Ontario Power Generation

Darlington Nuclear Generating Station Refurbishment Project

1. 0 Summary

Ontario Power Generation (OPG) is a corporation wholly owned by the Province. OPG generates more than half of the province's electricity primarily through more than 60 hydroelectric stations and two nuclear generating stations: Darlington Nuclear Generating Station (Darlington Station) located in the Durham region, and Pickering Nuclear Generating Station, located in Pickering.

Darlington Station began operating in 1990 and has four nuclear reactor units. It has generally produced over 15% of the electricity used in Ontario.

In 2006, at the direction of the Ontario government, OPG began assessing the feasibility of refurbishing Darlington Station's four nuclear reactor units, as these units' useful life was expected to end in the early 2020s.

In January 2016, about five months after appointing a new President and CEO, OPG publicly announced that it was ready to execute the Darlington Nuclear Generating Station Refurbishment Project (Project), which it estimated would:

- cost $12.8 billion ($10.8 billion of estimated Project costs and $2 billion in contingency to cover the cost of potential additional risks that might occur during the Project);
- take 10 years (from October 2016 to February 2026) to complete the main refurbishment work; and
- extend the useful life of Darlington Station's four nuclear reactor units to around 2055.

OPG has contracted the majority of Project work to external contractors, including a joint venture between SNC-Lavalin Nuclear Inc. and AECON Construction Group Inc. to complete the main nuclear reactor refurbishment work. As of June 30, 2018, OPG had about 980 of its own full-time-equivalent staff and about 1,500 contractor staff working on the Project.

Our audit focused on OPG's planning and execution of the Project and was conducted while OPG was executing the refurbishment work on the first of the four nuclear reactor units at Darlington Station. As of June 30, 2018, OPG had spent about $5 billion on the Project. About half of this amount relates to planning the Project and performing work that needed to be completed prior to actually refurbishing the nuclear reactors (such as building an additional emergency backup generator). The remaining half primarily relates to actual refurbishment work done on the first of the four nuclear reactor units. OPG plans to spend almost $8 billion more on the Project, mostly on the actual refurbishment work of its three other nuclear reactor units.

Overall, OPG forecasts the Project will meet the cost and time estimates it publicly announced in January 2016. These estimates factored in improvements OPG made to its processes based on lessons learned from its early Project work (such as on 18 prerequisite projects that OPG planned to start

before the actual refurbishment of Darlington Station's nuclear reactors) and from refurbishments of other nuclear generating stations. While OPG has applied lessons learned to the remaining Project work, several significant risks remain that could result in the Project going over its cost and time estimates, because the complexity of the Project will increase. For instance, OPG has only performed refurbishment work on one nuclear reactor unit to-date. It may face more challenges than it currently expects when, in 2021, it starts working on the refurbishment of more than one nuclear reactor unit at the same time. Therefore, it is incumbent on OPG to continue to remain vigilant in order to avoid or mitigate risks.

The following are some of our additional significant observations.

- **The pending shortage of skilled trades and the potential retirement of experienced executive and management staff put the Project at risk of not finishing on time and on budget.** OPG will be in competition for skilled trades (hired by contractors) during several years when the Project will overlap with another refurbishment project at the Bruce Nuclear Generating Station. OPG identified the potential shortage of boilermakers (who remove and install nuclear reactor unit components) as posing the biggest risk. OPG is still in the process of determining if the potential future supply of boilermakers will meet its demand. At the same time, OPG estimates that over 30% of its management staff and nearly all of its executives from its Darlington Refurbishment group working on the Project are eligible to retire by 2025 (before the Project's expected completion). While OPG has identified internal candidates who can take over most of these positions, it has not yet done this for 13 positions, including six management staff eligible to retire by the end of 2018.
- **OPG's costs have increased as a result of providing more assistance than expected to contractors not performing up to its expectations, but it is not considering the increased costs when paying profit to these contractors.** OPG estimated that it will pay contractors about $6.1 billion to complete Project work. This currently includes over $800 million related to contractors' overhead costs (to cover costs related to their senior management and support staff who do not directly perform Project work) and profit (which is generally tied to the contractors' performance compared to cost and time targets agreed upon with OPG). OPG has had to provide more assistance (mainly supervisory or management assistance) to contractors than it initially estimated to keep the Project on time and on budget. While OPG estimated that it will spend overall almost $50 million more on Project oversight and support than it initially estimated (including costs associated with providing additional support to contractors), it has not considered these additional incurred costs when determining the amount of profit to pay the contractors.
- **There have been no serious injuries to Project staff. However, OPG has not met its safety targets and could be more proactive to try to reduce recurring preventable safety incidents.** While the severity of safety incidents on the Project has been low (meaning that there have been no staff injured on the Project who had to miss work for more than one day), the frequency of safety incidents has remained mostly unchanged. Project staff's rate of safety incidents has remained about the same since 2016 (when actual refurbishment work started) at about 0.5 safety incidents for every 200,000 hours worked between 2016 and the first half of 2018. This is higher than OPG's targets of 0.24 in 2016 and 0.37 in 2017 and 2018. OPG investigated individual incidents but could do more to prevent recurring incidents (such as staff dropping tools from above ground that

nearly hit others). At one point, an incident occurred when a worker dropped a bag containing pieces of metal from over 35 feet above ground, almost hitting a worker. As there had already been eight incidents that year with a common cause (where workers had dropped tools and parts when working at heights above ground) and this incident could have resulted in a serious injury or the death of a worker, the contractor stopped its 800 staff from working on the Project for two days to develop improved safety procedures, costing OPG over $700,000 as it still had to pay the contractor's staff.

- **Prerequisite Project work is expected to cost over $725 million more than initially estimated and be completed later than planned.** Prior to starting the main refurbishment work on its four nuclear reactor units, OPG had to perform work on 18 prerequisite projects. The total cost of these 18 projects is expected to be over $725 million (or over 75%) more than OPG initially estimated. About $345 million of this significant cost overrun was already included as estimated spending in the Project's total cost estimate of $12.8 billion, which OPG publicly released in January 2016 (with the majority of the remaining cost overrun covered by the Project's contingency). The main causes for the cost overrun were:
  - OPG relied on initial prerequisite Project work cost and time estimates that were not based on a detailed understanding of the Project's complexity and technical requirements;
  - OPG did not accurately consider known risks when developing contingency amounts for prerequisite Project work;
  - some contractors were selected to perform prerequisite Project work largely based on their low bid prices even though competing contractors scored higher on technical criteria;
  - prerequisite Project work was assigned to OPG staff with limited relevant experience; and
  - project management and oversight of contractors performing prerequisite Project work were inadequate.

  Also, 14 of the 18 prerequisite projects were completed later than OPG initially estimated. In some cases, OPG required staff to work overtime in order to prevent delays in prerequisite work from disrupting other Project work. As a result, OPG spent almost $32 million to get project work completed faster, which could have been avoided or reduced if OPG had better planned its prerequisite work.

Overall Conclusion

While OPG faced significant challenges and experienced cost overruns and delays in Project work that was started prior to January 2016, it has applied lessons learned from that work to the remaining Project work and in the development of its cost and time estimates. OPG subsequently established time and cost estimates for the Project based on reliable information and reasonable assumptions. A fair and transparent procurement process was followed in the selection of the majority of contractors for the Project. A clear accountability structure is in place to ensure that staff and contractors working on the Project deliver services in adherence to contract terms and legislated safety and environmental standards and that their performance is monitored and appropriately addressed in a timely manner. Project timelines and costs are being managed, monitored and publicly reported on a regular basis and corrective actions are being taken when issues arise.

However, given the complexity of the Project and risks associated with work not yet done, uncertainty still remains as to whether the Project will be completed on time and on budget. Therefore, OPG must remain diligent until the completion of the Project to properly avoid or mitigate risks.

This report contains seven recommendations, consisting of 18 actions, to address our audit findings.

OVERALL RESPONSE FROM ONTARIO POWER GENERATION

Two years ago, Ontario Power Generation (OPG) began one of the largest and most complex infrastructure projects in Canada. The Darlington Refurbishment Project, Canada's largest clean energy project, will generate 30 more years of low-cost, emission-free and reliable energy for Ontario. With just over one year to go on the refurbishment of the first unit, this $12.8 billion project remains on time and on budget.

Safety remains the overriding priority for OPG. The safety incident rate for the Project itself is about 10 times better than the construction industry average overall. The Project has executed more than 9 million hours of work and it has not had any lost-time injuries (an injury leading to staff missing work for more than one day).

OPG's planning, preparation and oversight for the Project have been subject to much public and independent expert scrutiny. In December 2017, after a rigorous review of the Project costs, the Ontario Energy Board (OEB) stated that "experts agreed that the planning for the [Project] had been conducted according to industry standards." The OEB concluded that "OPG [had] developed reasonable project control systems to manage the cost and schedule of the [Project]. OPG also performed adequate risk assessment for the [Project] and put in place processes to address risks as they arise."

Since the beginning of the Project, OPG has:

- incorporated lessons learned from early challenges and established cost and schedule estimates based on reliable information and reasonable assumptions;
- used a fair and transparent procurement process in selecting contractors;
- implemented a clear accountability structure to ensure staff and contractors deliver services safely and with quality; and
- effectively monitored and managed the Project's cost and schedule, and transparently reported to the public on a quarterly basis.

OPG values the efforts and feedback of the Auditor General. With a large portion of the work on the first unit already completed, OPG remains committed to continuous improvement and will continue to pursue all opportunities, including those recommended by the Auditor General, to ensure that the Project is delivered on time, on budget, safely and with quality.

2.0 Background

2.1 Nuclear Energy

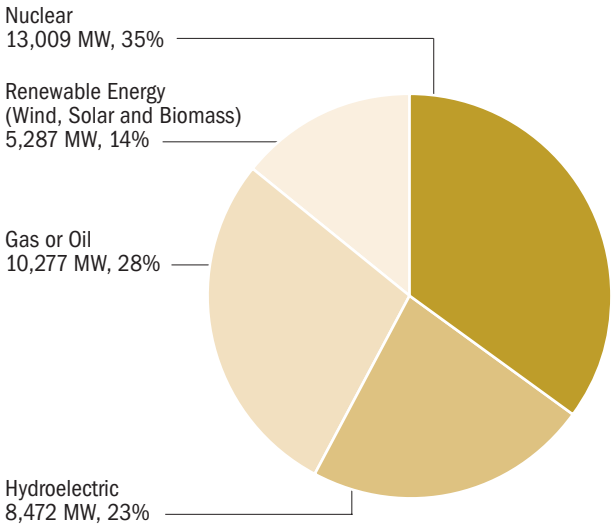
About 15% of Canada's electricity comes from nuclear energy, which is generated from four nuclear generating stations (containing 19 operating nuclear reactors). Three of these nuclear generating stations (containing 18 operating nuclear reactors) are located in Ontario: Bruce Nuclear Generating Station, Darlington Nuclear Generating Station and Pickering Nuclear Generating Station. Both the Darlington and Pickering Nuclear Generating Stations are operated by Ontario Power Generation (OPG), which is wholly owned by the Province. **Appendix 1** contains a glossary of terms used throughout the report. **Appendix 2** provides details on Ontario's three nuclear generating stations.

Currently, nuclear energy accounts for over one-third of the total maximum capacity of Ontario's energy supply. **Figure 1** shows Ontario's current maximum capacity by energy source.

Nuclear reactors generate electricity by using a fission process (whereby neutrons strike and split uranium atoms) to generate heat, which converts water into steam that rotates a turbine to generate electricity. **Figure 2** shows how a nuclear generating station works. (For ease of understanding, we have added a legend defining key terms to the illustration prepared by the Canadian Nuclear Association.)

Figure 1: Maximum Capacity of Electricity Supply in Ontario by Different Energy Sources, Megawatts (MW)

Source of data: Independent Electricity System Operator (IESO)



Note: Information as of June 2018.

2.2 Darlington Nuclear Generating Station

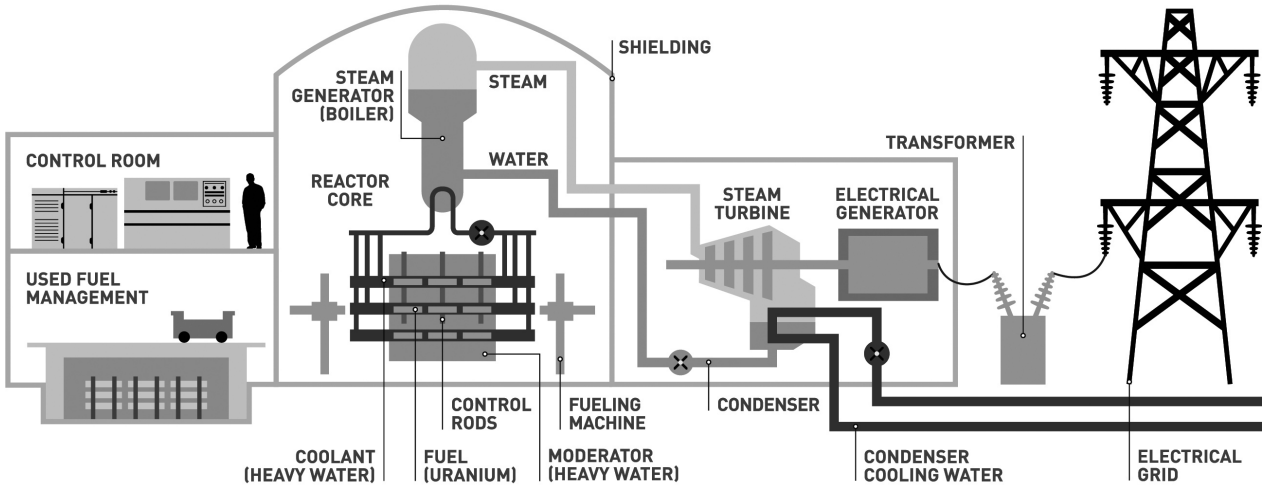
Darlington Nuclear Generating Station (Darlington Station) is located in the Municipality of Clarington, Ontario (in Durham Region). Each of Darlington Station's four nuclear reactor units was put into service to start generating electricity between 1990 and 1993. The nuclear reactor units collectively can generate about 3,500 megawatts of electricity, generally representing over 15% of Ontario's electricity demand over the past 10 years. Darlington Station is the second largest nuclear generating station in Canada (second to Bruce Nuclear Generating Station in Kincardine, Ontario).

Darlington Station uses Canada Deuterium Uranium (CANDU) nuclear reactor units. CANDU nuclear reactors utilize heavy water (or, more specifically, deuterium oxide or D_2O) instead of normal water (H_2O) as a moderator. This allows CANDU

Figure 2: How a Nuclear Generating Station Works

Source: Canadian Nuclear Association

CANDU REACTOR SCHEMATIC



- **Reactor Core**: Contains uranium, which is a chemical element to generate heat in a nuclear reactor.
- **Moderator**: A medium, such as water, that allows neutrons to slow down in order to cause further fission to occur.
- **Control Rods**: Components made of materials (such as stainless steel and cobalt) that absorb neutrons to stop the fission process, when required, and to control the level and distribution of power in the reactor.
- **Coolant**: A fluid circulating through the reactor core to absorb and transfer heat produced by the fission reaction, and maintain fuel temperature within acceptable limits.
- **Shielding**: Typically a meter-thick concrete and steel structure around the reactor and reactor components (like steam generators) to provide protection from intrusion, and to protect those outside from the effects of radiation in the event of any malfunction inside.

reactors to generate electricity using natural (unenriched) uranium. Other nuclear reactors that use normal water as a moderator need to modify (or enrich) the uranium before it can be used to generate electricity.

