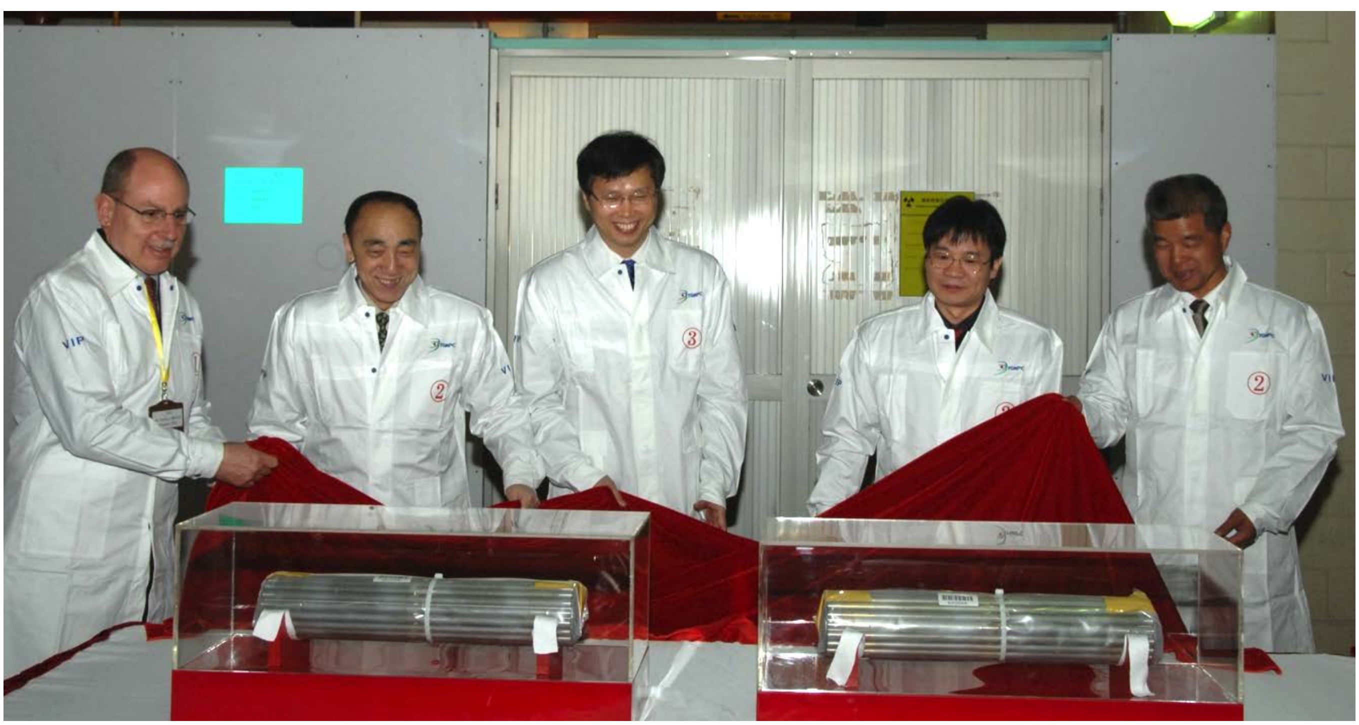
A priority area of collaboration between Canada and China focuses on development of advanced fuel cycle technology that will allow China to make the most of its limited sources of uranium. Joint research between CNNC and Candu Energy Inc. has resulted in adaptations to CANDU reactors so that they can use a uranium fuel generated from the spent fuel of light water reactors, which make up the bulk of China's nuclear fleet. Candu Energy's newest reactor, the Advanced Fuel CANDU Reactor (AFCR), has this fuel flexibility. Such a capability helps China reduce demand for fresh uranium as well as the volume of nuclear waste produced by China's other nuclear reactors.

As a result of this synergy, China may opt to implement an AFCR new build program. The AFCR received a positive review from an expert panel in China in 2014, a requirement before any new build can proceed.[60] Immediately after the approval, Candu Energy signed a framework joint venture agreement with CNNC to "build Advanced Fuel CANDU Reactor (AFCR) projects in China and develop opportunities for it globally."[61] The two companies aim to complete the joint venture arrangement by the end of 2016 and move into development in 2017.[62]

An additional area of interest for both China and India is the further development of fuel cycles that use the element thorium. Thorium has a number of advantages over uranium as a nuclear fuel. It does not produce plutonium, which can be used to produce a nuclear weapon, as a by-product. It is also abundant globally, making it highly desirable to countries that have small domestic uranium sources. India's three-phase nuclear plan aims for advanced heavy water reactors fuelled by thorium to be deployed post-2032, and the country's research institutes have been experimenting with a wide range of thorium technologies.[63]

China is also developing a number of reactor designs that use thorium. An advanced research centre was established by the Chinese Academy of Sciences in Shanghai in January 2014 with the aim of developing the world's first industrial reactor using thorium molten-salt technology by 2024. It has a preliminary design for a 10-megawatt thorium-based molten-salt reactor and plans to build two 2-megawatt demonstration reactors by 2020.[64]

Research on thorium fuel cycles is a growing priority for Canada's research collaborations with China both through private companies and government science and technology projects. The AFCR is thorium



Successful Test Irradiation of Natural Uranium Equivalent (NUE) fuel at Qinshan, 2011 capable, but further research will be conducted to further develop this capability.[65] Natural Resources Canada also entered into an MOU with China's National Energy Administration on development of advanced fuel cycles.[66] The Nuclear Power Institute of China (NPIC), a company owned by CNNC, is exploring thorium fuel cycle collaboration with Atomic Energy of Canada Limited (AECL), the government entity that supervises Canadian Nuclear Laboratories (CNL).[67] In 2011, CNL launched the Thoria Roadmap Project to identify the gaps in both internal and global knowledge on thorium fuel cycles.[68] The project identified 11 areas that could be ripe for international collaboration.

