Working Together to Deliver the Future of Nuclear in Ontario

An Interim Report on Collaboration to Extend Ontario’s Nuclear Fleet
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Benefits of Collaboration
Building Our Clean Energy Future
Achieving Success Together

A MESSAGE FROM MICHAEL RENCHECK AND JEFF LYASH

Ontario’s Long-Term Energy Plan (LTEP) outlines the government’s pledge to provide clean, reliable and affordable energy for Ontario – now and into the future. As part of this commitment, nuclear will remain the backbone of the province’s electricity supply, thanks to planned refurbishment at the Bruce and Darlington sites and the life extension of Pickering up to 2024.

With refurbishment comes the opportunity for Bruce Power and Ontario Power Generation (OPG) to build on our already successful relationship to realize the best value for Ontario customers.

We have long realized the importance of working together to achieve success, and by sharing our knowledge, leveraging economies of scale and delivering the nuclear refurbishment process outlined in the LTEP, we can help Ontario achieve its goal of a balanced – and affordable – electricity supply mix.

In a Memorandum of Understanding (MOU) dated November 12, 2015, we confirmed our commitment to improving our refurbishment programs through ongoing collaboration.

While the MOU recognizes that a significant amount of collaboration already takes place between our organizations, it also outlines additional ways we can work together to identify efficiencies to deliver ongoing value. This includes sharing lessons learned and best practices in both refurbishment and operations activities, and seeking opportunities to develop a coordinated approach in order to reduce costs, limit execution risk and ensure projects are completed on time and on budget.

As we enter a critical period in the life extension of our reactors, we look forward to collaborating on our respective refurbishment programs – for the benefit of our businesses, the province and, most importantly, the customer. We are pleased with the progress we continue to make between our two organizations.

Regards,

Michael W. Rencheck
President and Chief Executive Officer
Bruce Power

Jeff Lyash
President and Chief Executive Officer
OPG
Executive Summary

• For more than 40 years, Ontario’s nuclear fleet has provided a stable source of clean and affordable electricity for families, schools, hospitals and businesses. In 2016, nuclear has generated over 60 per cent of Ontario’s electricity at 30 per cent below the average price paid for power in the province. Recognizing the benefits of nuclear power, the Ontario government continues to implement its commitment to this energy source as noted in its 2013 Long-Term Energy Plan (LTEP).

• Ontario’s LTEP outlines the continued role for nuclear in the province with the refurbishment of the units at the Bruce and Darlington sites. The successful refurbishment of Ontario’s nuclear fleet will require investment in Units 3 to 8 at Bruce Power and Units 1 to 4 at Darlington between 2016 and 2033. This program will be undertaken as Ontario Power Generation (OPG) advances work to run the Pickering units up to 2024.

• The LTEP states, “The government will encourage the province’s two nuclear operators, Bruce Power and OPG, to find ways of finding ratepayer savings through leveraging economies of scale in the areas of refurbishment and operations. This could include arrangements with suppliers, procurement of materials, shared training, lessons learned, labour arrangements and asset management strategies.” This cannot be accomplished without collaboration.

• Bruce Power and OPG have long been collaborating in a range of areas that allow both operators to collectively leverage economies of scale to provide low-cost electricity to ratepayers. As the organizations enter critical refurbishment periods, this ongoing collaboration will continue as both sides look to improve their respective refurbishment programs.

• Bruce Power and OPG have made considerable progress in their refurbishment-related collaborations in the following key areas: asset management and inspection programs; procurement; tooling; replacement of major components, including de-tube, re-tube and feeder replacement work; lessons learned; waste management; labour arrangements; and logistics, including lead-in and lead-out activities.

• By sharing knowledge, leveraging economies of scale and delivering the nuclear refurbishment process outlined in the LTEP, Bruce Power and OPG can help Ontario achieve its goal of a balanced – and affordable – electricity supply mix that benefits the customer.
Overview of Bruce Power and OPG Operations

For decades, Ontario’s nuclear fleet has provided a stable source of clean and affordable electricity for families, schools, hospitals and businesses. In 2016, nuclear generated over 60 per cent of Ontario’s electricity at 30 per cent below the average price paid for power in the province.

Recognizing the benefits of nuclear power, the Ontario government renewed its commitment to this energy source in its 2013 Long-Term Energy Plan (LTEP). These activities have been carried out in a wide-range of nuclear projects both domestically and internationally, allowing Bruce Power and Ontario Power Generation (OPG) to adapt their programs according to lessons learned from across the industry.

With this commitment comes the need to refurbish 10 units – six at the Bruce Power site and four at the Darlington OPG site – to meet the province’s energy needs.

