

Ontario Nuclear Collaboration

2022 REPORT

ONTARIO **POWER**
GENERATION

BrucePower[™]
Innovation at work

Securing a Sustainable Future, Together:

Ontario Power Generation (OPG) and Bruce Power are committed to leading the energy transition to help our economy, our climate, and the families that rely on both.

Economy-wide electrification, decarbonization, and economic renewal aren't possible without nuclear power. The decision to refurbish our nuclear stations at both Bruce Power and Darlington Nuclear will help us on our journey toward a carbon-free future and support electrification.

While a significant amount of collaboration took place before the start of our refurbishments, this report outlines the additional ways we are working together to identify efficiencies and share resources, tooling, and equipment. This collaboration is further reducing costs, limiting execution risk, and ensuring our projects are completed safely, with quality, on time, and on budget. In addition, we are building and maintaining a strong supply chain network ensuring we are able to deliver clean, reliable, low-cost power while also supporting Ontario's industries and trades for the betterment of the consumer and the Province.

As our economy grows and electrifies, the demand for clean electricity will only grow as well; that is why nuclear power has never been more important than it is today. Our ongoing refurbishment programs will be critical to generating decades more clean and reliable energy to help meet the growing needs of our future, while helping Ontario achieve a balanced, reliable, and affordable electricity system.

As Ontario's largest power generators and clean technology innovators, we are working to secure a sustainable future, together.



Ken Hartwick

Ken Hartwick, OPG,
President and Chief Executive Officer

ONTARIOPOWER
GENERATION



Michael W. Rencheck

Michael W. Rencheck, Bruce Power,
President and Chief Executive Officer

BrucePower

On Nov. 12, 2015, OPG and Bruce Power signed a Memorandum of Understanding (MOU) that was facilitated by the Ministry of Energy to formalize and provide an annual summary report on the collaboration between the two organizations on nuclear refurbishment and power plant operation. The 2022 Ontario Nuclear Collaboration Report

focuses on the joint efforts of OPG and Bruce Power throughout their respective refurbishments. This collaborative effort has resulted in efficiencies and innovations that lower costs for ratepayers, by sharing lessons learned and leveraging economies of scale, to ensure Ontario's refurbishments remain on time and on budget.

Darlington Nuclear Generating Station



Bruce Power Generating Stations

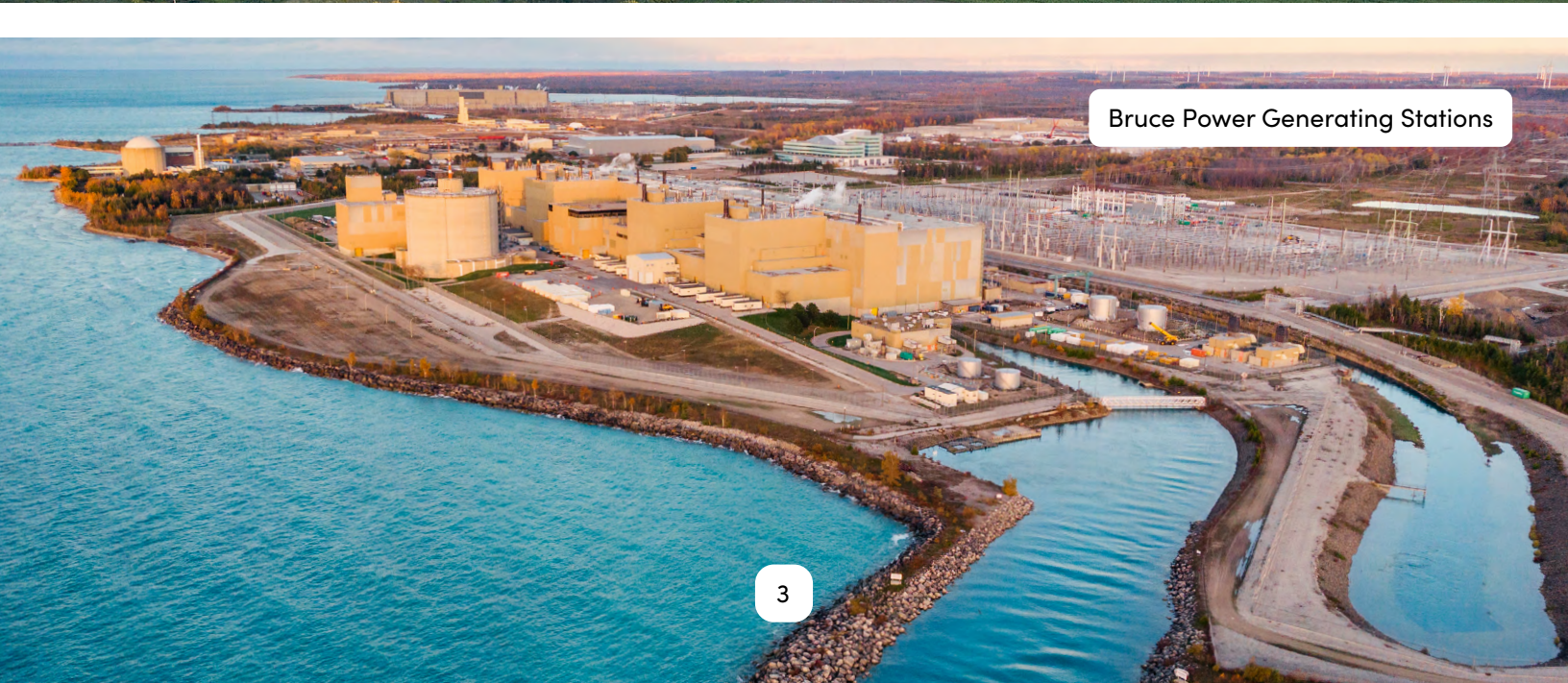


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Status of Refurbishments

20%

of the province's
electricity comes from
the Darlington
station

OPG

OPG is owned by the Government of Ontario and is a climate change leader and the largest electricity generator in the province, providing more than half of the power Ontarians rely on every day. OPG employs more than 9,300 people and is one of the most diverse generators in North America, with expertise in nuclear, hydroelectric, biomass, solar, and natural gas technologies.