PRESSURIZED HEAVY WATER REACTOR LIFE EXTENSION AND OTHER TECHNOLOGIES

As the originator of CANDU technology, Canada has a nuclear energy technology supply chain geared to servicing this type of reactor, and many companies have had success in the supply chain for CANDU reactors abroad. However, participants at APF Canada's December 2 workshop noted that highly self-sufficient and cost-effective supply chains in China and India mean that Canadian companies need to focus on providing highly innovative products on the high end of the value chain that China and India are not currently producing domestically.

One area of opportunity in Asia for Canadian companies is technology and services for refurbishing PHWR reactors. In the province of Ontario, 10 of its 18 pressurized heavy water reactors will be refurbished to extend their operational life. The refurbishment process involves modernizing and replacing major equipment in the reactor to extend its life for an additional two to three decades. As a result of the increase in refurbishment, Ontario's nuclear energy industry continues to develop innovative technologies and services in this area. India and South Korea are the two major markets with substantial numbers of PHWR reactors that will require life extensions.

In advance of a nuclear energy trade mission to India in 2015, key organizations in the nuclear energy industry identified that Canada has particular strength in technologies for assessing the fitness for service of nuclear parts and understanding the factors that limit the life of nuclear components. Many of these technologies focus on fuel channels, which support fuel bundles in the reactor. Canada also produces advanced technology for the operation of CANDU-type reactors. An excellent example is the reactor computer systems supplied by companies such as Montreal-based L-3 MAPPS.

Workshop participants noted that Canada's supply chain offers a range of technology and services that can be used not just in heavy water reactors but across reactor types. Canada has particular strengths in robotics and remote handling of nuclear waste, including tritium. Canada can also offer excellent project management services for helping companies to build or refurbish reactors on time and on budget.

SMRS AND NON-PHWR NUCLEAR TECHNOLOGIES

While Canada is a leader in PHWR technology, a number of Canadian companies are developing non-PHWR designs. These reactors differ from heavy water reactors in that they use substances other than heavy water as moderators and coolants. For example, a number of Canadian and international government agencies collaborated to develop a 1,200-megawatt design for a Gen IV supercritical water-cooled reactor under the Canadian National Program on Generation IV Energy Technologies.[69] This program was part of the Generation IV International Forum (GIF), which brings together expertise from a number of countries in North America, Europe and Asia, including Japan and South Korea.[70]

India and China, and China in particular, have very aggressive R&D programs for nuclear energy technology, and are developing many types of reactors. Both countries seek out international collaboration in the area of reactor design. For example, the Chinese Academy of Sciences and the U.S. Department of Energy have a cooperation agreement to develop molten-salt reactor technology.[71] The Nuclear Power Institute of China (NPIC) has an MOU for collaboration with CNL on supercritical water-cooled reactor (SCWR) thermal hydraulics.[72]

Many companies in Canada are pursuing reactor designs in a smaller delivery format referred to as a small modular reactor (SMR). Small modular reactors have a generation capacity of under 300 megawatts, substantially lower than the approximately 1,000 megawatts or higher provided by most nuclear power plants, and are manufactured at a plant before being brought to the site fully constructed.

For example, Toronto-based Terrestrial Energy is developing a molten-salt reactor while Montreal-based Star Core HTR is developing a helium-cooled pebble-bed reactor. SMRs have a lower initial setup cost than large nuclear power plants and may be a more viable alternative to large reactors in parts of the world that are not experiencing large incremental energy demand growth, such as North America. SMRs are also highly suited to some industrial applications, such as water desalination.[73]

China and India are especially interested in SMRs and are increasingly world leaders in developing this technology. In February 2006, China's State Council announced that the small high-temperature gas-cooled reactor (HTGR) was the second of two high-priority National Major Science & Technology Projects for the following 15 years. Lloyd's Register of the U.K. announced it has signed an agreement with NPIC to support the development of a floating nuclear power plant that will use an SMR.[74]

As noted at APF Canada's December 2 workshop, a number of SMR companies in Canada are looking to India and China for R&D partnerships and as potential manufacturing sites for SMR components. Canadian companies are interested in India and China as potential markets for SMRs. Participants did note that accessing these markets will be challenging since China and India are producing their own SMR technologies that will compete with Canada's technology abroad and, potentially, even in the Canadian market. Canadian companies will need to rapidly develop a high-quality low-cost product and aggressively market the reliability of Canadian engineering if Canadian SMRs are to compete against indigenous technology in India and China.

COLLABORATION ON THIRD-MARKET OPPORTUNITIES

As India and China become leaders in nuclear energy technology, they are seeking export market opportunities for their technology and engineering services. These exports create opportunities for Canada to collaborate with India and/or China on projects in third countries.

China has already had very strong success entering international markets in the area of new build. China has helped Pakistan develop nuclear reactors in the past and more are planned.[75] China General Nuclear Power Corp. (CGN) has taken a 33.5 percent stake in the Hinkley Point C Nuclear Power Station in the U.K. to be built in collaboration with French company EDF.[76] China has also signed MOUs with Kenya and Egypt to explore nuclear power plant construction.[77]

