Australia's National Science Agency

GenCost 2020-21

Final report

Paul Graham, Jenny Hayward, James Foster and Lisa Havas
June 2021

2

References

Aurecon 2021, *2020 costs and technical parameter review*, AEMO.

AUSTEn 2020 *Tidal Energy in Australia - Assessing resource and feasibility for Australia's future energy mix*. Milestone 4 report to ARENA

Australian Electricity Market Operator (AEMO) 2020, *Input and assumptions workbook v1 5 Jul 20*, AEMO.

Bureau of Resource and Energy Economics (BREE) 2012, *Australian Energy Technology Assessment*, BREE, Canberra.

Brinsmead T.S., Graham, P., Hayward, J., Ratnam, E.L., and Reedman, L. 2015, *Future Energy Storage Trends: An Assessment of the Economic Viability, Potential Uptake and Impacts of Electrical Energy Storage on the NEM 2015-2035*, AEMC, Australia.

Campey, T., Bruce, S., Yankos, T., Hayward, J., Graham, P., Reedman, L., Brinsmead, T., Deverell, J. 2017, *Low Emissions Technology Roadmap*, CSIRO, Australia.

Cavanagh, K., Ward, J. K., Behrens, S., Bhatt, A. R., E, O., & J, H. 2015, *Electrical energy storage: technology overview and applications.* CSIRO for AEMC.

CO2CRC 2015, *Australian Power Generation Technology Report*, CO2CCRC, Canberra.

Economic and Finance Working Group (EFWG) 2019, *SMR roadmap*, Canadian Nuclear Association.

Edmonds, J., Lucknow, P., Calvin, K., Wise, M., Dooley, J., Kyle, P., . . . Clarke, L. 2013, Can radiative forcing be limited to 2.6Wm(-2) without negative emissions from bioenergy and CO2 capture and storage? *Climatic Change, 118*(1), 29-43 SI. doi:10.1007/s10584-012-0678.2

Electric Power Research Institute (EPRI) 2010, *Australian Electricity Generation Technology Costs – Reference Case 2010*. Department of Resources, Energy and Tourism, Canberra.

Fraunhofer ISE, 2015. Current and Future Cost of Photovoltaics. Long-term Scenarios for Market Development, System Prices and LCOE of Utility-Scale PV Systems, s.l.: Study on behalf of Agora Energiewende

Gas Turbine World 2009, *Gas Turbine World Handbook*.

Gas Turbine World 2010, *Gas Turbine World Handbook*.

Gas Turbine World 2011, *Gas Turbine World Handbook*.

Gas Turbine World 2012, *Gas Turbine World Handbook*.

Gas Turbine World 2013, *Gas Turbine World Handbook*.

GHD 2018, *AEMO costs and technical parameter review: Report final Rev 4 9110715*, AEMO, Australia.

Government of India. 2016, *A new dawn in renewable energy*. India: Ministry of new and renewable energy. Retrieved from http://pib.nic.in/newsite/PrintRelease.aspx?relid=155612

3

Graham, P., Hayward, J., Foster, J. and Havas, L. 2020, GenCost 2019-20, Australia.

Graham, P.W., Hayward, J, Foster, J., Story, O. and Havas, L. 2018, *GenCost 2018,* CSIRO, Australia.

Graham, P. 2018, *Review of alternative methods for extending LCOE calculations to include balancing costs*. CSIRO, Australia.

Grübler, A., Nakicenovic, N., & Victor, D. G. 1999, Dynamics of energy technologies and global change. *Energy Policy, 27*(5), 247-280.

GWEC. (n.d.). *Global Wind Report Series 2006 to 2016.* Global Wind Energy Council.

Hayward, J. A., Foster, J. D., Graham, P. W., & Reedman, L. J. 2017. A Global and Local Learning Model of Transport (GALLM-T). In Syme, G., Hatton MacDonald, D., Fulton, B. and Piantadosi, J. (eds) MODSIM2017, 22nd International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2017, pp. 818-824. ISBN: 978-0-9872143-7-9. https://www.mssanz.org.au/modsim2017/F1/hayward.pdf [accessed 18 December 2018]

Hayward, J.A. and Graham, P.W. 2017, *Electricity generation technology cost projections: 2017-2050*, CSIRO, Australia, https://publications.csiro.au/rpr/download?pid=csiro:EP178771&dsid=DS2

Hayward, J. and Graham, P. 2013, A global and local endogenous experience curve model for projecting future uptake and cost of electricity generation technologies, *Energy Economics*, 40, 537-548.

International Energy Agency (IEA) 2008, *Electricity Information 2008 Edition.* Paris, France: IEA.

International Energy Agency (IEA) 2008, *World Energy Outlook.* Paris, France: IEA.

International Energy Agency (IEA) 2015,. *Projected costs of Generating Electricity* . Paris, France: OECD.

International Energy Agency (IEA) 2016a, *CSP Projects Around the World*. Retrieved from SolarPACES: http://www.solarpaces.org/csp-technology/csp-projects-around-the-world

International Energy Agency (IEA) 2016b, *World Energy Outlook* . Paris, France: OECD.

International Energy Agency (IEA) 2020, *World Energy Outlook* . Paris: OECD.

International Energy Agency (IEA) n.d. *Trends in Photovoltaic Applications Series from 2007 to 2016.* Paris, France: IEA.

IPCC, 2014, *Climate Change 2014: Mitigation of Climate Change*. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

IRENA 2019, *Renewable Power Generation Costs in 2018.* IRENA.

Jacobs 2017, *Report to the Independent Review into the Future Security of the National Electricity Market: Emission mitigation policies and security of supply*, Department of Energy and Environment, Canberra.

McDonald, A., & Schrattenholzer, L. 2001, Learning rates for energy technologies. *Energy Policy,* 29, 255-261.

Projected Costs of Generating Electricity

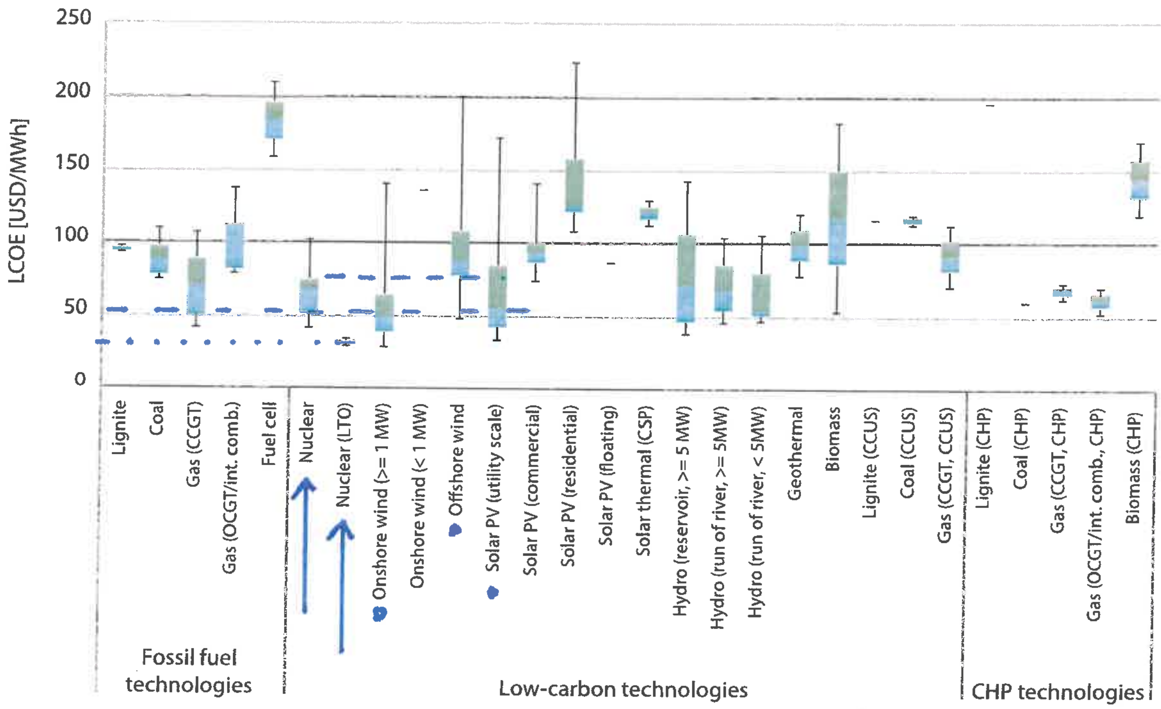
2020 Edition

International Energy Agency

NEA
NUCLEAR ENERGY AGENCY

Due to the indicated differences in input values also the LCOE of different electricity generation technologies vary significantly depending on the country, the technology and the properties of individual plants. It is thus not meaningful to point out a single power plant type, which would outcompete the others in terms of average costs. This is in particular true for renewable technologies, especially wind turbines and photovoltaics, whose costs are very much location dependent. Therefore, they are frequently tailored to individual requirements: not only are PV installations differing in size, from household rooftop installation and floating panels to utility scale open space PV installations, but also wind turbines range from being installed in small-scale individual units to large wind farms. The same holds true for hydro units, being connected to small streams or large rivers, in the form of run of river or reservoir. Figure 3.4 illustrates this range of technological options for generating electricity and associated costs.

Figure 3.4: Overview of LCOE values



Note: Values at 7% discount rate. Box plots indicate maximum. median and minimum values. The boxes indicate the central 50% of values, i.e. the second and the third quartile.

The multitude of categories also illustrates the diversity of options on the thermal technology side: several fuel categories are paired with technology options like CHP, CCUS and different turbine types. One of the most striking results is the large range of LCOE values for renewable technologies. Although utility-size power plants often have plant-level costs that are comparable to conventional power plants, smaller plants can still be several times more expensive.

The aggregated data for the 24 countries that provided data for this report does not tell the whole story of levelised generation costs. Due to more or less favourable sites for renewable generation, varying fuel costs and technology maturity, costs for all technologies can vary significantly by country and region. In addition, the *share* of a technology in the total production of an electricity system makes a difference to its value, load factor and average costs.

6

Cost reduction opportunities in the short term (up to 2030)

In the short term (up to 2030), with the previous drivers and conditions already in place, the cost of nuclear projects could be further reduced.

In technology and process innovation, a range of cost reduction opportunities could be exploited through the interplay between the reactor design and the associated delivery processes. These drivers are not necessarily sequential and can be mobilised even during early planning stages in order to accelerate learning.

There is evidence that countries in more advanced stages of learning are already benefiting from these opportunities and working on a continuous improvement basis similar to other industries. In addition, in order to maximise the potential of cost reduction, the right balance between improvement and replication needs to be found in order not to alter the positive learning dynamics. Timely decision making has also to be acknowledged with the objective to ensure the right pace of new construction and diminish the risk of over engineering.

At the reactor design level, the experience gathered in the first constructions can be used to reach higher levels of simplification, standardisation and modularisation as well as to integrate the latest technical advances. Organisational efficiencies can also be unlocked through a new set of innovative processes.

Additional opportunities in the longer run (beyond 2030)

Longer-term (beyond 2030) cost reductions are also possible. There are indications that countries in more advanced learning stages are moving in this direction.

Further cost reductions can be achieved by means of higher levels of harmonisation in codes and standards, and licensing regimes. Other highly regulated activities such as the aviation sector have already undertaken significant efforts in this field with positive results. Without neglecting the strong political dimension and the need to protect the sovereignty of national regulators, international collaboration for regulatory harmonisation has demonstrated that it is possible to reach common positions in some areas.[7]

8.4 Economic perspectives on small modular reactors (SMRs)

Small Modular Reactors (SMRs) are defined as nuclear reactors with a power output between 10 MWe and 300 MWe. Designs with power outputs smaller than 10 MWe, often designed for semi-autonomous operation, have been referred to as Micro Modular Reactors (MMRs).

SMRs are often designed for factory fabrication, taking advantage of the benefits of economies of series, to be transported and assembled on site, resulting in shorter construction times. This is one of the key elements that might prove to make SMRs cost competitive with other energy options.

7. See Multinational Design Evaluation Programme, www.oecd-nea.org/mdep/common-positions/PUBLIC%20USE%20DCP-EPR-01-%20EPR%20Instrumentation%20and%20Controls%20Design.pdf.

The most mature SMR concepts are based on LWR technology. Other concepts are Generation IV reactors that incorporate alternative coolants (i.e. liquid metal, gas or molten salts) and advanced fuels. SMR deployment configuration can vary between single-unit installations, multi-module plants, or mobile power sets such as floating (i.e. barge-mounted) units. In 2018, the International Atomic Energy Agency (IAEA) identified more than 50 concepts under development with different technology and licensing readiness levels, including four concepts that were under construction at the time.

Due to smaller reactor cores, very large water inventories and lower power densities, LWR SMRs may benefit from reduced shielding requirements and reduced or eliminated offsite Emergency Planning Zones (EPZ) which, in turn, will result in added flexibility for the siting of these reactors. SMR designs often include an integral nuclear steam supply system and take advantage of overall system simplification. Inherent passive safety systems provide SMRs with greater and, in some cases indefinite, coping times in case of a loss of offsite power. Many SMRs are designed to be installed below-grade resulting in higher physical protection and protection from external hazards.