The Darlington Nuclear Refurbishment Project (DNRP)

OPG's Darlington Nuclear Generating Station is a four-unit facility responsible for generating over 20 per cent of Ontario's electricity, which is enough to power a city the size of Toronto. In 2016, after 10 years of detailed planning and preparation, OPG's team of project partners, industry experts, energy professionals, and skilled tradespeople successfully shut down the first of four Darlington reactors scheduled for refurbishment over the next 10 years. The DNRP involves replacing core reactor components to enable the plant to operate safely for more than 30 more years. Each reactor is taken out of service for about three years to allow for:

- Replacement of fuel channels, feeder pipes, calandria tubes, and end fittings.
- Rehabilitation of steam generators, turbine generators, and fuel handling equipment.
- System improvements and plant upgrades to meet current regulatory requirements.

Current status

OPG is in year 7 of the 10-year DNRP; the \$12.8b mega-project is on-time and budget. Unit 2 is complete and more than 4,000 lessons learned have been applied to Units 3 and 1, which are currently underway.

On Unit 3, OPG is making excellent progress. By the end of 2022, there had been 6,240 new fuel bundles loaded into the reactor core, marking an important shift from construction phase to operational readiness. The work is now over 90 per cent complete and the team is expected to return Unit 3 to service later in 2023.

The Unit 1 refurbishment started in February 2022 and, for the first time, OPG is refurbishing two units at the same time. In April 2022, the fuel bundles were removed, allowing unit isolation and reactor disassembly to begin. The lower feeder removal series involved over 2,000 cuts to remove 960 lower feeder tubes from the reactor face – an impressive feat.

Unit 4 refurbishment preparations are ongoing and the team is on track to take the unit offline in 2023. With the continuation of strong project excellence, this mega-project will provide an additional 30 years of clean and reliable energy to Ontarians. OPG will complete the refurbishment of all units in 2026.



Bruce
Power meets
30%
of Ontario's
electricity
demands

Bruce Power

Bruce Power is a Canadian-owned public-private partnership of TC Energy, Ontario Municipal Employees Retirement Systems (OMERS), the Power Workers' Union, and The Society of United Professionals. The Bruce Power site is owned by the Province and the company employs more than 4,200 people. Established in 2001, Bruce Power is Canada's only private sector nuclear generator, producing approximately 30 per cent of Ontario's power each year.

Bruce Power further solidified its commitment to leading Canada on the path to a zero-emissions future by launching Bruce Power Net Zero Inc. It moves us one step closer to the Bruce Power commitment of being Net Zero by 2027 by building off foundational nuclear output as a key enabler of decarbonization. Bruce Power Net Zero Inc. leverages the business of Huron Wind, a 9 megawatt wind farm located in Tiverton, and seeks to identify opportunities to invest in clean energy initiatives that complement the role of nuclear and assist Bruce Power and Ontario in achieving their Net Zero targets. It also looks to unlock the potential of other complementary technologies to nuclear, including storage, hydrogen, carbon off-sets, renewables, and vehicle electrification to achieve a Net Zero Future.

Bruce Power Life-Extension Program and Major Component Replacement Project (MCR)

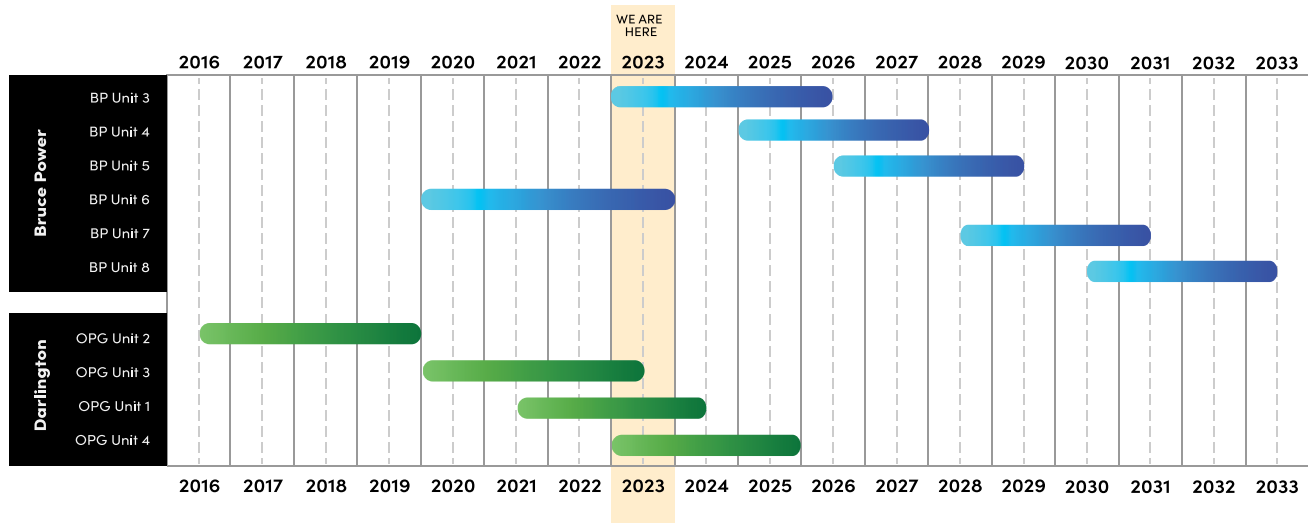
In 2015, Bruce Power reached an agreement with the Independent Electricity System Operator (IESO) to advance a long-term investment program to extend the life of its nuclear fleet and secure the site's operation until 2064. The Life-Extension Program started on January 1, 2016, and began with the replacement of older systems during regularly scheduled maintenance outages. As part of the Life-Extension Program, Bruce Power is carrying out an intensive MCR Project, which began in January 2020 on Unit 6, and focuses on the replacement of key reactor components in Units 3-8, including steam generators, pressure tubes, calandria tubes, and feeder tubes. The life-extension of each unit will add 30 to 35 years of operational life while other investments will add a combined 30 reactor years of operational life to the units, taking the site's operation out to 2064.

Current status

The first refurbishment on Unit 6 is progressing well and has entered into its return-to-service activities. With new fuel loaded into Bruce B's Unit 6, the project is now into the transition from the construction team back to Operations. As systems are energized, extensive testing and commissioning sequences will take place and approvals from the Canadian Nuclear Safety Commission (CNSC) will be needed at several key hold points for the unit to increase power and synchronize to the grid late in 2023.