Chinese and Canadian flags at Qinshan Nuclear Power Station, Zhejiang, China

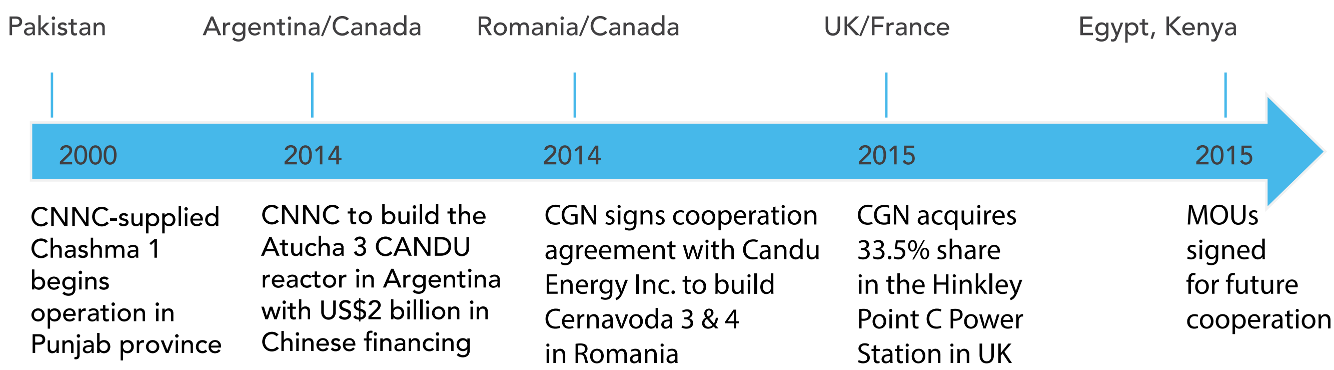


Figure 6: Selection of China's overseas nuclear energy collaborations[78]

Third-market collaboration has already proven to be an excellent way to combine Canada's nuclear energy brand name and know-how with lower cost expertise and construction services from Asian countries. China-Canada collaboration also helps to expand the reach of Canadian technology into third markets that may not have been able to access the technology without financing provided by Chinese companies.

For example, CGN and SNC-Lavalin are collaborating to build reactors in Romania, with SNC-Lavalin providing technology, engineering and safety services.[79] The build has also provided opportunities for Canadian companies in the nuclear energy supply chain to contribute components and services. For example, Canada-based L-3 MAPPS recently received a contract to upgrade training simulators for the Romanian reactors.[80] One workshop participant noted that the CGN–SNC-Lavalin project is of intense interest to the highest levels of Chinese government and that collaboration with non-Chinese companies will remain central to China's nuclear export approach.

Although India has yet to export new build reactors, Indian and Canadian nuclear sectors could explore joint third-party country opportunities. This would present an excellent opportunity for these countries to leverage their respective strengths in heavy water–based reactor technology. At the third annual Canada-India Joint Committee on Nuclear Cooperation in Mumbai in October 2015, companies on both sides agreed to work toward a business plan for potential cooperation in third markets.[81] One interviewee also noted that Canada-India-China collaboration in third markets on pressurized heavy water reactors could be of interest to all three countries.

A number of workshop participants from nuclear energy and engineering companies expressed interest in accessing funding from Canadian banks and other institutions for joint Canada-India collaborations in third markets.

Participants noted that the Government of Canada should ensure that sufficient export financing is available to support the sale of Canadian nuclear technologies abroad. However, as a participant in the OECD's *Arrangement on Officially Supported Export Credits*, Canada must follow certain guidelines on how it uses export credits.[82] For example, participant countries cannot provide support for more than 85 percent of the export contract value. The OECD also stipulates terms specific to export financing for nuclear power plants.[83]

MEDICAL ISOTOPES

Canada is one of the leaders in production of radio isotopes for nuclear health care needs. The National Research Universal (NRU) reactor at Chalk River Laboratories plays a significant role in the production of cobalt-60, used for radiation therapy machines, and technetium-99m (Tc-99m), used in 80 percent of nuclear diagnostic procedures in Canada. When the NRU had to unexpectedly cease production in 2007 and 2009/2010, many medical facilities were left without isotopes, highlighting the fragility of the supply chain that delivers medical isotopes, especially technetium-99m.[84]

The vast majority of the market for medical isotopes is in North America and Europe (70 percent), with substantial markets in Japan and growing markets in developing Asia.[85] In the Joint Statement between Indian Prime Minister Modi and former Canadian Prime Minister Harper, cooperation on isotopes for medical and other purposes was mentioned as a potential area of collaboration.[86]

India and Canada are specifically collaborating on mechanisms for producing isotopes without the use of a nuclear reactor. With the NRU anticipated to cease production of isotopes permanently in 2018, Canadian labs, such as TRIUMF in British Columbia, have been developing mechanisms to produce Tc-99m without nuclear reactors or uranium. TRIUMF has been collaborating with India's Variable Energy Cyclotron Centre (VECC) in Kolkata to refine accelerator technology to produce medical isotopes, with the ultimate objective of creating accelerators small enough to be deployed in hospitals.[87,88] Both TRIUMF and VECC are part of the Tesla Technology Collaboration network, which includes laboratories in India, Japan and South Korea as well as in Europe and North America, to advance the development of certain types of accelerator technology.[89]

CANADA-ASIA COLLABORATION ON BUILDING SOCIAL LICENCE FOR NUCLEAR ENERGY

After the meltdown of three nuclear reactors at Japan's Fukushima Daiichi Nuclear Power Plant in 2011, many countries halted nuclear energy expansion, in part due to the decline in "social licence" for nuclear energy. The term social licence generally refers to a "local community's acceptance or approval of a company's project or ongoing presence in an area."[90] It is increasingly recognized by governments and natural resource companies as a prerequisite for large natural resource or construction projects.

To address the question of whether Canada and countries in Asia can collaborate to build social licence for nuclear energy, speakers at APF Canada's December 2 workshop focused on the cases of South Korea and Japan. In Japan, the Fukushima incident resulted in a drop in public approval for nuclear energy. In South Korea, the safety concerns following Fukushima were further compounded by the revelation that fake safety certificates had been issued for some nuclear reactor components.[91] The proportion of South Koreans who consider nuclear power safe fell from 71 percent in 2010 to 40 percent in 2011 and 35 percent in 2012.[92]

In Japan, after Fukushima all nuclear reactors were shut down for maintenance and inspection. As one workshop participant noted, many protests have been carried out by residents of towns near but not in the immediate vicinity of nuclear power reactors, as these people feel that they shoulder much of the risk associated with nuclear reactors but derive few benefits. Japan is highly focused on decommissioning reactors and on enhancing emergency preparedness and response mechanisms. The participant further remarked that Canada, the U.S. and Japan could share best practices on safe decommissioning of plants and also on methods for communicating about decommissioning to surrounding communities.