8.4.1 Key economics drivers of SMRs

While smaller cores bring the benefits described above, they also have a negative effect on the economic competitiveness of the unit. Reactor designers have traditionally scaled reactors up to larger sizes to take advantage of the economies of scale. In other words, because the fixed costs associated with a nuclear reactor grow very slowly as the size of the reactor increases, it makes sense to increase the output of the reactor to reduce as much as possible the cost per unit of electricity produced. To counterbalance the impact of diseconomies of scale, the business case of SMRs is supported by economies of series production, which in turn relies on design simplification, standardisation and modularisation.

The benefits of serial construction have been well documented in other industries, such as the shipbuilding and aircraft industries, in which serial manufacturing have resulted in learning rates between 10 and 20% (NNL, 2014). For the first SMR units, serial production may also allow to amortise non-recurrent costs, such as research, development and design certification costs.

To support serial construction and achieve learning rates of the same order of magnitude as these other industries, several specific drivers have been identified as summarised in Figure 8.5 below:

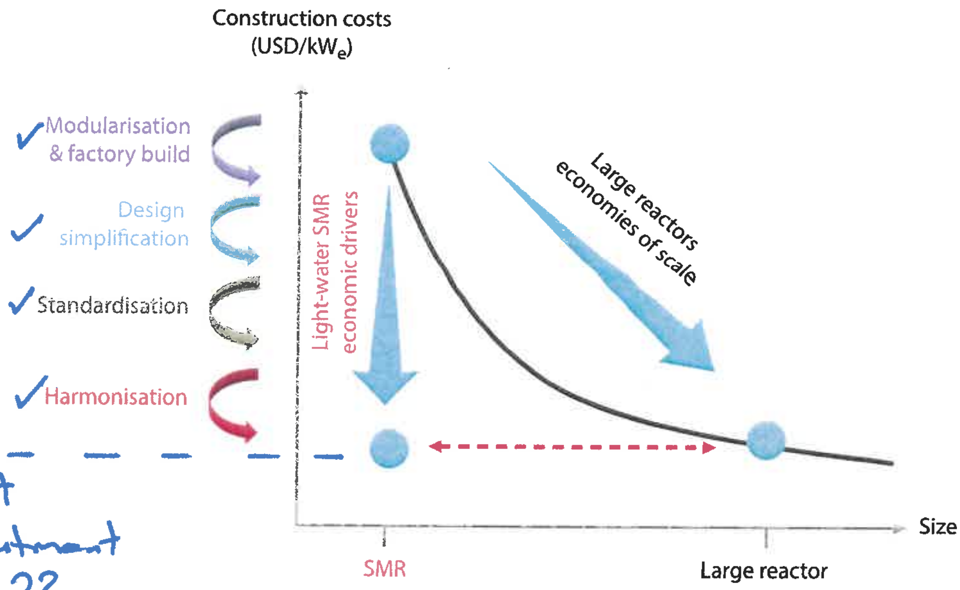
- Simplification: Passive mechanism improvements and greater design integration would reduce the number of components and result in containment building savings.
- Standardisation: The lower power output of SMRs reduces the need to adapt to local site conditions, raising the level of design standardisation compared with large reactors.
- Modularisation: Smaller SMR size means that transporting their modules would be easier than for large reactors. In fact, the degree of modularisation increases considerably for power outputs of less than 500 megawatts of electrical capacity (MWe). This trend could be improved with more aggressive modularisation techniques tailored to the logistical constrains and transport standards of each country. It is estimated that 60-80% factory fabrication levels are possible for SMRs (with power outputs below 300 MWe) (Lloyd, 2019). This would also facilitate the implementation of advanced manufacturing techniques such as electron beam welding and diode laser cladding by 2025 (EY, 2016). Others, such as powder-metallurgy hot isostatic pressing and additive manufacturing, are at lower technology readiness levels but significant progress is being made (EPRI, 2018).
- Harmonisation: Having access to a global market is necessary to foster series-production economies, but this is possible only with regulatory and industrial harmonisation.

In that respect, as highlighted in Figure 8.4, it is important to stress that SMR construction costs will be impacted by the key cost drivers identified for large Generation III nuclear reactors. However, some specific drivers will carry more weight. This is especially the case of the series effect, as well as simplification, standardisation, modularisation and harmonisation.

Attaining these economic benefits will require a co-ordinated effort between the different stakeholders, as well as a dedicated policy and regulatory framework. It is also imperative to appropriately estimate the size of the global market required to establish a robust supply chain and sustainable construction know-how that result in cost-competitive capital costs.

If SMRs can be serially manufactured in a manner similar to commercial aircraft, the economic benefits are significant. This requires, however, the market for a single design to be relatively large, which denotes the need for a global market. For this to be realised, regulators will need to consider how they might co-operate to enable a true global market for nuclear technologies.

Figure 8.6: SMR economic drivers that help compensate diseconomies of scale



BWRX-300

OPG Announcement & Govt investment See Pg 22

Source: NEA (2020).

8.4.2 Market potential for SMRs: Broadening the value proposition of nuclear power

The smaller size and the shorter delivery times predicted make the upfront investments needed for SMRs smaller. As a result, customers and investors may face lower financial risk, which could make SMRs a more affordable and attractive option. Given their smaller size, SMRs also offer more flexibility to meet demand growth in smaller increments, which would also improve their overall business case.

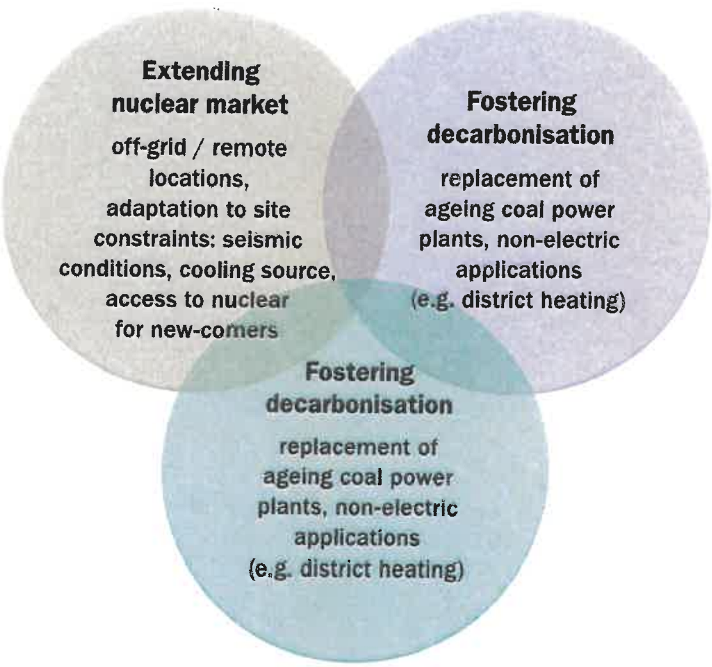
However, the anticipated advantages of series deployment will only be realised if SMRs can take advantage of a global supply chain and a global customer basis, which require a streamlined multinational licensing framework and co-ordinated international codes and standards for the manufacture of systems and components.

Although most SMR technologies are in the relatively early stages of development and significant uncertainties remain for their market outlook, at least three potential applications have been identified for SMRs, in addition to the traditional role of providing baseload electricity:

- Decarbonising energy systems by replacing coal plants and providing power for district heating and desalination applications. Most advanced designs such as non-LWR SMRs, that are designed to have higher operational temperatures, could supply process heat for industrial sectors where substituting carbon-intensive sources of energy would otherwise not be possible.
- Complementing the penetration of variable renewable energy (VRE) by providing system benefits based on the flexible operation of SMRs and the possibility to be part of an integrated portfolio of solutions in "hybrid" energy systems.
- Facilitating the expansion of the nuclear sector in regions where economic, geographical and/or grid-related constraints do not allow the use of large nuclear power plants. For such markets, SMRs may already be a cost-competitive way to replace diesel generators to produce electricity, heat and fresh water.

These different market drivers are therefore expected to broaden the value proposition of nuclear power as part of future integrated energy systems, supporting in particular the decarbonisation of hard-to-abate sectors. SMRs should therefore be seen as complementary to large Generation III nuclear power plants as they will address different market needs.

Figure 8.7: The market opportunities for SMRs



Source: NEA (Forthcoming, b).

10

8

8.5 Conclusions

The general cost projections and specific cost drivers identified in this chapter suggest that nuclear power support cost-effective decarbonisation in several complementary ways.

First, LTO remains one of the most cost-competitive options to generate low-carbon dispatchable electricity in many regions with a LCOE ranging USD 30-50/MWh. Thanks to lower CAPEX needs and back up by a solid industrial infrastructure, LTO faces limited project risks and represents a significant pool of "shovel-ready" projects to maintain SDS emissions targets within reach.

Second, thanks to the experience gained with recent FOAK projects, new nuclear can enter in a phase of rapid learning in western OECD countries with near-term overnight costs reductions of 20% to 30% compared to today's levels. Moreover, leveraging several factors that arise at the technical, organisation and regulatory level could unlock additional cost reductions in new projects alongside with higher predictability in their delivery. More active government intervention in risk allocation and mitigation strategies for new projects will also have significant impact on financing. As result, financing costs, which can represent 80% of the total investment costs, could notably fall further improving the economic performance of nuclear.

Third, SMRs propose cost and risk reductions with factory built construction and higher affordability of the projects. Nevertheless, while some of these benefits have been documented in other industries, they still need to be proven in the nuclear sector. The construction of first prototypes may materialise some of the announce benefits of SMRs and thus accelerate their commercial viability. Government support is also essential on this front.

This is step in US ...

Countries envisaging to pursue the nuclear option will benefit from the mobilisation of these three complementary solutions. In these countries, while LTO may be more economically attractive, new nuclear projects are required to prepare the renewal of the fleets and ensure that nuclear power is on track to meet its long term contribution to decarbonisation. Progress made with the development of large Generation III reactors will also support the development of SMRs as most of the cost reductions drivers are not technology-specific. Finally, SMRs have specific value propositions and target specific markets and applications that could accelerate the decarbonisation of hard-to-abate sectors.

References

DGEC (2015), "Audit sur les modalités d'évaluation des charges brutes permettant le calcul des provisions de déconstruction des réacteurs d'EDF en cours d'exploitation", Direction générale de l'énergie et du climat, France, www.ecologique-solidaire.gouv.fr/sites/default/files/061015Synth%C3%A8se%20rapport%20audit%20Dampierre_0.pdf.

EPRI (2018), "Advanced Nuclear Technology: Demonstration of Powder Metallurgy-Hot Isostatic Pressing", Electric Power Research Institute, www.epri.com/#/pages/product/000000003002010500/?lang=en-US.

Ernst & Young (2016), "Small Modular Reactors: Can Building Nuclear Power Become More Cost-Effective?", March 2016, www.researchgate.net/publication/321715136_Small_modular_reactors_Can_building_nuclear_power_become_more_cost-effective.

IAEA (2018), *The economic Assessment of Long-Term Operation of Nuclear Power Plants: Approaches and Experience*, International Atomic Energy Agency, Vienna, www-pub.iaea.org/MTCD/Publications/PDF/PUB1813_web.pdf.

IAEA (2008), *Ageing Management and Development of a Programme for Long-Term Operation of Nuclear Power*, International Atomic Energy Agency, Vienna, www-pub.iaea.org/MTCD/Publications/PDF/P1814_web.pdf.

IEA (2020), "Nuclear power", in *Tracking Clean Energy Progress*, IEA, Paris, www.iea.org/reports/nuclear-power.

IEA (2019), *The role of nuclear power in clean Energy systems*, IEA, Paris, www.iea.org/reports/nuclear-power-in-a-clean-energy-system.

IEA/NEA (2015), *Projected Costs of Generating Electricity 2015*, OECD Publishing, Paris, https://doi.org/10.1787/cost_electricity-2015-en.

IEA/NEA (2010), *Projected Costs of Generating Electricity 2010*, OECD Publishing, Paris, https://doi.org/10.1787/9789264084315-en.

IEA/NEA (2005), *Projected Costs of Generating Electricity 2005*, OECD Publishing, Paris, https://doi.org/10.1787/9789264008274-en.

Lloyd, C.A. (2019), "Modular Manufacture and Construction of Small Nuclear Power Generation Systems, PhD thesis", University of Cambridge, www.researchgate.net/publication/337937287_Modular_Manufacture_and_Construction_of_Small_Nuclear_Power_Generation_Systems.

NEA (Forthcoming a), *Long-Term Operation of Nuclear Power Plants: Economic, Technical and Policy Aspects*, OECD Publishing, Paris.

NEA (Forthcoming b), "Prospects for Small Modular Reactors: Challenges and Opportunities", OECD Publishing, Paris.

NEA (2020), *Unlocking Reductions in the Construction Costs of Nuclear: A Practical Guide for Stakeholders*, OECD Publishing, Paris, https://doi.org/10.1787/33ba86e1-en.

NEA (2019), *The Costs of Decarbonisation: System Costs with High Shares of Nuclear and Renewables*, OECD Publishing, Paris, https://doi.org/10.1787/9789264312180-en.

NEA (2016), *Costs of Decommissioning Nuclear Power Plants*, OECD Publishing, Paris, https://doi.org/10.1787/9789264255555-en.