About Bruce Power

Bruce Power operates the world’s largest nuclear facility and is the source of approximately 30 per cent of Ontario’s electricity. Formed in 2001, Bruce Power is Canada’s only private sector nuclear operator and is a Canadian-owned partnership of Borealis Infrastructure Trust Management (a division of the Ontario Municipal Employees Retirement System), TransCanada, the Power Workers’ Union and The Society of Energy Professionals. It operates eight CANDU units under long-term lease from OPG.

In December 2015, Bruce Power signed a long-term agreement with the province to refurbish six of its units over the next two decades, investing billions of private funds in these publically owned assets.
About Ontario Power Generation

OPG operates a diversified portfolio consisting of two nuclear (Darlington and Pickering), 65 hydroelectric and three thermal generating stations. Through these facilities, OPG generates about 50 per cent of Ontario’s electricity.

In January 2016, OPG announced that it would be moving forward with the refurbishment of the four-unit Darlington Nuclear Generating Station while also continuing the operation of the Pickering Nuclear Generating Station until 2024.

Working Together

Bruce Power and OPG have a long-standing relationship as operators of CANDU reactors, sharing best practices and information through a range of industry forums including the CANDU Owners Group (COG) and the World Association of Nuclear Operators (WANO).

Both organizations have a history of operational performance excellence and are committed to the value of ‘Safety First.’ They achieve this high standard through active collaboration, transparency and continuous improvement.

How the independent, federal regulator, the Canadian Nuclear Safety Commission, rates Ontario’s nuclear plants:

<table>
<thead>
<tr>
<th>Plant</th>
<th>Rating</th>
</tr>
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<tbody>
<tr>
<td>Bruce A</td>
<td>Fully Satisfactory</td>
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<tr>
<td>Bruce B</td>
<td>Fully Satisfactory</td>
</tr>
<tr>
<td>Darlington</td>
<td>Fully Satisfactory</td>
</tr>
<tr>
<td>Pickering</td>
<td>Fully Satisfactory</td>
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Pickering Nuclear Continued Operation

Pickering is a critical generating asset to the Province of Ontario. In January 2015, the Province announced that it had approved OPG’s plan to pursue continued operation of the Pickering Generating Station beyond 2020, up to 2024.

This life extension will save Ontario electricity customers up to $600 million while providing low-cost electricity and protecting 4,500 jobs across Durham Region. In addition, the operation of Pickering during the Bruce and Darlington nuclear refurbishments will ensure a safe, reliable supply of electricity and will also help the province avoid eight million tonnes of greenhouse gas emissions, which is the equivalent to taking 490,000 cars off Ontario roads.

The plan to extend the operation of Pickering to 2024 is a direct reflection of a positive Environmental Assessment and an Integrated Safety Report, which confirms the safety and strength of the station’s condition. All six units would operate until 2022; two would then shut down, and four would run to 2024. OPG has started work on a licence application for Canadian Nuclear Safety Commission approval in 2018.

Since 2010, more than $200 million has been invested in Pickering, which recently achieved its best operating reliability performance in the station’s history. This strong performance will be vital as the Darlington refurbishment ramps up.

History

The first four Pickering Nuclear reactors went into service in 1971 and continued to operate safely. In 1997, these reactors were placed in voluntary lay-up as part of what was then Ontario Hydro’s nuclear improvement program. In September 2003, Unit 4 was returned to commercial operation, as was Unit 1 in November 2005. Units 2 and 3 remain in a safe shutdown state. Units 5, 6, 7 and 8 at Pickering Nuclear continue to operate safely since they were brought into service in 1983. They have a combined capacity of approximately 2,100 megawatts.
Economic Development

Bruce Power and OPG are committed to investing in Ontario, and continuing operations at the Bruce and Darlington sites will not only benefit local communities, tradespeople, and Ontario-based manufacturers and suppliers, but also the province as a whole.

The continued operation of the Pickering facility to 2024 is also a critical component to the industry as refurbishment activities are underway at both Bruce Power and Darlington.

By refurbishing six units at the Bruce site and the four units at the Darlington site, Bruce Power and OPG are helping to ensure the long-term sustainability of power prices while creating thousands of jobs, increasing Ontario's tax revenue and investing billions into the province's economy.

The refurbishment and continued operation of the Darlington reactors through to 2055 will see an average of 14,200 jobs created per year, with government revenues of $9.3 billion and corporate profits before tax of $7 billion. Every dollar invested into the station results in a $1.40 increase to the GDP, thus providing an $89.9 billion boost to Ontario's economy though the project and subsequent 30 years of station operation.