However, concern about nuclear energy in South Korea and Japan did not arise solely from the Fukushima incident. Nuclear waste disposal has also been a large social licence challenge in both countries. Communities with proposed nuclear waste repositories have generally protested against the construction of the facilities. This challenge is very apparent in the case of South Korea, which has spent nearly 20 years seeking a central spent-fuel storage site but has not yet found one. The storage facility siting has been a long process fraught with conflict. A participant at APF Canada's December 2 workshop called it the "oldest drama" and described that the government has undertaken 10 different efforts to find a permanent nuclear waste storage facility.

The participant noted that the central government followed a mostly top-down decision making approach to siting the facility, which the presenter characterized as the "decide announce defend and abandon" (DADA) approach. The government selected a series of sites, provided monetary compensation as an incentive and asked these selected sites to present a proposal. However, due to public opposition, none of these selected sites were interested in participating. Thus, these were abandoned and a new set of sites were chosen. The compensation amount was gradually increased as more of the chosen sites declined to host a nuclear waste facility.

Currently, South Korea is building a low- to intermediate-level waste facility in Gyeongju, after providing substantial incentives and promises of jobs. Gyeongju municipality was not only offered monetary compensation but was also promised that the Korea Hydro & Nuclear Power headquarters would be moved to the new facility. The Gyeongju people voted on the matter before a decision was finalized by the authorities. The popular vote (89.5 percent in favour) did not create a consensus on many aspects of implementation. For example, there was disagreement about where in the community the new headquarters should be located.

Canada is currently seeking a location for a long-term nuclear waste storage facility, a process that is managed by the Nuclear Waste Management Organization (NWMO). The NWMO has created a community-driven nine-step process to select a site.[93] The process is designed to ensure that the site selected is safe, secure and has social licence to operate, from the community. The process encourages interested communities to engage with First Nation and Métis communities, as well as with municipalities in the surrounding area. Though this process is specific to Canada and might not be

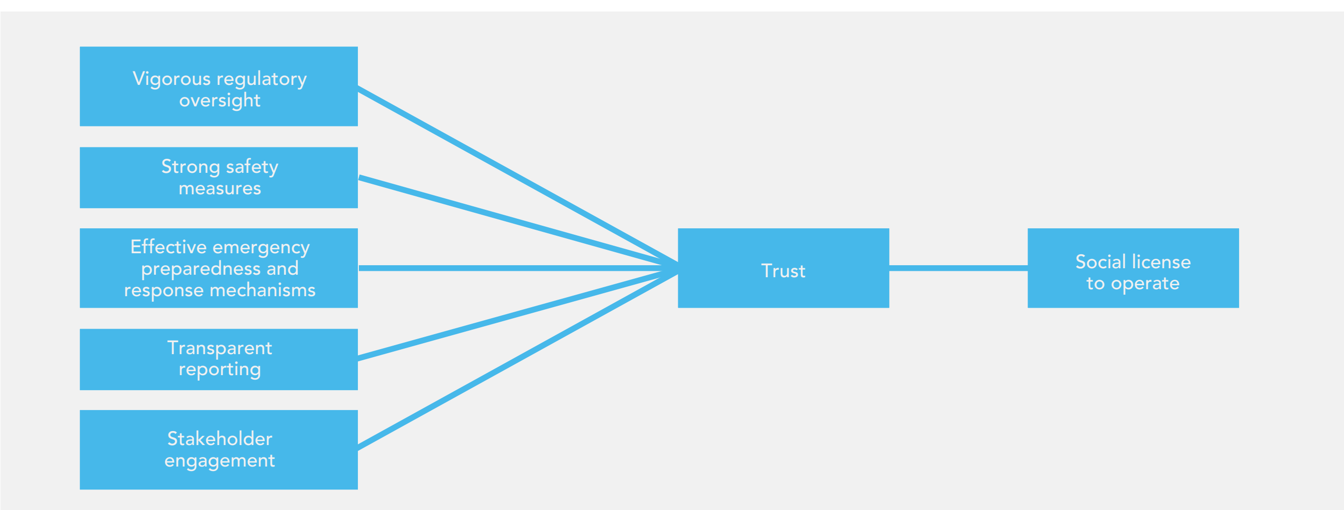


Figure 7. Inputs for building social licence

applicable to other countries as is, it highlights key aspects of community engagement, collaboration and adaptation that any nuclear facility siting effort could incorporate for success. The NWMO engages in two-way sharing of best practices with nuclear waste management organizations in Asia.[94]

Workshop participants concluded that the cases of South Korea, Japan and Canada illustrate that gaining social licence is not a formulaic process and even community-driven processes are not guaranteed to yield success. Processes can be very community specific and approaches may not cross cultural boundaries. However, trust is universally an important factor for obtaining social licence. Figure 8 highlights aspects that are important for building trust around nuclear energy projects.

Participants in APF Canada's December 2 workshop noted that Canada has strengths in regulatory frameworks and emergency preparedness and response that are essential components to building social licence. These issues will be discussed in the following section.

CANADA-ASIA COOPERATION ON FURTHERING NUCLEAR SAFETY

Since the beginning of the nuclear energy industry, there have been three nuclear accidents (Three Mile Island, Chernobyl and Fukushima Daiichii) that have particularly drawn the public's attention to nuclear safety challenges. The latter two highlighted the cross-border implications of nuclear accidents and resulted in an increase in international cooperation, as well as the variety of stakeholders and activities, involved in the maintenance of nuclear safety.