While Unit 6 is on the home stretch to begin a new life of generation for the next 30+ years, Bruce A's Unit 3 MCR began with breaker open on March 1, 2023. The Unit 4 MCR will start in 2025 and once complete, will mark the end of life-extension activities at Bruce A. Focus will then shift back to Bruce B to complete MCR on Units 5, 7 and 8 for the balance of this massive infrastructure project.

Refurbishment Schedule



Areas of Collaboration



In 2015, long-term agreements were made to revitalize Ontario's nuclear fleet at both OPG and Bruce Power. Together, with the IESO, we developed a long-term schedule to complete Bruce Power's six-unit MCR and Life-Extension Program and OPG's DNRP while ensuring the Province has the reliable baseload power it needs. Throughout these projects, our focus on collaboration has led to the sharing of lessons learned, innovations, resources, and tooling and equipment, resulting in more efficient and successful projects for both companies.

The following areas are a summary of the collaboration efforts in 2022; they build upon the efforts and established relationships fostered throughout the projects as outlined in past reports. With OPG completing its first unit refurbishment ahead of Bruce Power, there has been significant collaboration to ensure subsequent refurbishments are implementing the lessons learned from preceding work. The value generated through our ongoing collaboration includes cost savings, schedule improvements, risk reduction, resource management, and worker dose reductions.

Some examples of our ongoing collaboration efforts related to our refurbishments:

- OPG and Bruce Power conduct monthly lessons learned meetings to share best practices and detailed information on complex evolutions. This back-and-forth exchange of information has helped with tooling enhancements and streamlined workflows.
- The Project Risk Management teams have a quarterly collaboration meeting to share lessons learned on current and in-progress initiatives with the goal of improving performance within both organizations.
- Executive team members have weekly calls to address and mitigate risks to projects and schedules.
- Bruce Power's Life-Extension team and Darlington's Return to Service (RTS) team meet regularly to share best practices with the integration of daily operations and RTS challenges.
- OPG and Bruce Power hold quarterly meetings to review vendor performance, quality, and supply challenges.
- OPG and Bruce Power meet quarterly with the CANDU/Refurbishment Forum Group to share lessons learned and other experiences across the international fleet of CANDU owners.

COLLABORATION IN NUMBERS



OPG delivered the world's single largest climate change action to date when we closed our coal stations.

70%

of the power the province needed to shut down coal stations was provided by the return of Bruce Power Units 1-4.

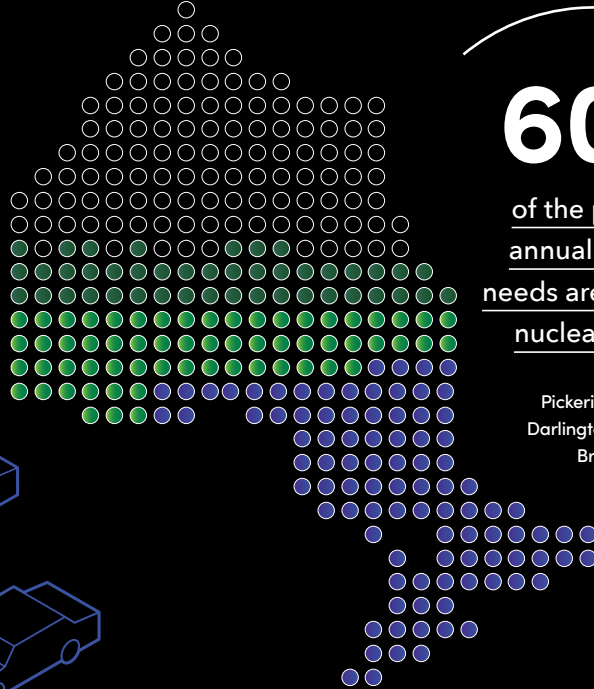


The quality of our air has improved immensely - decreasing smog days from 53 in 2005 to 0 in 2022.

80 million

tonnes of CO₂ emissions per year are avoided with nuclear power.

That's roughly the equivalent of taking 15 million passenger vehicles off the road.



60%

of the province's annual electricity needs are met by our nuclear stations.

Pickering Nuclear (14%)
Darlington Nuclear (20%)
Bruce Power (30%)



\$89.9 billion in economic benefits for Ontario will be generated by the DNRP + 30 years of operation.

ONTARIO **POWER**
GENERATION



Over 22,000 jobs will be secured directly and indirectly by our Life-Extension Program and MCR Project.

BrucePower

Together, we directly employ over

13,500 people.

Bruce Power (4,200+)

OPG (9,300+)

In 2022, our collaboration success included, but was not limited to:

Document and Information Sharing

- The sharing of outage lead-out initiatives by OPG allowed Bruce Power to review and compare their testing strategies to potentially align and make system testing comprehensive and simple across the stations.
- Bruce Power and OPG put planning and execution teams together to share lessons for challenging evolutions such as lower feeder installation, RTS key evolutions, moderator fill, and bulkhead removal. The Bruce Power team has attended lessons learned meetings to hear first-hand from OPG team members involved in refurbishment execution work.
- The Darlington Reactor Area Bridge (RAB) installation team provided Bruce Power with construction work packages for RAB install, which assisted them with validating logic for their Unit 6 RAB, resulting in a successful evolution. OPG attended Task Analysis Meetings where they provided insight to challenges during ball screw inspection and functional testing, and elevator overhauls.
- Historical documentation received from OPG aided Bruce Power in reducing worker dose during component replacement activities, particularly during the removal and installation of feeder tubes. This work will take place later this year.

- Collaboration on reactor physics commissioning activities for our respective refurbishment projects include:
 - Regulatory strategies aimed at reducing scope compared to past refurbishments.
 - Technical information on each of the planned reactor physics tests.
 - Flux scanning project, both on a technical and planning front; in addition, both companies are using the same vendor for these projects.
- Bruce Power has collected over 3,000 lessons from the Unit 6 MCR that will improve overall performance and create efficiencies with subsequent units. In addition, Bruce Power has prepared approximately 20 detailed lessons learned reports for each major refurbishment work series on Unit 6, and these reports have been shared with OPG.

Training and Qualifications

OPG and Bruce Power are continuing to work toward alignment in various training requirements to enable a more seamless transfer of employees between the stations.

