

UPGRADING & UPRATING |



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Building a CANDU future

In Ontario, Canada, more than 60% of the electricity used in 2017 was produced with nuclear power. With successful completion of two huge refurbishment projects, the province can expect four more decades of power from nuclear, **Jacquie Hoornweg** reports



A recent workshop enabled CANDU operators to share lessons from past refurbishment projects

TOPPING THE LIST ON CANADA'S Top 100 infrastructure projects for 2017 are two energy projects. This is not surprising in a country known for its oil and gas resources and its large hydro infrastructure. But the projects are neither fossil nor water. They are nuclear refurbishments by Canada's largest province, Ontario, home to 13.6 million people. The projects are part of the provincial government's commitment to eliminate coal use (the province achieved its coal-free goal in 2014) and move to a long-term clean energy mix. In Ontario's most recent long-term energy plan, the province's clean energy future is built on a baseload

supply of nuclear at least into the early-2060s, just as it has been for the past four decades.

The projects

The first refurbishment project is at Ontario Power Generation's Darlington plant, a four-unit 3500MW station, which is now in execution on its first unit. It is followed closely, with some overlap of execution in the early and mid-2020s, by a life extension project starting in 2020 for six of the eight Bruce Power units at the company's 6300MW station, which includes major component replacement.



Far left: **The Darlington turbine hall. For the first time all turbine blades and rotors were removed and reinstalled to ensure continued operation for another 30 years**

Left: **Turbine casings from Darlington 2 waiting for reinstallation**

Bruce Power returned the first two units to service from refurbishment projects in 2012 and 2013.

Between them, the Darlington refurbishment and Bruce Power life extension account for almost \$26 billion of investment until the final unit returns to service at the Bruce site in the early 2030s and then through continued life extension activities at Bruce. The economic impact of that investment is exponential, multiplied through the supply chain, employment and spin-off spending and development that is rippling through the entire economy.

Already, the effects of the combined projects are being felt in communities that house Canada's nuclear supply chain of more than 200 largely Ontario-based companies. Along with the operators, the supply chain from the largest contractors to the smallest sub-contractors and suppliers are continuously hiring workers and procuring materials and services. In addition to supplying manpower on the project site, they are filling orders for tooling, plant equipment and components. The project has been an opportunity to enter into new advanced-technology manufacturing to meet the need for artificial intelligence and virtual reality (VR) to assist with equipment and software, for applications ranging from supplementary VR training to prepare new workers for a nuclear environment, to robotics that will execute the most invasive work in high radiation areas. For example, laser-scanning technology digitally captures exact shapes and sizes of objects and spaces allowing for replication for tool testing and training. The images are then displayed in a 3D format workers and designers can access through virtual reality holographic headsets that immerse users into the plant environment allowing scenarios and task sequences to be played and replayed without the cost and safety constraints of real-reactor time. Artificial intelligence is also providing interactive and responsive supplemental training for the large number of new workers being on-boarded into a nuclear environment for the first time (see also *NEI December 2017, p27-29*).

Ontario's refurbishment challenge

It is estimated the projects will create about 60,000 jobs throughout the Canadian nuclear industry. This is a significant economic impact. It is also a logistical challenge. The industry needs to on-board and train numbers of workers and impart safety culture amongst people who come from a construction, project management or administrative background and, in many cases, are entering the nuclear arena for the first time.

Building on lessons from their other mega projects, the companies are taking several steps to smooth the transition from an operations mindset to a project focus including:

- Adjusting to new demands in human performance and development and refinement of high-function project management skills; 📌

Darlington nuclear's refurbishment

OPG moved into project execution at Darlington unit 2, the first of its units to enter refurbishment, in October 2016. The unit is now at the halfway mark. Already some areas of Darlington 2 have returned to service and the project is tracking ahead of the promised schedule. The company has received government approval to start preparing to refurbish the next unit, Darlington 3 from 2020.

Work at Darlington was announced in 2010 and started even before that. The plant's operator OPG undertook eight years of planning and preparation while the station continued to operate.

Nevertheless, the announcement was accompanied by a chorus of naysayers who had seen big infrastructure projects go far over budget and past their schedule for reasons that ranged from mid-project government policy changes to a failure of sufficient planning for long-lead and obsolete parts. OPG knew that if the first unit did not go well, there would be no chance for a second unit, says Dietmar Reiner, senior vice president of nuclear projects who emphasises the need to "get it right."

Preparing for the refurbishment included technical assessments of all major components, condition assessments of balance of plant components, initiation of regulatory processes and an integrated safety review and environmental assessment. Planning was followed by several years of preparation for long-lead procurement, engineering, tool testing and worker training.

The project came with an exit clause in the event things did not go as planned. Contractors and suppliers, like the company itself, had to take a leap of faith as they invested to supply that first unit, says Reiner.

The preparation for the Darlington 2 refurbishment included a full-scale

mock reactor. This mockup included not only the reactor face, but also considered the other issues workers would encounter in the plant right down to the overhead clearance on doors where equipment would be brought in – things that had caused delays on past projects.

Execution phase and lessons learned

As Darlington progressed through planning and preparation, OPG relied on lessons learned from its own nuclear and hydro projects as well as the CANDU refurbishments that came previously.