By providing the best value for Ontario customers, strengthening the provincial economy for the long term, and creating and preserving local jobs, the refurbishment and continued operations of the Bruce Power and Darlington sites will have a substantial and long-lasting economic impact in the province.

At its peak, the refurbishment of the Bruce Power site will create 22,000 direct and indirect jobs annually while also securing the organization's future. The project will provide $3 to 4 billion in annual economic benefit – or $132 billion to $176 billion over the lifetime of the refurbishment and continued operations – with 90 per cent of the spend taking place across the province.
Overview of Bruce Power and OPG Operations

Greenhouse Gas Reduction

Nuclear energy plays a fundamental role in Ontario’s clean-energy equation. In fact, 60 per cent of Ontario’s daily electricity needs are supplied by the province’s nuclear power with virtually no greenhouse gas (GHG) emissions.

Ontario was the first jurisdiction in North America to end its use of coal-fired electricity, which it accomplished in 2014, and much of this success was made possible by Ontario’s nuclear industry. Moving forward, it is important for Ontario to have a balanced supply mix that allows for the continued advancement of renewable technology, along with nuclear, to maintain these emission-reduction efforts.

Bruce Power and OPG strive to support Ontario’s short-, medium- and long-term climate change goals. Through their respective refurbishment programs, both organizations can continue to provide Ontario with the carbon-free energy its needs, ensuring clean air for many generations to come.

Without the nuclear fleet at the Bruce and Darlington sites, the province would need to replace over 9,500 MW of clean, reliable and affordable electricity. This could only be done by reintroducing coal or increasing natural gas, which would both result in a sharp increase in GHG emissions.

To put that into perspective, the Bruce Power site, with its eight reactors, annually avoids 31 million tonnes of CO2, which is the equivalent of taking six million cars off the road and almost equivalent to the air pollution released by coal plants in 2001.

Darlington’s four refurbished reactors will reduce GHG emissions by an estimated 297 million tonnes – that is almost 10 million tonnes per year for 30 years – which is the equivalent of removing two million cars per year from Ontario’s roads.

In addition to playing a major role in helping Ontario shut down its coal plants, Bruce Power and OPG realize that there is more that can be done to help the province lower its GHG emissions.

Bruce Power Greenhouse Gas Reduction

\[ 31 \text{ million tonnes of CO2 emissions} \quad \downarrow \quad 6 \text{ million cars off the road} \]

Darlington Greenhouse Gas Reduction

\[ 10 \text{ million tonnes of GHG emissions} \quad \downarrow \quad 2 \text{ million cars off the road} \]

*annually
Bruce Power and OPG are committed to sustainable development and social responsibility, which are reflected in their efforts to minimize the environmental footprint of their operations while meeting their obligations to safely produce power for the residents of Ontario. From electric vehicles to more energy efficient buildings, Bruce Power and OPG continue to look for opportunities to better serve the long-term energy needs of the province.

Recognizing that transportation is the largest contributor to GHGs in Ontario, Bruce Power and OPG have embraced the use of electric vehicles. Electric vehicles emit approximately 90 per cent less CO₂ than gas-powered cars, and Ontario-made electricity is generally 90 per cent less expensive than gasoline.

As part of its commitment to electric vehicles, Bruce Power has installed two dual-wand charging stations at its Visitors’ Centre. In addition, the organization has partnered with Plug’n Drive to install, or explore the installation of, charging stations in five local communities. Bruce Power’s long-term plan is to replace its on-site, gas-powered fleet with electric vehicles, and this corporate strategy will continue to develop in the coming years.

OPG has significantly reduced its car fleet by partnering with the Ministry of Transportation to use its public sector fleet of vehicles. OPG staff now have access to more than 400 vehicles across the province, two-thirds of which are either hybrid or plug-in hybrid electric vehicles.

It is this commitment to a cleaner Ontario that sets Bruce Power and OPG apart from a number of other energy sources throughout the province.
Cobalt-60 Production

The benefits of nuclear power also extend to the medical industry. For the healthcare sector, the impact of nuclear power is two-fold – it can be counted on to power lifesaving equipment and it is a reliable source of Cobalt-60, a medical isotope used to sterilize hospital equipment, including sutures, syringes, gloves, surgical gowns and masks, as well as pharmaceutical wares and cosmetics. In addition, Cobalt-60 can be used to eliminate harmful bacteria in many food products.

Cobalt-60 can also be utilized to help stop the spread of the Zika virus as it is a key component of the Sterile Insect Technique (SIT), a process aimed at eliminating or, at a minimum, suppressing the population of insects that spread disease or damage agricultural crops.