For example:

- Last year, Bruce Power added new training qualifications including Spacer Location And Repositioning (SLAR) – these inspections are used to maintain the overall fitness for service of the fuel channels in a CANDU reactor.
- OPG and Bruce Power are working toward potential alignment in welding qualifications and general employee training.

Sharing Tooling and Assets

End Fitting Insertion Carriage Tool:

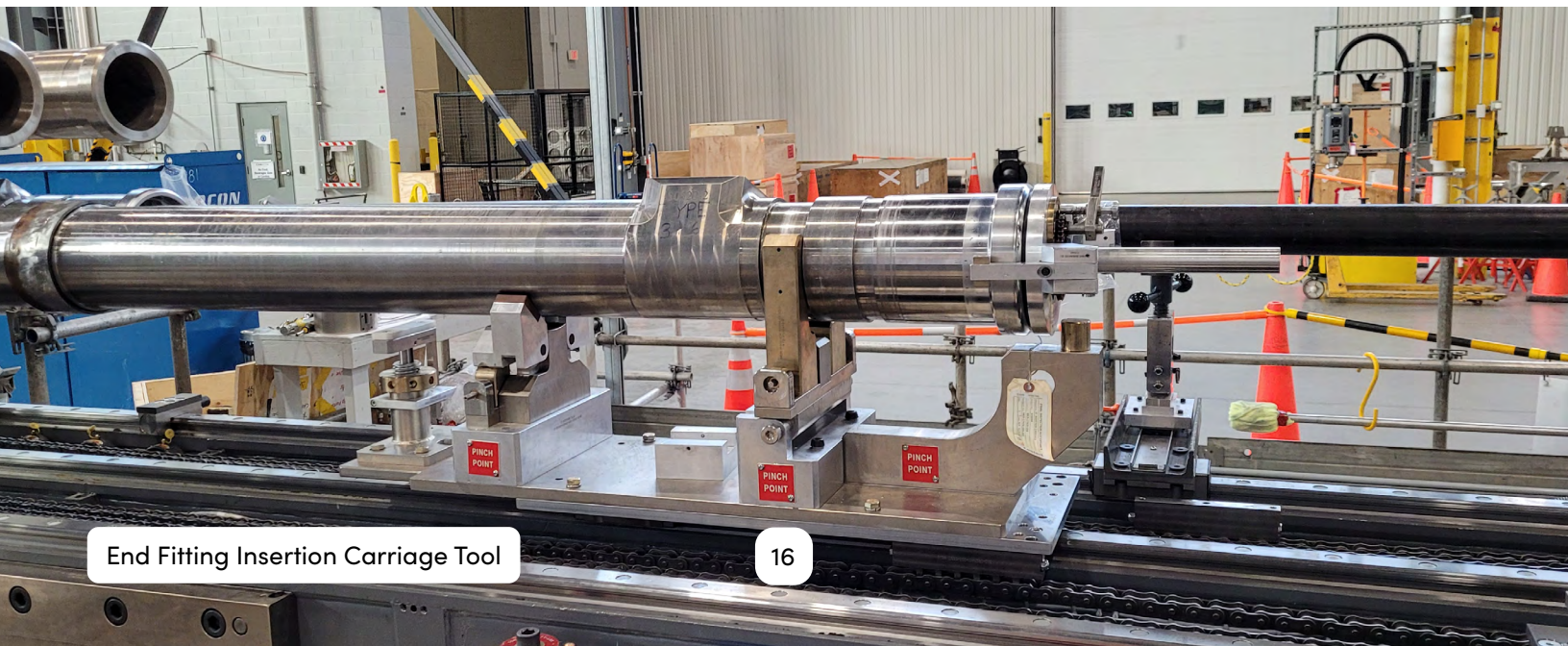
Throughout Bruce Power's MCR, the team has been using an end fitting insertion carriage tool. OPG borrowed one of these carriages to carry out testing at the Darlington Energy Complex Training and Mock-Up Facility to confirm its suitability to interface with the DNRP fuel channel installation tools. OPG along with contract partner, CanAtom, tested the tool and was able to use it during critical path execution to improve work activities and increase efficiencies. The tool was a simple drop-in replacement for the previously used tool.

Slide Hammer Tab Bender Tool:

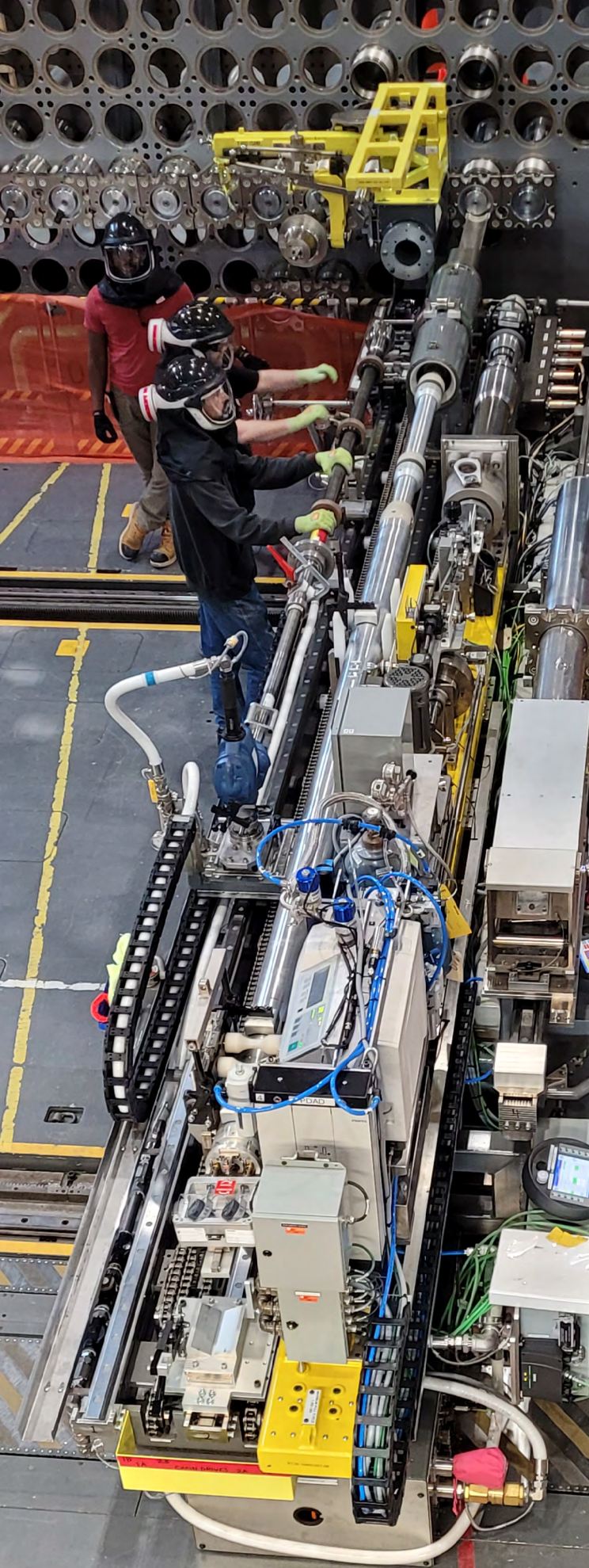
Bruce Power shared their slide hammer tab bender tool design with OPG and CanAtom with the intent to improve tool rigidity and reliability. The new design was able to sustain more force and help reduce OPG's critical path and tooling breakdowns for the Darlington Unit 1 feeder work.