NEA (2015), *Questionnaire on Long-Term Operation of Commercial Nuclear Power Plants*, OECD Publishing, Paris, www.oecd-nea.org/nsd/docs/2015/csni-r2015-13.pdf.

NEA (2012), *The Economics of Long-Term Operation of Nuclear Power Plants*, OECD Publishing, Paris, https://doi.org/10.1787/9789264992054-en.

NEA (2006), *Nuclear Power Plant Life Management and Longer-term Operation", Nuclear Development*, OECD Publishing, Paris, https://doi.org/10.1787/9789264029255-en.

NEA/IEA (2015), *Technology Roadmap: Nuclear Energy*, OECD Publishing, Paris, https://doi.org/10.1787/9789264229938-en.

NNL (2014), *Small Modular Reactors (SMR) Feasibility Study*, UK National Nuclear Laboratory.

NRC, *Status of Subsequent License Renewal Applications*, www.nrc.gov/reactors/operating/licensing/renewal/subsequent-license-renewal.html.

WENRA (2011), *Pilot Study on Long-Term Operation of Nuclear Power Plants*, www.wenra.org/media/filer_public/2012/11/05/ltoofnpps_1.pdf.

Yemm, R., D. Pizer , C. Retzler, and R. Henderson (2012), "Pelamis: experience from concept to connection", *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, No. 370(1959), pp. 365-380, https://royalsocietypublishing.org/doi/full/10.1098/rsta.2011.0312.

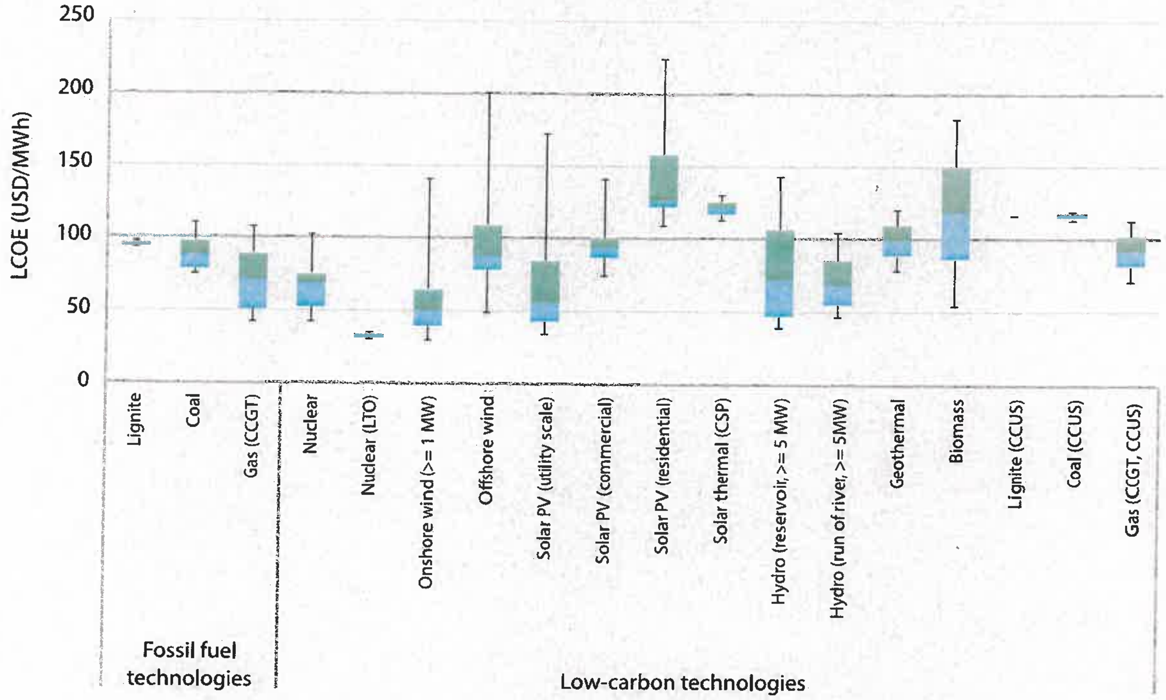
Meeting Climate Change Targets:

The Role of Nuclear Energy

NEA
NUCLEAR ENERGY AGENCY

To be clear: while all technologies impose some system costs, variable, intermittent, and uncertain sources of power generation impose far greater grid-level system costs, which is why it is so important to take a systems level perspective when comparing costs of variable renewables with nuclear, baseload hydro, and fossil generation.

Figure 19. **Levelised cost of electricity (LCOE) for different sources of electricity**



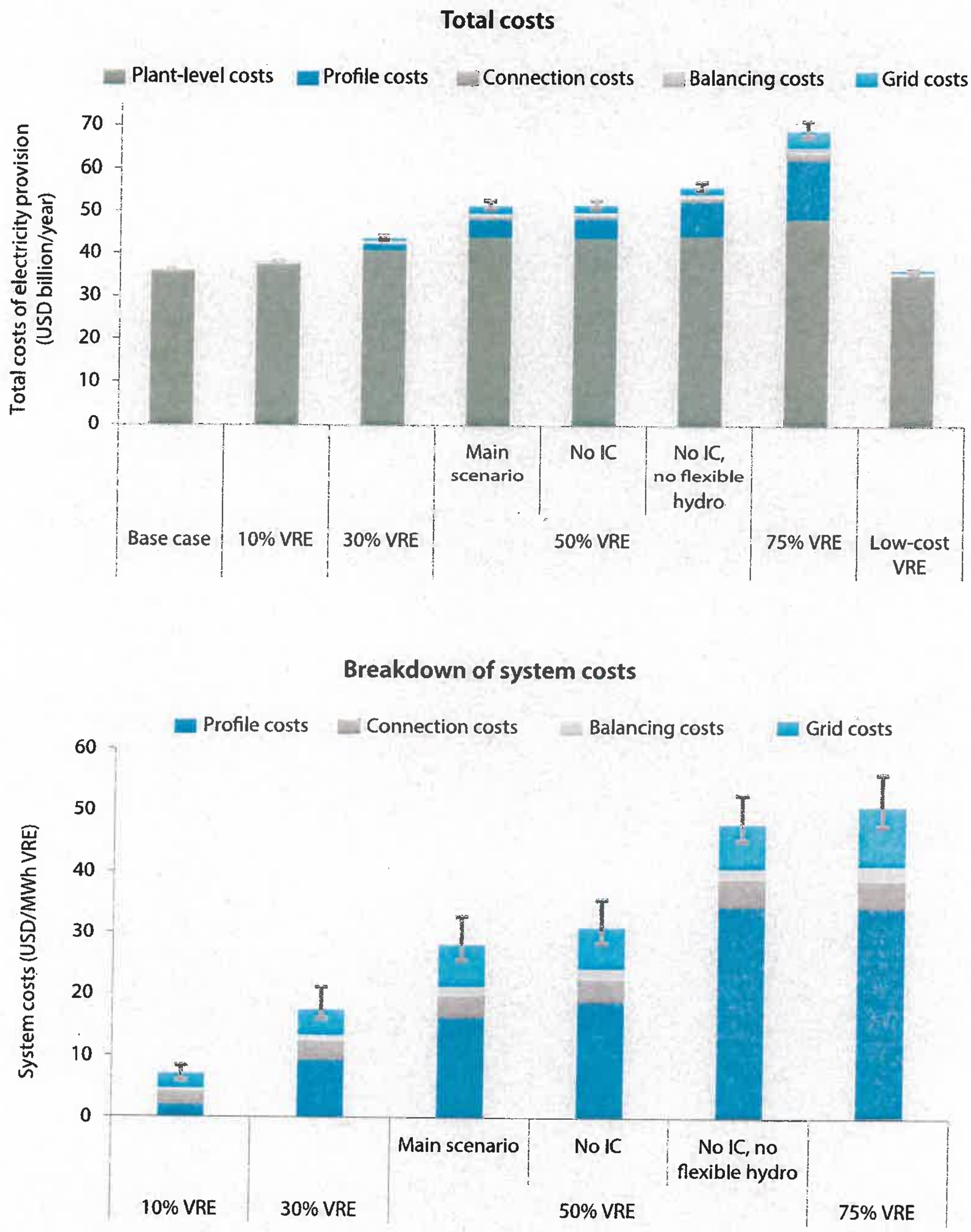
Source: IEA/NEA (2020).

The first step for cost comparisons remains LCOE analysis. Presented in Figure 19, an analysis of system costs from more than 20 IEA and NEA member countries concluded that the lowest cost option for generating electricity is long-term operation of nuclear power plants (IEA/NEA, 2020). Equally notable was the finding about the range of costs for solar and wind generation, which depend heavily on regional endowments and conditions. These results can be reproduced, and tested with different input parameters, with the IEA-NEA online LCOE calculator at: www.oecd-nea.org/lcoe.

LCOE analysis, considering technologies one by one, only tells part of the story though. It is crucial also to assess the interaction of different technologies in a mix of generating sources with different shares in the electricity supply. In order to analyse this, a recent NEA study compared a range of scenarios, starting with a base case with 0% variable renewables, then considering mixes with increasing shares of variable renewables, up to 75% variable renewables in the mix.

As shown in Figure 20, total costs rise as the share of variable renewables increases. This is due, in part to the rise in average plant-level costs, which in reality depends on the regional endowments and meteorological conditions in different countries. Under all circumstance, however, the system costs will rise as the growing share of variable renewables imposes greater costs on the grid for stability and flexibility.

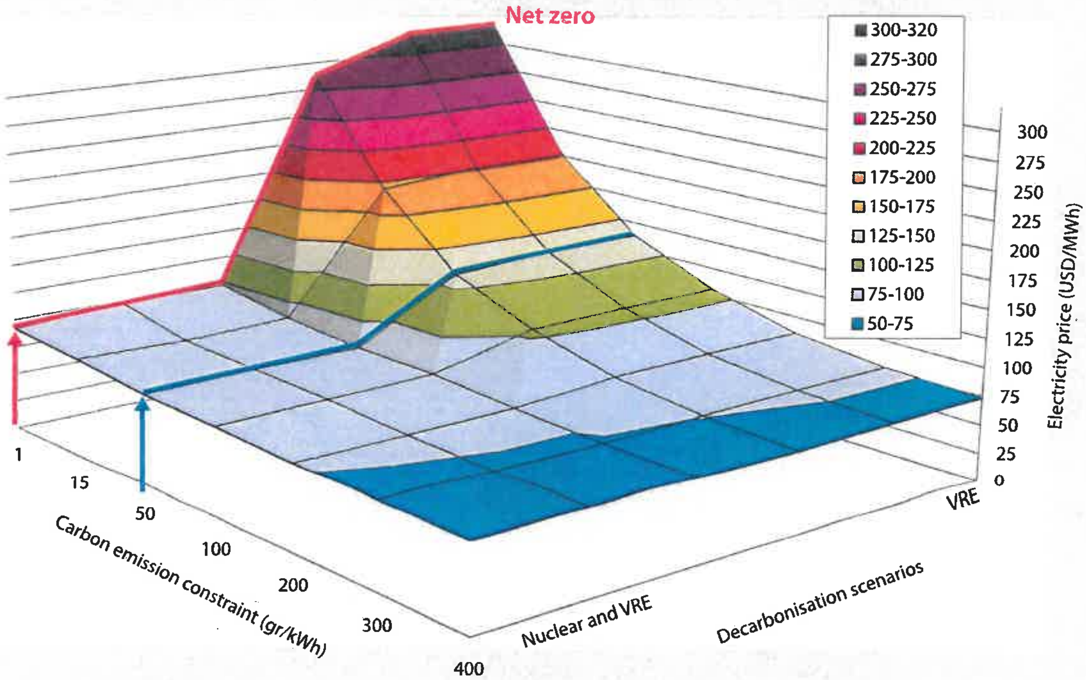
Figure 20. **Total costs for different mixes of electricity (with a carbon constraint of 50 grams per kWh)**



Source: NEA (2019).

Figure 20 shows the break-down of system costs as the share of variable renewables grows from 10% to 75% of the mix, including profile costs (to compensate for variability and intermittency), connection, distribution, and transmission costs, and balancing costs (to compensate for uncertainty). A key finding is that profile costs (to compensate for variability and intermittency) are the dominant driver of increasing total costs as the share of variable renewables grows.

Figure 21. **Total costs for different mixes of electricity (driving to net-zero emissions)**



Source: Based on Sepulveda (2016).

System costs are also a function of overall carbon constraints. Figure 21 shows the total costs (the sum of plant-level and grid-level system costs) as a function of carbon constraints (on the horizontal axis pointing left) and share of variable renewables (on the horizontal axis pointing right). The previous 2-dimensional graph (shown in Figure 20 above) illustrated how total costs increased significantly in scenarios with high shares of variable renewables. On the three-dimensional graph (shown in Figure 21), this is represented by the blue line, which cuts the three-dimensional image at a carbon constraint of 50 grams per kilowatt hour.

The 3-dimensional graph shows the effects on total costs as carbon emissions are increasingly constrained. The red line shows what happens to total costs when carbon constraints reach net-zero emissions. The relationship between the share of variable renewables and systems costs, driven by profile costs to compensate for variability, is even more pronounced when carbon constraints become more stringent.