While preventing a nuclear accident was originally seen as solely the responsibility of individual countries, the Chernobyl incident resulted in major changes to the international regime around nuclear safety, as well as the way operators viewed their responsibility to the public. The international community adopted the Convention on Nuclear Safety, which outlined minimum safety standards that member countries should implement, as well the Convention on the Early Notification of a Nuclear Accident. The IAEA also founded the Operational Safety Review Team (OSART) program to provide three-week operational safety reviews of specific plants at the invitation of the host country.[95]

Industry, regulators and industry associations focused on implementing a "nuclear safety culture," defined as "the core values and behaviours resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals, to ensure protection of people and the environment."[96] A number of international industry associations, such as the World Association of Nuclear Operators and the CANDU Owners Group, were formed in response to Chernobyl and began undertaking educational collaborations among their members in order to implement best practices for nuclear safety.[97]

The Fukushima incident in 2011 once again shined a light on nuclear safety challenges. Industry associations such as the World Association of Nuclear Operators (WANO), the IAEA and national regulators undertook thorough reviews of their approaches to nuclear safety. Canada, which has an excellent nuclear safety record, recognized the need to improve the ability of reactors to withstand "beyond design basis" accidents (such as those caused by earthquakes or severe storms) and to improve emergency response to nuclear accidents. Canada also committed to enhancing international collaboration on nuclear safety.[98]

As the nuclear energy industry grows in Asia, Canada can continue to engage with the region on emerging nuclear safety challenges. Participants at APF Canada's December 2 workshop identified the following as priority areas and mechanisms for engagement in this area.

A. **Capacity building and management education on leadership and nuclear safety:** China, India, South Korea, and Japan have strong programs for educating nuclear power plant operators. An area of relative strength for Canada, however, is in management and leadership education aimed at building a nuclear safety culture. Canada can deliver these services in a number of ways:

   - **Community college and university engagement with Asian countries:** Canada's community colleges and universities with nuclear energy expertise could aim to recruit more students for training in Canadian educational institutions and to deliver programs in Asia.

   - **Provision of training technology for operation of reactors:** For example, the Canadian company L-3 MAPPS provides training simulators for reactors in China, Japan and South Korea, among other countries.

   - **Training incoming delegations in Canada:** The CANDU Owners Group, an association of all the operators of CANDU reactors globally, already runs a well-established training program for Chinese operators on advanced management and nuclear safety culture. Individual companies provide exchanges and training for their members. NPCIL has agreed to exchanges with Canadian operators.[99]

   - **Government-supported fellowship programs:** Canada hosts personnel exchanges with Indonesia and Malaysia through the IAEA Fellowship Program.

B. **Bilateral regulatory lesson sharing:** The Fukushima incident highlighted the challenges of prioritizing nuclear safety when regulatory regimes do not sufficiently separate the interests of regulators, operators and government agencies.[100] Over the last five years, both Japan and South Korea have made changes to their regulatory structures to enhance their independence from political decision makers. Japan created a more centralized, independent regulatory body called the Nuclear Regulation Authority, while South Korea has created the Nuclear Safety and Security Commission.

   All nuclear energy producing countries benefit from sharing best practices on nuclear energy regulation and safety. In Asia, Canada has MOUs on technical cooperation and exchange of regulatory information with Indonesia, Japan, India and South Korea.[101] An area of emerging regulation both in Canada and in Asia is around the use of SMRs. Canada's regulatory framework for licensing small reactors is better established than in most countries and may provide some interesting lessons for countries currently developing their own regulations.[102]

C. **Multilateral co-operation on nuclear safety:** The International Atomic Energy Agency administers a number of international conventions on nuclear safety. One of the most recent is the Convention on Nuclear Safety, which came into effect in 2006. Unlike many conventions on nuclear security, nuclear safety regimes are largely voluntary with respect to implementation. The IAEA provides a range of voluntary services, such as peer reviews of nuclear power plants, for helping countries achieve robust regulatory regimes and nuclear safety protocols. Canada is an active participant both in providing experts for the development and delivery of these services and in participating as a recipient of peer review. For example, Canadian Nuclear Safety Commission staff led an IAEA Integrated Regulatory Review Service mission to India in 2015.[103] Canada's Bruce Nuclear Generating Station received an OSART team in 2015 and Pickering Nuclear Generating Station will participate in the program in 2016.[104]

Canada also participates (and can expand participation) in non-IAEA multilateral arrangements for furthering nuclear safety. ASEAN has founded ASEANTOM to encourage collaboration among the region's nuclear regulators. Canada can participate as an outside expert, as requested, on ASEANTOM, the Top Regulators Meeting (led by South Korea) and other regional nuclear energy related fora. Canada also plays a leadership role in the CANDU Senior Regulators Meeting that takes place annually under the auspices of the IAEA. In this venue, the Canadian Nuclear Safety Commission has the opportunity to address nuclear safety issues specific to CANDU type reactors.

D. Operator-to-operator lessons sharing: Operators from around the world benefit from sharing operational experience as it relates to nuclear safety. Canadian operators have taken a leadership role in global operator organizations that have developed mechanisms specifically for this purpose, such as the World Association of Nuclear Operators (WANO) and the CANDU Owners Group (COG). COG, for example, runs peer groups, technical committees and workshops to share best practices on topics such as equipment reliability, training, and fuel handling. COG also manages an operational experiences database to which all members can contribute and has signed a practical agreement with the IAEA for cooperation on nuclear safety, including participation in peer review processes.[105]

Participants noted that operator organizations need to continue building mechanisms for the sharing of operational experience across national boundaries. This requires a building of trust between operators and, in some cases, working with national governments to alter regulations and approaches that limit information sharing. Participants further noted that operators and global operator organizations can further engage with suppliers to develop a nuclear safety culture in the supply chain domestically and internationally.