In early 2016, the International Atomic Energy Association deployed the SIT using gamma radiation from Cobalt-60 to combat the spread of the Zika and West Nile viruses as well as dengue. SIT poses no risk to the environment or to public health and, in fact, is considered one of the most environmentally friendly insect pest control methods ever developed because the insects are not killed, they simply do not self-replicate or become established in the environment.

Medical Cobalt, more precisely known as High Specific Activity (HSA) Cobalt-60, is used worldwide for cancer treatment and radiation therapy for the treatment of complex brain conditions.
Bruce Power and OPG provide 70 per cent of the world’s Cobalt-60 supply. It is produced in Bruce Power’s four Bruce B reactors and OPG’s Pickering reactors by using adjuster rods that contain Cobalt-59 inserts. Over time, some of the Cobalt-59 inserts absorb a neutron and change at the atomic level to become Cobalt-60. Approximately every two to three years, the Cobalt-60 rods are safely removed and shipped to the processing facility. While there, the Cobalt-60 is processed into sources for industrial or medical use before being shipped to the customer.

With plans to extend the life of the Bruce Power and Darlington reactors through refurbishment, there will be stable sources for Cobalt-60 for many more years to come, which is welcome news to the global medical community.
Fleet Safety: Canadian Nuclear Safety Commission Ratings

The Canadian Nuclear Safety Commission (CNSC) is Canada’s independent nuclear regulator, and each year it publishes a report of the safety performance of Canada’s nuclear facilities. The annual report assesses how well plant operators are meeting regulatory requirements and program expectations in areas such as human performance, radiation and environmental protection, and emergency management and fire protection.

In the 2015 report, released in June 2016, Bruce Power and OPG received overall ‘Fully Satisfactory’ rankings, confirming their continued commitment to safe operations. In public communications, the CNSC has compared a Fully Satisfactory rating to an ‘A+’ and a Satisfactory rating to an ‘A.’
The chart below summarizes the 2015 safety performance of the Bruce Power and OPG nuclear sites. While the rating categories used by the CNSC include ‘Fully Satisfactory’ (FS), ‘Satisfactory’ (SA), ‘Below Expectations’ (BE) and ‘Unacceptable’ (UA), both Bruce Power and OPG received strong FS and SA ratings in all categories.

<table>
<thead>
<tr>
<th>SAFETY AND CONTROL AREA</th>
<th>BRUCE A</th>
<th>BRUCE B</th>
<th>DARLINGTON</th>
<th>PICKERING</th>
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<tr>
<td>Management system</td>
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<tr>
<td><strong>INTEGRATED PLANT RATING</strong></td>
<td>FS</td>
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Ontario’s Refurbishment Plan

AN OVERVIEW OF BRUCE POWER’S AND OPG’S INTEGRATED SCHEDULES

Ontario’s LTEP outlines the continued role for nuclear in the province with the refurbishment of the units at the Bruce and Darlington sites.

Overlap of Bruce Power and Darlington Refurbishment Schedules

These graphs reflect the overlap in the Bruce Power and Darlington refurbishment schedules only.

The successful refurbishment of Ontario’s nuclear fleet will require investment in Units 3 to 8 at Bruce Power and Units 1 to 4 at Darlington between 2016 and 2033.
In the LTEP, the government laid out the following principles to guide the nuclear refurbishment process in Ontario:

- Minimize commercial risk on the part of ratepayers and the government
- Mitigate reliability risks by developing contingency plans that include alternative supply options if contract and other objectives are at risk of non-fulfillment
- Entrench appropriate and realistic off-ramps and scoping
- Make site, project management, regulatory requirements, supply chain considerations, and cost and risk containment the primary factors in developing the implementation plan
- Take smaller initial steps to ensure there is opportunity to incorporate lessons learned from previous refurbishments, including collaboration between operators

Based on these principles, Bruce Power and OPG have identified a number of opportunities for collaboration on the effective planning and execution of future refurbishments. These include a collective approach to:

- Asset management and inspection programs
- Procurement of long-lead materials
- Common tooling
- Replacing major components
- Lessons learned
- Waste management
- Labour agreements with all building trades covering both the Bruce and Darlington sites
- Lead-in and lead-out logistics
Areas of Collaboration

The LTEP states, “The government will encourage the province’s two nuclear operators, Bruce Power and OPG, to find ways of finding ratepayer savings through leveraging economies of scale in the areas of refurbishment and operations. This could include arrangements with suppliers, procurement of materials, shared training, lessons learned, labour arrangements and asset management strategies.”

This cannot be accomplished without collaboration.

Bruce Power and OPG have long been collaborating in a range of areas that allow both operators to collectively leverage economies of scale to position nuclear power as a low-cost provider of electricity to ratepayers. As the organizations enter critical refurbishment periods, this ongoing collaboration will continue, with both sides looking to improve their respective refurbishment programs.