The policy implications of these systems costs findings are significant. It may be possible to reduce emissions to meet 2030 targets by growing the share of variable renewables in the mix. However, the costs of reaching net zero with high shares of variable renewables are likely prohibitive. *Why?* In part, because initially, as variable renewables are introduced, they can be backed up with a low cost option, which in the absence of a serious carbon constraint is likely to be natural gas. But eventually, in a carbon constrained world, the options for backing up variable renewables become increasingly expensive. Dispatchable hydro power and nuclear energy are the only economic options while batteries remain prohibitively expensive for anything other than very short-term storage.

16

Mr ZIMMERMAN: Can you unpack that a little bit more? It sounds remarkably vague, in the sense that GHD has relied on a website, and, when you've sought to fact check that website, you can't find the $16,000 yourself, but then you talk about a range. It doesn't sound like a massively thorough process, if I can put it that way. I'm interested in your response to that. It sounds highly vague. Basically, you're relying on a third party, who's relying on a website, and you haven't been able to fact check that information yourself. It doesn't seem to provide the certainty—I know it's speculative, but you'd certainly be relying on it if you're making decisions about a significant investment in a new form of energy.

Dr Hayward: It is a tough one because it is so speculative. We have these stakeholder workshops where be put the numbers to them. We actually invite about 100 stakeholders, and we get about 20 to 30 to 40 coming along. We've interrogated those numbers with the stakeholders, and they seem to think that it's a perfectly reasonable number given the range of uncertainties out there.

Ms STEGGALL: Who are the stakeholders?

Dr Hayward: We could probably provide you with the list, I think.

Mr ZIMMERMAN: That would be helpful.

Mr JOSH WILSON: Can we have a broad indication? Do these people have expertise in small modular reactors?

Dr Hayward: It's a diverse range of people across the energy space. I believe some experts in nuclear were invited. I'm not 100 per cent sure—I don't think they came along to the workshops.

CHAIR: So they didn't include experts in nuclear?

Dr Hayward: They were invited.

CHAIR: But they didn't attend?

Dr Hayward: No.

CHAIR: So you're relying on validation from stakeholders who do not have expertise in nuclear energy?

Dr Hayward: They're experts across the energy sector. I'm not 100 per cent sure of all their expertise.

CHAIR: Sticking on this topic, are there any follow-ups?

Mr BURNS: To follow up on Mr Zimmerman's question, is that an accurate statement? CSIRO has relied on GHD, who's got a number from a website. Is that correct?

Dr Hayward: It's the World Nuclear Association—

Mr BURNS: I'm aware of the association.

Dr Hayward: so it's a reputable source.

Mr BURNS: But in terms of a thorough analysis and reliability—we are looking to make recommendations, decisions based on some of this information. It just doesn't sound terribly thorough.

Jane Coram: If I may, the difficulty in any modelling is that usually you're trying to predict something that you don't understand particularly well, so we're frequently forced into using ranges and picking a number within a range. At CSIRO we do source our figures in as much detail as we possibly can, but frequently when we're exploring new scenarios we don't necessarily have a definitive source of information. We can certainly provide the justification for the figures that have been used. But they have not been plucked out of the air. They've been justified as comprehensively as we can.

Mr HOGAN: Just to come back to that statement, why wouldn't CSIRO utilise someone who did know what they were doing?

CHAIR: Is that a question or a statement?

Mr HOGAN: It's a question.

Jane Coram: Could we possibly get back to you with the basis for the figures—the comprehensive basis—because it has been done as comprehensively as we can within the time frames. There is limited information to draw upon.

Mr BURNS: I certainly have sympathy in modelling a technology that isn't actively available right now. It is a complex task, and I'm glad you're working on it not me. On technologies that are available now where we can have perhaps a more accurate look at some of their prices: I'd be interested in your comments in relation to the *GenCost 2018* report, especially around firm renewables—the trend of firm renewables and the cost around firm renewables, as well as the long-term trend around large-scale nuclear reactors. Is it true that large-scale reactors have never gotten cheaper? And what is the long-term trend around firm renewables?

Ontario's Electricity Grid

Ontario's demand for electricity varies throughout the day, requiring different forms of supply to perform different roles to meet reliability. Learn how Ontario's electricity system works.

IN THIS SECTION...

Supply Mix and Generation

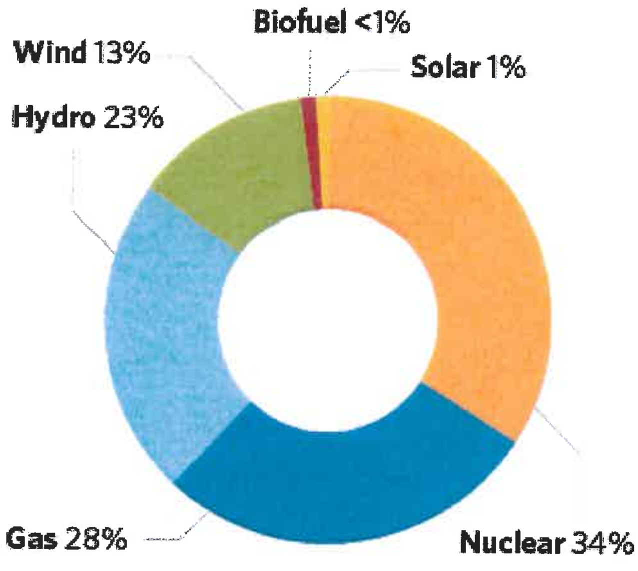
Ontario has a clean electricity grid with a range of diverse resources, including hydro, nuclear, natural gas and renewables. Each resource generates electricity differently and has unique operating characteristics. Because no single resource can meet all of the system's needs at all times, maintaining a diverse supply mix is an effective way to ensure the ongoing reliability of Ontario's electricity system.

Capacity

Capacity is a measure of the maximum amount of electricity the province's system can supply at any given time. Ontario's capacity is constantly changing as new supply comes online, older generators are taken out of service and new technologies are introduced.

Transmission-Connected Capacity

This is the capacity of resources that are connected directly to the high-voltage provincial grid, which is controlled by the IESO. Typically, these are industrial-scale power plants and wind and solar farms that can produce large amounts of electricity. Transmission-connected resources are the backbone of Ontario's electricity system and they supply most of the province's energy needs.



Nuclear	13,089 MW or 34%
Gas/Oil	10,482 MW or 28%
Hydro	8,868 MW or 23%
Wind	4,883 MW or 13%
Biofuel	296 MW or <1%
Solar	478 MW or 1%

Transmission-Connected Capacity as of September 2022 (Source: Reliability Outlook)

Distribution-Connected Capacity

This is the capacity of resources that are connected to a low-voltage community grid, which is controlled by your local hydro company. Typically, these are small-scale generators, demand response resources or energy storage that are owned and maintained by individuals, local facilities or other businesses. These resources serve some, or all, of the energy needs of their owners, reducing demand on the provincial grid.

Ontario's distribution-connected electricity supply on contract as of July 2022 broken down as: Solar = 2,171 MW or 61 per cent, Wind = 591 MW or 17 per cent, Hydro = 333 MW or 9 per cent, Gas = 320 MW or 9 per cent, Bio-fuel = 110 MW or 3 per cent and Waste = 24 MW or less than 1 per cent..

Distribution-Connected Capacity as of July 2022 (Source: Progress Report on Contracted Electricity Supply)

Energy Output

While capacity represents the maximum amount of electricity that the system can supply at any given time, the actual amount of energy produced varies. For example, while natural gas represented about 28 per cent of Ontario's total transmission-connected capacity in 2021, it only accounted for about nine per cent of actual generation. Most of the electricity produced in Ontario is generated at nuclear and hydro plants, which produce low levels of greenhouse gas emissions.

Ontario's electricity output by source in 2021 broken down as: Nuclear = 83 TWh or 58%, Natural Gas/Oil = 12.2 TWh or 8.6%, Hydro = 34.2 TWh or 24%, Wind = 12 TWh or 8.4%, Biofuel = 0.4 TWh or less than 1% and Solar = 0.75 TWh or less than 1 %.

Total Electricity Output by Source in 2021 (Source: Year End Data)

Different Types of Electricity Generation

- **Baseload Generation**
  Nuclear and run-of-the-river hydro plants generate a constant, steady supply of electricity - 24 hours a day, 7 days a week. The output of these generators is consistent and reliable, but rarely changes. Because of these operating characteristics, they are typically used first to meet Ontario's energy needs.
- **Intermediate and Peaking Generation**
  As demand rises and falls throughout the day, more flexible intermediate forms of electricity generation are used. Generators such as natural gas plants and hydro dams – which can adjust their output up or down quickly – play a crucial role in matching supply and demand throughout the day. These generators can also be called upon to meet peak demand when electricity use is at its highest.
- **Variable but Controllable Generation**
  Wind and solar farms generate more or less electricity based on how sunny or windy it is. While the amount of electricity they produce is always changing, their operation is very flexible and their output can be adjusted quickly in response to the electricity system's needs.

Different Sources of Electricity Generation

6 Key Requirements for SMR Feasibility in Ontario

6.1 On-grid SMR development at the Darlington nuclear site

6.1.1 Project Objectives

The Objectives of an SMR project at the Darlington site include:

- To maintain a diverse generation supply mix to minimize carbon emissions from electricity generation in the province
- To demonstrate a FOAK SMR to be ready for deployment across Canada by 2030
- To ensure economic development by securing Canadian content both for domestic and export projects from the developer in exchange for providing the opportunity to deploy their FOAK unit and be a first mover towards an SMR fleet

6.1.2 Project Description

The project is to build a 300 MW class SMR at the Darlington site

Project schedule – To be in service by 2028. A preliminary project schedule is shown in the figure below.

Figure 18 DNNP Potential Milestones and Timeline

Technology – To be selected through a collaboration between OPG, Bruce Power and SaskPower planned for 2021. A FOAK design is acceptable. A review process is underway, and based on progress to date, it is anticipated that a suitable technology will be available.

Project Cost – The capital cost of the project is expected to be less than $3 Billion (overnight capital cost) resulting in an LCOE of less than $100/MWh.

Additional Support – OPG and its partners Bruce Power and SaskPower are requesting support from the federal government over 4 years to support FOAK costs and risks in licensing and to acknowledge the costs incurred that will benefit future customers across Canada such as SaskPower.

6.1.3 Assessment of Feasibility

a. *The market* - Ontario's system operator's (IESO) reference case planning assumes modest but positive load growth: approximately 1% annually through 2040 in both energy and summer peak load. With the scheduled Pickering closure in 2024/2025, 3000 MW of baseload low carbon generation will be lost. OPG's assessment is that undertaking

MEDIA RELEASES

OPG advances clean energy generation project

GE Hitachi Nuclear Energy selected as Small Modular Reactor technology development partner

DECEMBER 2, 2021

Clarington, ON – Today, Ontario Power Generation (OPG) is announcing it will work together with GE Hitachi Nuclear Energy to deploy a Small Modular Reactor (SMR) at the Darlington new nuclear site, the only site in Canada currently licensed for a new nuclear build. Leveraging a strong Ontario-based supply chain, this clean energy project will create jobs across the province and cement Durham Region's position as the clean energy capital of Ontario.

OPG and GE Hitachi will collaborate on the SMR engineering, design, planning, preparing the licencing and permitting materials, and performing site preparation activities, with the mutual goal of constructing Canada's first commercial, grid-scale SMR, projected to be completed as early as 2028.

Learn more about the **GE Hitachi BWRX-300**.

Watch the announcement

Environmental impact

The Darlington SMR will provide a critical new source of clean nuclear energy for Ontario's future projected energy capacity needs – a demand widely expected to ramp up as transportation and other sectors electrify, using Ontario's clean power to help decarbonize the broader economy. International bodies, including the International Energy Agency (IEA), have been clear: climate change initiatives will fall short without nuclear power as part of the electricity supply mix.

A single SMR of about 300 megawatts in size can prevent between 0.3 megatonnes (MT) to 2 MT of carbon dioxide emissions per year, depending on where it is located and what kind of power it is displacing.

Economic impact and jobs

A 2020 **study** undertaken by the Conference Board of Canada shows strong economic benefit to Ontario from construction and 60 years of operation of a single SMR facility in the province. According to the report:

- Direct, indirect and spin-off related employment would result in an annual average of approximately: 700 jobs during project development; 1,600 jobs during manufacturing and construction; 200 jobs during operations; and 160 jobs during decommissioning.
- The estimated positive impact on Gross Domestic Product (GDP) could reach more than $2.5 billion and result in an increase of provincial revenues of more than $870 million.

Beyond that, construction of a new nuclear generator at Darlington is expected to:

- Drive employment and economic growth, thanks to the strong existing Ontario- and Canada-based nuclear supply chain. It is anticipated that 70 to 80 per cent, or more, of the necessary components and materials for OPG's SMR will be sourced in Ontario.

- Spur SMR deployment elsewhere in Canada and abroad. Saskatchewan is also looking to follow Ontario and build SMRs to replace its coal fleet, building up to four SMRs with the first unit in Saskatchewan being in service in the early 2030s. Other countries, including the United Kingdom, the United States, France, Poland and Estonia have all expressed interest in building SMRs, and Ontario would be well placed to contribute to the Canadian and international supply chain.
- Provide significant environmental benefits to Ontario and reduce emissions elsewhere: clean nuclear power could be used to maintain Ontario's low carbon electricity grid and help meet emerging electricity needs in the short term due to Pickering closure and electrification, as well as support other jurisdictions' efforts to phase out coal and Canada's goals of becoming net zero by 2050.