2.3 Darlington Station Refurbishment Project

2.3.1 Decision to Refurbish Darlington Station

On June 13, 2006, the Minister of Energy (Minister) directed the Ontario Power Authority (which merged with the Independent Electricity System Operator on January 1, 2015) to prepare an Integrated Power System Plan with various goals, which included planning for initiatives to reduce peak electricity demand, increasing cleaner energy sources to replace coal-fired generation, and maintaining nuclear capacity to meet electricity requirements. Three days later, the Minister issued a directive to OPG, requiring it to begin feasibility studies and environmental assessments on the refurbishment of its existing nuclear reactor units at Darlington Station and Pickering Station. At that time, the Minister identified a potential need for OPG's nuclear generating stations to operate beyond their expected end-of-life.

In November 2009, OPG completed a feasibility study that indicated that refurbishing Darlington Station was a more economical solution than other types of energy generation that OPG could have produced (such as natural gas). As a result of this study, OPG's Board of Directors approved about $240 million in spending to continue OPG's planning for the Darlington Station Refurbishment Project (Project), including the planning for a number of projects necessary for the Project to occur (such as a building to safely store components of the nuclear reactors that would be removed as part of their refurbishment). **Appendix 3** identifies key dates related to the Project.

In addition to the Project, the other two nuclear generating stations in Ontario are also having their useful life extended (see **Appendix 2**):

- OPG's Pickering Station has six nuclear reactor units that were initially expected to stop operating in 2020. In November 2015, OPG's Board of Directors approved extending the useful life of all six nuclear reactor units (two until 2022 and the remaining four until 2024), in part to ensure a reliable supply of electricity while the Project is under way. OPG expects this to cost about $310 million.
- Bruce Nuclear Generating Station, which is operated by a private-sector company, Bruce Power Limited Partnership (Bruce Power), has eight nuclear reactor units. Refurbishment was completed on two units in 2012. In January 2016, Bruce Power began a multi-year Life Extension Program (with work occurring until 2053) on the remaining six units, allowing them to operate through to 2064. Bruce Power estimates this will cost about $13 billion in total.

2.3.2 Regulatory Approval for the Project

In order to refurbish Darlington Station, OPG needed to obtain regulatory approval from the Canadian Nuclear Safety Commission (Commission), an independent federal agency that regulates the production and use of nuclear energy in Canada. OPG was required to identify any potential gaps between Darlington Station's operations at that time and the newest modern safety standards and practices and to develop a plan for addressing those gaps. For example, OPG was to build a third emergency power generator that could withstand a higher level seismic event (earthquake) than the two existing emergency power generators at Darlington Station were designed to withstand. In total, OPG planned to spend over $190 million to improve the safety of Darlington Station.

In December 2015, after obtaining regulatory approval from the Commission, OPG was granted

a 10-year operating licence, allowing it to operate Darlington Station from January 1, 2016, to November 30, 2025. OPG will need to apply again closer to the date its current licence is set to expire to obtain a licence to operate Darlington Station past the end of November 2025. With regulatory approval, OPG anticipates being able to continue operating Darlington Station until 2055.

2.3.3 Project Timeline

OPG is using a three-phase approach for the Project:

- **Initiation Phase:** OPG completed this phase in 2009. This involved performing the initial feasibility assessment and preliminary planning for the Project.
- **Definition Phase:** OPG began this phase in 2010 and completed it in 2015. This included performing detailed planning of refurbishment activities identified by OPG and completing prerequisite work that was necessary to allow refurbishment work on the actual nuclear reactors to occur, such as building facilities for processing and storing materials to be removed from the nuclear reactor units.
- **Execution Phase:** OPG started this phase in 2016 and currently expects to complete it in 2026. This involves performing refurbishment work on all four nuclear reactor units, such as shutting down the units before starting refurbishment work, and replacing or repairing most of the components in the units.

Figure 3 identifies the main activities and timing for each phase of the Project.

Even though each of the four nuclear reactor units needs to be refurbished, Darlington Station will remain operational during the entire Project. This is possible due to OPG's ability to isolate, shut down and refurbish each reactor unit without impacting the others from operating normally.

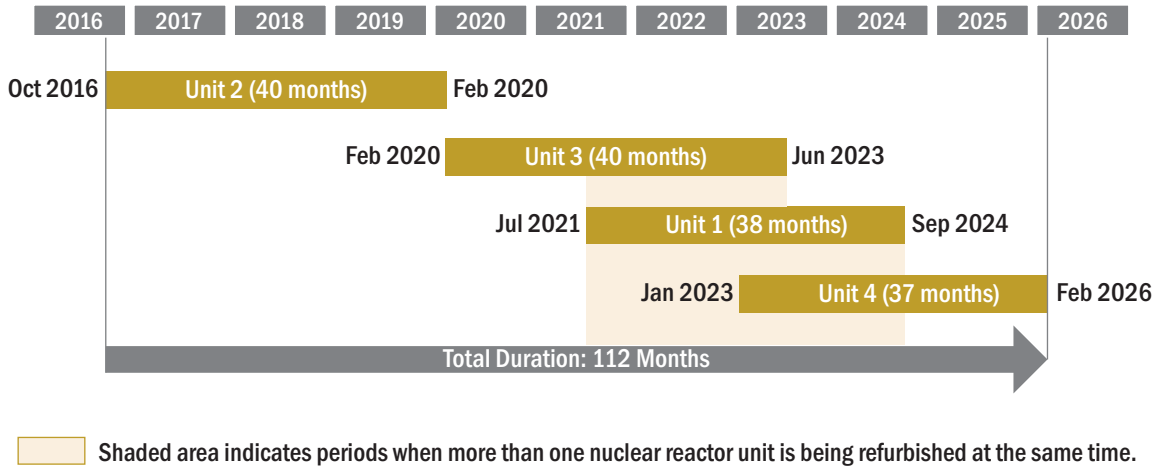
Figure 3: Three Phases of the Project

Source of data: Ontario Power Generation

	Phase 1 (2007–2009): Initiation Phase	Phase 2 (2010–2015): Definition Phase	Phase 3 (2016–2026): Execution Phase
	• Determine initial Project scope through technical assessments, condition assessments, and initiation of regulatory processes • Develop initial Project plans for initial cost and schedule estimates • Establish project management approach and governance • Establish overall contracting strategy	• Obtain regulatory approvals • Implement project management and oversight • Implement safety improvements • Award major contracts to external contractors to perform Project work • Finalize project scope and complete engineering work • Complete prerequisite work (projects necessary to allow refurbishment of actual nuclear reactors to occur) • Construct a nuclear reactor mock-up and test tooling to be used in the Execution Phase • Develop total Project cost and schedule estimate • Mobilize and train staff	• Shut down and remove fuel (uranium) from nuclear reactor units • Execute all refurbishment work • Meet all regulatory commitments • Execute plant maintenance and inspection activities • Load fuel into nuclear reactor units • Return nuclear reactor units to service
Total of Planned Spendng ($)	**2.4 billion***		**10.4 billion***

* See **Figure 5** for detailed breakdown of the total budget of $12.8 billion for the Project.

Figure 4: Timeline for the Execution Phase of the Project
Source of data: Ontario Power Generation



At the time of our audit, OPG was only refurbishing one nuclear reactor unit (Unit 2). As **Figure 4** shows, starting in 2021, OPG plans to perform work on two nuclear reactor units at the same time.

2.3.4 Project Cost

OPG started estimating the Project's cost in 2009 during the Initiation Phase and updated the cost estimate based on new information since then. Specifically:

- In November 2009, when OPG completed a feasibility study as mentioned in **Section 2.3.1**, it estimated that the Project would cost about $10.3 billion (in 2009 dollars).
- In OPG's 2013 annual report, it identified that the "[r]efurbishment of the four Darlington [Station nuclear reactor] units is currently estimated to cost less than $10 billion in 2013 dollars" excluding interest and inflation (which totalled $3 billion in OPG's 2009 internal Project cost estimate). OPG later identified that this cost estimate would be $14 billion if converted into 2015 dollars and if based on a better understanding of expected interest and cost increases to staff and material costs over the duration of the Project.
- In November 2015, OPG's Board of Directors approved the plan for the Project at a total estimated cost of $12.8 billion. This cost estimate was based on a better understanding of the Project's scope and actual costs than OPG's prior estimates.
- In January 2016, OPG publicly announced that the Project will cost about $12.8 billion to complete.

Figure 5 provides the breakdown of the total estimated Project cost by the three phases of the Project. The majority of the Project's estimated cost relates to the repair or replacement of components to allow the nuclear reactor units to operate for an additional 30 years. While there are differences in the exact work that needs to be performed on each nuclear reactor unit, generally, OPG estimates that work will be completed faster on subsequent units based on experience gained from doing the same work on the earlier units. For example, OPG estimated that it will complete some of the main refurbishment work on the nuclear reactor units over 7% faster on the final nuclear reactor unit compared to the first nuclear reactor. OPG's estimate incorporated its research of other nuclear generating station refurbishment projects in Canada in recent years (including the refurbishment of Point Lepreau Nuclear Generating Station in New Brunswick and

Figure 5: Total Estimated Project Cost and Actual Spending, as of June 30, 2018 ($ million)

Source of data: Ontario Power Generation

	As of Public Estimate in January 2016			As of June 30, 2018	
Project Work	**Estimated Spending[1]**	**Estimated Contingency[1]**	**Total**	**Spending to Date**	**Expected Cost**
Initiation and Definition Phases[2]					
Prerequisite[3]	1,133[4]	32	**2,426**	1,300	1,417
Detailed Planning	1,261	–		1,191	1,257
Execution Phase[2,5]					
Unit 2	2,704	696		2,215	3,152
Unit 3	1,884	524		169	1,993
Unit 1	1,756	406	**10,374**	42	1,749
Unit 4	1,895	349		21	1,915
Common[6]	160	–		70	164
Total	**10,793**	**2,007**	**12,800**	**5,008**	**11,647**
Remaining Contingency					**1,153**
Total Estimated Cost					**12,800**

1. Estimated spending and estimated contingency amounts are as the OPG publicly announced in January 2016. Estimated contingency has been allocated to each part of the Project based on risks that OPG believes might occur during that part.
2. See **Figure 3** for a description of the three phases of the Project.
3. OPG included the costs for 13 prerequisite projects in the total estimated cost that it publicly announced in January 2016. There were five additional prerequisite projects that were not included in this total estimated cost as they were either deemed not Project work (they were required even if the Project did not happen) or paid out of segregated funds that OPG had already set up. See **Appendix 5** for a list of these five prerequisite projects.
4. $1,109 million of $1,133 million relates to 13 prerequisite projects (see **Section 4.6**). The remaining $24 million relates to additional tasks that had to be done, such as the demolition of old facilities.
5. The nuclear reactor units are listed in the order in which they will be refurbished during the Execution Phase. See **Figure 4** for the timeline of when OPG expects to refurbish each unit.
6. This refers to work that is related to all four nuclear reactor units, such as the replacement of eight cooling mechanisms storing used radioactive fuel located throughout Darlington Station.

the refurbishment of two nuclear reactor units at Bruce Nuclear Generating Station in Kincardine, Ontario, which were both completed in 2012).

Figure 6 provides the breakdown of the total estimated Project cost of $12.8 billion by three cost categories:

- **Contracted Costs:** About $6.1 billion (or almost 48%) represents payments to external contractors (from the private sector), which have been contracted by OPG to perform the majority of the Project work.
- **Internal Costs:** About $4.7 billion (or approximately 37%) is for OPG's direct costs on the Project.
- **Contingency Costs:** About $2 billion (or approximately 15%) to cover the additional cost of risks that OPG has identified might occur during the Project.

As identified in **Appendix 3**, in November 2015, OPG's Board of Directors approved the total estimated Project cost of $12.8 billion. Since the Project contains over 450 sub-projects (which are individual tasks that must be completed before the end of the Project), OPG's Board releases funding at various stages of the Project instead of all at once. For example, when the Project's total cost was publicly announced in January 2016, OPG's Board had released about $3 billion in total to fund work related to the Initiation and Definition phases of the Project and the beginning of the Execution Phase.

Figure 6: Breakdown of Total Estimated Cost of the Project by Type of Cost ($ million)

Source of data: Ontario Power Generation

Type of Cost	Main Responsibilities	Cost	Total
Contracted Costs[1]			
SNC-Lavalin/AECON Joint Venture	Perform the main Project work on the nuclear reactor units (such as removal, replacement and repair of core components of the nuclear reactors) as well as other tasks such as maintenance and refurbishment of turbine generators	4,460	
ES Fox	Supply and install replacements for the main components of the fuelling machine power track system	840	
Alstom	Supply equipment and provide technical services on the refurbishment of the turbine generators	355	
BWXT	Perform inspections and maintenance of steam generators, as well as removal of fuel from each core reactor	180	
Other[2]	Perform certain prerequisite projects planned to be completed prior to starting the main refurbishment work	265	**6,100**
Internal Costs			
Project Supports	Provide support to the Project through various business units (such as monitoring radiation levels and making sure staff work with necessary safety equipment)	2,600	
Project Oversight	Directly oversee the external contractors contracted to complete Project work	600	
Interest Costs	Finance the Project	1,300	
Execution Costs	Work on part of the Project (such as removing uranium fuel from the nuclear reactors)	200	**4,700**
Contingency Costs[3]			
	Cover the additional cost of risks that might occur during the Project		**2,000**
Total Estimated Project Cost			**12,800**

Note: All numbers in this figure have been rounded.

1. These contracted costs are OPG's estimates as of January 2016 of what each contractor on the Project will be paid.
2. "Other" primarily relates to work contracted with Black & McDonald, including the Heavy Water Storage and Drum Handling Facility (see **Section 4.6.3** for more details on this project).
3. Depending on which risks do actually occur, this could result in additional payments to contractors (such as performing more work than was initially contracted to them) or additional direct costs to be incurred by OPG.

2.3.5 Project Oversight

A number of groups or bodies external and internal to OPG are responsible for overseeing the Project. **Figure 7** identifies the main oversight groups or bodies for the Project.

2.3.6 Contractor Procurement

Project work is primarily performed by external contractors. OPG selects the majority of the contractors by following a competitive procurement process, including the selection of a joint venture between SNC-Lavalin Nuclear Inc. and AECON Construction Group Inc. in March 2012 to perform the detailed planning of some of the main nuclear reactor refurbishment work.