To achieve manageable refurbishment schedules and support the life extension of their units, Bruce Power and OPG must carry out asset management and inspection activities on a range of nuclear and non-nuclear systems. Not only does this approach support the LTEP schedule, but it also ensures the ongoing safe, reliable operations of the units at both the Bruce and Darlington sites for the remainder of their full operational lives.

Sharing knowledge of asset management and inspection best practices is an important aspect of Bruce Power and OPG refurbishment collaborations.

Through the Gaseous Fission Product (GFP) monitoring system joint project, Bruce Power and OPG are working together to design and procure a new GFP system with longer-lasting equipment and improved features. This will provide a permanent solution to GFP system obsolescence, with a 20-year life extension of GFP system operations, improved life cycle management and increased reliability.
Both organizations are also active in the COG Research and Development Program and Industry Standard Toolset Program. Shared participation is essential in ensuring the required CANDU technical assistance with regards to supporting plant life extension, addressing plant aging/operating margin issues and addressing regulatory requirements.

The qualification of film forming amine (FFA) preservation of steam generators project is another COG program in which both organizations are active participants. The goal of this project is to qualify for CANDU stations the AREVA FFA process to preserve metal in the condensate, feed water and boiler systems against corrosion.

This process may have substantial benefits for sites that are in lay-up for long periods of time – like with a refurbishment outage – and may also help reduce normal operating corrosion product transport.

The Aging Management Peer Group also provides an information sharing opportunity for Bruce Power and OPG with regards to the development of a common CANDU industry approach to addressing aging asset issues. Sharing of operational experience (OPEX), methodologies and consistent approaches to aging management issues provides a fundamental benefit to both operators.
As referenced in the Memorandum of Understanding (MOU) on Collaboration during Ontario’s Refurbishment Period, Bruce Power and OPG have agreed to consider opportunities to leverage economies of scale in the areas of procurement. Given the overlap of the Bruce and Darlington refurbishment projects, it is important that both organizations work together to develop their commercial strategies to ensure the capability and capacity of the supply chain.

The key elements of the refurbishment projects, including steam generator replacement, de-tube and feeder replacement, require the procurement of components and materials. This is an area in which Bruce Power has a high degree of comfort given its experience with the refurbishment of Units 1 and 2, and the organization has been able to share its experiences with OPG to assist with their refurbishment procurement process.

Steps taken so far to support procurement collaboration as it relates to refurbishment activities include implementing a non-disclosure agreement to allow the sharing of information between Bruce Power and OPG and drafting a three-way agreement to allow the sharing of information between the organizations when intellectual property is owned by suppliers.

Development of an agreement to facilitate the secondment of Bruce Power staff to OPG, and vice versa, is in progress. Both parties are also reviewing the existing processes and opportunities with regards to the use of job clocks, which record the arrival and departure time of contractors in order to capture the number of hours worked.

Vendor performance management is also a work in progress as Bruce Power and OPG continue to work together to develop a consistent approach in this area. This includes participating in their respective vendor summits to ensure message consistency as well as sharing information to establish/confirm adequate vendor capability and capacity.

The sharing of information is also important to the successful execution of procurement activities at both sites. Bruce Power and OPG are engaged in the sharing of templates for major contracts (e.g., tooling contracts), and collaborating on approaches to the Real Time Invoice Review Front (RTIRP) to facilitate effective contract oversight.
Tooling refers to the design and construction of unique machinery and tools. For refurbishment, specially designed tools are required for component removal and installations, as well as for inspections and repairs. Tooling is a major expense and an effective execution strategy is required.

High-quality training, with the right tools in the right environment, will help maximize efficiencies and minimize costs. By sharing lessons learned, OPEX on requirements for tool testing and tooling strategies, Bruce Power and OPG can ensure success in their respective tooling programs.

Bruce Power and OPG continue to hold monthly meetings to share technical information regarding tooling and processes. Topics include general tooling, training and mock-up requirements, the power distribution system, the generic tool control system, the vision alignment system, the tool simulator and cabling strategies. The organizations have also shared insight into some of the decisions that were made on the instrumentation and control, electrical and software aspects of the tools required for refurbishment.

More in-depth discussions were also held on the Single Fuel Channel Replacement (SFCR) process for refurbishment and the replacement of major components. This is particularly helpful to Bruce Power as it looks to decide where best to place the SFCR in its schedule.

Sharing tooling information is mutually beneficial to both parties as it helps to reduce risk and maximize efficiency.
Areas of Collaboration

Replacing Major Components

The replacement of major components has been carried out in a wide range of nuclear projects both domestically and internationally, allowing Bruce Power and OPG to adapt their programs according to lessons learned from across the industry.