Site preparation will begin in the spring of 2022, pending appropriate approvals. This work will include installation of the necessary construction services. OPG's goal is to apply to the Canadian Nuclear Safety Commission (CNSC) for a License to Construct by the end of 2022.

Quick facts

- Darlington Nuclear Generating Station is one of the top-performing nuclear stations in the world and generates about 20 per cent of Ontario's electricity each day.
- The Darlington New Nuclear Project is the only site in Canada with an approved Environmental Assessment and regulatory licence for new nuclear.
- Ontario, New Brunswick, Saskatchewan and Alberta have signed a **Memorandum of Understanding** to collaborate on the advancement of SMRs as a clean energy option to address climate change and regional energy demands, while supporting economic growth and innovation.
- A **2019 study** for the Canadian Nuclear Association and Organization of Canadian Nuclear Industries shows the nuclear industry contributes $17 billion per year to the Canadian GDP and supports about 76,000 jobs in Canada.
- Learn more about the **Canadian SMR Action Plan**, Canada's plan for development, demonstration and deployment of SMRs.

Quotes

"We know nuclear is a key proven zero emissions baseload energy source that will help us achieve net zero as a company by 2040, and act as a catalyst for efficient economy-wide decarbonization by 2050," said **Ken Hartwick**, OPG's President and CEO. "By moving forward, with our industry-leading technology partner GE Hitachi, on deployment of innovative technology for an SMR at Darlington, OPG is paving the way on the development and deployment of the next generation of nuclear power in Canada and beyond."

"With today's announcement, Ontario is leading the way in new nuclear technologies – like SMRs – that represent tremendous economic and environmental opportunities for our province and all of Canada," said **Todd Smith**, Minister of Energy. "SMRs can provide reliable and emission-free energy while creating jobs, economic growth and export opportunities. Our opportunity to be a leader in this technology and showcase Ontario's nuclear expertise to the world is right now."

"We are so pleased to be working with OPG to bring SMR technology to life at Darlington," said **Jay Wileman**, President and CEO, GE Hitachi. "This is a significant and concrete action in the fight against climate change that will also create jobs across Ontario and Canada as we leverage the robust and growing nuclear supply chain."

About OPG

As a global climate change leader and the largest, most diverse electricity generator in the province, OPG and its family of companies are helping lead the charge to a post-carbon economy.

For further information, please contact:

OPG Media Relations
416-592-4008 or 1-877-592-4008
Follow us **@opg**

Charter: Collaboration on GE Hitachi's BWRX-300 Design

A Collaborative Information Sharing Effort by the U.S. Nuclear Regulatory Commission and the Canadian Nuclear Safety Commission

September 2022

Approved by

Daniel H. Dorman
Executive Director for Operations
United States Nuclear Regulatory Commission

Ramzi Jammal
Executive Vice-President and
Chief Regulatory Operations Officer
Canadian Nuclear Safety Commission

Charter: CNSC and USNRC Collaboration on the review of the BWRX-300

The MOC and this Charter do not in any way alter the national regulatory requirements of either country or alter licensing decision-making. This Charter does not constitute an international agreement and does not create rights and obligations governed by international law.

Background

In April 2022, the Tennessee Valley Authority (TVA) and Ontario Power Generation (OPG) announced plans to jointly work to help develop and deploy small modular reactors (SMRs) in both Canada and the United States. They have signed a Memorandum of Understanding (MOU) that allows the companies to coordinate efforts on the design, licensing, construction, and operation of SMRs. Both TVA and OPG have announced plans to apply for licences to construct and operate the GE Hitachi Nuclear Energy Americas, LLC (GEH) BWRX-300 SMR design in Canada and the United States.

Differing regulations, regulatory guidance, and review practices for licensing in Canada and the United States may impact the licensing and construction timelines for the two proposed GEH BWRX-300 SMR projects in North America. The TVA and OPG MOU enables industry to share experience regarding multi-national applications to maximize the standardization of the BWRX-300 SMR design between both countries, while enhancing safety, efficiency, and timeliness of deployment.

Overall Objectives

CNSC and USNRC intend to enhance their cooperative work under their Memorandum of Cooperation (MOC) on Advanced Reactor and Small Modular Reactor Technologies by working on regulatory and safety issues in the licensing review of the BWRX-300 SMR design. Objectives for CNSC and USNRC include collaborating to reduce duplication of licensing review efforts, jointly utilizing third party verification, identifying areas for collaborative verification, sharing expertise and leveraging analysis done by each organization. These activities will be accomplished in a manner that supports each regulator's adherence to national laws and regulations and is consistent with the MOC. The ultimate goal will be joint safety reviews and/or a risk-informed acceptance of the other regulator's technical conclusions.

Activities

This charter establishes the collaborative relationship and the overall work to be done by CNSC and USNRC on the BWRX-300 SMR design project. The charter is subject to update and revision as the project progresses.

CNSC and USNRC are currently engaged in pre-application activities with OPG and TVA, respectively, to prepare for pending license applications in Canada and the United States. Additionally, GEH is engaged in pre-application activities with both CNSC and USNRC with respect to GEH-led design activities. The activities under this charter are intended to further enhance these pre-application activities and carry forward into future reviews of applications.

OPG, TVA and GEH will identify licensing topics for consideration by the CNSC and USNRC for cooperative reviews. Further, OPG, TVA, and GEH will identify challenges with applying existing guidance or frameworks, provide technical information to facilitate timely and efficient safety reviews, and ensure efficient communication with both regulators.

CNSC and USNRC will develop work plans to identify specific deliverables under this charter, conduct coordinated and efficient technical reviews within established schedules, and strive to align on common regulatory technical positions that enhance standardization of the GEH BWRX-300 SMR design, to the extent practicable.

This work will be monitored by the Advanced Reactor Technologies and Small Modular Reactors Sub Committee (ART-SMR Sub Committee) and as set out under the Terms of Reference for the MOC between the CNSC and the USNRC. Working groups of the CNSC and USNRC staff will be established as needed.

Routine meetings between CNSC, USNRC, OPG, TVA and GEH will be scheduled for updates and discussion. These meetings will be arranged and led by the ART-SMR Sub Committee or the working groups.

Oct 26, 2022
by Darrell Proctor

Nuclear

Canada Bank Group Pledges Millions Toward Nuclear Power Project

The Canadian government has pledged more financing toward development of a grid-scale small modular reactor (SMR), as the country continues to support nuclear power as a way to cut emissions of greenhouse gases from its power generation sector.

Natural Resources Minister Jonathan Wilkinson on Oct. 25 said C$970 million ($708 million) is targeted for a project being developed by Ontario Power Generation (OPG). A spokesperson for the ministry said it would be the first commercial grid-scale SMR developed by the Group of Seven (G7) nations, which includes Canada, France, Germany, Italy, Japan, the UK, and the U.S.

The plan includes construction of a 300-MW SMR that will be adjacent to the existing 3,500-MW Darlington Nuclear Generating Station in Clarington, Ontario. OPG expects the SMR project will be completed by 2030. The reactors are designed by GE Hitachi Nuclear Energy, an alliance between General Electric and Japan's Hitachi Ltd.

OPG in December 2021 announced the project will feature a GE Hitachi BWRX-300 SMR.

Low-Interest Debt

The financing announced Tuesday will come as low-interest debt from the Canada Infrastructure Bank (CIB), which has earmarked funds for investments in clean power generation. Officials said the investment would go toward project design and site preparation work prior to construction of the SMR. OPG on Tuesday said site prep will begin by year-end.

DARLINGTON NEW NUCLEAR PROJECT NEWS

OPG applies to Canadian Nuclear Safety Commission for Licence to Construct

OCTOBER 31, 2022

On October 31, 2022, OPG completed a significant project milestone by submitting an application for a Licence to Construct to the Canadian Nuclear Safety Commission (CNSC). This licence application is the next step in the deployment of a Small Modular Reactor (SMR) at the Darlington site.

The application was developed collaboratively between OPG and GE Hitachi, and is comprised of a number of information packages that will be submitted to the CNSC in sequence, over the next six months. This licence is required before any nuclear construction work on the SMR at Darlington can begin.

This licence submission comes after another significant milestone, the beginning of site preparation activities earlier in October.

Site preparation work consists of non-nuclear infrastructure activities, such as clearing and grading a portion of the new nuclear site to build roads, utilities and support buildings. Execution of site preparation work is planned to continue into 2025.

How can I participate in the Licence to Construct Application process?

The Licence to Construct process includes opportunities for Indigenous Nations and Communities and the public to discuss the application, ask questions and raise areas of interest. The process will culminate in a public hearing, held by the CNSC, likely in 2024.

For more information on the Darlington New Nuclear Project (DNNP), continue to visit our website at **opg.com/newnuclear**.

Learn more about the CNSC licensing process, public hearings and participant funding program, visit the **CSNC's webpage**.

Related news

FEASIBILITY OF Small Modular Reactor DEVELOPMENT AND DEPLOYMENT IN CANADA

Prepared by SaskPower, Énergie NB Power, Bruce Power and Ontario Power Generation (March 2021)

Executive Summary

This feasibility report was prepared by Ontario Power Generation (OPG), Bruce Power, NB Power and SaskPower for the governments of Ontario, New Brunswick and Saskatchewan. The report provides a feasibility assessment of Small Modular Reactor (SMR) development and deployment, and contains the power companies' business case for SMR implementation in each of the three provinces.

Background

SMRs are the next generation of nuclear energy innovation, with the potential to help address challenges and opportunities related to climate change and economic growth. The 2018 Canadian SMR Roadmap[1] concluded that SMRs provide a source of safe, clean, affordable energy, with the ability to contribute towards a resilient, low-carbon future. SMRs can promote key benefits for Canada and Canadians, such as:

- meeting Canada's climate change commitments;
- unlocking opportunities for job creation and economic growth; and
- sustaining and expanding Canada's leadership in research and innovation.

With these drivers in mind, the provinces of Ontario, New Brunswick and Saskatchewan signed a Memorandum of Understanding (MOU)[2] on December 1, 2019, that establishes a framework for deployment of SMRs in each respective jurisdiction. This feasibility report represents one of the early deliverables from the MOU.

The three provinces share a collective interest in SMRs as a clean energy option to address climate change and meet regional energy demands, while responding to the need for economic growth and innovation. The provinces have also agreed to engage with the federal government on key issues related to SMR deployment, including technological readiness, regulatory frameworks, economics and financing, nuclear waste management and public and Indigenous engagement.

Canada and its provinces are already home to a world-class nuclear industry with extensive experience in the design, construction and servicing of reactors in Ontario, New Brunswick and around the globe. The nuclear sector plays a key role in Canada's economy, contributing $17 billion annually, while supporting 76,000 Canadian jobs[3] (i.e. direct, indirect and induced). In addition, Canada is home to the planet's richest uranium resource – the Athabasca basin in Saskatchewan – and is the second-largest producer of uranium in the world.

1 Canadian Small Modular Reactor Roadmap Steering Committee (2018). A Call to Action: A Canadian Roadmap for Small Modular Reactors. Ottawa, Ontario, Canada. www.smrroadmap.ca

2 https://news.ontario.ca/opo/en/2019/12/premier-ford-premier-higgs-and-premier-moe-sign-agreement-on-the-development-of-small-modular-reacto.html

3 https://cna.ca/news/new-study-finds-nuclear-industry-accounts-for-76000-jobs-across-canada/

of SMRs will provide a post refurbishment growth opportunity for Ontario's nuclear supply chain while creating a SMR manufacturing/export business in New Brunswick. Looking to new domestic markets, SMRs are likely to be deployed in Saskatchewan, Alberta and northern Canada providing not only the benefit of low cost, reliable, clean electricity to enable economic development but the potential to add new, innovative, high value jobs. Like all new economic opportunities, there is a significant first-mover advantage and Canada must move now to secure that advantage.

In November 2018, the Canadian SMR Roadmap was issued[5]. The SMR Roadmap used a collaborative approach to bring together industry, federal, provincial, and territorial governments, as well as utilities and other interested stakeholders that wanted a pan-Canadian conversation about new options for nuclear energy.

The roadmap clearly set out the opportunity for Canada and concluded that collaborative activities in each of four pillars are required to turn this roadmap into reality:

- Demonstration and deployment – to realize benefits for Canadians and for Canada.
- Capacity-building and indigenous and stakeholder engagement – to increase access to information.
- Policy, legislative and regulatory measures – to make the framework more efficient.
- International partnerships and marketing – to position Canada for leadership in global value chains.

In addition to participating in the development of the SMR Roadmap, The Government of New Brunswick invested $10 million to establish the Advanced Nuclear Research Centre to progress the research and design of two Advanced Generation IV (Stream 2) SMR designs. This initial funding was matched by two technology vendors: ARC Clean Energy Canada and Moltex Energy who subsequently opened offices in Saint John. In early 2021 the Government of New Brunswick committed $20 million towards the next phase of development of an advanced SMR research cluster in New Brunswick, which will be supplemented by $30 of developer funding to progress development activities of their advanced technologies[6]. In March of 2021, the Federal Government announced funding to progress the development of advanced SMR development in New Brunswick[7].