FUN FACT: AFTER COMPLETING JUST ONE REFURBISHMENT EXECUTION (UNIT 2), \$120 MILLION IN SAVINGS WERE ATTRIBUTED TO THE DARLINGTON ENERGY COMPLEX MOCK-UP AND TRAINING FACILITY.



End Fitting Insertion Carriage Tool



Multi-Purpose Installation Worktable (MIWT) and Vision Alignment System (VAS) Calibration Fixture:

OPG implemented a MIWT based on Bruce Power's MCR design, which uses a VAS to help accurately line up with the reactor lattice site. The VAS design was shared with OPG for manufacturing build-to-print tools and to improve both set-up and commissioning time. It also helps ensure the VAS system on MIWT is calibrated accurately to reduce errors during execution of calandria tube installation.

MIWT Lessons Learned:

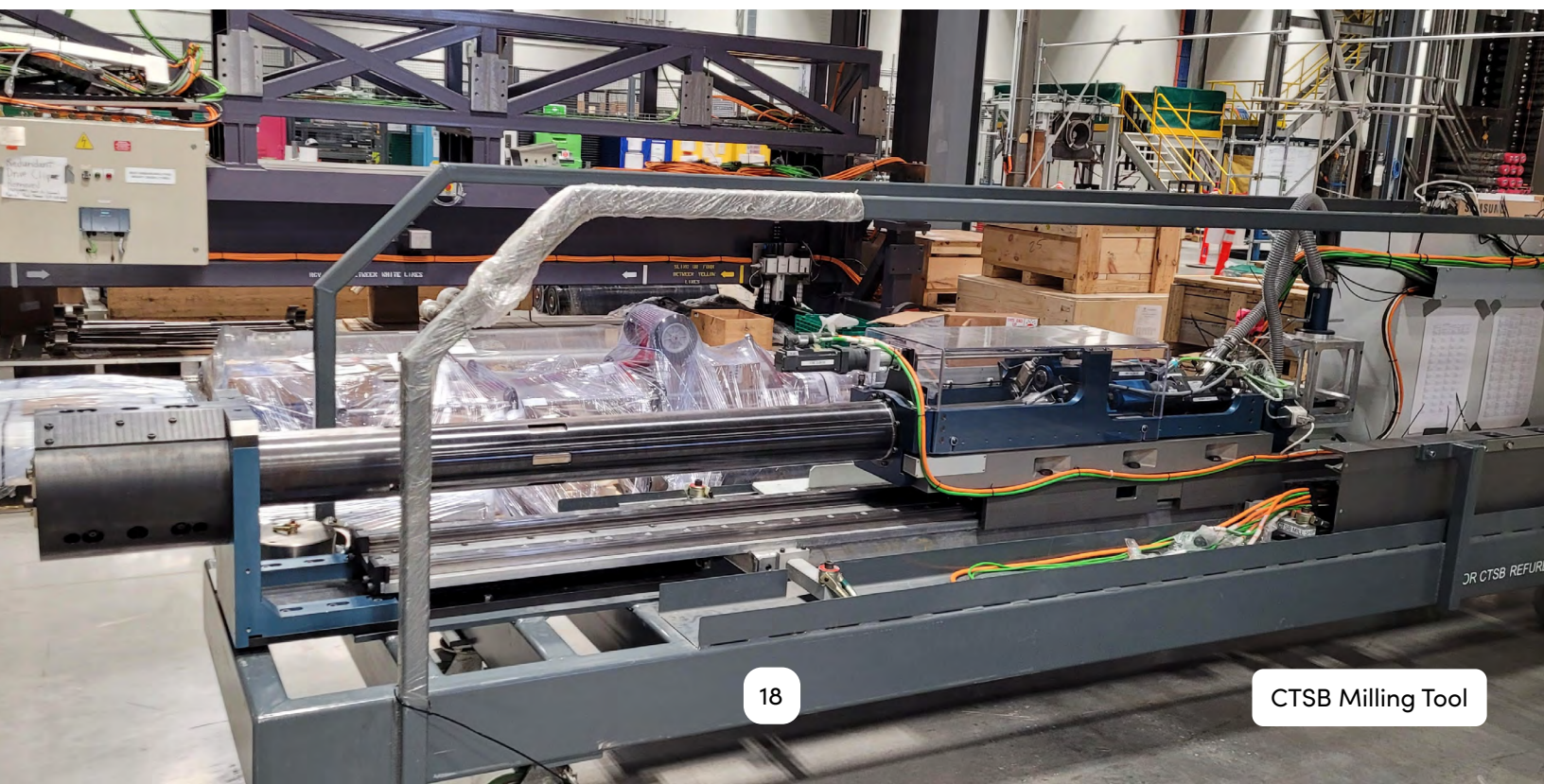
Bruce Power shared vital lessons learned with OPG related to rigging and lifting of the MIWT. At a vendor facility, the team observed that the mounting blocks on the rails shifted and impacted the load distribution while lifting a MIWT. This was shared and a solution was implemented at both sites by installing a locking mechanism for the blocks on rails.