As part of its competitive procurement process, OPG first identified potential contractors that were qualified to do specific Project work based on their qualifications and previous work experience. OPG then asked these contractors to submit a bid to perform specific Project work, which included an estimated cost for the contractor to do the work and evidence of the contractor's previous experience

Figure 7: Roles of the Main External and Internal Groups and Bodies Overseeing the Project

Prepared by the Office of the Auditor General of Ontario

Oversight Group or Body	Oversight Focus or Purpose	Roles and Responsibilities
External Oversight		
Canadian Nuclear Safety Commission	Project Safety	• Specifies safety standards that all nuclear generating stations in Canada must comply with in order to obtain a licence and be able to operate • Has approved (as part of its operating licence) OPG to commence the Project based on its review of a number of safety-related activities performed by OPG (such as an Environmental Assessment to identify areas where OPG did not meet current standards and practices, and OPG's actions to address those areas for improvement) • Has assigned about 20 of its staff members (including 10 on-site inspectors at Darlington Station) responsibility for inspecting and evaluating work to ensure OPG is complying with the terms of its operating licence while generating electricity at Darlington Station and throughout the Project
Ministry of Energy, Northern Development and Mines	Project Status and Performance	• Represents the Ontario government as the sole shareholder of OPG, with the authority to stop the Project or adjust the Project's scope by issuing shareholder directives to OPG • Has engaged an external advisor, who sits on the Darlington Refurbishment Committee of OPG's Board of Directors (see below) as an observer and non-voting member, to provide regular briefings and semi-annual reports to the Ministry on areas such as progress and risk management of the Project
Ontario Energy Board	Project Cost	• Is Ontario's electricity regulator, which is responsible for reviewing and approving the costs charged by OPG, as the only rate-regulated electricity operator, as well as other regulated electricity utilities (e.g., transmitters and distributors) and rates charged to electricity ratepayers • Reviews OPG's rate application for its two nuclear generating stations (Darlington and Pickering) and 54 regulated hydroelectric generating stations every five years • Approved $4.8 billion related to the Project in the rate application submitted by OPG for the period 2017–2021
Internal Oversight		
Darlington Refurbishment Committee of OPG's Board of Directors	Project Status and Performance	• Oversees the Project's execution, which includes monitoring the Project's progress and performance against its schedule and budget, and making recommendations to OPG's Board • Has retained an external advisory group* to support its oversight responsibility • Receives regular reporting on the status of the Project from OPG senior management.
Refurbishment Construction Review Board	Project Status and Performance	• Consists of external industry experts with relevant experience with megaprojects to provide assessments of the Project's progress and to advise OPG senior management (including the Chief Executive Officer, Chief Nuclear Officer and Senior Vice President of Nuclear Projects) • Provides quarterly reports to OPG senior management (such as the President and the Chief Executive Officer) and provides updates to the OPG's Board of Directors on the status of the Project
OPG's Project Senior Management Team	Project Status and Performance	• Consists of OPG senior management responsible for the Project (such as the Senior Vice President of Nuclear Projects) • Receives regular reporting from OPG Project staff (such as directors and managers who are responsible for overseeing contractors perform Project work)

* The external advisory group comprises representatives from Burns & McDonnell and Modus Strategic Solutions Inc. It performs a quarterly assessment on the status of the Project (by reviewing materials provided to and prepared by OPG's Project Senior Management Team) to identify and report to the committee on areas of risk.

and technical ability to perform the work. OPG assessed the bids received using a scorecard that applied a specific predetermined weighting to two main criteria: bid price and technical ability of the contractors to perform the work they bid on. The weighting applied to these criteria differed based on OPG's judgment. Generally, for more complex project work, OPG would give more weight to a contractor's technical ability to perform this work than the bid price. OPG would then enter into a contract with the contractor whose bid OPG assessed as having the highest overall score.

2.3.7 Project Impact on Electricity Rates

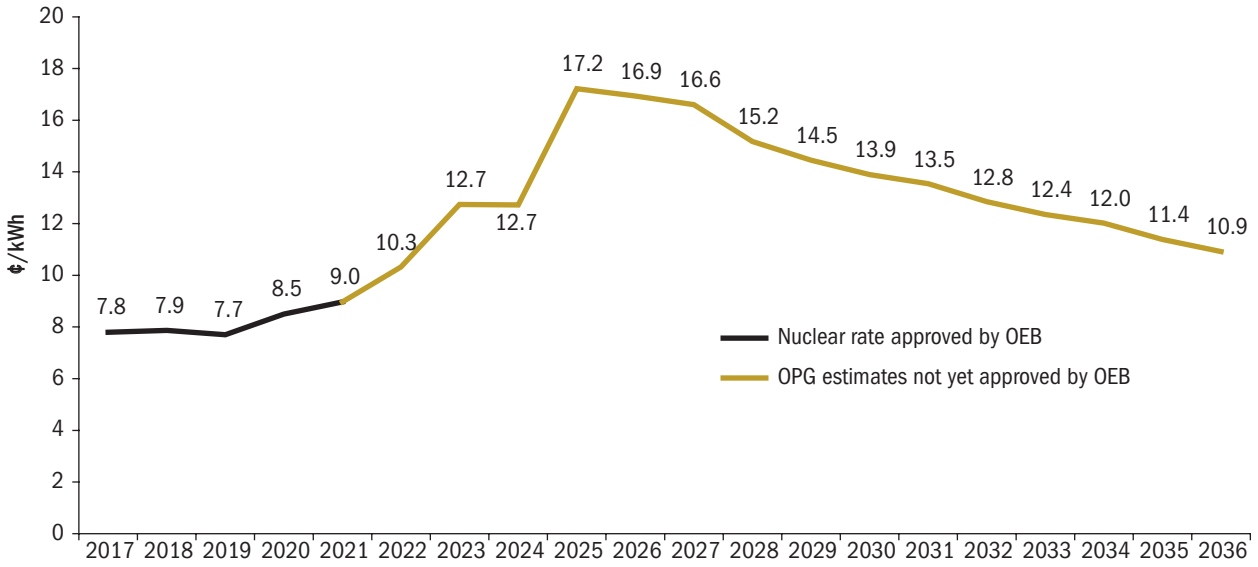
As shown in **Figure 7**, the Ontario Energy Board (OEB) is Ontario's energy regulator. OPG submits a rate application once every five years to the OEB, which determines what rates OPG can charge for the nuclear electricity it generates. For example, in December 2017, the OEB approved OPG's nuclear electricity rate application for the 2017–2021 period. OPG was approved to earn a rate of about 7.8 cents per kilowatt hour in 2017, which increases to 9.0 cents per kilowatt hour in 2021, representing an increase of about 15% over five years (or on average of over 3.5% per year).

As OPG completes the refurbishment work on its four nuclear reactor units, it adds the costs associated with refurbishing those units to the cost of electricity charged to ratepayers as soon as each unit returns to service and begins to generate electricity again.

Based on OPG's current cost estimates for both its Darlington and Pickering Stations (as OPG charges one nuclear electricity rate based on the total amount of nuclear energy generated at both stations), OPG expects (subject to approval by the OEB) its nuclear rate to increase at less than 2% per year on average between 2017 and 2036. **Figure 8** shows OPG's expected nuclear electricity rate growth from 7.8 cents per kilowatt hour in 2017 to 10.9 cents per kilowatt hour in 2036. The rate will be higher during the Project because of the refurbishment costs and because OPG generates less electricity while its nuclear reactor units are shut

Figure 8: Ontario Power Generation's Actual and Estimated Charges to Ratepayers for Nuclear Electricity, 2017–2036

Source of data: Ontario Power Generation



Note: OPG charges one rate for the electricity it generates at both its Darlington Nuclear Generating Station and Pickering Nuclear Generating Station. At the time of our audit, the Ontario Energy Board (OEB) had approved OPG's rates for 2017–2021. Rates shown for the period 2022–2036 are OPG estimates and have not been approved by the OEB. OPG estimates that rates can decline after 2025 because by then the Project will be finished (so construction costs will be less) and production capacity will be greater than during the Project.

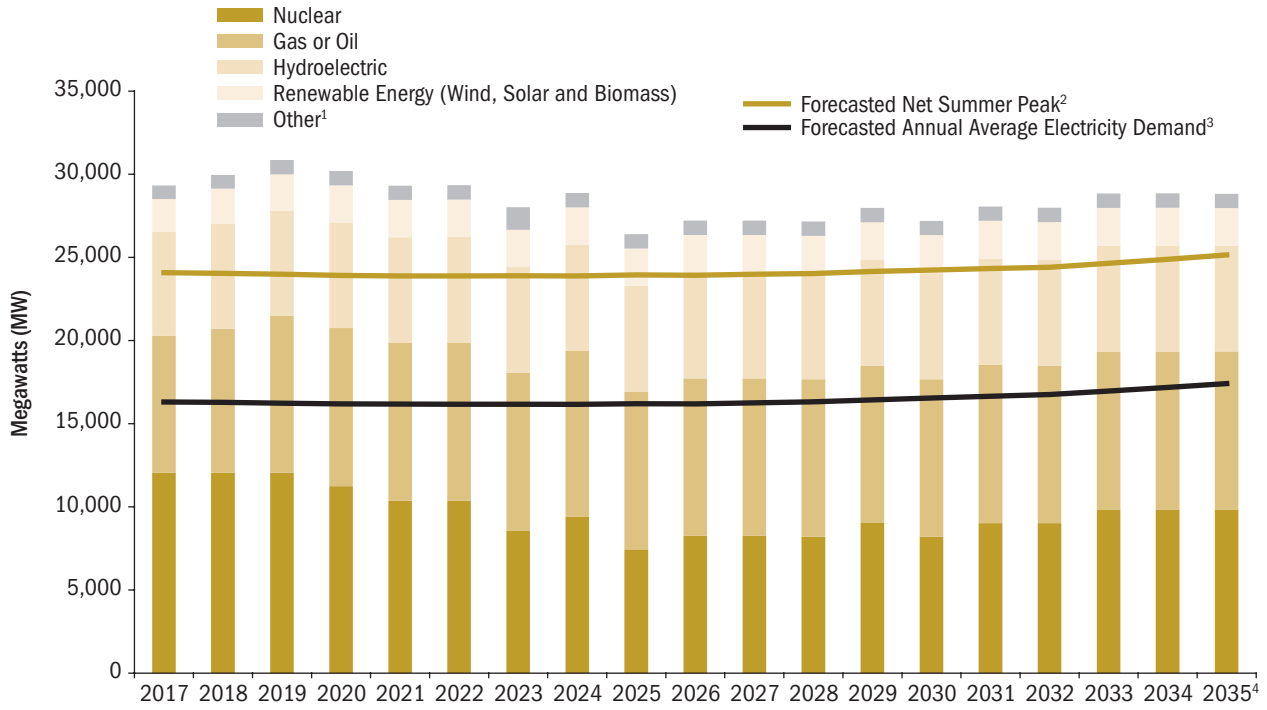
down to be refurbished. Thus, as **Figure 8** shows, the rate (which has not yet been approved by the OEB) will peak at 17.2 cents per kilowatt hour in 2025 (before the Project's expected completion), then decrease in subsequent years.

While the cost of nuclear electricity is expected to increase after the Project's completion, the Project has been identified as cost-effective by the Financial Accountability Office of Ontario (FAO), which is an independent office of the Legislative Assembly of Ontario responsible for providing analysis on the state of the Province's finances and trends in the provincial economy. In November 2017, the FAO released a report on the planned refurbishment of the province's three nuclear generating stations. It reported that "despite near-term Nuclear Price increases, [plans to refurbish the three nuclear generating stations] provide ratepayers with a long-term supply of relatively low-cost, low emissions electricity."

2.3.8 Estimated Future Electricity Supply

We obtained projections on Ontario's electricity supply and demand (from 2017 to 2035) made by the Independent Electricity System Operator (IESO), which is responsible for the long-term planning for electricity and procuring the generation capacity Ontario needs. **Figure 9** shows the projected electricity demand and supply from 2017

Figure 9: Ontario's Forecasted Electricity Supply and Demand, by Fuel Type, 2017 to 2035, in Megawatts (MW)
Source of data: Independent Electricity System Operator (IESO)



Note: Data is based on the forecast performed by the IESO as part of its work on the 2017 Long-Term Energy Plan. 2017 data is therefore forecast but not actual. To comply with reliability standards established by the North American Electric Reliability Corporation and Northeast Power Coordinating Corporation (not-for-profit organizations responsible for enhancing the reliability of interconnected electricity system in North America), the IESO's forecasts includes a 17% reserve margin in excess of peak demand to ensure system safety and reliability and to deal with unexpected events such as changes in demand and equipment failure. If there is not enough electricity being generated to meet the 17% reserve requirement in certain years, the IESO informed us that this could be addressed through a number of different options, including importing electricity from nearby provinces or states, extending existing contracts with electricity generators or increasing the amount of electricity requested during auctions.

1. "Other" primarily relates to electricity supply from sources such as the demand response program (which provides incentives to residential, commercial and industrial consumers to reduce or shift their electricity consumption as needed), energy storage and electricity import from other jurisdictions.
2. Ontario's peak demand for electricity is generally highest in the summer and lower during the winter. In 2017, actual summer peak demand was about 22,000 MW.
3. Ontario's annual average electricity demand is calculated by dividing the total electricity demand of a year by the number of hours for that year. In 2017, actual average electricity demand was about 15,000 MW.
4. 2035 is the furthest year for which the IESO is currently forecasting electricity supply and demand.

to 2035 in Ontario. For each year during this period, the projected electricity supply (about 29,000 megawatts) is expected to be sufficient to meet the projected electricity peak demand (about 25,000 megawatts), which typically occurs during summer. This indicates that even though all three nuclear generating stations in Ontario will be undergoing some degree of refurbishment work in the coming years as mentioned in **Section 2.3.1**, the IESO does not expect this to put the total projected electricity supply below the projected peak demand.

3.0 Audit Objective and Scope

The objective of our audit was to assess whether Ontario Power Generation (OPG) has effective systems and procedures in place to:

- plan and execute the Darlington Nuclear Generating Station Refurbishment Project (Project) in a cost-effective and timely manner in accordance with applicable legislation and standards; and
- manage, monitor and publicly report on the progress and performance of the Project to protect the interest of Ontarians.

Before starting our work, we identified the audit criteria we would use to address our audit objective. We based these criteria on a review of applicable legislation, policies and procedures, and internal and external studies. Senior management at OPG reviewed and agreed with our objective and associated criteria as listed in **Appendix 4**.

We conducted our audit work primarily at OPG's Darlington Nuclear Generating Station (Darlington Station) and its head office in Toronto. We obtained written representation from OPG that, effective November 8, 2018, it has provided us with all the information it is aware of that could significantly affect the findings of this report. We also met with key personnel at OPG involved in the Project and reviewed related documentation and data on the Project's status. We met with OPG's internal audit staff to understand their audit work related to the Project, key findings and recommendations from their audit work, as well as actions taken by management to address such recommendations. Unless otherwise indicated, all information reviewed is based on the status of the Project as of June 30, 2018.

As well, we reviewed relevant documents and data related to the Project, including:

- plans and business cases (including initial cost and time estimates) for the Project to determine its reasonableness and completeness;
- documents related to the selection of external contractors for the Project to assess its fairness and compliance with OPG's policies;
- contracts OPG entered into with its main contractors to understand payment and other contract terms;
- reports provided by Project managers and directors to OPG's Board of Directors and senior management on the status of the Project;
- reports provided by external advisors (including the advisor engaged by the Ministry of Energy, Northern Development and Mines, the advisor to the Darlington Refurbishment Committee of OPG's Board of Directors and the chairperson of the advisory group that advises OPG senior management) on the status of the Project;
- audit reports, including reports from external auditing firms (engaged by OPG's internal audit to review payments OPG made to external contractors) to ensure contractors billed OPG appropriately according to the contract terms; and
- data on safety incidents, staff availability and incentive pay structure related to the Project to identify trends and issues.

In addition, in order to obtain a better understanding of the progress and impact of the Project, we met or spoke with various external parties involved in the Project, including:

- staff from the Ministry of Energy, Northern Development and Mines (Ministry) to understand the Ministry's role in the Project;
- external advisors on the Project (including the Ministry's advisor, the advisor to the Darlington Refurbishment Committee of OPG's Board of Directors and the chairperson of the advisory group that advises OPG senior management) to understand their thoughts on the current status of the Project;
- staff from the Canadian Nuclear Safety Commission to understand its assessment of OPG's compliance with nuclear safety standards during the Project; and
- staff from the Independent Electricity System Operator to understand the impact of the Project on Ontario's electricity supply.

Further, we engaged an external advisor who is a Professional Engineer with experience in the design and refurbishment of nuclear generating stations.

We conducted our work and reported on the results of our examination in accordance with the applicable Canadian Standards on Assurance Engagements—Direct Engagements issued by the Auditing and Assurance Standards Board of the Chartered Professional Accountants of Canada. This included obtaining a reasonable level of assurance.