Since the release of the Canadian SMR roadmap, work amongst the provincial governments, power utilities and technology vendors has accelerated. On December 1, 2019, the Provinces of Ontario, New Brunswick and Saskatchewan signed a Collaboration Memorandum of Understanding (MOU)[8] that puts in place a framework for action on deployment of SMRs in their respective jurisdictions including:

5 Canadian Small Modular Reactor Roadmap Steering Committee (2018). A Call to Action: A Canadian Roadmap for Small Modular Reactors. Ottawa, Ontario, Canada. www.smrroadmap.ca

6 https://www2.gnb.ca/content/gnb/en/departments/premier/news/news_release.2021.02.0094.html. https://www.arcenergy.co/news/31/39/ARC-Canada-Awarded-20-Million-in-Funding-from-the-Province-of-New-Brunswick

7 https://www.canada.ca/en/innovation-science-economic-development/news/2021/03/government-of-canada-invests-in-research-and-technology-to-create-jobs-and-produce-non-emitting-energy.html

8 https://news.ontario.ca/opo/en/2019/12/premier-ford-premier-higgs-and-premier-moe-sign-agreement-on-the-development-of-small-modular-reacto.html

Designing and building the first land-based SMR

The ACP100 is a third-generation SMR design that maximizes the use of mature technologies and equipment. The reactor has a thermal power capacity of 385 MWt and a net electric output of up to 126 MWe.

The first unit is being built at Changjiang in Hainan province, where two CNP-600 reactors are already in operation and two 1100 MWe Hualong One reactors are under construction. Once completed, the Changjiang ACP100 reactor will be capable of producing 1 billion kilowatt-hours of electricity annually, enough to meet the needs of 526,000 households.

The project at Changjiang involves a joint venture of three main companies: CNNC subsidiary China National Nuclear Power as owner and operator; the Nuclear Power Institute of China (NPIC) as the reactor designer; and China Nuclear Power Engineering Group being responsible for plant construction.

When first concrete was poured on 13 July 2021, the ACP100 demonstration model became the first land-based commercial SMR to start construction in the world.

The containment vessel bottom head - which will support the steel containment shell - was assembled on-site from50 pre-fabricated steel plates. The assembled component was hoisted into place by crane onto the plant's concrete foundation plate on 24 October 2021.

The lower section of the containment shell - some 15 metres in height and weighing about 450 tonnes - was lowered into place upon the vessel bottom head on 26 February this year, 46 days ahead of schedule. The total construction period is scheduled for 58 months, and it is currently on schedule.

China National Nuclear Corporation (CNNC) started R&D work on the ACP100 in 2010 and the design passed the IAEA Generic Reactor Safety Review on 22 April 2016.

In October 2017, the Chinese Nuclear Society recognized the ACP100 technology to be one of "China's Top 10 Advances in Nuclear Technology in 2015-2017".
As an innovative SMR design, the ACP100 design has passive safety features that are expected to handle extreme environmental conditions and multiple failures without any significant radioactive release.

Changjiang SMR

Type	PWR
Reactor thermal capacity	385 MWt
Electrical capacity (net)	126 MWe
First concrete	13 July 2021

The ACP100 also features integrated reactor design technology, modular design and fabrication, and integral steam generator with the reactor coolant pump mounted on the pressure vessel nozzle. All these technologies provide high inherent safety to prevent large-scale loss of coolant accidents (LOCAs).

These design innovations allow the reactor manufacturing, transport and site installation processes – and the economics of the ACP100 – to be optimized.

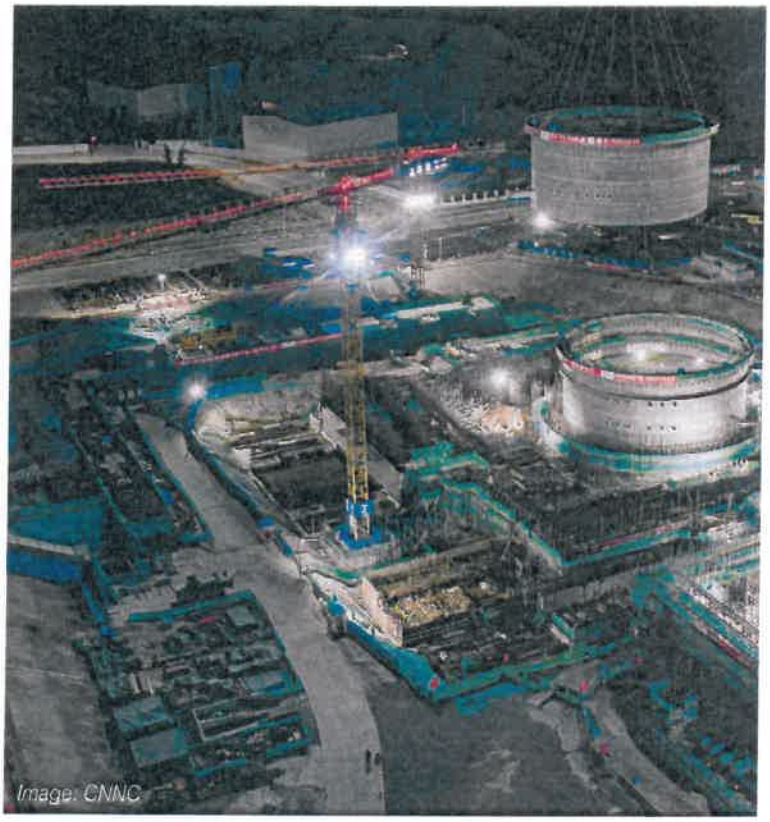


Image: CNNC

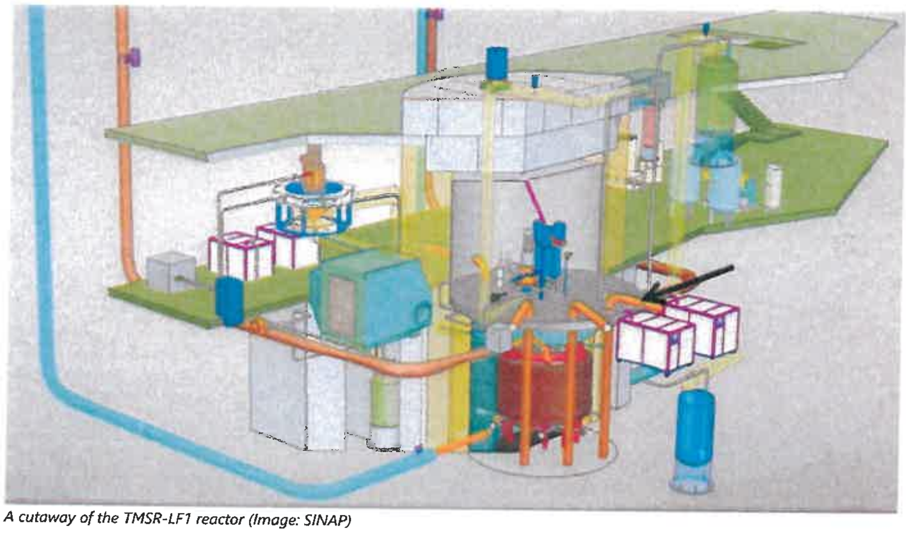
world nuclear news
Celebrating 15 years

Chinese molten-salt reactor cleared for start up

09 August 2022

Share

The Shanghai Institute of Applied Physics (SINAP) - part of the Chinese Academy of Sciences (CAS) - has been given approval by the Ministry of Ecology and Environment to commission an experimental thorium-powered molten-salt reactor, construction of which started in Wuwei city, Gansu province, in September 2018.



A cutaway of the TMSR-LF1 reactor (Image: SINAP)

In January 2011, CAS launched a CNY3 billion (USD444 million) R&D programme on liquid fluoride thorium reactors (LFTRs), known there as the thorium-breeding molten-salt reactor (Th-MSR or TMSR), and claimed to have the world's largest national effort on it, hoping to obtain full intellectual property rights on the technology. This is also known as the fluoride salt-cooled high-temperature reactor (FHR). The TMSR Centre at SINAP at Jiading, Shanghai, is responsible.

Construction of the 2 MWt TMSR-LF1 reactor began in September 2018 and was reportedly completed in August 2021. The prototype was scheduled to be completed in 2024, but work was accelerated.

"According to the relevant provisions of the Nuclear Safety Law of the People's Republic of China and the Regulations of the People's Republic of China on the Safety Supervision and Administration of Civilian Nuclear Facilities, our bureau has conducted a technical review of the application documents you submitted, and believes that your 2 MWt liquid fuel thorium-based molten salt experimental reactor commissioning plan (Version V1.3) is acceptable and is hereby approved," the Ministry of Ecology and Environment told SINAP on 2 August.

It added: "During the commissioning process of your 2 MWt liquid fuel thorium-based molten salt experimental reactor, you should strictly implement this plan to ensure the effectiveness of the implementation of the plan and ensure the safety and quality of debugging. If any major abnormality occurs during the commissioning process, it should be reported to our bureau and the Northwest Nuclear and Radiation Safety Supervision Station in time."

The TMSR-LF1 will use fuel enriched to under 20% U-235, have a thorium inventory of about 50 kg and conversion ratio of about 0.1. A fertile blanket of lithium-beryllium fluoride (FLiBe) with 99.95% Li-7 will be used, and fuel as UF_4.

The project is expected to start on a batch basis with some online refuelling and removal of gaseous fission products, but discharging all fuel salt after 5-8 years for reprocessing and separation of fission products and minor actinides for storage. It will proceed to a continuous process of recycling salt, uranium and thorium, with online separation of fission products and minor actinides. The reactor will work up from about 20% thorium fission to about 80%.

Most read

Cracks found in all four OL3 feedwater pumps

OPG applies for construction licence for Darlington SMR

World's largest chloride salt system in place

Chinese molten-salt reactor cleared for start up

Cause of OL3 feedwater pump damage yet to be determined

Fuel loading under way at Vogtle 3

France outlines plans to speed new nuclear

Poland's Westinghouse choice 'deepens strategic relationship' with USA

Poland's government confirms Westinghouse for nuclear plant

Related Stories

Kairos and Materion commission molten salt purification plant

IMSR to be considered for ammonia production

Related Information

Molten Salt Reactors

If the TMSR-LF1 proves successful, China plans to build a reactor with a capacity of 373 MWt by 2030.

As this type of reactor does not require water for cooling, it will be able to operate in desert regions. The Chinese government has plans to build more across the sparsely populated deserts and plains of western China, complementing wind and solar plants and reducing China's reliance on coal-fired power stations. The reactor may also be built outside China in Belt and Road Initiative nations.

The liquid fuel design is descended from the 1960s Molten-Salt Reactor Experiment at Oak Ridge National Laboratory in the USA.

Researched and written by World Nuclear News

Related topics

China | New build | Operation and maintenance | Regulation

Share

Nuclear Power in China

33

Related Links

MEE

SINAP

world nuclear news
Celebrating 15 years

US regulator to issue final certification for NuScale SMR

02 August 2022

Share

The US Nuclear Regulatory Commission (NRC) has announced it will issue the final rule that certifies NuScale's small modular reactor (SMR) design for use in the USA. The reactor is the first SMR design to be certified by the NRC.

A rendering of how the first plant using NuScale's SMR design could look (Image: UAMPS)

Design certification means that the NRC has determined a nuclear power plant design meets all its applicable safety requirements, independent of an application to construct or operate a plant. Any subsequent application for a combined construction and operating licence referencing that design will not need to address any of the issues already covered by the design certification, but will instead address remaining site-specific safety and environmental issues for the proposed plant.

NuScale submitted an application to the NRC on 31 December 2016, to certify the company's small modular reactor design which uses natural, passive processes such as convection and gravity in its operating systems and safety features. A plant would comprise up to 12 of the pressurised water reactor modules, submerged in a safety-related pool built below ground level.

The final safety evaluation report (FSER) for the reactor - the first-ever FSER to be issued by the NRC for an SMR - was issued in August 2020. November 25 is pencilled in on the regulator's timeline for publication of the final rule.

"The affirmation of NuScale's design and strong safety case could not have come at a more crucial time - when around the world, people are struggling from the compounding crises of volatile energy prices and climate change-driven extreme weather events," NuScale President and CEO John Hopkins said. "We are pleased with this continued recognition of our technology's inherent safety design and our potential as a timely, carbon-free energy solution to meet our global community's needs."

NuScale's SMR will be the seventh reactor design to be certified by the NRC, following GE Nuclear Energy's Advanced Boiling Water Reactor, Westinghouse's System 80+, AP600, and AP1000, GE-Hitachi Nuclear Energy's Economic Simplified Boiling Water Reactor, and Korea Electric Power Corporation and Korea Hydro & Nuclear Power Co's APR1400. Of those, only the AP1000 design - currently being built at Vogtle units 3 and 4 - have progressed to construction in the USA.