Calandria Tube Removal Tool and Calandria Tube Sheet Bore (CTSB) Milling Tool:

OPG worked with Bruce Power on their calandria tube removal by sharing lessons learned resulting from Retube and Feeder Replacement (RFR) tooling issues. This improved the removal forces by maximizing the hydraulic pressures and increasing gripping force.

OPG also loaned Bruce Power a set of RFR gripper jaws that utilizes a saw-tooth design to eliminate slippage, proving to be an asset for the calandria tube removal.

- OPG's RFR team proactively loaned Bruce Power the CTSB Milling Tool in the event they had to repair damaged bores created from the removal series. Bruce Power performed extensive testing with the tool and shared this information with the RFR team. They also developed multiple cutter designs for bore re-conditioning that could also be utilized by OPG if required in the future.
- Throughout 2022, a lot of information has been shared with Bruce Power on OPG's tooling and processes from the Darlington RFR project. OPG has shared training, execution and tooling operating experience on bellows replacement, bellows sever, calandria tube rolled joint leak testing, and end fitting lapping.



Additional Areas of Collaboration Success

Our history of collaboration goes back further than the start of our refurbishments projects and has continued to evolve in many areas. Last year, OPG and Bruce Power collaborated on the largest station outages we execute in nuclear – a Vacuum Building Outage (VBO).

In May 2022, OPG sent several people to observe the execution of the Bruce A VBO, and subsequent lessons learned meeting. The visit resulted in several learnings and strategies being incorporated into OPG's Pickering Nuclear VBO plan. The result – OPG's most efficient VBO in its history. OPG reciprocated by inviting Bruce Power to attend the VBO lessons learned meeting to share strengths

and innovations. Bruce Power will use this information as they plan and execute a VBO on Bruce B during the spring of 2024. A VBO is no small feat and requires significant planning, preparation, and a whole lot of innovation, and together, we've found a way to collaborate to improve efficiencies, saving time and money.

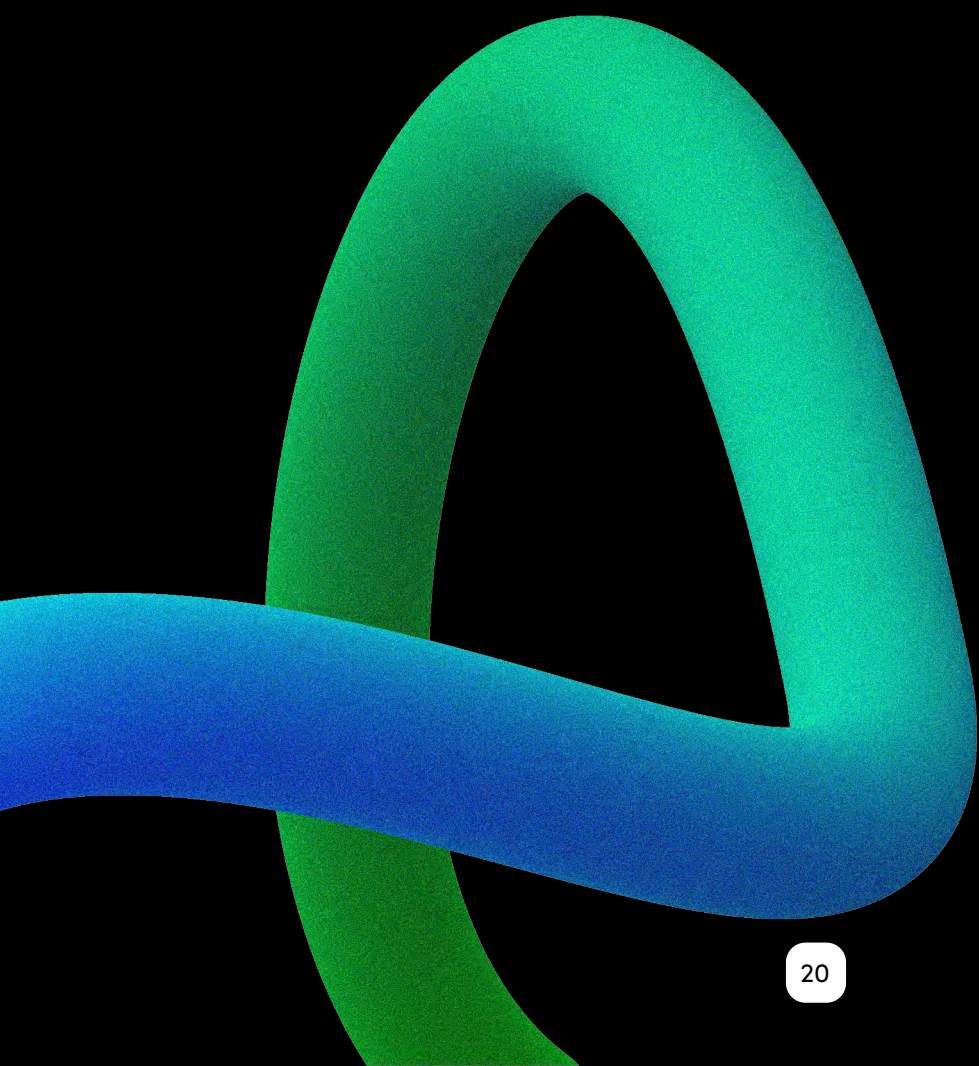
Some examples of innovations that both companies shared include OPG's use of drones as the primary inspection tool to meet regulatory requirements and divers to complete the Emergency Water Storage Tank inspection program. At Bruce A, the team deployed vacuum trucks for the first time, resulting in a 12-hour gain on critical path near the end of the outage.



FUN FACT: THE VACUUM BUILDING, A CYLINDRICAL CONCRETE STRUCTURE STANDING MORE THAN 50 METRES HIGH, IS A UNIQUE SAFETY FEATURE OF CANDU STATIONS.



A Look Forward



A Look Forward

OPG and Bruce Power continue to establish relationships throughout our organizations to ensure fluidity of knowledge transfer, lessons learned, innovations, and efficiencies strengthening our operations and the nuclear industry in Ontario and across Canada. Our success in this long-standing partnership will continue through the successful completion of our individual refurbishment projects as well as future endeavours as we remain committed to delivering the best value to Ontario's ratepayers.