De-tube and Re-tube

Most of the critical path activities are driven by the de-tube/re-tube program, and the successful interaction between these activities is essential to maintaining the refurbishment schedule.
In October 2015, Bruce Power and OPG began discussions around the most effective way to share knowledge regarding the critical de-tube and re-tube work at both the Bruce and Darlington sites. The sharing of design decisions, component procurement and vendor OPEX were covered.

A dialogue around bellows qualification testing was also initiated in October 2015 and included discussions on the scope of the qualification programs, a ‘leak before break’ strategy and the sharing of materials for qualification testing.

Discussions on qualification testing of components other than the bellows are also ongoing. Bruce Power and OPG continue to share information on their qualification programs, with Bruce Power potentially making use of qualification tests already completed by Darlington. Sharing materials for spacer qualification testing also continues to be a topic for discussion.

In March 2016, Bruce Power and OPG began talks on regulatory issues and strategies. OPG shared its OPEX, which Bruce Power will take into consideration as it develops its own regulatory strategy. At this time, the two organizations also discussed Canadian Nuclear Safety Commission (CNSC) correspondence and engagement, registration packages, and repair and replace strategies, as well as their list of variances (concessions).
Areas of Collaboration
Feeder Replacement

Replacing feeder pipes inside each reactor is a critical part of the refurbishment process. To accomplish this work properly and effectively, highly trained workers use uniquely designed and carefully calibrated tools. Much of this work is performed in tight spaces and under challenging conditions. Using remote-controlled and precise tools ensures the safety of the workers and the accuracy of the work.

OPG has developed a unique approach to testing tools and training staff ahead of the actual work in the reactor vault, and has constructed a world-class training facility that includes a full-scale reactor mock-up, warehouse space for equipment and training classrooms inside its new Darlington Energy Complex (DEC).

With regards to feeder replacement, the majority of collaboration to date has been related to the work being done at the DEC, with OPG sharing insight, OPEX and access to the facility.

To date, Bruce Power has performed two walkdowns at the DEC involving OPG and joint venture personnel to better understand the functional requirements OPG considered in the development of its mock-ups.

During these walkdowns, Bruce Power focused on the following areas:

• Lower horizontal feeder mock-up, to train on grayloc shear/install and feeder-to-feeder fit and welding
• Lower vertical feeder mock-up, to train on grayloc shear/install and feeder-to-feeder fit up and welding
• Upper feeder mock-up, to train on feeder-to-feeder fit up and welding, and full reactor face and partial upper feeder/Primary Heat Transport (PHT) header mock-up
• Welding cells to support the development of feeder-to-feeder and feeder-to-PHT header welding processes and procedures, as well as validating welding processes and procedures in-situ on the mock-ups referenced above

Bruce Power was also provided with the opportunity to view the DEC storage facility, adjacent to the mock-up facility, to better understand space usage, square footage and lessons learned. This assisted with the development and validation of its own facility and infrastructure requirements. Observation at the DEC has proven very helpful to Bruce Power as it works to progress its own mock-up planning.

OPG has also shared OPEX on how the feeder mock-up arrays initially supported the development of their processes, procedures and comprehensive work packages.

Recently, Bruce Power and OPG met to collaborate on project oversight and audit approaches, focusing on oversight and audit from a quality assurance (QA) and quality control (QC) perspective; documentation/records processes and management; QA/QC personnel and training, including options to jointly develop and share resources; and the component procurement approach, including lessons learned from the QA/QC perspective.

Bruce Power and OPG continue to share information regarding platform and scaffold strategies for feeder removals and installation. OPG is sharing information based on its advanced program development, and Bruce Power is contributing OPEX on scaffold implementation and management from its Restart feeder program.
Bruce Power and OPG have each developed a range of lessons learned through their respective operation of CANDU reactors and are committed to sharing their experiences with one another on a regular basis.

The Refurbishment Peer Group, in which Bruce Power and OPG are both participants, provides a forum to bring together, on a regular and timely basis, past experience, lessons learned and best practices to allow current and future refurbishment projects to benefit.