The Office of the Auditor General of Ontario applies the Canadian Standards of Quality Control and, as a result, maintains a comprehensive quality control system that includes documented policies and procedures with respect to compliance with rules of professional conduct, professional standards and applicable legal and regulatory requirements.

We have complied with the independence and other ethical requirements of the Code of Professional Conduct of the Canadian Professional Accountants of Ontario, which are founded on fundamental principles of integrity, objectivity, professional competence and due care, confidentiality and professional behaviour.

4.0 Detailed Audit Observations

4.1 Ontario Power Generation Estimates Project Will Meet Time and Cost Estimates, but Should Remain Diligent Until Project Completed

At the time of our audit, Ontario Power Generation (OPG) estimated that the Darlington Nuclear Generating Station Refurbishment Project (Project) would be completed on time (February 2026) and within its total estimated cost ($12.8 billion) that was publicly announced in January 2016. As of June 30, 2018, the estimate of $12.8 billion included about $11.6 billion in expected spending (compared to $10.8 billion announced in January 2016) and $1.2 billion still available as contingency (compared to $2 billion announced in January 2016) to cover the cost of any risk that may still occur on the Project. However, we noted that a number of significant risks remain, which require OPG to be vigilant in order to keep to its budget and timeline for the Project.

Updated Estimated Project Costs

As shown in **Figure 5**, the total estimated Project cost of $12.8 billion originally announced in January 2016 consisted of estimated spending of about $10.8 billion and an estimated contingency of $2 billion. As of June 30, 2018, we noted that:

- OPG had spent about $5 billion (or almost 40% of the Project's total estimated cost) on the Project. This includes about $2.5 billion spent in the Project's Initiation and Definition phases related to the substantial completion of prerequisite Project work needed prior to the start of refurbishing the four nuclear reactor units, or for continued operations of Darlington Station and detailed planning of the refurbishment work. The remaining

approximately $2.5 billion is mostly related to performing actual refurbishment work on the nuclear reactor units. At the time of our audit, OPG had refurbished more than half of the first of four nuclear reactor units (Unit 2).

- OPG has allocated about $800 million of the $2 billion contingency to cover the cost of Project risks that have already been identified by OPG or occurred (such as cost overruns related to the prerequisite Project work that are discussed in **Section 4.6**), leaving $1.2 billion as contingency to cover the cost of any risks that emerge over the remainder of the Project.

Lessons Learned

In our review of OPG's planning process for the Project's Execution Phase, we noted that OPG has been able to keep the Project within its original time and cost estimates mainly as a result of applying lessons learned from different sources. For example:

- OPG has researched and applied lessons from other large construction and nuclear refurbishment projects. This included the refurbishment of Point Lepreau Nuclear Generating Station in New Brunswick and the refurbishment of two nuclear reactor units at Bruce Nuclear Generating Station in Kincardine, Ontario, which were both completed in 2012.
- OPG has also applied lessons learned from its prerequisite Project work (discussed in **Section 4.6**) that had cost overruns and schedule delays due to various factors. These include:
  - OPG overrelied on initial cost and time estimates provided by contractors without obtaining a detailed understanding of the complexity and technical specifications of the work during planning. OPG now requires its staff to demonstrate a better understanding of the technical specifications of Project work before establishing initial cost estimates (see **Section 4.6.1**).
  - OPG had poor risk management in planning and executing prerequisite work, resulting in project contingency amounts not being adequate to cover the actual cost of risks that materialized. Since then, OPG has established a risk management team to ensure that project managers accurately and consistently consider and identify Project risks, using a computer simulation to determine an appropriate amount of contingency to include in the Project's cost estimate (see **Section 4.6.2**).
  - OPG selected some contractors that scored lower on technical criteria than competing contractors to complete the prerequisite work. For the more recent contracts related to the main Project work, OPG selected the contractors that were evaluated higher on technical criteria compared to competing contractors to perform the work (see **Section 4.6.3**).
  - OPG assigned prerequisite work to staff who had limited relevant experience with complex projects. OPG now has another group, the Darlington Refurbishment group (with five members of senior management who had direct experience with the refurbishment of Point Lepreau Nuclear Generating Station), to oversee the main Project work (see **Section 4.6.4**).
  - OPG had poor project management and oversight of external contractors on prerequisite work. OPG now takes a more proactive approach to overseeing contractors, including more frequent meetings to review contractor progress on Project work (see **Section 4.6.5**).

It is important that OPG continue to incorporate such learning in its planning and execution of the remaining Project work in order to avoid preventable mistakes.

Final Project Cost Remains Uncertain

A significant portion of the Project remains to be completed, including three nuclear reactor units that need to be fully refurbished. As shown in **Figure 5**, of the total estimated Project cost of $12.8 billion originally announced in January 2016, we noted that OPG had spent about $5 billion as of June 30, 2018, meaning that OPG still has to spend almost $8 billion over more than seven years to complete the Project.

While OPG believes that the Project will be completed on time at a total cost of $12.8 billion (which includes contingency funding of $1.2 billion that is still available to cover any additional risks that may emerge over the remainder of the Project), if some (or all) of these risks do not occur, the Project may be completed below the $12.8 billion cost estimate. On the other hand, however, the $1.2 billion contingency may not be sufficient as there remain a number of risks on the Project with which OPG does not yet have direct experience or that are not fully within its control. Therefore, it is still possible that, if these risks occur, the Project could cost more or take longer to complete than OPG estimated. Examples of these risks include:

- OPG has only started its actual refurbishment work on one nuclear reactor unit (Unit 2). Starting in July 2021, OPG plans to work on more than one nuclear reactor unit at the same time. OPG has acknowledged that working on two nuclear reactor units at the same time will be more challenging than just working on one unit, so it may face new challenges not currently anticipated or with which it does not yet have experience.
- OPG has to perform certain work on the remaining nuclear reactor units that it has no prior experience doing. For example, OPG has to replace parts of the turbine generator in Unit 3 that are reaching the end of their useful life. Similar work was not required when refurbishing Unit 2 because the turbine generator in Unit 2 was in better condition and only required maintenance work (to be performed in 2022).
- OPG will return its first refurbished nuclear reactor unit (Unit 2) to service generating electricity before starting the execution of refurbishment work on the next unit (Unit 3). In compliance with its operating licence, OPG must receive approval from the Canadian Nuclear Safety Commission at various stages before Unit 2 can be returned to service. This requires system testing and submission of documentation. Although OPG has designated staff to oversee these activities, the required testing and approval processes, which involve external groups such as the Canadian Nuclear Safety Commission, could result in delays or additional costs.

As part of its risk management process, OPG indicated that it has mitigated some of the risks identified above by setting a tighter internal work schedule with an earlier completion date than what it publicly reported, giving it extra time or "buffer" to complete work on each nuclear reactor unit. For example, OPG's internal work schedule estimates (as of June 30, 2018) that Unit 2 will be completed in September 2019, which is about six months earlier than the February 2020 date in OPG's publicly reported schedule. Unit 3 is estimated to be completed in July 2022 according to OPG's internal work schedule, which is about a year earlier than the June 2023 date in OPG's publicly reported work schedule. Since OPG has so far only set this tighter internal work schedule for refurbishment work on the first two nuclear reactor units, it is important that it continue to take action to mitigate risks for refurbishment work on the remaining units, and to update its cost and time estimates and make decisions based on the best information available.

We also noted that, since 2017, OPG has been publicly reporting on a quarterly basis certain performance measures related to the Project (such as how the Project is meeting its cost and time estimates publicly announced in January 2016). In our review of the information used by OPG in preparing these public reports, we found that OPG has been accurately reporting the progress of the Project

publicly against the cost and time estimates publicly announced previously as well as other performance measures and targets.

RECOMMENDATION 1

To ensure that the Darlington Nuclear Generating Station Refurbishment Project (Project) is completed in a timely and cost-effective manner and that public reporting on Project progress is complete and accurate, we recommend that Ontario Power Generation continue to:

- reassess Project risks on a regular basis and update time estimates, cost estimates and contingency amounts accordingly;
- review and apply lessons learned from completed Project work to the remaining work on the Project; and
- publicly report its progress against Project targets at least quarterly.

RESPONSE FROM ONTARIO POWER GENERATION

Ontario Power Generation (OPG) agrees with the Auditor General's recommendations.

Prior to beginning the Darlington Refurbishment Project, OPG spent years preparing and conducting detailed planning, using industry best practices, to arrive at a cost and schedule estimate that it has confidence it could achieve.

As part of that planning, OPG developed a robust risk management process where risks are identified, classified, quantified and mitigated to the extent possible. In a project of this size and scope, global experience dictates that there will be uncertainties that cannot be entirely mitigated or avoided. Accordingly, OPG developed a detailed inventory of risks and contingency amounts in accordance with the recommended practices of the Association for the Advancement of Cost Engineering, a leading authority in the area of project cost estimation. These contingency amounts are expected to be used over the course of the Project.

With a large portion of the work on the first unit completed and with continued modelling, OPG is confident that the Project will still be completed within its $12.8 billion budget. As recommended by the Auditor General, OPG will continue to use its risk management and project control processes to assess Project risks on a regular basis and update cost estimates and contingency amounts accordingly.

OPG's planning efforts also include a detailed review and incorporation of thousands of lessons learned from other megaprojects across the world, including other large nuclear projects. OPG will continue to identify, document, evaluate and incorporate lessons learned from ongoing and past projects into future work, leading to opportunities to execute work more efficiently.

Since beginning the execution phase of the Project two years ago, OPG has transparently and publicly reported on the progress of the Project on a quarterly basis. OPG will continue to publish these quarterly reports.

4.2 Pending Shortage of Skilled Trades and Potential Retirement of Experienced Executives and Management Staff Remain a Significant Risk to Completing Project on Time and on Budget

A shortage of skilled tradespeople hired by contractors who are responsible for performing critical and technical work directly on the Project, and the eligibility of nearly all of OPG's executives and over 30% of its management staff (who are part of its Darlington Refurbishment group) to retire before the Project's completion, pose a serious risk for OPG to complete the Project on time and on budget.

4.2.1 Shortage of Skilled Trades Poses Risk of Project Delays

OPG faces the risk that there will not be sufficient experienced skilled trades working on the Project, which could increase the risk of errors being made and delays on the Project.

At the time of our audit, about 1,500 external full-time-equivalent staff hired by contractors were working on the Project. They are primarily qualified skilled trades, such as boilermakers and millwrights (who remove and install nuclear reactor unit components), performing the actual refurbishment work on the nuclear reactor units.

Starting in 2020, OPG will be in competition with another nuclear generating station for these skilled trades. During that year, Bruce Power Limited Partnership (Bruce Power) begins the main repair and replacement work on the first of its six nuclear reactor units at Bruce Station in Kincardine. Work on its six units will continue over 13 years, until 2033 (see **Appendix 2**). As a result, for more than six years, from 2020 to 2026, both OPG and Bruce Power will be refurbishing their stations at the same time.

OPG indicated that it has taken action to address the shortage of skilled trades, including performing an assessment of its needs for skilled trades on the Project, consulting trade unions, analyzing external data from BuildForce Canada (a national industry-led organization that provides construction labour market information), and identifying specific skilled trades with the biggest staffing challenges for the Project. Based on our review of OPG's data and analysis, we noted that:

- OPG identified a potential shortage of boilermakers as one of its biggest risks to the Project. In 2018, the Project will require about 260 boilermakers; this will more than double to almost 550 in 2021.
- Working together, OPG and Bruce Power estimated that, between 2021 and 2025, collectively they will need at most about 1,000 boilermakers for their refurbishment activities, with the greatest need for boilermakers prior to completion of the Project occurring in 2021.
- In January 2018, BuildForce Canada released a report that estimated that nearly 20% of Ontario's current overall construction workforce is expected to retire in the next decade. Therefore, OPG will potentially have access to fewer experienced skilled trades in the labour market as the Project continues.

OPG indicated that it has been working with Bruce Power to assess both organizations' need for boilermakers. At the time of our audit, it was also in the process of forecasting the future supply of boilermakers based on information provided by the International Brotherhood of Boilermakers trade union—but it did not yet have a clear understanding of whether the projected supply of boilermakers would meet its projected need. Given that many training programs for skilled trades take between four and five years for a person to complete and obtain qualification, it is urgent that OPG determine if it is likely to experience a shortage of boilermakers and, if so, take immediate action.

RECOMMENDATION 2

To ensure that the Darlington Nuclear Generating Station Refurbishment Project (Project) has enough skilled tradespeople to perform the necessary refurbishment work, we recommend that Ontario Power Generation (OPG):

- complete a forecast of the future supply of skilled trades identified as being at risk of shortage to determine the impact of this risk on the Project, and take action to prevent or mitigate such risk;
- work with Bruce Power Limited Partnership (Bruce Power) continuously and closely to manage the demand for staffing resources during the period when both OPG and Bruce Power have refurbishment work under way, and adjust the Project's work plans where appropriate; and

- collaborate with other stakeholders (such as the federal and provincial governments, trade unions and colleges) to increase the supply of skilled trades (particularly boilermakers) needed on the Project.

RESPONSE FROM ONTARIO POWER GENERATION

OPG agrees with the Auditor General that ensuring access to a sufficient pool of qualified trades is key to the success of the Project.

At its peak, the Project will require 11,800 additional jobs per year across the industry. OPG agrees that a shortage of skilled trades is a risk for the Project. OPG identified this risk early in the Project and has taken mitigating actions, which are tracked at both the Project and enterprise levels and regularly reported to Senior Management and the Board of Directors.

OPG continues to address skilled trades supply gaps. In particular, OPG will continue its collaboration with Bruce Power, relevant unions, educational institutions and other stakeholders to minimize potential cost and disruptions to the Project. This collaboration involves three streams to mitigate the trades risk, as outlined below:

- Collaboration among OPG, Bruce Power, vendors and trade unions to develop enhanced supply and demand data on skilled trades.
- Initiatives to build capacity within the current supply of trades by streamlining processes at both OPG and Bruce Power, including co-ordinated security processing and training as well as modified shift schedules to attract talent.
- Building up new sources of supply by promoting trades programs through recruitment initiatives at local job fairs and community outreach, and specific initiatives to increase the level of interest of women and Indigenous peoples in trades. OPG is working with various provincial entities and other Canadian organizations to support skilled trades initiatives across the country. OPG welcomes the support of the Province, trade unions, colleges and other stakeholders to increase the supply of skilled trades.

4.2.2 Nearly All OPG Executives and Over 30% of Management Staff Working on the Project Are Eligible to Retire before the Project's Completion

OPG faces a potential risk related to the possible retirement of a significant number of executives and management staff who work on the Project prior to its completion.

At the time of our audit, OPG had about 980 internal full-time-equivalent staff working on the Project. This includes over 150 executives and management staff as part of its Darlington Refurbishment group who spend some or all of their time working on the Project. **Figure 10** shows the staff count by category (executives and management staff) and the number of staff eligible to retire at the end of 2018, 2021 (when the Project's Execution Phase is expected to be 50% complete) and 2025 (just prior to the Project's expected completion in February 2026). About 75% of executives working on the Project are eligible to retire in 2021, growing to almost 90% in 2025. Over 25% of management staff working on the Project are eligible to retire in 2021, increasing to almost 35% in 2025.