NuScale in June announced a strategic shift from product development to product delivery as it progresses with commercialisation of the reactor, which is being offered as VOYGR plants of twelve, six or four modules. The first commercial deployment of a NuScale VOYGR power plant is

Most read

US regulator approves methodology for SMR emergency planning

IAEA's Grossi holds talks with Russia's President Putin

Ukraine, Russia and control of Zaporizhzhia nuclear power plant

US, Canadian regulators further SMR collaboration

Constellation seeks licence extensions for Illinois plants

Zaporizhzhia relying on diesel generators after losing off-site power

Kyushu applies for 20-year extensions for Sendai 1 and 2

Vets and volunteers help stray dogs of Chernobyl

Bruce 7 starts producing innovative therapeutic isotope

WNN is a public information service of World Nuclear Association

WORLD NUCLEAR ASSOCIATION

Related Stories

SMR company NuScale pivots from development to delivery

Completion of merger creates publicly traded SMR company

Full-scale production of NuScale SMR to begin expected to be as a six-module unit for Utah Associated Municipal Power Systems' (UAMPS) Carbon Free Power Project, which is to be built at a site at the Idaho National Laboratory in the USA.

Researched and written by World Nuclear News

Related topics

Plant licensing | Regulation | Small Modular Reactors | USA

Share

NuScale SMR receives US design certification approval

35

Related Information

Nuclear Power in the USA

Small Nuclear Power Reactors

Related Links

NRC

NuScale

world nuclear news
Celebrating 15 years

US regulator approves methodology for SMR emergency planning

28 October 2022

Share

The US Nuclear Regulatory Commission's acceptance of NuScale's methodology for determining the appropriate size of the Emergency Planning Zone (EPZ) around small modular reactor (SMR) plant sites is a "tremendous 'first'", the company's CEO said. The methodology can now be used to determine an EPZ for the NuScale SMR that provides the same level of protection to the public as the 10-mile radius used for existing US nuclear power plants.

A rendering of the proposed UAMPS plant: the new methodology could see the EPZ limited to the site boundary (Image: UAMPS)

NuScale CEO John Hopkins' comments followed the US Nuclear Regulatory Commission's Advisory Committee on Reactor Safeguards' (ACRS) decision, published on 19 October.

The EPZ is the area surrounding a nuclear power plant where special considerations and management practices are pre-planned and exercised in case of an emergency. The requirements for US emergency planning (and sizing of EPZs, which are based on a generic plume exposure pathway with a radius of 10 miles) are set out in regulation NUREG-0396, which was issued in 1978 - and based on large reactors.

"Since then, the knowledge base and analytical tools have advanced considerably, allowing for a more mechanistic, systematic approach to sizing the plume exposure pathway EPZ rather than using a bounding generic EPZ radius," the ACRS said in its decision.

The "source terms" - the types and amounts of radioactive or hazardous materials that could potentially be released following an accident - are much less for SMRs than for large reactors. SMR designs also incorporate emergency planning considerations as part of the design, with enhanced safety margins and passive or inherent safety systems built in. Such reactors are therefore envisaged as requiring a much smaller EPZ than larger plants - an important consideration for siting.

NuScale's integrated pressurised water reactor is the first SMR design to receive approval from the US Nuclear Regulatory Commission. The methodology the company has developed for assessing plume exposure pathway EPZ sizing for a NuScale SMR plant is risk-informed, provides a technically consistent approach (with NUREG-0396) for EPZ sizing, and adequately considers seismic and multi-module impacts, the ACRS said.

Using the newly approved method means an EPZ that is limited to the site boundary of the power plant is achievable for a "wide range of potential plant sites" where a NuScale VOYGR SMR power plant could be located, the company said. Limiting an EPZ limited to the site boundary

Most read

US regulator approves methodology for SMR emergency planning

IAEA's Grossi holds talks with Russia's President Putin

Ukraine, Russia and control of Zaporizhzhia nuclear power plant

US, Canadian regulators further SMR collaboration

Constellation seeks licence extensions for Illinois plants

Zaporizhzhia relying on diesel generators after losing off-site power

Kyushu applies for 20-year extensions for Sendai 1 and 2

Vets and volunteers help stray dogs of Chernobyl

Bruce 7 starts producing innovative therapeutic isotope

WNN is a public information service of World Nuclear Association

WORLD NUCLEAR ASSOCIATION

Related Stories

US regulator to issue final certification for NuScale SMR

SMR company NuScale pivots from development to delivery

US Department of Energy backs proposed SMR regulation

means that users of the plant's output, such as off-takers of process heat, can be located nearer to the plant, and significantly reduces emergency planning costs for plant owners.

"Safety is NuScale's priority, and on top of our design approval in 2020, this endorsement from a world-class regulator - the US NRC - and the ACRS shows the global community our unmatched, innovative technology is first and foremost safe," Hopkins said. "This also means NuScale's game-changing technology can be sited where it's needed most - powering our economy, communities, and lives."

Portland, Oregon-based NuScale plans to build its first SMR power plant for Utah Associated Municipal Power Systems' (UAMPS) Carbon Free Power Project at a site at Idaho National Laboratory, with the first unit expected to begin generating power in 2029.

Researched and written by World Nuclear News

Related topics

Regulation | Small Modular Reactors | USA

Share

NRC seeks public comment on SMR regulation

37

Related Information

Nuclear Power in the USA

Small Nuclear Power Reactors

Related Links

NRC

NuScale

Ms STEGGALL: You mentioned the CSIRO and the social licence to operate, and the waste management aspects. Part of our terms of reference for this inquiry is: what are the prerequisites for considering lifting the moratorium? We're not going down the step of recommending a source of energy. But part of considering those prerequisites is looking at what the factors are that would influence it. Clearly, cost is a big one, and we have been poring over the report. It's a big issue. I'd like to hear from both groups in terms of the social licence to operate: how do you factor that aspect, the social licence, in to your consideration?

Jane Coram: I'll call on John Phalen, who has been working extensively on this issue

Mr Phalen: Thanks for the question. What I would say is that the nuclear power plants are not really a technical challenge to overcome. It's really mostly a social challenge. It's one that would require a number of years of community consultation. This is not something that you could do in a six- to 12-month process. You would need extensive Indigenous consultation. You would need to develop community consent processes, and, if you have a look at success around the world trying to get either waste disposal systems in place or new power plants in place, it's not a very good track record—

CHAIR: My apologies, the division bells are ringing. We are going to have to go. I'll suspend the hearing for now, but we should have time to come back.

Proceedings suspended from 11:03 to 11:15

CHAIR: I declare the public hearing resumed. I think you were in the midst of an answer, Mr Phalen. Why don't you finish that and then we'll go to Ms Steggall.

Mr Phalen: Sure. Given the time, I will summarise based on the South Australian experience, which is the largest consultation process in Australia on this particular topic. There were three reasons why the community said that they weren't participating in that process. The first was that they said they didn't know enough about the topic to comment. The second was they didn't have the time to participate, so that spoke to it being too quick. And the third was that they didn't trust the government would listen to them. So there is an element of transparency that would be very critical to any process that we would conduct in regard to establishing a nuclear industry in Australia.

Ms STEGGALL: Essentially, we have to assess the upsides and downsides of recommending lifting the moratorium; it will be the government's call. What do you see are the benefits and the negatives of lifting the moratorium at this point? We really haven't had that public consultation.

Mr Phalen: The first benefit would being able to provide better information to committees like this because we would be able to conduct research and have more definitive answers to the types of questions you ask. It does free organisations like ours to explore these topics in a bit more detail.

Ms STEGGALL: I don't quite understand: the moratorium stops you from investigating? We've had a number of inquiries, so I don't understand how the moratorium stops you from properly investigating.

Mr Phalen: It's just that you can't spend public money on, for example, high-level nuclear waste facilities. That's one of the reasons. Those sorts of bans would need to be lifted in order to conduct public money research on that type of activity. What are the benefits and the downsides? There are always two sides to every story. Obviously, this type of topic is very sensitive to many Australians. Therefore, it would need to be conducted in a very inclusive and respectful manner. CSIRO is independent, obviously; we're not for or against these types of things. We focus on the science and on the facts, and those are what we would be focusing on presenting to anyone making advice to anyone making decisions on this type of matter.

Mr JOSH WILSON: I have a question for Geoscience Australia. We had a submission from Dr Gavin Mudd. He presented a little snapshot of uranium mining operations and where their site management and rehabilitation, if appropriate, were up to. It was a bit of a bleak picture. In almost every case there were instances of contamination, ongoing rehabilitation and so on. Does Geoscience Australia maintain a watching brief on those instances as part of its assessment of what managing uranium mining operations really amounts to?

Mrs Costelloe: It's not immediately in our mandate, but we do provide advice to our department and the state and territory geological surveys which that falls under. We don't have the funds to maintain or regularly assess those over time, but we definitely have the expertise to help in the local measures put forward. We also advise on the EPBCs.

Mr JOSH WILSON: So you do it when requested rather than on kind of a watching basis?

Mrs Costelloe: That's correct.

Mr JOSH WILSON: But you have the resources? If you were asked at some point to provide an across-the-board snapshot, you could?

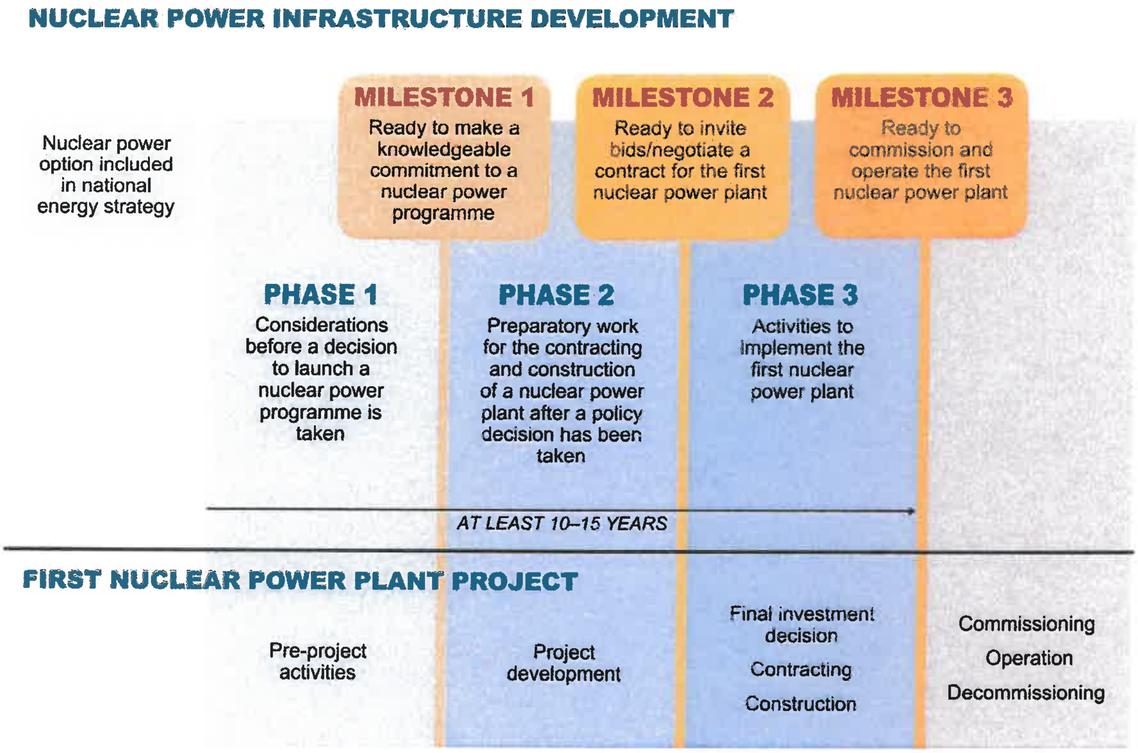


FIG. 2. Milestones for infrastructure development to support a nuclear power programme (reproduced from Ref. [6]).

demonstrate their progress during the planning stages, and to show national and international stakeholders their commitment to nuclear safety and the control of nuclear material. In this regard, the infrastructure for a nuclear power programme includes the elements necessary for the safe, responsible and sustainable use of nuclear technology.

Even countries with a large nuclear fleet should assess the impact that the deployment of an SMR fleet would have on the existing nuclear infrastructure. Special attention should be paid to the procurement of new fuel types and their compatibility with existing strategies for the interim and long term disposal of nuclear fuel and the resultant intermediate level waste. Depending on the SMR technology of choice, significant and costly upgrades might be required to existing infrastructure, which have to be carefully accounted for in the life cycle plan.

In Section 2.3.1, it is assumed that SMR deployment will take place in a country which already possesses the *infrastructure* necessary to support the deployment of nuclear power technology (including SMR technology). This infrastructure will include not only a so-called *hard* infrastructure (such as an adequate electrical grid) but also a *soft* infrastructure (such as a regulatory framework, policies on radioactive waste management, human resources policies, etc.). If key components of this infrastructure are not in place when a country first contemplates deploying SMR technology for electricity generation, it will be necessary to develop them in advance of such deployment.

The IAEA recommends a systematic approach to preparing the infrastructure for nuclear facility deployment which is relatively high level — and thus generally applicable across technologies ranging from *traditional* large reactors of various types through research reactors to SMRs: the IAEA's Milestones approach. In this approach, activities needed to prepare the infrastructure for nuclear power are split into three phases, with the duration of each phase dependent on the degree of commitment and resources allocated in the country. The term *infrastructure milestone* is used to identify the point at which the activities required in that phase of development have been successfully completed. Each therefore

TABLE 2. INFRASTRUCTURE ISSUES [6]

The 19 infrastructure issues	
National Position	Stakeholder Involvement
Nuclear Safety	Site and Supporting Facilities
Management	Environmental Protection
Funding and Financing	Emergency Planning
Legal Framework	Nuclear Security
Safeguards	Nuclear Fuel Cycle
Regulatory Framework	Radioactive Waste Management
Radiation Protection	Industrial Involvement
Electrical Grid	Procurement
Human Resource Development	

organizations involved in infrastructure development. In this publication, this mechanism is called the nuclear energy programme implementing organization (NEPIO). It should be noted that this designation is used for illustrative purposes only. The country may organize the activity in a manner most appropriate to its own customs and needs.