E. Developing emergency preparedness and response mechanisms: International and national reviews of Japan's emergency response to the Fukushima incident concluded that action was impeded by a lack of coordination between bodies. Response mechanisms must be developed to prevent the need to evacuate people from their homes in the event of a nuclear accident.

As a result of Fukushima, regulators and operators from around the world have recognized that response to nuclear accidents is as important as prevention. The IAEA provides voluntary peer review of member countries' emergency preparedness and response mechanisms through its Emergency Preparedness Review Services.[106] Canada could expand participation in this program by contributing experts and undergoing review itself.

Canada also runs regular emergency response exercises, which can be attended by international observers. For example, in 2014, Ontario Power Generation (OPG) held a three-day nuclear emergency exercise at Darlington Nuclear Power Station involving 54 organizations from all levels of government. The exercise included an observer program for international agencies and Canadian departments not directly involved in the exercise.[107] Workshop participants noted that Canadian operators and government agencies would be interested in observing emergency preparedness exercises in Asian countries.

F. Continued implementation of technology and processes to further nuclear safety objectives: Canada can contribute technologies that make nuclear power safer. Candu Energy is developing its Advanced Fuel CANDU Reactor with advanced safety features, and Canada's engineering firms and nuclear reactor operators can provide engineering and refurbishment services to ensure that reactors are operating with the highest safety standards. Canadian companies are also at the forefront of non-PHWR reactor designs with unique safety features.

BARRIERS TO REALIZING CANADA-ASIA NUCLEAR ENERGY COOPERATION

While Canada has many strengths to offer countries in Asia, barriers remain on both the demand and supply side, especially in accessing commercial opportunities. Some of these barriers are unique to the nuclear energy industry, but most reflect the types of challenges experienced by many technology companies seeking to enter Asian markets. The following barriers were identified by the participants of APF Canada's December 2 workshop and through interviews with additional stakeholders. Recommendations for addressing these barriers will be reserved for Section VIII.

DEMAND-SIDE BARRIERS

- **Low cost producers in target markets:** Many Asian companies can provide nuclear energy technology and services to their home markets at a lower cost than can Canadian companies.
- **High self-sufficiency within the domestic industry:** Many Asian countries that produce nuclear energy have or are rapidly developing highly self-sufficient supply chains.
- **Strong international competition:** Canadian companies face strong competition in Asian markets from leading nuclear energy companies from around the world, including from Asia itself.
- **Administrative/legal barriers to trade:** Some Canadian companies experience challenges navigating the bureaucracy related to nuclear in Asian countries. In the case of India, the most pressing issue is the *Civil Liability for Nuclear Damage Act*, which could hold nuclear energy suppliers to potentially unlimited liability in the case of a nuclear accident. As a result of this law, many Canadian, European, American and even Indian companies are reticent to sell into India's nuclear energy supply chain. (See Page 39 for further discussion)
- **Intellectual property (IP) violation:** A number of companies operating in Asian markets have either had direct experiences with IP violation or are concerned that it will occur.

SUPPLY-SIDE BARRIERS

- **Dominance of non-heavy water reactor technology in the international market:** Canada's reactors are predominantly heavy water reactors, which make up a small percentage of the global market. Canada's nuclear energy supply chain has been shaped around this technology.

- **Canada's SME access challenge:** Canadian energy technology and services companies are small and often do not have the financial or human resources to explore Asian markets. Some companies may also have difficulty providing the scale of services large markets require.

- **Lack of domestic new build activity:** Expansion of the nuclear energy industry helps to drive innovation and provision of new services. Under the Long-Term Energy Plan, the Province of Ontario has deferred, perhaps indefinitely, the addition of two new reactors at the Darlington Nuclear Generating Station.

- **Lack of recognition of Asia's nuclear energy strengths:** Collaboration on nuclear energy technology and nuclear safety can be hampered if Canadians fail to approach engagement with Asian countries as a two-way exchange between equal parties.

INDIA'S CIVIL LIABILITY FOR NUCLEAR DAMAGE ACT: A BARRIER FOR CANADA'S NUCLEAR ENERGY SUPPLIERS

Over the last half century, the international community has developed a number of conventions to ensure sufficient compensation to victims in the event of a nuclear accident. One such convention is the Convention on Supplementary Compensation, which India signed but has not yet ratified. Signatories to these conventions agree to develop domestic laws in keeping with the standards in the conventions.

The conventions have a number of provisions to streamline the compensation system and to make nuclear energy projects insurable. One of the most notable is that only the operator of a nuclear power plant (not suppliers to the plant) can be found liable in the event of a nuclear accident. The operator can only be held accountable under the nuclear liability law and is held accountable irrespective of fault.[108]

In 2010, the Government of India enacted the Civil Liability for Nuclear Damage Act, to provide compensation to individuals and companies in the event of a nuclear accident. There are two sections of the law that are perceived by many in the nuclear energy industry in India and internationally as breaking the norm of "operator-only" liability: section 17(b) and section 46.

While other sections of the act state that operators are liable for damage up to the amount of approximately US$240 million, section 17(b) states that operators have a "right of recourse" to suppliers up to that amount if the supplier contributed to the accident. Section 46 provides that the act does not prevent the operator from being held accountable under other laws.[109] Suppliers both in India and internationally are concerned that operators could use their right of recourse to hold them liable for damage under other laws. Many of these companies are small or medium enterprises that do not have the resources to mitigate these risks. As a result, many suppliers are opting not to operate in the Indian market.