Having experienced staff continuously working on the Project is important to ensure that past mistakes will not be repeated and new challenges can be managed as quickly and cost-effectively as possible. While OPG has taken action to address the risk of losing experienced staff, we noted more needed to be done to ensure the smooth transfer of knowledge by identifying and training competent staff who can fill in if experienced staff decide to retire earlier. OPG informed us that it has identified staff retention as a Project risk and has implemented succession planning to mitigate this risk, particularly for those in a management position. Specifically, at the time of our audit:

Figure 10: OPG Executives and Management Staff Working on the Project and Their Eligibility for Retirement
Source of data: Ontario Power Generation

OPG Staff Categories	# of Staff as of June 30, 2018	Cumulative Total # of Staff Eligible to Retire by Year-End			% of Cumulative Total Staff Eligible to Retire by Year-End		
		2018	2021	2025	2018	2021	2025
Executive	8	4	6	7	50	75	88
Management	149	19	40	51	13	27	34
Total	**157**	**23**	**46**	**58**			

Note: Includes regular staff of OPG's Darlington Refurbishment group, who spend some or all of their time working on the Project.

- OPG indicated that it has identified individuals who will be able to take over 45 out of the 58 management and executive positions where the current staff are eligible to retire by the end of 2025. This leaves 13 positions for which OPG currently has not identified replacement candidates. Six of these are for individuals eligible to retire by the end of 2018.
- OPG informed us that it may be able to fill some of its Project staffing needs from staff currently working at its Pickering Station, as two nuclear reactor units at Pickering Station are scheduled to stop producing electricity in 2022 and the four remaining units are expected to shut down in 2024 (see **Appendix 2**). However, at the time of our audit, OPG has not determined specifically when or how many of the almost 1,800 staff working at Pickering Station will be brought onto the Project. While OPG's staff from Pickering Station are more familiar than external new hires would be with OPG's processes, governance and controls associated with working in a nuclear generating station, they would still need to receive additional training on refurbishment-specific processes, which are different than the routine operational processes at Pickering Station.

RECOMMENDATION 3

To ensure that Ontario Power Generation (OPG) has competent and experienced staff working on the Darlington Nuclear Generating Station Refurbishment Project (Project) throughout the life of the Project, we recommend that OPG identify and train staff to be able to take over work being done by the existing staff (especially executives and management staff) who work primarily on the Project and are eligible to retire before the completion of the Project.

RESPONSE FROM ONTARIO POWER GENERATION

OPG agrees that access to an experienced team on an ongoing basis is key to the success of the Project. OPG has a number of programs to attract, retain, align and develop qualified resources for the Project.

Attrition rates at OPG are well understood, and management will continue to use corporate-wide succession planning and talent review processes to identify and prepare future leaders to assume key roles as the Project unfolds.

OPG also has a pool of staff in Pickering who have extensive nuclear and project management experience, and will be trained on refurbishment-specific activities as needed.

OPG has a number of programs in place to develop internal talent into potential successors, including an Enterprise Projects Organization focused on implementing a standardized and scalable project delivery model throughout OPG. This enterprise organization has developed internal and external training specifically designed to advance project management

capability across the organization. In addition, OPG has detailed succession planning and mentoring programs designed to ensure it has sustained bench strength to manage refurbishment.

As with any project, there is a risk that Project staff may leave the organization for a variety of reasons. OPG has already identified succession candidates for the key roles in the Project, and other roles will be filled through internal or external recruitment or will be eliminated where possible. To date, OPG has been successful in attracting external talent where required skill sets could not be developed internally. However, going forward, OPG will have to ensure it has the necessary tools to attract and retain rare skill sets in a very competitive market.

4.3 OPG Incurred Additional Costs as Contractors Did Not Perform up to Expectations but Contractors Continue to Be Eligible to Receive Their Full Profit

Since external contractors are responsible for performing the majority of the Project work, contractors with poor performance or not performing up to OPG's expectations can result in cost overruns and delays. In some cases, OPG has proactively provided additional assistance to support contractors to perform Project work more efficiently, which has helped the Project to remain on time and to be completed within its cost estimate. While OPG has not paid contractors for work that does not meet OPG's quality standards and has achieved settlements of over $50 million with contractors as compensation for their involvement in cost overruns and schedule delays to Project work so far, we question the fact that contractors continue to receive or remain eligible to receive their full profit despite OPG providing additional assistance to help them achieve the level of performance needed to earn such profit. When evaluating the contractors' performance to determine the amount of profit, OPG did not consider the cost it incurred in providing additional assistance to those contractors that did not fully meet OPG's initial expectations, and did not consider the fact that those contractors actually performed some aspects of their work less independently as a result of receiving OPG's assistance.

OPG entered into contracts with external contractors to perform the majority of the Project work. As shown in **Figure 6**, of the total estimated Project cost, about $6.1 billion (or about 48%) pays external contractors to perform Project work. OPG entered into different types of contracts with the contractors depending on the nature of the contractors' work; generally, OPG's payment covers the contractor's direct cost, overhead cost and profit. Of the total amount that OPG currently expects to pay to Project contractors, over $800 million is to cover their overhead costs and profit. The actual amount that is paid under most contracts is linked to how well the contractors meet agreed-upon performance targets (related to a targeted cost and time to complete the Project work) established with OPG.

About $4.7 billion covers OPG's internal costs. Of this amount, about $3.2 billion is to be spent on Project oversight and support (overseeing the contractors performing Project work and providing Project support to both OPG staff and contractors). The remaining $1.5 billion is to cover interest (to finance the Project) and OPG's costs to perform Project work itself (such as removing uranium fuel from the nuclear reactors).

As of June 30, 2018, OPG estimated that it will spend almost $50 million more overall on Project oversight and support than it initially estimated. While OPG informed us that this cost increase is due to its underestimating the actual amount of people and time it would take to oversee the Project, this increase also includes the additional support that OPG has had to provide to contractors to complete Project work on time and on budget. However, when paying profits to contractors, OPG did not consider the additional cost it incurred as a result of providing additional support to them. For example:

- OPG spent about $1.4 million to implement a collaborative front-end planning process with

contractors when planning how work will be performed. This meant that the contractors would work less independently than was originally planned as OPG engineers now worked alongside contractor staff to assist them in completing the planning documents.

- Since April 2016, OPG has loaned (or seconded) seven of its experienced staff to a contractor for Project work. These secondments have ranged from about three months to 21 months in various roles (including managerial roles) on the contractor's team (such as providing training to the contractor's staff and assistance to help the contractor's staff plan for upcoming Project work). These loaned staff are directly supervised and managed by the contractor, but they have remained on OPG's payroll and have cost OPG an estimated $1.2 million in total. While the terms of the secondment agreements allow for OPG to have the contractor "bear the [r]eimbursable [c]osts" of the seconded employee (which includes base salary and expenses), OPG has chosen not to do so.

In both cases, OPG did not consider the additional cost and support it provided when paying profit to the contractors. This is because, in the majority of contracts, the amount of profit the contractors can earn is dependent on the contractor's performance on the Project work, but such performance is evaluated largely based on the contractor's adherence to its targeted completion date and its own cost (but not OPG's cost). Therefore, as OPG incurs additional costs to support the contractors to meet their cost and schedule targets, the amount of profit that the contractors are eligible to earn is not impacted.

In another case, in 2017, OPG noticed that a contractor was struggling to resolve Project-related issues on its own (such as ensuring that the necessary staff and tools are identified and made available so that future Project work is not delayed). To address these issues, in early 2018, OPG and the contractor developed an integrated team in which about 40 OPG staff work directly with the contractor's project management team to provide active support.

While being part of an integrated team does not result in OPG taking on contractor responsibilities, this has resulted in the contractor estimating the cost of completing its current work to decrease by about $8 million, primarily due to planning work performed by this team. Because the contractor's own cost will therefore likely be lower than the targeted cost for this work, the contractor's opportunity to earn more profit will also increase. As OPG's assistance contributed to these lower costs and potentially comes at an additional cost to OPG, we question whether the contractor should be eligible to earn the same profit as if it performed the work independently.

We noted that OPG senior management also raised concerns about contractors' performance. In 2017, OPG senior management wrote a memorandum to OPG's Board of Directors indicating a number of areas in which contractors generally performed below OPG's expectation and where OPG had to provide additional assistance to the contractors. For example:

- The contractors did not effectively plan Project work to meet OPG's documentation requirements although OPG communicated such requirements to the contractors in advance.
- The contractors did not provide effective training to staff on safety standards in a nuclear generating station as many of the supervisory staff came from a non-nuclear construction background.
- The contractors did not effectively monitor the procurement of materials needed for Project work to ensure the materials would arrive on time when needed and not cause unnecessary delays or work stoppages.

RECOMMENDATION 4

To ensure that contractors working on the Darlington Nuclear Generating Station Refurbishment Project (Project) only receive profit if their performance meets Ontario Power Generation's (OPG's) expectation and that the Project is completed on time and on budget, we recommend that OPG:

- continue to provide contractors with additional assistance when the contractors are unable to successfully achieve OPG's cost and time targets for Project work;
- track and consider taking action to recover the cost of additional support provided to contractors above what was expected when contracts with the contractor were signed; and
- take any assistance and support provided to contractors into consideration when evaluating contractors' performance and determining contractors' profit.

RESPONSE FROM ONTARIO POWER GENERATION

OPG agrees with the Auditor General that it is important to hold contractors accountable and ensure that payments are aligned with performance. OPG's contract management approach allows for early identification and quick resolution of issues, while holding each party to its respective accountabilities in accordance with contract terms and conditions. OPG's contract provisions tie contractors' incentives to the long-term success of the Project and align OPG's and contractors' goals. This approach was developed from lessons learned in other refurbishment projects and is considered an industry best practice.

OPG's extensive contract management processes track contractors' costs and performance and ensure issues are addressed. OPG has and will continue to exercise its contractual rights to withhold payments where contractors' performance is deemed to be unsatisfactory and to implement disincentives where contractually appropriate.

Within its contract management approach, OPG uses a variety of arrangements to oversee its contractors. OPG performs its obligations as the owner, and the contractors perform their contractual obligations—even when OPG and contractors are functioning as an integrated team. In rare instances, where OPG believes that the unique expertise lies within its own organization (plant-specific knowledge, nuclear expertise, etc.), it steps in to assist contractors directly. This is the most cost-effective way to address risks. In these cases, OPG tracks the costs associated with the support provided and retains contractual rights to recover these amounts at a later date. Ultimately, OPG is responsible for the Project and takes the necessary steps to ensure that it is successful.

As recommended by the Auditor General, OPG will continue this collaborative approach to project management. OPG will also continue to track costs where additional support is provided to the contractors, and OPG's existing contracts will continue to ensure that contractors are given the incentive to perform well and that OPG and contractor goals are aligned. Ensuring that OPG and its contract partners work well together and are aligned to common objectives is critical to delivering the Project on time and on budget.

4.4 Insufficient Action to Prevent Recurring Safety Incidents Affects Worker Safety and Project Costs and Timelines

Since 2010, when prerequisite work on the Project began, about 30 safety events have happened at Darlington Station where Project staff required medical treatment. While the severity of safety incidents has been low (meaning they did not result in any serious injuries where staff missed work for more than one day), the frequency of these

incidents has remained constant. OPG has not met its safety targets and has not taken effective action to reduce the recurrence of preventable safety incidents on the Project. This has caused delays and additional costs of over $700,000.

Safety incidents put individuals working on the Project in potentially harmful situations. They can also prevent OPG from completing the Project on time because any serious or major safety incident could result in an investigation by the Ministry of Labour and the Canadian Nuclear Safety Commission, which can halt Project work or even limit OPG's operations until corrective actions are implemented.

4.4.1 Safety Targets Not Met despite No Serious Injuries to Project Staff

Figure 11 shows OPG's safety performance related to the Project from 2014 through June 30, 2018. OPG has monitored and assessed its safety performance related to the Project through the following measures:

- **Rate of safety incidents:** The number of safety incidents for every 200,000 hours worked by staff against a target, which was 0.24 in 2016 and 0.37 in 2017. OPG's President and Chief Executive Officer increased the target to 0.37 in 2017 in recognition of the fact that the number of safety incidents would likely increase as a result of more complex work being performed in the Project in 2017 than previously.
- **Number of injuries:** The number of injuries (including those that did not result in days lost from work).
- **Number of near-miss safety incidents:** The number of incidents in which no one actually got hurt but where there was the potential for someone to have been hurt.

Based on our review of OPG's rates of safety incidents related to the Project since 2016 (when the actual refurbishment work on the first nuclear reactor unit began), we found that OPG did not meet its safety incident rate targets, and the number of injuries requiring medical treatment also increased. Specifically:

- OPG's rate of safety incidents related to the Project in 2016 (0.5), 2017 (0.49), and the first six months of 2018 (0.48) remained almost the same and did not meet the targets (0.24 in 2016 and 0.37 in 2017 and 2018).

Figure 11: Project Safety Performance, January 2014 through June 2018

Source of data: Ontario Power Generation

Year	Safety Incident Rate (# of Events per 200,000 Hours Worked)[1]	# of Injuries			# of Near-Miss Safety Incidents		
		Lost Time Injuries[2]	Medically Treated Injuries[2]	First Aid Injuries[2]	High-Risk[3]	Medium-Risk[3]	Low-Risk[3]
2014	0	0	0	Not tracked for Project	4	0	Not tracked for Project
2015	0.29	0	1		3	0	
2016	0.5	0	9	26	6	3	159
2017	0.49	0	14	46	14	3	214
Jan–Jun 2018[4]	0.48	0	7	19	1	2	104

1. The safety incident rate is calculated by the number of medically treated injuries divided by the total number of hours worked in the year then multiplied by 200,000.
2. A lost time injury is a work-related injury or illness that results in death, a permanent disability or a critical injury. A medically treated injury is a work-related injury or illness requiring treatment beyond first aid but that does not result in days lost from work. A first aid injury is an injury that also does not result in days lost from work but that is treated without a physician (such as use of bandages, cleaning of wounds, and use of hot and cold compress).
3. High- and medium-risk near-miss safety incidents are incidents where death, a permanent disability or a critical injury has a reasonable potential to occur (for example, someone working at a height of 12 feet above the ground leaned on a gate that was not closed properly but caught themselves before potentially falling). A low-risk near-miss safety incident is an incident where there is an unlikely occurrence of death, permanent disability or a critical injury (for example, someone being struck on their hard hat and shoulder by pliers dropped from seven feet above).
4. Data is shown for the six-month period from January 1, 2018, to June 30, 2018.

- The total number of injuries increased from 35 in 2016 to 60 in 2017, of which the number of injuries that required medical treatment by a physician (such as a worker who cut their thumb while stripping wire) also increased from nine to 14. For the first six months of 2018, there were still seven injuries that required medical treatment by a physician. These injuries caused harm to staff but did not result in staff missing any days of work.

In 2016, OPG and an external advisor identified concerns over Project staff safety. Specifically:

- In a briefing to the Ministry of Energy in May 2016, OPG noted, "The [contractor staff] is unable to see the connection between Nuclear Safety, and the work that they perform." OPG believed this to be the case in some circumstances due to contractor staff not having previous experience working in a nuclear generating station.
- In December 2016, the Refurbishment Construction Review Board (hired by OPG senior management to assist them with overseeing the Project) noted during its tours of Project work sites a number of incidents of non-compliance with OPG's safety requirements (such as the failure of Project staff to secure a wrench properly when working at heights above ground). The advisory group attributed these findings to a "lack of communication and enforcement of expectations" by OPG.

To address these safety concerns, OPG implemented a number of safety improvement initiatives in early 2017, which included communicating its expectations on nuclear safety to its staff and contractors' staff. For example, in March 2017, OPG started quarterly meetings attended by the Project's contractors, staff union representatives, and OPG's Health and Safety group to discuss their performance against OPG's safety expectations, safety trends and any corrective actions to create a safer work environment.