There were benchmarking trips and staff were embedded at other stations during projects. In one, new technology calandria tools were loaned to Nucleoeléctrica in Argentina, for Embalse, a one-unit CANDU station refurbishing just ahead of Darlington 2. Embalse got the benefit of using the new tool being developed by OPG, which benefitted from metrics on how the tool performed.

Today, with the Darlington 2 project now through the initial planning and preparation phases and more than 500 days into execution, OPG has lessons for the next unit. These are being documented and analysed for integration into plans, and they are being shared with Bruce Power and with other international CANDU operators starting to think about future mid-life refurbishments.

With each unit it refurbishes, OPG expects to tighten cost and schedule, says Reiner. As Bruce Power does its own analysis of the Darlington work, it passes knowledge back to OPG for use on the later Darlington units.

With the corner turned toward return to service on the first unit at Darlington, Reiner is quick to volunteer his optimism that this refurbishment will be on time and on budget. ■

Right: **Mike Rencheck, Bruce Power's President and CEO announces \$914 million in advanced manufacturing contracts for its major component replacement project in April 2018**



Bruce Power and the supplier connection

On 23 April, Mike Rencheck, Bruce Power's president and CEO was standing on a stage in the middle of a manufacturing facility in Cambridge, Ontario. It was one of its largest, and oldest, suppliers, the Canadian arm of BWXT Technologies, whose predecessor first served the station when it went online with its first unit in 1977. BWXT Canada had recently opened an additional office near the plant. Rencheck has been clear that project success does not start and end with the operator. Suppliers are expected to be physically present on the project and actively engaged in Bruce Power's life extension success.

BWXT supplies Bruce Power with field services to inspect, repair and maintain the plant's critical nuclear components. Many of those components, such as steam generators, are also manufactured by BWXT.

On this day, Rencheck was at BWXT to announce the supplier had been awarded a \$642 million contract. It was the biggest of several, cumulatively worth just under \$1 billion, being announced simultaneously across Ontario at various suppliers. BWXT will

supply 32 new steam generators when Bruce Power begins execution in 2020.

Rencheck told the assembled workers that signing the contracts would extend operation to 2064. "We look forward to growing our already excellent relationships with these supplier partners and unions as we work toward our common goal of continuing to keep Canada's largest infrastructure project on time and on budget," he said.

In December 2015, the company had entered a long-term agreement for the multi-year life-extension programme to continue through 2053, allowing Bruce Power's units to operate to 2064. The company has been doing hundreds of millions of dollars a year in preparation work since 2016, which will continue until the major component replacement gets under way.

The Canadian nuclear industry hopes these projects will be a beginning, not an end, to the Canadian nuclear story. It hopes the rest of Canada will see Ontario's success and move beyond the current programmes that exist in Ontario and New Brunswick to new builds, possibly SMRs. ■

- Familiarising and providing exacting standards of oversight on documentation from all project workers to ensure restart approvals go smoothly on tens of thousands of tasks, even when approvals come months after some of the tasks have been completed;
- Training vendors throughout the supply chain on large-scale nuclear parts procurement to avoid fraudulent and counterfeit parts, which could fail or introduce cyber security risks into the plant;
- Ensuring strong quality control for parts manufacturing and task completions. In projects the wrong work, or poor-quality parts, can have an impact far down the road and mean millions of dollars of rework; and
- Developing a common understanding of the reactor work space, including the variables that will be encountered when taking apart a nuclear reactor that has been operating for decades and putting it back together again.

Once the utilities have done this, they must take the mega-project and complete it in an operating station where several other units continue to produce electricity alongside it. The added challenge for Bruce Power and OPG is to choreograph the human, equipment and parts resources required to complete synchronised and overlapping work across the two stations.

These challenges call for the strongest collaboration and engagement the industry has undertaken to date. Government and regulators will be watching closely each step of the way. With years of preparation already in the rearview, the operators are confident they will succeed.

An industry collaboration model

In a memorandum of understanding, Ontario Power Generation (OPG) and Bruce Power confirmed their commitment to improve their refurbishment programmes through collaboration. This included sharing lessons learned and best practices in refurbishment and operations, and coordinating efforts to reduce costs and limit execution risk. Specific initiatives include asset management and inspection programmes, procurement, tooling and replacement of major components (including de-tube, re-tube and feeder replacement work). They have collaborated on labour arrangements and logistics.

Through organisations like the CANDU Owners Group (COG), the entire CANDU industry, including other operators worldwide and the supply chain, is working to ensure success of the two projects and innovate to manage human and technical performance. Activities undertaken through COG include:

- **A refurbishment forum:** allowing operators to share information, identify needs for the refurbishment projects and develop new initiatives to solve challenges.
- **Supply chain knowledge and training:** COG's supplier participant programme brings together utility and supply chain leaders to discuss challenges, expectations and potential initiatives to develop knowledge. They are building knowledge in nuclear safety, safety culture, leadership and training.
- **Return to service workshop:** A recent COG three-day workshop provided an opportunity for CANDU utilities to talk about lessons learned from past projects. COG is developing an inventory of best practices and operating experience to be applied as future units come back online at Embalse, Darlington, Bruce Power and others. ■

Right: **BWXT Canada Inc. is manufacturing 32 steam generators at its Cambridge facility for Bruce Power's major component replacement**