A comprehensive lessons learned exercise was completed after Bruce Power’s refurbishment of Units 1 and 2. The task was divided into six work streams: technical, commercial, financial, human resources, operations, and program and project management. Each work stream structured its approach on relevant industry standards and criteria, and was informed by other relevant lessons learned exercises. Key findings have been shared with OPG.
## Summary of Key Lessons Learned

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<tr>
<th>THEME</th>
<th>KEY LESSONS</th>
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| Governance           | • Ensure that the independent governance team has the requisite representation.  
                        | • Document clear accountabilities.                                                                                                             |
|                      | • Monitor the governance structure.                                                                                                          |
|                      | • Ensure there is knowledgeable representation from each functional area that represents a strategy of the project.                         |
| Strategies           | • Conduct a detailed current state evaluation of the plant.                                                                                   |
|                      | • Develop a suite of integrated strategies for project execution.                                                                              |
|                      | • Ensure all station direct programs are consulted/represented during the planning phase of the project.                                       |
|                      | • Formalize a commercial menu of, and process for, use of various commercial price models.                                                    |
| Planning & Setup     | • Involve commercial at the start of the planning and set up of the project.                                                                     |
|                      | • Develop the schedule, resource estimates and cost estimates based on the scope.                                                               |
|                      | • Allow suitable lead time and provide an appropriate level of budget commensurate with project size for planned activities.                 |
|                      | • Ensure all aspects of scope are clearly defined and included in all statements of work and technical specifications.                      |
|                      | • Generate a clear, consistent work breakdown structure for the project life.                                                                   |
| Oversight &          | • Ensure that appropriate class estimates are produced by qualified estimators.                                                                |
| Management           | • Develop scoping procedures for the entire project life cycle.                                                                               |
|                      | • Rigorously pursue the implementation of applicable lessons learned.                                                                          |
|                      | • Ensure that there are clear roles and responsibilities for those who are in key positions as well as an adequate number of resources to manage the work. |
|                      | • Implement a QC/QA program that emphasizes field oversight.                                                                                   |
|                      | • Develop a definitions and acronyms document.                                                                                                 |
| Skills & Resources   | • Ensure an estimating organization is in place at the start of the project.                                                                     |
|                      | • Develop a skills and resource strategy, which includes proactive skills needs identification, alignment of resource capacity to the volume of work, training and qualification needs. |
|                      | • Invest in commercial and financial awareness training and education for key positions upfront.                                               |
|                      | • Formalize a structured and objective contractor pre-qualification process.                                                                     |
|                      | • Develop a workforce database to track requirements, qualifications and security documents for contract staff.                                 |
| Infrastructure       | • Assess the adequacy of the Bruce Power systems at project initiation.                                                                          |
|                      | • Set up one suite of folders for reporting.                                                                                                   |
|                      | • Develop a comprehensive facilities plan at project initiation.                                                                                |
| Integration          | • Develop a fully integrated control schedule at the start of a project and at a level appropriate to the complexity of the project.          |
|                      | • Ensure all project members have well understood, common goals and a sound working relationship.                                               |
|                      | • Ensure contract managers understand the full scope of their contract(s).                                                                        |
Effective waste management, with a focus on reduction, is another important area of collaboration for both operators. Given Bruce Power’s unique lease agreement, which sees it lease its two stations from OPG, the two organizations work very closely on their waste management strategies, striving to remain on the cutting edge of developments in the industry.

Bruce Power and OPG continue to work together to identify opportunities to become more efficient in the reduction of waste generated from their nuclear facilities and refurbishment activities by implementing best practices and new technologies. All precautions and diligence are being considered to ensure the safe handling and packaging of waste, and this prudent approach will protect workers and the environment at both sites.

Bruce Power’s Major Component Replacement (MCR) Waste Working Team is currently exploring options to minimize the storage footprint of refurbishment waste in current OPG buildings on site. The team is also evaluating opportunities to efficiently stage and store existing Unit 1 and Unit 2 waste to increase available storage space, and is looking for ways to minimize the metal content of waste sent to OPG and ultimately the Deep Geologic Repository (DGR).

Bruce Power and OPG have also created a Refurbishment Collaboration Team to identify general lessons learned from previous refurbishments. Specific lessons learned in regards to waste are shared so that both organizations can benefit from their collective expertise. In addition, the team also discusses container design and is collaborating on an effective approach to loading/handling waste.

In 2015, Bruce Power and OPG also teamed up with COG to organize the COG workshop for radioactive waste. Chaired by Doug Metcalf of OPG, the workshop included discussion of common challenges to refurbishment waste management and allowed both organizations to learn from each other and from the other utilities and vendors who were present.
Labour Arrangements

Bruce Power and OPG share a similar labour relations environment, with their two primary unions being the Power Workers’ Union (PWU) and The Society of Energy Professionals. Both operators also have bargaining arrangements with the Building Trades Union (BTU) through the Electrical Power Systems Construction Association (EPSCA) for construction labour.

In the most recent MOU, the organizations outlined their commitment to pursuing a collaborative approach to their labour relations strategies to ensure appropriate resourcing while best leveraging economies of scale.