Table 2 shows the 19 infrastructure issues that need to be considered for each milestone [6]. The order does not indicate relative importance. Each issue is important and requires careful consideration. Different organizations will need to consider which issues relate most to them and to plan their work and resources accordingly. The three key organizations — the government, the owner/operating organization and the regulatory body — need to ensure awareness of all issues.

Milestone 1: Ready to make a knowledgeable commitment to a nuclear power programme

At the beginning of Phase 1, it is assumed that a country has determined that it needs additional energy and has considered nuclear power as a possible option to meet some of these needs. During Phase 1, the country will analyse all issues that would be involved in introducing nuclear power, so that at the end of Phase 1, it is in a position to make a knowledgeable decision on whether or not to introduce nuclear power.

In Phase 1, it is essential that the country acquires a comprehensive understanding of the obligations and commitments involved, and what would be required to fulfil them, before any decision on implementation is taken. It is important that the country has a clear understanding of its energy needs and the potential role of nuclear power within its long term energy and economic development plans.

A country considering nuclear power probably already has an infrastructure in place for nuclear security, radiation safety and emergency preparedness to cover existing facilities and activities. Building on the existing infrastructure and associated experience will assist the country in establishing the necessary infrastructure for a nuclear power programme.

In Phase 1, the NEPIO should ensure overall coordination and the engagement of all key parties, compile the information and studies necessary for a knowledgeable policy decision on whether to proceed with nuclear power, and, at the end of Phase 1, provide a comprehensive report that should recommend a positive national decision, and that defines and justifies a national strategy for nuclear power. Any pre-feasibility study conducted during Phase 1 can be a significant input to the report, although it is important that the report fully addresses all 19 infrastructure issues described in Table 2.

This work, as with all other work paid for by the USDOE (US Department of Energy), must be performed in the United States.

This funding is of a scale that will ensure progress towards demonstration.

In parallel the US Department of Defence has initiated "Project DiLithium" to investigate small (1-10 MWe), transportable (<40 tonnes) SMRs to support tactical deployments. With a clear customer, full funding, and the possibility of fast track licensing this could bring about the first fully developed SMR units and a guaranteed early fleet market.

Further, in April 2020, based on the work of the US Nuclear Fuel Working Group, the Secretary of Energy announced The Strategy to Restore American Nuclear Energy Leadership which recommends:

- Taking ***immediate and bold action to*** strengthen the uranium mining and conversion industries and ***restore the viability of the entire front-end of the nuclear fuel cycle.***
- Utilizing American technological innovation and advanced nuclear RD&D investments to consolidate technical advances and ***strengthen American leadership in the next generation of nuclear energy technologies.***
- Ensuring that there will be a ***healthy and growing nuclear energy sector*** to which uranium miners, fuel cycle providers, and reactor vendors can sell their products and services.
- Taking a whole-of-government approach to ***supporting the U.S. nuclear energy industry in exporting civil nuclear technology in competition with state-owned enterprises.***

In May 2020, the DOE Announced $27 Million for Advanced Nuclear Reactor Systems Operational Technology. And in June, the US International Development Finance Corporation (DFC) has proposed policy changes that would remove a prohibition on it providing support for nuclear power projects. This would enable the DFC to offer financing for projects to deploy technologies such as small modular reactors (SMRs) in developing countries. On October 13, 2020 the USDOE announced[15] that X-energy and TerraPower were selected under the Advanced Reactor Demonstration Program (ARDP) and will each receive $80 Million of funding towards deploying their designs in the US within 5 to 7 years. They plan to invest $3.2 Billion over 7 years in support of this program. On October 16[16], the USDOE approved a multi-year cost share award that could provide up to $1.4 billion to help demonstrate and deploy a 12-module NuScale power plant located at Idaho National Laboratory with the first power module operating at the lab by 2029.

15 https://www.energy.gov/ne/articles/us-department-energy-announces-160-million-first-awards-under-advanced-reactor

16 https://www.energy.gov/ne/articles/doe-approves-award-carbon-free-power-project

MEDIA RELEASES

Federal clean energy initiatives will help advance SMRs and other clean technologies

NOVEMBER 3, 2022

Toronto, ON – Ontario Power Generation (OPG) welcomes the latest clean energy initiatives by the Federal Government outlined in the Fall Economic Statement, including the proposed investment tax credit that would benefit Small Modular Reactors (SMRs) and other forms of clean energy technology including hydroelectric, hydrogen, and pumped storage. OPG also welcomes the commitment to improve the efficiency of federal environmental Impact Assessments Act.

> ***"The powerful combination of Federal and Provincial government support sends a resounding message that Ontario and Canada are ready to lead the world in clean energy development."***
>
> *OPG President and CEO, Ken Hartwick*

OPG and its subsidiaries are leading the development of SMRs, examining new hydroelectric potential, working to electrify the transportation sector, advancing the development of hydrogen and exploring pumped hydro storage. OPG's Darlington Nuclear refurbishment will also provide decades of additional GHG-free power, as would the possible redevelopment of the Pickering B Nuclear Generating Station, the feasibility of which is currently being explored.

Recently, the Canada Infrastructure Bank (CIB) announced a loan of $970M to develop the first commercial SMR at OPG's Darlington site. SMRs are a new class of nuclear reactors that are approximately 300 megawatts or less, have a smaller footprint and a shorter construction schedule, compared to traditional nuclear generating stations, and can provide zero-carbon baseload power across all regions.

Quotes

"These measures will help ensure this critical infrastructure is successfully completed, while reducing costs for ratepayers," said OPG President and CEO, Ken Hartwick. "The powerful combination of Federal and Provincial government support sends a resounding message that Ontario and Canada are ready to lead the world in clean energy development."

Quick facts

- OPG owns and operates 66 hydroelectric stations and 241 dams, which account for nearly 21 per cent of Ontario's total generation.
- A 2020 Conference Board of Canada study highlights strong economic benefits from construction and 60 years of operation of a single SMR facility. This includes average annual direct and indirect employment of approximately:
- 700 jobs during project development;

Energy experts say there is no path to bringing the world's carbon emissions to zero by 2050 without nuclear. The CIB's $970 million investment will help OPG construct Canada's first small modular reactor. As our largest clean power investment, we are supporting technology which can accelerate the reduction in greenhouse gases while also paving the way for Canada becoming a global SMR technology hub.

- Ehren Cory, CEO, Canada Infrastructure Bank

We know nuclear energy, including from SMRs, is an essential part of the electricity mix to help meet our climate change goals. This low-interest financing helps us advance the Darlington New Nuclear Project, paving the way for development and deployment of the next generation of nuclear power in Canada.

- Ken Hartwick, OPG President and CEO

Today's announcement represents a significant step towards the development of a non-emitting electricity grid and a prosperous net-zero future. The deployment of one of Canada's first Small Modular Reactors (SMR) at Darlington Station will further enhance Canada's leadership in nuclear technology, create sustainable jobs, and reduce emissions. This announcement represents an important step forward for energy security and availability in Canada.

- The Honourable Jonathan Wilkinson, Minister of Natural Resources

Ontario is leading the way when it comes to new nuclear technologies and the world is watching as we build the first ever grid-scale SMR at Darlington. Today's investment is a demonstration of the incredible opportunities of SMRs and nuclear power as a way to produce clean electricity to attract new investment, create jobs, and grow our economy while supporting electrification.

- The Honourable Todd Smith, Minister of Energy

Quick facts

- CIB's long-term capital can ensure critical, large-scale clean energy infrastructure projects are built.
- OPG is an Ontario-based electricity generation company wholly-owned by the Province of Ontario and has more than 50 years of experience operating nuclear facilities.
- With an approved Environmental Assessment already in place, the Darlington site is the only location in Canada licensed for new nuclear.
- The Darlington New Nuclear Project is being managed in a gated approach, subject to OPG board approval at each gate.
- A 2020 study undertaken by the Conference Board of Canada shows strong economic benefits from construction and 60 years of operation of a single SMR facility. According to the report, direct, indirect employment would result in an annual average of approximately:
  - 700 jobs during project development;
  - 1,600 jobs during manufacturing and construction;
  - 200 jobs during operations;
  - and 160 jobs during decommissioning.
- Through its Clean Power priority sector, the CIB has committed $5 billion towards clean power, renewables, district energy, storage, interties, and transmission.
- All CIB investments are subject to approval of its board of directors.

- 30 -

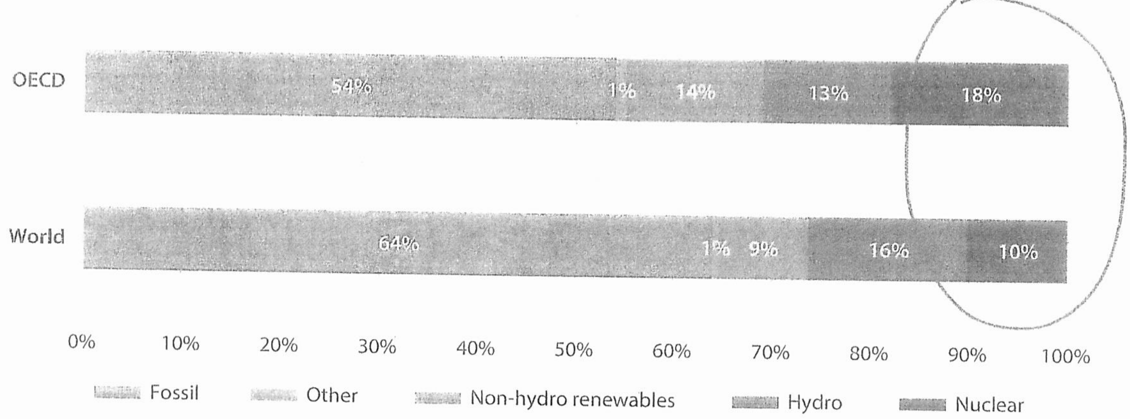
For further information, please contact:

Ross Marowits
Canada Infrastructure Bank
416-347-3358
rmarowits@cib-bic.ca
www.cib-bic.ca

OPG Media Relations
416-592-4008 or 1-877-592-4008
Follow us @opg
www.opg.com

Nuclear energy supplies approximately 10% of the world's electricity and is the world's fourth largest source of electricity, following coal, gas and hydroelectricity, which supply approximately 38%, 23%, and 16% of the world's electricity, respectively (WNA 2020). Nuclear energy, therefore, is the world's second largest source of non-emitting electricity, following hydroelectricity, and the largest source of non-emitting electricity in the group of OECD countries (Figure 5). In regions that are not rich in hydroelectric potential, nuclear is generally the most significant non-emitting option for electricity generation.

Figure 5. **OECD and World Electricity Mixes (2018)**



Source: Based on IEA (2021a).

The United States Energy Information Administration's *International Energy Outlook* projects that global nuclear capacity will continue to grow at a rate of 1.5% per year through 2040 (EIA, 2017). The geopolitical landscape for nuclear energy is transforming in important ways. While some NEA countries do not include nuclear in their future plans (e.g. Germany) or face questions about the future of current installed nuclear capacity (e.g. Japan, United States), growth in nuclear energy is driven principally by non-NEA countries (e.g. China and India). Accordingly, whereas over 80% of global installed nuclear capacity has been within OECD countries, by mid-century, this percentage could fall below 50% (EIA 2017), with significant geopolitical implications, including global shifts in high-value, strategic industrial capacity, human resource capabilities, policy influence, and the development of vital technologies.

While conditions exist to support growth in global nuclear energy development and deployment, the nuclear energy sector faces many challenges. Global energy demand is expected to continue growing, driven primarily by China, India, and South East Asia. Concerns over climate change are rising and will drive demand for non-emitting energy. However, uncertainties in global resource markets, as well as increases in resource nationalism and protectionism, are having chilling effects on global trade in uranium and nuclear technologies, and geopolitical instability is giving rise to non-proliferation concerns. Moreover, lack of key infrastructure and enabling frameworks creates barriers to access in key markets for new nuclear energy.

An increasingly networked global civil society has high expectations for transparency, accountability, social engagement, environmental protection, safety (post-Fukushima), and benefits sharing. Civil society also has high expectations for the potential of renewables, storage, and demand-side management to fully address climate change and energy security concerns.

Nuclear energy is often excluded from public and political discourse, creating significant challenges for the nuclear sector. Even countries that include nuclear in their existing and future energy plans often remain silent on the role of nuclear in international clean energy and climate change fora. This dynamic is deeply problematic. Nuclear energy must be included alongside other options in discussions about energy transition in order to maintain the integrity and evidence base of the policy dialogue. While energy policy makers may take different values-based decisions on the role of nuclear energy in their respective national contexts, the analyses and assessments that inform policy debates must be complete and evidence-based. Including all options in the analyses is necessary to ensure that the complex trade offs between options can be accurately understood and contemplated.