The Government of India has stated that the agreement is consistent with the Convention on Supplementary Compensation and that suppliers will not be held liable under section 46 of the act.[110] However, there is no legally binding document stating this fact. The Government of India and private insurers have established an insurance pool for operators and suppliers, which is intended to help all parties cover cost of liabilities.[111]

Overall, an impasse has been reached on this issue. The Government of India has stated that it will not make changes to the law,[112] while many nuclear energy suppliers (including suppliers in India) are opting not to engage in the supply chain.

RECOMMENDATIONS

Canada has more than 70 years of experience in the development and implementation of nuclear energy technology and services. Participants at APF Canada's December 2 workshop as well as interviewees suggest that Canadian governments and industry should consider the following recommendations in order to overcome barriers to Canada-Asia engagement on nuclear energy, maximize existing synergies and further nuclear safety.

1. **Develop a Canadian nuclear energy agenda:** Canadian federal and provincial governments need to define what they want to achieve domestically and internationally through engagement with Asian countries on nuclear energy, not simply respond to the needs of Asian countries. Canada should embed its approach to engagement within the broader context of its climate agenda, and economic and geopolitical interests.

2. **Use nuclear energy expertise to further the global climate agenda:** Canadian federal and provincial governments, the nuclear energy industry and the research community should contribute know-how on nuclear energy technology and regulation to help countries in Asia meet their climate reduction targets safety and effectively.

3. **Evolve the Canada-India Joint Committee on Nuclear Cooperation:** The existing Joint Committee, which is guiding Canada-India nuclear energy engagement, will need to continue emphasizing commercial and research collaboration, not only non-proliferation issues. The Government of Canada should consider formulating annual work plans and/or establishing an advisory group that can provide insight on priority areas for discussion and action. A potential model for an advisory group could be the U.S.-India "contact group."

4. **Strengthen the implementation of global nuclear safety standards:** The Government of Canada should recommend that the IAEA assume an explicit role in monitoring adherence by members to peer reviews and a set of safety standards. Canada should work with like-minded states to explore how the oversight regime can be strengthened. This could involve publically disclosing the names of member states that do not submit their nuclear programs to IAEA peer review.

5. **Advocate for expansion of voluntary offer list:** Canada should continue to advocate that China add more fuel fabrication and other nuclear related facilities to the IAEA's voluntary offer list, thereby opening these facilities to inspection. Canada is only permitted to provide uranium, technology and services to facilities that are under IAEA safeguards. Extending IAEA access in China would both benefit nuclear safety and security as well as further the sale of Canada's nuclear energy related products and expertise.

6. **Seek clarity on India's Civil Liability for Nuclear Damage Act:** The Government of Canada needs to continue advocating for a solution to the nuclear liability law issue in order to permit access for Canadian companies.

7. **Provide visible government support for nuclear energy exports:** Due to the connection between nuclear energy technology and national security, federal and provincial government involvement is essential to opening doors in Asia for Canadian nuclear energy technology companies. The Government of Canada and provincial governments will need to continue to endorse Canada's nuclear industry abroad and provide ministerial level support for trade missions where possible.

8. **Enhance export readiness of small and medium enterprises:** Many companies in the nuclear supply chain are small- to medium-sized enterprises that often do not have the financial and human resources to explore Asian markets. The Government of Canada, provincial governments and industry associations need to continue providing services and assistance to help SMEs export technology and services.

9. **Ensure a strong nuclear energy R&D industry:** Canada has more than 70 years of strong R&D experience in the area of nuclear energy. The Government of Canada and provincial governments need to continue providing nuclear energy R&D/S&T funding to university research centres, labs and industry to ensure the future health of the sector.

10. **Improve domestic transportation infrastructure:** Canada needs to continue to enhance rail, road and port infrastructure and accessibility to facilitate export of Canadian uranium and other products to Asia.

11. **Ensure financing for the export of nuclear energy technology and services:** The Government of Canada needs to ensure that its agencies are offering sufficient export credit to support export of nuclear energy technology, within guidelines set by the OECD. In the future, financing third-market Canada-India or Canada-China nuclear energy projects could be explored by selected sectors such as Canadian pension funds and insurance companies.

12. **Nurture company-to-company relationships:** Canadian nuclear energy technology companies should not rely on government to promote them in Asia. While government sets the framework, Indian and Chinese companies decide who they will partner with on contracts. Canadian companies should seek to establish joint ventures with Indian and Chinese companies, as these are the best way to gain market share.

13. **Deepen collaboration on nuclear safety:** As India and China increase their use of nuclear energy, government and industry in Canada should continue to collaborate with these countries to enhance nuclear safety both at home and abroad. Canada should negotiate MOUs on technical cooperation and exchange of regulatory information with countries in Asia that are developing (or are considering developing) nuclear energy, including Malaysia and Vietnam.

14. **Consult with the Canadian public:** The Canadian government and the nuclear energy industry should consult with the public about Canada's potential role in the nuclear energy industry in Asia.

Canada's nuclear energy industry shares many synergies with the energy needs of Northeast and South Asia. Canada needs to carefully consider its approach to the nuclear energy file. However, strong competition from Asia and other leaders in nuclear energy technology and services means that Canada cannot expect opportunities to wait indefinitely. Canada must choose an approach and then quickly and consistently implement it.

MAXIMIZING CANADA'S NUCLEAR ENERGY OPPORTUNITY IN ASIA WORKSHOP AGENDA

DECEMBER 2, 2015

TORONTO, CANADA

8:00 a.m.-8:30 a.m.

Registration

8:30 a.m.-9:00 a.m.

Opening Remarks:

- **STEWART BECK**, President & CEO, Asia Pacific Foundation of Canada
- **CHRIS FLOOD,** Counsel, Blake, Cassels & Graydon LLP
- **THE HONOURABLE REZA MORIDI**, Minister of Training, Colleges and Universities and Minister of Research and Innovation

9:00 a.m.-10:30 a.m.