However, as previously mentioned and shown in **Figure 11**, OPG's safety improvement initiatives have not significantly reduced OPG's rates and number of safety incidents. Therefore, OPG needs to further strengthen its safety improvement initiatives throughout the remainder of the Project to prevent or reduce safety incidents in order to protect staff working on the Project, and mitigate the risk of cost overruns and delays that can be caused by any safety incidents.

Our review of the number of near-miss safety incidents (where harm did not occur but could have) related to the Project in 2016 and 2017 also found that both higher-risk and low-risk incidents increased as shown in **Figure 11**. Specifically:

- For higher-risk near-miss safety incidents (which incorporate incidents that OPG classifies as both high and medium risk that could have resulted in death or critical injuries such as a disability), OPG reported 17 cases in 2017, up from nine in 2016.
- For low-risk near-miss safety incidents (which would not likely result in death, a permanent disability or a critical injury), OPG reported 214 cases in 2017, up from 159 in 2016.

For the first six months of 2018, while there were only three higher-risk near-miss safety incidents, the number of low-risk near-miss safety incidents remained high at 104 cases. We also noted that the majority of the higher-risk near-miss safety incidents that occurred in 2017 had two common causes: (1) staff violating OPG's safety requirements on preventing falls when working at heights above ground; and (2) staff dropping tools and parts when working at heights above ground. We found that although OPG investigated each of these incidents, it could have taken steps earlier to identify the common causes of these incidents and take action to prevent their recurrence.

4.4.2 Lack of Proactive Action to Reduce Recurring Preventable Safety Incidents

From January to July 2017, seven of the 10 higher-risk near-miss safety incidents that occurred were related to staff violating OPG's safety requirements

relating to preventing falls when working at heights above ground, and could have resulted in death or critical injuries. In one case, an individual working at 12 feet above the ground leaned on a gate that did not close properly. In another case, an individual did not wear a harness while working at almost 20 feet above the ground.

While OPG investigated each of these incidents separately, it did not identify the common cause of these repetitive but preventable incidents until July 2017 when the seventh incident happened. As a result of its investigation completed in September 2017, OPG required contractors to attempt to reduce the frequency of this type of incident by taking various actions, such as conducting meetings before work begins to identify and document specific hazards. Since then, one similar higher-risk near-miss safety incident (where an individual did not wear a harness while working more than 10 feet above ground) occurred in November 2017 and five similar low-risk near-miss safety incidents occurred between October 2017 and the time of our audit. This suggests that if OPG had identified the common cause of this type of repetitive safety incident earlier, the frequency of similar incidents that occurred between January and July 2017 could have been reduced.

From January to September 2017, of the low-risk near-miss safety incidents that occurred, six were related to staff dropping tools or parts from above ground that nearly hit others below. In September 2017, two higher-risk near-miss safety incidents with the same cause also happened. Although OPG investigated each of these incidents separately, it did not identify why this type of incident was regularly occurring. However, one contractor working on the Project told OPG that it had performed an investigation into this pattern of recurring incidents. The contractor identified corrective actions, such as installing netting beneath above-ground work areas, and inspecting work areas between shifts to ensure tools and parts are securely stored.

In November 2017, the same type of incident occurred again when a worker dropped a bag containing pieces of metal from almost 35 feet above ground, almost hitting another worker. As a result, the contractor stopped about 800 of its staff from working on the Project for two days: about 500 staff stopped working while another 300 staff in supervisory and management roles gathered at Darlington Station to develop safety improvement plans and procedures. The contractor's staff were still paid for these two days when they did not work, which cost OPG over $700,000.

Subsequent to the incident in November 2017, another 10 safety incidents related to falling objects occurred, including one in May 2018 where a piece of steel fell 23 feet, which could have resulted in the death of, or critical injury to, nearby staff. While the contractor noted in its corrective action plan that "[h]uman errors will occur in the best of organizations. They cannot be completely eliminated," the contractor also noted that its "[m]anagement and supervision have not established high standards and expectations for preventing dropped or falling objects," which can be done if "[d]ropped and [f]alling [o]bjects [are] [s]trongly [r]eacted to [b]y [m]anagement."

RECOMMENDATION 5

To ensure that the number of safety incidents on the Darlington Nuclear Generating Station Refurbishment Project (Project) remains as low as possible, we recommend that Ontario Power Generation:

- perform a review of its process for reviewing safety incidents to determine why previously identified corrective actions (such as those related to falling objects) have not effectively reduced the number of safety incidents occurring on the Project;
- develop new initiatives to address safety concerns related to the Project and meet its safety performance targets; and
- modify its process to investigate safety incidents that are the same or similar in order to identify their common cause in order to take action to prevent their recurrence.

RESPONSE FROM ONTARIO POWER GENERATION

Ontario Power Generation (OPG) agrees with the Auditor General that it is important to ensure that the number of safety incidents on the Project remains as low as possible. In fact, safety is the overriding priority for OPG, which has led to its having the lowest injury rate in the Canadian electricity sector. The Canadian Electricity Association (CEA) awarded OPG its President's Award of Excellence for OPG's safety performance in 2017. Additionally, the Canadian Nuclear Safety Commission has awarded the Darlington Nuclear Generating Station the highest possible safety performance rating for the last eight consecutive years in publicly released safety assessments.

In order to maintain this top safety performance, OPG continues to set very challenging targets for its day-to-day operations. Notwithstanding that the Project work is being executed by contractors and trades in a very complex construction environment, OPG purposefully sets the same challenging targets and expects the same level of performance from the Project. This expectation has resulted in a Project safety incident rate that is about 10 times better than the construction industry average overall.

OPG employs a variety of leading indicators to ensure that issues are addressed before incidents occur. OPG's practice of proactively tracking events where no injuries occur, but where there is potential for harm, is one example of a leading indicator. This practice exceeds the standards of other construction industries and companies, where these events are not similarly tracked. OPG carefully logs and reviews each of these incidents and adopts corrective actions to prevent future incidents. In addition, OPG has rigorous, best industry processes to review safety incidents, analyze trends and initiate common cause investigations. In 2017, the first full year of execution, there was a significant increase in the number of people working on refurbishment, which resulted in a proportional increase in the number of incidents with higher potential for harm, as described by the Auditor General. As depicted in **Figure 11** of the Auditor General's report, in 2018 the number of these incidents dropped significantly, demonstrating the effectiveness of OPG's rigorous approach to safety.

Given its commitment to continuous improvement, OPG will review the safety incidents cited by the Auditor General to identify potential enhancements to its corrective action program and timeliness of the common cause investigation process. As recommended by the Auditor General, OPG will consider new initiatives to address safety concerns and enhance safety performance, where there are adverse trends. Safety will continue to remain OPG's priority.

4.5 Post-payment Audits Need to Be Continued to Identify and Prevent OPG's Overpayments to Contractors

OPG has hired external auditing firms to perform post-payment audits in order to assess whether it paid contractors working on the Project accurately according to the terms of the contracts. Since these audits have resulted in almost $4 million in recovery of overpayments to contractors, OPG needs to continue to conduct these audits to encourage contractors to remain focused on accuracy when billing OPG for work performed and to help OPG identify overpayments throughout the duration of the Project.

OPG has processes in place to ensure that contractors only charged OPG for work they actually performed, such as reviewing the number of labour hours charged by contractors and the invoices submitted by contractors on their purchases. However, these processes are not enough to ensure that contractors are paid accurately for Project expenses. For example, OPG cannot fully verify whether contractors actually paid their staff the rates they

charged to OPG without reviewing data from the contractors' own payroll systems. Therefore, post-payment audits where auditors review data from the contractors' own information systems are an important control to help OPG identify ineligible payments to the contractors. Since November 2015, OPG has recovered almost $4 million in overpayments to the contractors based on the findings from these post-payment audits.

Previous audits identified that OPG needed to improve its processes to validate contractors' compliance with contract terms in order to ensure that the contractors only charged OPG for eligible expenses and did not overstate their actual costs or commit fraud. Examples of findings from previous audits include:

- Our 2013 audit of OPG's human resources identified that the hours reported by contractors as being worked were not always properly supported or reconciled to documents (such as overtime approvals or timesheets) by OPG staff, which could lead to OPG overpaying these contractors.
- In February 2014, OPG's Internal Audit group issued a report on the contractor invoicing and payment process related to two contractors hired by OPG to perform both Project and non-Project work. As part of its report, Internal Audit identified that OPG had not exercised its right to perform post-payment audits of contractors' charges for contracts in place at that time.

In response to these previous audits, starting in 2014, OPG has engaged external auditing firms to perform post-payment audits in order to determine if the contractors charged OPG appropriately based on contract terms and if these charges were accurate and supported by appropriate documentation (such as employee timesheets and invoices for purchased goods). For example:

- In November 2015, post-payment audits found and recovered about $3.6 million in overpayments (related to payments between February 2012 and March 2015) from two contractors, mostly related to payroll deductions in excess of regulatory limits (such as for Canadian Pension Plan and Employment Insurance premiums) related to the contractors' own employees and sub-contractors.
- In November 2016, a post-payment audit of one Project contractor's billings from 2014 and 2015 resulted in OPG recovering about $300,000 in overpayments to the contractor. These related to the cost of information technology resources that were not reimbursable in accordance with the contract.
- In June 2017 and June 2018, two other post-payment audits found another $2.7 million in potential overpayments to two contractors performing Project work. These related to excessive payroll deductions (such as Workplace Safety Insurance Board premiums) and billings for hours not supported by appropriate documentation. At the time of our audit, OPG was in the process of reviewing the audit findings with the contractors to determine the amount of recovery.

Based on the results of the post-payment audits, OPG has modified its processes to reduce the likelihood of additional overpayments to contractors. For example, subsequent to the November 2015 post-payment audits, OPG developed a process that requires contractors' project management staff to obtain prior approval from OPG before obtaining a living-out allowance (for staff who have to stay away from home due to Project work).

As subsequent post-payment audits continue to identify other areas where overpayments to contractors occurred, OPG needs to continue making changes to its invoicing and payment processes in order to prevent or minimize overpayments. At the time of our audit, post-payment audits had saved OPG about $3 million (almost $4 million in overpayments recovered minus about $1 million spent to perform these audits), so they clearly remain a useful and cost-effective tool to identify overpayments and signal to contractors that their billings are being thoroughly reviewed.

RECOMMENDATION 6

To ensure Darlington Nuclear Generating Station Refurbishment Project (Project) contractors are paid only for eligible expenses that have actually been incurred, we recommend that Ontario Power Generation:

- continue to perform post-payment audits regularly on Project contractor payments and recover any overpayments identified in these audits from contractors; and
- where cost-effective, make changes based on the results of the post-payment audits to its contractor invoicing and payment processes to reduce the likelihood that overpayments occur.

RESPONSE FROM ONTARIO POWER GENERATION

Ontario Power Generation (OPG) agrees with the Auditor General that it is important to ensure that contractor payments are accurate and that regular post-payment audits are performed.

Before paying contractor invoices, OPG uses a rigorous, multi-step invoice approval process to ensure that payments are only made in accordance with contract terms and conditions.

In addition, OPG has incorporated the right to audit all financial and other records in its contracts with Project vendors. OPG proactively engages independent third-party auditors to ensure that contractor payments are properly supported by a complete set of documentation, appropriate to the circumstances and in compliance with OPG contract terms and conditions. Contract provisions allow OPG to recoup any overpayments.

All major refurbishment contracts are routinely audited by independent third parties. These audits are performed to ensure the eligibility of charges. Historically, the post-payment audits for OPG's contracts have resulted in findings well below what is typical in the industry. This demonstrates the effectiveness of OPG's invoice approval process, even before payments are made.

As recommended by the Auditor General, OPG will continue to perform regular post-payment audits for all major contracts and, where cost-effective, look for opportunities to make changes to its invoicing process to reduce the likelihood of overpayment.

4.6 Prerequisite Project Work Costs over $725 Million More Than Initially Estimated and Will Be Completed Later Than Planned

Prior to starting the main refurbishment work on the Project, OPG had to perform work on 18 prerequisite projects that were necessary to allow refurbishment work on the actual nuclear reactors to occur, such as building facilities for processing and storing materials to be removed from the nuclear reactor units. The total cost of these prerequisite projects is expected to be over $725 million (or over 75%) more than OPG's initial cost estimate. Fourteen of these projects were or are expected to be completed later than OPG initially estimated.

As part of its planning for the Project, OPG identified 18 prerequisite projects that it planned to start prior to starting the refurbishment work on the nuclear reactor units. We noted that the estimated Project total cost publicly announced by OPG in January 2016 only included 13 of 18 prerequisite projects, as OPG reclassified five of these projects prior to its public announcement primarily because this work would have been performed even without the Project. We included these five projects as part of our review and analysis of prerequisite projects since they are all required for the continued operation of Darlington Station. **Appendix 5** provides a list of all 18 prerequisite projects and the reasons that OPG did not include five of these projects in its Project cost estimate publicly released in January 2016.

Figure 12 shows a comparison between the original estimated costs for all 18 of these prerequisite

Figure 12: Cost and Completion Date Estimates for 18 Prerequisite Projects

Source of data: Ontario Power Generation

Prerequisite Projects	Original Estimated Cost[1] ($ million)	Cost as of June 30, 2018[2] ($ million)	Cost Above Original Estimate[2] ($ million)	# of Projects Above Original Cost	# of Projects Completed Later than Original Plan[2]
13 included in total estimated Project cost[3]	762	1,402	640	11	11
5 not included in total estimated Project cost[3,4]	193	280	87	4	3
Total	**955**	**1,682**	**727**	**15**	**14**

Note: See **Appendix 5** for a list of all 18 projects and details on each of the projects.

1. OPG created a number of estimates at various stages of each project, such as when the need for the project work was first identified, when the project work was fully planned and when OPG was ready to start the main construction work on the project. Generally, we have identified OPG's cost and time estimates just prior to the start of construction work on the project as its original estimate, because earlier estimates may not have been developed based on a complete understanding of the conceptual design chosen for the project. Cost estimates include contingency amounts.
2. Amounts and completion dates are based on OPG's estimates for each prerequisite project as of June 30, 2018. Since two prerequisite projects have not been completed as of June 30 2018, the actual total cost of prerequisite projects and completion dates compared to original estimates are not known.
3. The total estimated Project cost is $12.8 billion, which OPG publicly announced in January 2016.
4. Three of the five prerequisite projects were originally considered as Project work but were later removed from the Project's cost estimate as OPG determined this work would have been performed even if the Project did not occur. The remaining two prerequisite projects were related to nuclear waste management projects that OPG funds through segregated funds and were therefore not included in the Project's overall cost estimate. See **Appendix 5** for a list of these five prerequisite projects.

projects and their costs as of June 30, 2018, and the number of these projects completed later than the original plan. **Appendix 5** provides more details on each of these projects. Of the 18 projects, 16 had been completed and the remaining two were under way as of June 30, 2018. We found that:

- Fifteen of these 18 prerequisite projects had cost increases. The total cost of these projects is estimated to be over $725 million more than originally estimated. The majority of this cost overrun was related to one prerequisite project, the Heavy Water Storage and Drum Handling Facility (see **Section 4.6.3**). Specifically, of the $725 million cost overrun, about $345 million was already included as estimated spending in the Project's $12.8 billion total cost estimate that OPG publicly released in January 2016. Since then, an additional $295 million has been allocated from the Project's contingency to cover these projects cost overruns. The remaining cost overrun of about $85 million related to the five prerequisite projects was not included in OPG's total estimated Project cost of $12.8 billion for the reasons stated above.
- Fourteen of the 18 prerequisite projects were or are expected to be completed later than originally planned. While late completion has not resulted in delays to other Project work (mainly because OPG required staff to work more hours in order to prevent delays in prerequisite work from disrupting other Project work), OPG spent almost $32 million to complete project work faster (such as having staff work overtime), which could have been avoided or reduced if OPG had planned its prerequisite work better (see **Section 4.6.1**).