A cleaner future for a brighter tomorrow

As we continue to progress through our refurbishments in parallel, OPG is seeking the CNSC's approval to continue operating Pickering Units 5-8 to the end of September 2026; Units 1 and 4 will retire at the end of 2024 as planned. Continued operations of these units will have many benefits to our customers, the economy, and the environment, including:

- Reducing CO2 emissions by 2.1 megatonnes in 2026 – the equivalent of taking up to 643,000 cars off the road.
- Protecting 4,500 jobs.
- Ensuring a stable supply of Cobalt-60, a critical medical isotope used in cancer-fighting treatments and sterilization of medical devices. Pickering provides 20 per cent of the North American supply and 10 per cent of the world's supply.
- A cost-effective option to help meet electricity system needs given the current inflationary and supply chain challenges around the world.



FUN FACT: IN 2021, PICKERING'S UNITS 4 AND 6 RANKED AMONG THE TOP 10 PERFORMING CANDU REACTORS IN THE WORLD, HELPING PICKERING SEE ITS STRONGEST PERFORMANCE AND RELIABILITY RATINGS EVER.

Looking beyond 2026, the Province has also asked OPG to conduct a feasibility assessment on the potential for refurbishing Units 5-8 at Pickering Nuclear. In 2023, OPG will conduct a comprehensive technical examination and submit a final recommendation to the Province.

Powering Up to Drive Ontario Forward

Project 2030 is a Bruce Power initiative that will support Ontario's climate change targets and future clean energy needs by targeting a site net peak capability of 7,000 megawatts by the early 2030s. Project 2030 will incrementally increase the site generation output through

asset optimization, innovation, and leveraging new efficient technology. This additional generation will be equivalent to adding about a ninth large-scale reactor to the Bruce Power site without the need to build additional infrastructure and will power upwards of 450,000 homes and businesses.

Big Things Start Small – The Darlington New Nuclear Project (DNNP)

The development of Small Modular Reactors (SMRs) is another tool to secure a cleaner energy future and help Canada meet its Net Zero 2050 commitment. OPG and its partners



are advancing the DNNP – to deploy a 300 megawatt SMR at the Darlington site. SMRs can help combat climate change by producing safe, reliable, low-emission baseload power. An SMR can power about 300,000 homes.

The momentum continues to build for the project with three recent, significant milestones. In 2022, after regulatory approval, early site preparation activities began, including non-nuclear infrastructure activities, such as clearing and grading a portion of the new nuclear site to build roads, utilities, and support buildings. This work will continue into 2025 and supports more than 100 new jobs in the Region of Durham. OPG also submitted a License to Construct application with the CNSC in 2022. The licensing process includes opportunities for Indigenous communities and the public to discuss the application and ask questions at a public hearing, held by the CNSC, likely in 2024. In January 2023, OPG signed an agreement with GE Hitachi, SNC-Lavalin and Aecon, to leverage a diverse range of expertise to execute the

DNNP including design, engineering, and construction. OPG's preliminary schedule is to complete construction of the reactor by 2028, with commercial operation in 2029, pending regulatory approvals. The Darlington site is the only site in Canada licensed for a new nuclear build with an accepted environmental assessment.

Nuclear Innovation Institute

A partnership between Bruce Power and the County of Bruce, the Nuclear Innovation Institute (NII) is an independent, not-for-profit, membership-based organization created as a platform for innovation in the industry. NII leads projects and programs that drive the clean energy transformation, improve our health and environment, and promote new skills and knowledge in our communities. Bruce Power is meeting the challenges of climate change and global energy demand through progressive technology and reinvesting in our current infrastructure.

Generation for the future

While Bruce Power's focus remains on the safe, reliable operation and Life-Extension Program, there's an understanding that new technologies are emerging.

As Bruce Power supports the baseload generation that allows new generation technologies to be developed, it is also an active participant in supporting a stable, long-term clean energy supply mix that will help Ontario meet its climate change goals.

Through its Next Gen initiative, Bruce Power is taking a targeted approach in assessing new nuclear opportunities including large scale nuclear, SMRs, advanced nuclear and micro-reactors, as well as complementary technologies to lead the industry to meeting or exceeding the expected 2050 generation gap and Net Zero targets.



FUN FACT: WITH ABOUT 60 NUCLEAR INDUSTRY BUSINESSES LOCATED IN THE CLEAN ENERGY FRONTIER REGION OF BRUCE, GREY AND HURON COUNTIES, THE NII WILL HARNESS THIS STRONG FOUNDATION AND CONSOLIDATE THE MANY EXISTING ACTIVITIES TO ADVANCE THE WORK OF EACH PARTNER.

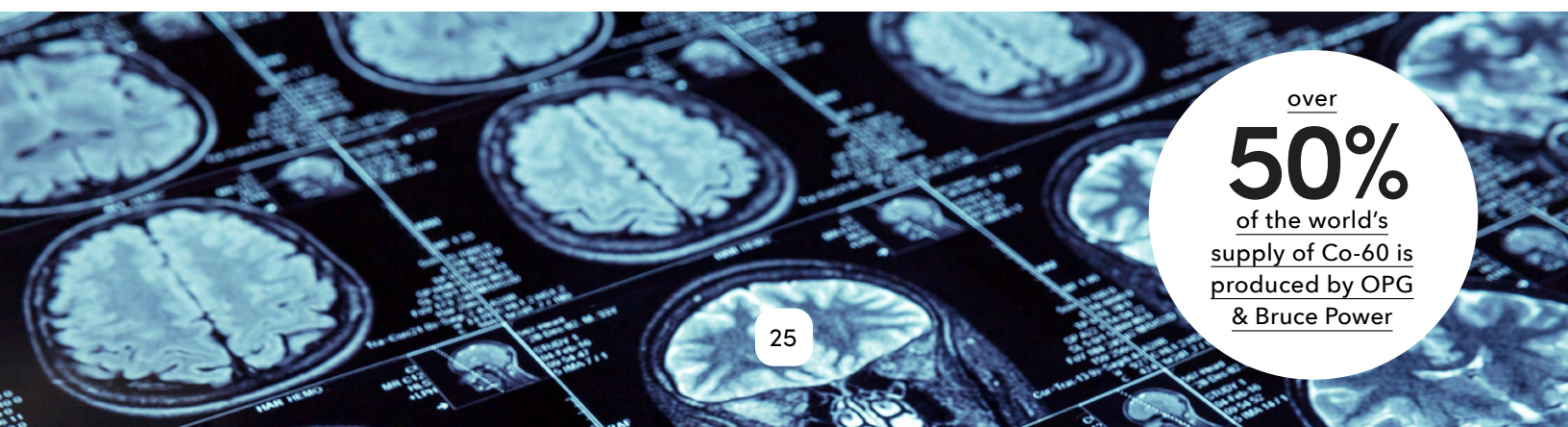
Medical Isotopes

Together, OPG and Bruce Power produce more than half of the world's supply of cobalt-60 (Co-60). Co-60 is extracted from reactors at OPG Pickering and Bruce Power's Bruce B station every 24 to 30 months. About 40 per cent of the world's single-use medical devices, such as syringes, gloves, implants, and surgical instruments, are irradiated and sterilized with Co-60; it is also used in the treatment of brain tumours for millions of patients worldwide.