PANEL ONE: Realizing the Full Potential of Canada-India Civil Nuclear Co-operation

The Government of India has long supported nuclear power as a means of addressing India's growing energy needs. India currently has 21 operating nuclear reactors, most of which are indigenized pressurized heavy water reactors derived from Canadian technology. According to the World Nuclear Association, six reactors are under construction and more than 20 are planned.

In 2013, Canada and India ended 40 years of inactivity on nuclear energy co-operation with the implementation of the Canada-India Nuclear Cooperation Agreement. While the agreement has resulted in some concrete outcomes over the last two years, many opportunities have yet to be realized. Our panel of experts from Canada, India and the U.S. will address how Canada and India can accelerate nuclear energy co-operation for the maximum benefit of both countries.

PANELLISTS

- **STEWART BECK |** President & CEO, Asia Pacific Foundation of Canada (Moderator)
- **DALE AUSTIN |** Manager, Government Relations, Cameco Corporation
- **M.V. KOTWAL |** Former Member of the Board and Former President, Heavy Engineering, Larsen & Toubro, India
- **RON OBERTH |** President, Organization of Canadian Nuclear Industries
- **VIJAY SAZAWAL |** Principal, International Atomic Energy Consulting (IAEC)

10:30 a.m.-10:45 a.m.

Break

10:45 a.m.-12:20 p.m.

PANEL TWO: Maximizing Canada-China Co-operation on Nuclear Energy

Government policy in China strongly supports the implementation of nuclear energy and, as a consequence, China has emerged as the growth engine of the global nuclear industry.

Canadian companies have already had some substantial success in China's growing nuclear energy market. However, the China-Canada nuclear energy relationship is not just about opportunities for Canada to sell into China's domestic market. China has growing capabilities in nuclear energy technology and services to share and is a leader in the export of nuclear power plant construction and operation services, financing and components. Canadian and Chinese companies are already collaborating in third markets and some Chinese companies have indicated an interest in expanding involvement in Canada's nuclear energy and uranium sectors.

Our panel of experts from Canada, China and the U.S. will examine how Canada can best leverage China's growing nuclear energy needs, technological know-how, export capacity and capital to benefit both countries.

PANELLISTS

- **JOHN BARRETT |** President & CEO, Canadian Nuclear Association (Moderator)
- **WEI LIU |** Technical Director, China General Nuclear Power Corporation (CGN) Romanian Nuclear Power Company (Preparatory)
- **DAMIEN MA |** Fellow, Paulson Institute
- **DAVE MURPHY |** Minister (Commercial), Embassy of Canada to China
- **JIAN RONG |** Director, Program Development Division, Nuclear Power Department, National Energy Administration
- **DEZI YANG |** Senior Vice-President, China Accounts, Candu Energy Inc.

12:20 p.m.-1:00 p.m.

Lunch

1:00 p.m.-2:00 p.m.

PANEL THREE: Strategies for Furthering Canada-Asia Co-operation on Nuclear Safety

After Fukushima, nuclear safety has taken a central place in discussions about nuclear energy, not only among nuclear regulators and operators, but also among the public and governments in nuclear and non-nuclear countries alike.

With the world looking for reliable and low-greenhouse-gas-emitting sources of electricity, nuclear energy is seen by many countries, especially in Asia, as an important part of the energy mix. However, the international community wants to ensure that this increased adoption of nuclear energy is done in a manner that is safe for people and the environment. Maintaining a high level of operational safety is critical for all nuclear power plants, as a nuclear accident has repercussions not only for local residents but also for the inhabitants of neighbouring regions.

This panel and roundtable discussion will explore nuclear safety challenges in Asia, Canada and the U.S. and will address how Canada and countries in Asia can deepen collaboration on nuclear safety in the Asia Pacific region.

PANELLISTS

- **KEVIN LYNCH |** Vice-Chair, BMO Financial Group (Moderator)
- **MICHAEL BINDER |** President & CEO, Canadian Nuclear Safety Commission
- **PAUL DICKMAN |** Senior Policy Fellow, Argonne National Laboratory

2:00 p.m.-2:15 p.m.

Break

2:15 p.m.-3:45 p.m.

PANEL FOUR: Building Social Licence for Nuclear Energy: Perspectives from the Asia Pacific

Around the world, public involvement in decision making about energy and mining projects is increasing. While this involvement can bring positive outcomes, it can also produce costly delays. As a result, many companies in the energy and natural resources sectors aim to gain support for their activities from concerned groups or stakeholders over and above meeting any legal requirements. In Canada, this process is typically referred to as "obtaining social licence to operate."

In the nuclear industry, the need to build social licence occurs at every stage of the fuel cycle from uranium extraction and fuel manufacturing to nuclear waste storage and fuel reprocessing. This is not new. However, following the Fukushima Daiichi incident in Japan in 2011, the public debate about the desirability of nuclear energy intensified globally. Many countries delayed plans to increase the role of nuclear in the energy mix or vowed to abandon nuclear energy entirely.

The Building Social Licence for Nuclear Energy: Perspectives from the Asia Pacific panel will evaluate what South Korea, Japan and Ontario can learn from each other about best practices for building local community support for nuclear energy.

PANELLISTS

- **MALCOLM GRIMSTON |** Senior Research Fellow, Imperial College (Moderator)
- **TED GRUETZNER |** Vice-President, Corporate Relations and Communications, Ontario Power Generation
- **EUNJUNG LIM |** Lecturer, John Hopkins SAIS
- **JAMES PLATTE |** Lecturer, Merrimack College
- **DEREK TEEVAN |** Senior Vice-President, Corporate and Aboriginal Affairs, Detour Gold

3:45 p.m.-4:00 p.m.

Closing Remarks

EVA BUSZA, Vice-President, Research & Programs, Asia Pacific Foundation of Canada

THANK YOU

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