As shown in **Figure 12**, even if we excluded the five projects that were not included in the Project's $12.8 billion public cost estimate from our review and analysis, the 13 prerequisite projects that OPG included in the Project are expected to cost more and take longer to complete than initially estimated. Specifically:

- Eleven of these 13 prerequisite projects had cost overruns. The total cost of these projects is now estimated to be about $640 million more than originally estimated.

- Eleven of these 13 prerequisite projects were or are expected to be completed later than originally planned.

We found that the significant cost overruns and delays on the prerequisite projects were due to five main factors:

- lack of detailed planning and understanding of project work complexity resulted in inaccurate estimates and scoping as well as underestimation of project costs (see **Section 4.6.1**);
- poor risk assessment (see **Section 4.6.2**);
- underweighting technical criteria when selecting contractors to complete the work (see **Section 4.6.3**);
- assigning prerequisite work to staff with limited relevant experience with complex project work (see **Section 4.6.4**); and
- poor project management and oversight of external contractors (see **Section 4.6.5**).

We found that in most cases, several of these factors played a role in the cost overrun for individual prerequisite projects.

As discussed in **Section 4.1**, OPG has applied lessons learned from these prerequisite projects to the remaining Project work by implementing changes such as improving its understanding of the technical specifications of Project work before establishing initial cost estimates, using a computer simulation to determine an appropriate amount of contingency for Project work, and taking a more proactive approach to contractor oversight.

4.6.1 Lack of Detailed Planning and Understanding of Project Work Complexity Resulted in Inaccurate Estimates and Scoping as Well as Underestimation of Project Costs

OPG staff did not develop accurate initial cost and time estimates for most of the prerequisite projects because they did not have a detailed understanding of the complexity and specific technical requirements of the work when the estimates were made. As a result, a number of prerequisite projects were not appropriately scoped, which contributed significantly to the underestimation of project costs and cost overruns described earlier in this section (totalling over $725 million). Further, better planning may have allowed OPG to avoid almost $32 million in costs (such as having staff work overtime to complete project work faster) it incurred on these prerequisite projects.

In our review of planning documents for the Project, we noted that the majority of the prerequisite projects had cost increases that were partially due to OPG's reliance on cost estimates provided by the contractors during the planning process when it did not understand the full complexity and requirements of the Project work. In other words, OPG inappropriately treated or classified the initial cost estimates as being reasonable without actually knowing the complexity and requirements of the work. OPG indicated to us that execution work on some of the prerequisite projects had to start before the completion of detailed engineering to ensure that there would be no delays to the start of the refurbishment work on the actual nuclear reactor units.

As part of the planning process of prerequisite work, OPG staff (such as project managers and directors) are required to provide OPG senior management with a project business case that includes cost and time estimates for completing the work. There are best practices for developing cost and time estimates, such as those established by the American Association of Cost Engineers (AACE) International, which is an association that shares knowledge and certifies cost engineers and estimators. AACE International has developed a cost estimate classification system that classifies projected work on the basis of the degree of certainty known about the details of a project at a particular point in time. For instance, as **Figure 13** shows, Class 5 designates work that is relatively preliminary, with many unknowns, while Class 1 signifies a very high degree of certainty.

Figure 13: American Association of Cost Engineers (AACE) International Estimate Classification System

Prepared by the Office of the Auditor General of Ontario

	Class 5	Class 4	Class 3	Class 2	Class 1
Level of project definition required[1]	0 to 2%	2 to 15%	15 to 40%	40 to 70%	70 to 100%
Expected accuracy range[2]	−50 to +100%	−30 to +50%	−20 to +30%	−15 to +20%	−10 to +15%
Typical purpose of estimate/possible end usage of estimate	• Concept screening • Assessment of initial viability • Evaluation of alternatives	• Detailed strategic planning • Determination of feasibility • Preliminary budget approval	• Basis for budget authorization • Support project funding requests	• Control baseline for monitoring project cost and progress	• Final control baseline for monitoring variations between all actual project costs and the budget

1. Level of project definition required refers to the percentage of engineering and project design that has been completed. AACE's estimate class system identifies that some levels of project definition could possibly relate to two different estimate classes. For ease of understanding, we removed these overlaps.
2. This represents the typical ranges of accuracy of cost estimates to actual project costs. For example, for a Class 5 cost estimate, typically actual project costs might be as much as 100% greater than the estimated cost or might be as much as 50% lower than the estimated cost.

One of the main causes of cost overruns on prerequisite projects was the initial misclassification of contractors' estimates—misclassification that indicated a higher degree of understanding, and lower degree of risk, than was actually the case. This meant that the contractors' initial estimates were not nearly as reliable as OPG staff believed. As those projects proceeded and their actual complexity and requirements became more evident, the project work had to be altered, resulting in significant additional costs. Some of these costs (including almost $32 million spent by OPG to complete these projects faster, such as by having staff work overtime) could have been avoided if OPG had properly classified contractor cost estimates or obtained more accurate cost and time estimates prior to starting project work. Two examples of projects where OPG relied too heavily on contractors' initial estimates are the Auxiliary Heating System and the Containment Filtered Venting System.

Auxiliary Heating System

The final cost to build an Auxiliary Heating System (Heating System) is estimated to be $61 million more than OPG staff's original estimate in large part because staff, relying on information provided by the contractor, initially classified the cost estimate as Class 3 (according to AACE International standards) but it subsequently proved to be Class 5.

In 2012, OPG senior management approved the business plan for building the Heating System, which is a back-up to the main heating system at Darlington Station in case all four nuclear reactor units shut down in the winter months. OPG staff developed the business plan (including cost and time estimates) largely based on information from the contractor that OPG hired to build the Heating System. At that time, the Heating System was estimated to cost about $39 million (or $46 million after factoring in a contingency of $7 million to cover potential risks) and be completed in April 2015. OPG staff classified this cost estimate as Class 3, which is suitable for budget approval or funding request according to AACE International standards (see **Figure 13**).

As part of the business plan submitted to OPG senior management for the Heating System, OPG staff identified seven alternative options to building the Heating System. Examples of these alternatives included renting portable boilers during an emergency to provide heating when necessary

and using other types of fuel (such as electric or gas as opposed to steam) to operate the Heating System. OPG staff estimated that the costs of these alternatives ranged from about $43 million to about $121 million. OPG informed us that it rejected these alternatives for various reasons; for example, some alternatives were too costly and would not meet OPG's heating needs in an emergency.

In 2014, OPG realized its original cost estimate for the Heating System should have been classified as Class 5, which is the most basic and least accurate type of estimate, instead of Class 3. This misclassification occurred because OPG staff relied on the cost estimate provided by the contractor without obtaining a detailed understanding of the complexity and specific technical requirements to build the Heating System at that time. As a result, the Heating System was completed in March 2016 (almost a year later than the original estimated completion date of April 2015) and cost about $107 million (or about $61 million more than the initial estimate of $46 million), making the Heating System more costly than almost all the alternatives considered.

We noted that the Ontario Energy Board (OEB) also expressed its concern over the cost of the Heating System. In December 2017, the OEB issued a decision for OPG's 2017–2021 rate application and specifically stated that, in relation to the Heating System, "[i]t is not obvious whether the best alternative was selected or whether costs for the alternative selected were contained" and "there were other options available to OPG when selecting a contractor that may not have been adequately explored." As a result, the OEB disallowed OPG from including about half of the cost overrun of the Heating System above the initial cost estimate into its rate base, meaning that OPG is unable to charge electricity ratepayers for the amount disallowed by the OEB. The actual amount disallowed by the OEB was about $27 million, which represents the amount of the Heating System cost that the OEB considers not to have been prudently spent by OPG.

Containment Filtered Venting System

A similar situation occurred with another prerequisite project related to building a Containment Filtered Venting System (Venting System), which limits the amount of radiation released in the case of an incident within a nuclear reactor unit. In 2014, OPG senior management approved the business plan for building the Venting System. The business plan (including cost and time estimates) was developed by OPG staff primarily based on information from the contractor that OPG selected to build the Venting System. At that time, the Venting System was estimated to cost about $77 million and be completed in April 2016.

After OPG obtained a more in-depth understanding of the needs for the specific design of the Venting System, it realized that building the Venting System was more complex than initially estimated. The Venting System was completed almost a year late, in March 2017, at a total cost of over $110 million, over 40% (or $33 million) more than initially estimated.

As a lesson learned from this work, OPG acknowledged that "[the (c)ontractor's] estimates should be appropriately classified to reflect [the] lack of engineering definition. [The (c)ontractor's] estimates should not be relied on until they are fully vetted and understood by OPG."

4.6.2 Poor Risk Assessment Resulted in Higher Costs than Estimated

OPG did not accurately consider the cost of potential risks related to the prerequisite work when developing initial cost estimates for the work.

As mentioned in **Section 4.6.1**, OPG largely based its cost estimates for prerequisite work on estimates provided by contractors that contracted with OPG. The contractors estimated the costs by considering various factors, such as material costs and direct labour costs. OPG staff then added a contingency amount to the estimated cost to cover the costs of potential risks, such as materials costing more than expected or workers taking longer to

complete work than expected. When determining the contingency amount, OPG staff have to consider both the likelihood of risks occurring and the potential dollar impact of the risk.

The external advisor hired by OPG's Board of Directors to help oversee the Project identified that OPG "failed to identify or mitigate known risks" and that "risk management was not taken seriously" when it came to developing contingency amounts for prerequisite work. As shown in **Figure 12**, the original estimated cost for the 18 prerequisite projects was about $955 million, which included about $100 million that OPG added as contingency. As discussed in **Section 4.6.1**, OPG indicated that it did not have time to complete its cost and time estimates for prerequisite work based on a detailed understanding of the work's complexity and technical specifications, resulting in misclassification of its estimates. It was therefore inappropriate for OPG to assume that the level of contingency allocated to the prerequisite work was appropriate based on the reasonability of the cost estimates it developed. We identified several examples where the contingency amounts were insufficient to cover risks in the prerequisite work.

Contingency Amounts Not Sufficient to Cover Soil Contamination Issues

In May 2014, based on information from OPG staff working on the Project, the external advisor engaged by OPG's Board of Directors identified that "there was a high likelihood that there would be contaminated soil issues" during OPG's prerequisite work. Our discussion with Project staff indicated that concerns about contaminated soil were partially based on an incident in 2009, where an underground tank at Darlington Station leaked water that contained tritium (a radioactive by-product created in a nuclear reactor). Excessive consumption of tritium can cause negative health effects. At the time of the spill, OPG's analysis indicated that the spill did not pose health consequences to the nearby population.

While OPG added contingency amounts in its cost estimates for prerequisite work to address the risk of potential soil contamination, we found prerequisite projects where the contingency amounts were not sufficient to cover the actual cost incurred by OPG to deal with the issue. Two examples are related to the additional Emergency Power Generator and the Island Support Annex prerequisite projects.

Emergency Power Generator

In 2014, OPG senior management approved a cost estimate of about $88 million for the prerequisite work of building an additional Emergency Power Generator, which is used in case the backup generators at the Darlington Station fail during an emergency such as an earthquake. This estimate included almost $9 million in contingency to address any potential risks.

OPG now expects the Emergency Power Generator to cost almost $150 million, which is about $62 million or 70% more than initially expected. The significant cost increase is partially due to tritium-contaminated soil being found on the Emergency Power Generator site, which increased the cost to remove and dispose of the soil. While other factors (such as regulatory changes requiring OPG to build the generator so that it can withstand stronger earthquakes) also increased the cost of this work, OPG indicated that "[s]oil contamination was a risk identified by the project team and incorporated in the development of the original project budget via contingency" and acknowledged that "the impact of the soil contamination and the cost to manage the excavated soil was beyond what was initially budgeted for."

When we asked OPG to provide a detailed breakdown of the contingency amounts for each risk factor included in its initial cost estimate for this work, it was unable to provide this information. OPG indicated that the initial contingency amounts estimated for these projects were based on a percentage of the overall project cost as well as on the judgment and discretion of the project manager.

Island Support Annex

In 2013, OPG senior management approved a cost estimate of about $31 million for the prerequisite work of building an Island Support Annex, which is used by contractors as office space and an area for performing preparatory work activities outside of the nuclear reactor units. This included almost $5 million in contingency to address any potential risks. As part of its earlier risk assessment in relation to this work, OPG identified that the potential impact from encountering poor soil conditions was "low."

In 2016, OPG's cost estimate for the Island Support Annex increased by $15 million (or about 50%) to about $46 million. At that time, OPG identified that one of the major factors contributing to the increased cost was that OPG's initial cost "estimate for subterranean risks was not sufficient to cover actual risks encountered." In addition to inadequate consideration of risk related to poor soil conditions, OPG indicated that the cost increase was also related to the cost of locating and removing materials buried underground on the building site because OPG had not recorded the buried materials in its worksite plans.

4.6.3 Underweighting Technical Criteria When Selecting Contractors Contributed to Cost Overruns and Delays

Project work is primarily performed by external contractors. OPG selected the majority of contractors using a competitive bidding process. Overall, we identified that OPG's procurement process generally complied with its own policies and the Broader Public Sector Procurement Directive. However, in our review of OPG's evaluations of contractor bids for 17 of the 18 prerequisite projects (OPG was not able to locate the contractor bid evaluation information for one prerequisite project), we found five projects where OPG selected contractors that submitted lower bid prices but scored lower on the technical criteria than the competing contractors. Collectively, these five prerequisite projects are expected to cost about $500 million more than originally estimated. If OPG had scoped prerequisite projects appropriately by obtaining a detailed understanding of these projects' complexity (as discussed in **Section 4.6.1**) and placed greater weighting on technical criteria when selecting contractors, it would have saved money and avoided delays.

As part of its competitive bidding process, OPG creates a scorecard to evaluate each contractor's proposal based on two main criteria: bid price and technical ability to complete the specific project work. OPG determines weighting for each evaluation criterion prior to receiving the contractors' proposals and communicates the weightings to potential contractors in advance of them submitting their proposals. While the exact weighting OPG applies to each bid evaluation differs according to the complexity of the work, we noted that for half (or nine) of the 18 prerequisite projects, OPG assigned a score of 40% to bid price and 60% to technical ability to complete the work. OPG then selected the contractor with the overall highest score.

On five projects, the contractors that OPG selected to complete the specific project work were given a lower score on technical criteria than the competing contractor. **Appendix 6** summarizes the scores of contractors that bid on these five projects. It also shows the cost increase on each of these projects compared to OPG's initial cost estimate. Apart from the total cost increase of over $500 million for these five projects (which is primarily due to OPG relying on initial cost estimates without having a detailed understanding of project work's complexity and technical requirements, as discussed in **Section 4.6.1**), there have been costs and delays associated with having to replace contractors on the Project. For example, as discussed in detail further on, OPG incurred $14 million in costs directly due to the replacement of one contractor that was selected to perform a prerequisite project even though it scored lower on the technical criteria than a competing contractor.

Heavy Water Facility to Cost about $400 Million More than Initial Estimate

Of these five projects, the most significant cost increase—about $400 million—was related to building a Heavy Water Storage and Drum Handling Facility (Heavy Water Facility), which is used to safely store and process radioactive heavy water extracted from each nuclear reactor unit being refurbished.

In 2012, OPG received bids from two contractors (Black & McDonald and a competing contractor) related to the Heavy Water Facility. As shown in **Figure 14**, OPG evaluated both contractor bids against the same scorecard, which attributed 50% of the overall score to the contractor's bid price and 50% to the contractor's technical expertise, risk management plans and overall quality of the proposal.