Recently both OPG and Bruce Power successfully completed bargaining with the Canadian Union of Skilled Workers (CUSW). Through open communication, Bruce Power and OPG were able to share proposed language and collective agreement improvements that both companies were able to realize through the negotiation process.

Similarly, Bruce Power and OPG regularly discuss work assignment and trade jurisdiction issues related to the distribution of skilled trades work between the various unions to gain improvements and efficiencies in the execution of skilled trades work on the generating sites.

As preparations continue for the Darlington refurbishment, OPG has recently implemented a Project Committee, which is a forum to communicate project status updates and other important communications to all BTU leaders. OPG has shared lessons learned and has extended an invitation to Bruce Power to participate in upcoming sessions as Bruce Power works towards developing and implementing its own Project Committee in 2017.

In addition, the two companies are also working together in partnership with EPSCA to oversee and evaluate the implementation of a Nuclear Qualified Worker (NQW) program, in which the unions will provide trained and pre-qualified workers to the job site, reducing training costs and improving productivity.

The effective management of the skilled trades and project management personnel that will be executing the work at both sites is critical to the success of the refurbishment programs. By working together on project labour arrangements, Bruce Power and OPG can ensure both sites are set up for success.
Lead-in and lead-out work is critical to the success of any refurbishment program. During the lead-in process, the unit being refurbished will be fully de-fuelled, protective bulkheads will be installed, heavy water will be removed from key systems, and activities will be carried out to prepare the vault for the critical de-tube/re-tube activities.

Commissioning immediately follows the construction program and involves a number of activities necessary to bring the units into service. Electricity, water and steam are re-introduced to components and systems which must be tested to verify performance to demonstrate correct operation under normal and specific abnormal operating conditions.

Successfully commissioning each system for return to service is a vital stage of the project.

Given the weight of the lead-in and lead-out work, it is important that Bruce Power and OPG continue to work together to share knowledge, whether that be through OPEX or lessons learned.

In February 2015, the two organizations met in Darlington for a general overview of the status of projects. During discussions, they identified a gap between Bruce Power’s de-fuel window and Darlington’s de-fuel window; Darlington’s window was 50 per cent longer than Bruce Power’s and Bruce Power believed its de-fuel window could be shortened further.
The teams regrouped in September 2015, when Bruce Power hosted a delegation from Darlington to compare data on the projected de-fuel window logic. This meeting identified several reasons why the Darlington duration was as long as it was, and Bruce Power provided OPEX on how it had shortened its window and discussed initiatives it was taking to shorten it even further. While some of the differences were system-driven and justified, together the organizations identified areas where early engagement with Fuel Handling Operations, supported by strong refurbishment oversight, could provide quick improvements.

Over the winter of 2015-16, Bruce Power and OPG continued collaboration in this area over email before regrouping for a second OPEX meeting at Darlington in February 2016. Here, Bruce Power’s MCR team met with engineers from OPG’s Refurbishment group as well as Operations staff to offer OPEX on lead-in/lead-out planning assumptions, highlighting areas where an increased operations focus could drive improvements.

As part of the Darlington refurbishment project, OPG repaired its service area rehearsal facility system. Bruce Power is currently reviewing this OPEX for its needs. In addition to sharing OPEX, benchmarking trips have also taken place. For instance, members of the Darlington Chemistry team recently visited Bruce B to examine Bruce Power’s Chemistry lab capabilities and staffing plans to determine if the opportunity existed at OPG to streamline lab efforts and adjust resourcing accordingly.

Leveraging work done at both sites is also an important part of the collaboration process. Darlington has executed some redesign work on the flow restricting outlet bundle, which Bruce Power is able to draw from for its own needs with the possibility of also avoiding the associated design costs.

In addition, Bruce Power is also able to leverage the redesign work Darlington had done to enhance its abilities regarding fuel push and fuel grapple techniques needed for a core de-fuel. In this instance, Bruce Power is able to utilize this work for migration needs in some of its accident recovery scenarios.

Collaboration on the moderator and PHT drain and dry projects has also occurred, with discussions centred on effective moderator drain and dry logic.
The LTEP encourages Bruce Power and OPG to work together to share knowledge and leverage economies of scale. The value generated through this ongoing collaboration includes potential cost savings, schedule improvements, risk reduction, dose reduction and more.

It is not just Bruce Power and OPG that gain from these collaborative efforts – Ontarians benefit, too. By working together, the two operators can provide the province with a reliable and clean source of electricity while delivering the best value to Ontario consumers, now and for decades to come.

Benefits of Collaboration

By working together, we can deliver the best value to Ontario consumers.