An innovative collaboration between OPG's wholly-owned subsidiary, Laurentis Energy Partners, and BWXT Medical (BWXT) will see Molybdenum-99 (Mo-99) harvested from reactors at Darlington Nuclear. Mo-99 is used in over 40 million diagnostic and medical imaging treatments around the world each year, helping to detect illnesses like cancer and heart disease. The production of Mo-99 at Darlington will be a world first from a commercial power reactor - ensuring a stable

domestic supply of this critical product without interrupting the station's generation of clean energy.

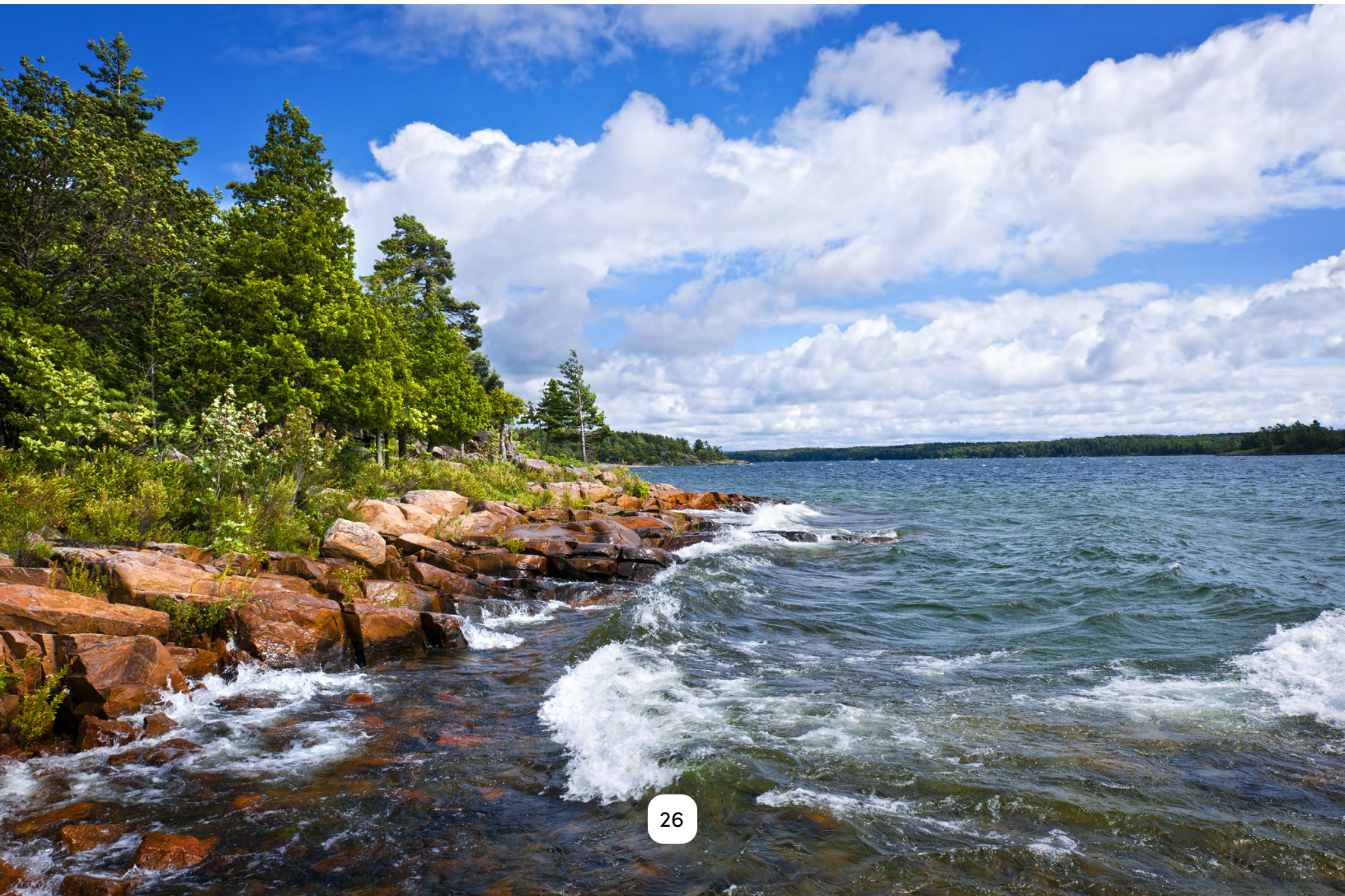
Bruce Power is the first commercial power reactor in the world to use an Isotope Production System (IPS) to produce Lutetium-177 (Lu-177), a short-lived medical isotope currently used to treat neuroendocrine tumours and has applications for prostate and breast cancer treatments. The Lu-177 IPS leverages Bruce Power's continual operations 24-hours a day, seven-days a week to provide a consistent and scalable supply of cancer-fighting isotopes that will be used by doctors to treat patients around the world.

The background of the bottom half of the page is a collage of various medical scans, including MRI and CT images of human brains and internal organs, rendered in a blue and white color scheme.

over
50%
of the world's
supply of Co-60 is
produced by OPG
& Bruce Power

In Closing

OPG and Bruce Power recognize the importance of our continued collaborative relationship, and the efficiencies and successes that will benefit both companies. Together, we will continue to produce reliable, emissions-free electricity every day to help support Ontario's economic growth and lead the fight against climate change.





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Innovation at work