As part of the bid evaluation, OPG identified that the competing contractor had some experience with parts of a different nuclear generating station's Heavy Water Facility, while Black & McDonald's experience with this type of project was limited. OPG also identified that compared to Black & McDonald's bid, the competing contractor's bid was more thoroughly thought out.

Figure 14 shows that even though OPG gave Black & McDonald's proposal a significantly lower technical score than the competing contractor, it selected Black & McDonald as the winning contractor as a result of its lower bid price.

In 2013, largely relying on information from Black & McDonald's proposal, OPG estimated the Heavy Water Facility to cost $110 million and be ready for use by October 2015.

In October 2014, OPG terminated its contract with Black & McDonald to construct the Heavy Water Facility. At that time, OPG believed that Black & McDonald's performance on the project was poor. In March 2015, OPG estimated that the Heavy Water Facility would actually cost over $380 million—about $270 million or almost 3.5 times more than originally planned—and not be completed until May 2017: two years later than originally planned.

Figure 14: OPG's Assessment of Contractors' Bids for the Heavy Water Storage and Drum Handling Facility

Source of data: Ontario Power Generation

	Score	
Criteria	**Winning Contractor***	**Competing Contractor***
Price	50/50	25/50
Technical Expertise, Risk Management Plans and Overall Quality of Proposal	32/50	49/50
Total	**82/100**	**74/100**

* Only two contractors bid on this project.

In July 2015, OPG replaced Black & McDonald with a new contractor that was selected through a competitive bidding process. OPG adjusted scorecard weightings by allocating 25% of the scorecard to the contractor's bid price and 75% to the contractor's technical ability to perform the project work, reflecting the more complex scope of work at that time. If OPG had used this weighting instead of the original weighting (50% to bid price and 50% to technical ability) to evaluate the contractors' bids received for the Heavy Water Facility in 2012, it would have selected the competing contractor over Black & McDonald (assuming the bidding contractors would not have submitted different proposals in response to the different weighting). At the time of our audit, OPG had already paid Black & McDonald over $83 million for the work completed on the Heavy Water Facility.

In 2015, OPG approved the request of the newly selected contractor (a joint venture between SNC-Lavalin Nuclear Inc. and AECON Construction Group Inc.) to change the design of the Heavy Water Facility. In a project business case for the Heavy Water Facility, OPG identified that this was based on the contractor's view at that time that design changes would not increase the cost to perform the project work; however, these actually resulted in further cost increases (about $130 million, primarily related to design changes suggested by the new contractor in addition to changes to the

project's scope and other factors) and delays to the Heavy Water Facility.

At the time of our audit, the Heavy Water Facility was expected to cost about $510 million—about $400 million or over 4.5 times more than originally estimated, and not to be completed until May 2019—three-and-a-half years later than originally estimated. This includes approximately $130 million primarily related to allowing the newly selected contractor to make design changes (in addition to other factors, as mentioned above) and about $14 million related to selecting the new contractor and transferring the work to it from Black & McDonald.

4.6.4 Assigning Prerequisite Project Work to Staff with Limited Relevant Experience with Complex Project Work

OPG assigned prerequisite work to its Projects and Modifications group, which had limited appropriate experience with complex projects related to effectively planning and executing the prerequisite Project work.

OPG established its Projects and Modifications group in 2001 to maintain and upgrade operational parts in its nuclear generating stations and nuclear waste facility. Prior to the execution of prerequisite work, the group's average annual spending was about $225 million. This more than doubled to about $530 million in 2014 when the group started performing prerequisite work.

In January 2010, OPG formally created another group, the Darlington Refurbishment group, to focus on planning and eventually overseeing the Project's Execution Phase. In order for this new group to focus on detailed planning for the Project, OPG senior management assigned the prerequisite work to its Projects and Modifications group. However, the prerequisite work contained a number of complex projects that the Projects and Modifications group did not have previous experience performing because it only performed routine or smaller scale capital projects at its nuclear facilities, such as replacing air conditioning units, radiation detection systems and a water treatment system. In contrast, the Darlington Refurbishment group has included five people in senior management positions who had direct experience working on the Point Lepreau Nuclear Generating Station refurbishment project in New Brunswick, which had started in 2008.

Since OPG planned to complete the majority of the prerequisite work prior to starting the refurbishment of nuclear reactor Unit 2 in 2016, the Projects and Modifications group had little opportunity to develop the refurbishment-specific skills it required because it needed to meet the fixed deadline.

4.6.5 Poor Project Management and Oversight of Contractors Performing Prerequisite Project Work

Based on our review of the reports issued by different external oversight parties on the Project, we noted that one of the main causes for cost overruns and delays of prerequisite work was OPG's poor oversight of external contractors due to its "hands-off" project management approach by allowing contractors to plan the projects without appropriate monitoring. Once prerequisite project work began, OPG did not challenge or put enough pressure on the contractors to meet the Project's cost and time estimates, and to explain why these estimates were not achieved. Specifically:

- In May 2014, a Project advisor engaged by OPG's Board of Directors indicated that OPG had a "hands-off" approach in its oversight of contractor planning of prerequisite work, "leading to a series of cascading management failures and contractor performance issues."
- In July 2016, a group of advisors engaged by OPG senior management identified weaknesses in OPG's contractor oversight and project management culture (such as "a cultural tolerance for acceptance of work delays" and "[weak m]anagement behaviour when [s]chedule expectations are missed"). In particular, the advisory group stated that "the

prevailing 'discussion' at a meeting is focused on when the new target completion date is, but little to no discussion as to why was it missed, why [were] there no previous warnings or requests for assistance [and] why there was not a previous recovery plan to ensure the target completion date would not be missed."

- In December 2017, the OEB stated in its decision on OPG's 2017–2021 rate application that having robust project controls in place is "a critical component of good planning and execution of capital projects that allow projects to be completed on time and on budget." However, it is "not convinced that project controls are as robust as they could be" as part of OPG's oversight of the prerequisite work.

In response to the concerns raised by various oversight parties, OPG has made changes to improve its oversight and project management approach for the remainder of the Project. Examples of changes include having review meetings between OPG's management and contractors to discuss reasons or risks for Project work not being completed on time, and requiring contractors to report Project estimated costs on a weekly basis.

RECOMMENDATION 7

To ensure that mistakes made during prerequisite project work on the Darlington Nuclear Generating Station Refurbishment Project (Project) are not repeated, we recommend that Ontario Power Generation continue to:

- perform detailed planning of Project work diligently and appropriately before allowing its senior management team to release funding for refurbishment work during the remainder of the Project;
- review the evaluation scorecards for the remaining Project work not yet contracted and adjust the weightings applied to technical criteria and bid price as necessary to appropriately consider the importance of technical criteria when selecting contractors; and
- review and apply lessons learned on project management approaches from completed Project work (including those recommended by advisors) to the remaining work on the Project.

RESPONSE FROM ONTARIO POWER GENERATION

OPG agrees with the Auditor General's recommendations. As stated by the Ontario Energy Board (see Overall Response), OPG followed industry best practices to develop detailed plans and established robust controls and risk management processes to successfully manage the Project. Notwithstanding the challenges faced during the prerequisite project work, the Darlington Refurbishment is on track to be completed on time, on budget, safely and with quality.

OPG's procurement processes for the prerequisite work were aligned with the principles and applicable requirements in the Ontario Public Service Procurement Directive. To evaluate the contractors bidding on the work, OPG established evaluation criteria and weightings based on the expected complexity and scope of the projects at the time. The work was awarded to the contractors who had the highest overall score.

The prerequisite projects were complex projects with unique scopes of work. Early on, OPG established the initial estimates based on conceptual designs that did not reflect the true complexity or scope of the required work. At the time, OPG was still strengthening its project management capabilities and incorrectly characterized these estimates as having a higher degree of certainty than they actually did. Contrary to OPG's Class 3 characterization at the time, the initial estimates were Class 5 values with an expected accuracy range of −50% to +100% (see **Figure 13**). The cost and schedule increases described by the Auditor General are

not unusual for this type of initial estimate and fall within the expected accuracy range.

The majority of cost increases for the prerequisite work were due to evolution of project scope or unforeseen conditions during construction. As identified by an external advisor to OPG's Board of Directors, "the increased budgets [were] simply reflective of the true project costs had they been estimated properly at the outset."

In 2015, OPG established more detailed Class 3 estimates for these projects as part of the overall Refurbishment estimate, which included sufficient contingency amounts based on detailed evaluation of risks. At this time, the cost of the prerequisite work continues to be within the expected accuracy range of these estimates, and Project contingency continues to be adequate to address future risks.

The prerequisite scope of work became a valuable source of lessons learned for the remainder of the Project. Prior to releasing funds to enter the execution phase of Refurbishment, OPG ensured that detailed engineering work was completed, a Class 3 overall estimate was established, and sufficient contingency was calculated based on a comprehensive evaluation of risks. The external advisor to OPG's Board of Directors and expert testimony at the Ontario Energy Board concluded that the organization had learned early and essential lessons from these projects and that there was no evidence that the remainder of the Project would face similar challenges. Going forward, OPG will continue these practices, which are aligned with the Auditor General's recommendations.

Appendix 1: Glossary of Terms

Prepared by the Office of the Auditor General of Ontario

Bruce Nuclear Generating Station: A nuclear generating station operated by Bruce Power Limited Partnership in Kincardine, Ontario. Two of its eight nuclear reactor units were refurbished in 2012. The station's operations will be extended to 2064 through a life-extension program that began in January 2016. This includes the refurbishment of the remaining six units and is expected to be completed in 2053.
Canadian Nuclear Safety Commission: An independent federal agency that regulates the use of nuclear energy in Canada. It specifies safety standards that all nuclear generating stations in Canada must comply with in order to obtain a licence and be able to operate. It approved Ontario Power Generation (OPG) to start the Darlington Nuclear Generating Station Refurbishment Project (Project) based on its review of safety-related activities performed by OPG (such as an Environmental Assessment).
contingency: Funds that are allocated to cover the potential costs if certain risks occur. OPG allocated about $2 billion of its estimated $12.8 billion total Project cost to address potential risks and uncertainties the Project faced. This amount was determined using a computer simulation based on the likelihood of certain risks to occur on the Project and the estimated cost to OPG if those risks were to occur.
contractor: External construction and engineering vendors hired and overseen by OPG to perform the majority of work on the Project. Includes a joint venture between SNC-Lavalin Nuclear Inc. and AECON Construction Group Inc. to complete the main nuclear reactor refurbishment work.
Definition Phase: During this phase of the Project, from 2010 to 2015, OPG performed detailed planning of refurbishment activities and substantially completed prerequisite work that was necessary to allow refurbishment work on the nuclear reactors to occur. This included activities such as building facilities to process and store materials to be removed from the nuclear reactor units.
Execution Phase: This phase of the Project started in 2016 and is estimated to be completed in 2026. During this phase, OPG will be performing refurbishment work on all four nuclear reactor units. This includes shutting down the units before starting refurbishment work, and replacing or repairing most of the components in the units.
external advisor: One of three external groups on the Project—an advisor who reports to the Ministry of Energy, Northern Development and Mines, an advisor who reports to the Darlington Refurbishment Committee of OPG's Board of Directors, or an advisory group that advises OPG senior management. (This does not refer to the external advisor the Office of Auditor General of Ontario engaged on this audit who has experience in the design and refurbishment of nuclear generating stations.)
Independent Electricity System Operator (IESO): Administrator of the Ontario wholesale electricity market that matches electricity supply with demand. Also responsible for the long-term planning for and procuring the generation of Ontario's electricity needs.
Initiation Phase: This phase of the Project occurred from 2007 to 2009 when OPG performed the initial feasibility assessment and preliminary planning work for the Project.
nuclear reactor unit: An assembly of equipment including a reactor core, steam generator and steam turbine used to generate electricity. See **Figure 2** for a visual depiction of the nuclear reactor unit as part of how a nuclear generating station works.
Ontario Energy Board (OEB): Regulator of electricity in Ontario that is responsible for reviewing and approving the costs charged by electricity generators (such as OPG) and rates charged to electricity users. It reviews OPG's rate application for its two nuclear generating stations every five years.
Pickering Nuclear Generating Station: A nuclear generating station operated by OPG located in Pickering, Ontario. The station has six operating nuclear reactor units, of which two units are scheduled to stop producing electricity in 2022. The four remaining units are expected to shut down in 2024.
Point Lepreau Nuclear Generating Station: A nuclear generating station with one operating nuclear reactor unit operated by New Brunswick Power Corporation, located approximately 40 kilometres west of Saint John, New Brunswick. Its nuclear reactor unit was refurbished between 2008 and 2012.
prerequisite Project work: Construction of buildings and infrastructure (such as water, sewer and piping systems) planned to be completed prior to the starting of refurbishment work or needed for the continuing operations of Darlington Nuclear Generating Station.

Appendix 2: Overview of Ontario's Nuclear Generating Stations

Prepared by the Office of the Auditor General of Ontario

	Bruce Nuclear Generating Station	Darlington Nuclear Generating Station	Pickering Nuclear Generating Station
Operator	Bruce Power Limited Partnership	Ontario Power Generation	Ontario Power Generation
Location	Kincardine	Clarington	Pickering
# of nuclear reactor units	8	4	6[1]
Year started operating[2]	1977	1990	1971
Installed capacity as of June 2018 (MW)	6,232	3,512	3,100
Plans for the station	Extending the useful life of six nuclear reactor units through the repair and replacement of nuclear reactor components	Refurbishing all four nuclear reactor units	Extending the useful life of the nuclear reactor units past 2020 through maintenance work
Estimated cost of life extension/refurbishment work	$13 billion	$12.8 billion	$0.3 billion
Estimated timing of life extension/refurbishment work	2016–2053[3]	2016–2026	2016–2020
Nuclear reactors can remain operational after refurbishment	Until 2064	Until 2055	Until 2024[4]

1. Pickering Nuclear Generating Station had eight nuclear reactor units. Two units stopped operating in 1997.
2. Year when the first nuclear reactor unit at a station started operating.
3. In January 2016, Bruce Power began a multi-year Life Extension Program on six of its eight nuclear reactor units. The Program has two parts: 1) Major Component Replacement (that will continue through 2033 with execution work starting in 2020); and 2) Asset Management program (that will run until 2053). Refurbishment work on the other two of its eight nuclear reactor units had been completed in 2012.
4. Two nuclear reactor units at Pickering Nuclear Generating Station will stop operating in 2022, with the remaining four units continuing to operate until 2024.

Appendix 3: Key Dates Related to the Project

Prepared by the Office of the Auditor General of Ontario

Date	Event
June 2006	The Minister of Energy (Minister) directs the Ontario Power Authority (which was merged with the Independent Electricity System Operator in January 2015) to prepare an Integrated Power System Plan with various goals for Ontario's energy supply. This includes planning for nuclear energy to meet Ontario's base-load energy requirement.
June 2006	The Minister directs Ontario Power Generation (OPG) to conduct feasibility studies on refurbishing its Darlington Nuclear Generating Station (Darlington Station) and Pickering Nuclear Generating Station.
Initiation Phase	
November 2009	OPG completes its economic feasibility assessment business case summary for the Darlington Nuclear Generating Station Refurbishment Project (Project). OPG identifies the refurbishment of Darlington Station's four nuclear reactor units as the recommended option to pursue in part because it would be more economical than other options (such as building new gas generating facilities).
November 2009	OPG's Board of Directors approves $241 million for further planning of the Project, including planning and partial completion of prerequisite Project work.
Definition Phase	
January 2010	OPG formally establishes the Darlington Refurbishment group with accountability for the Project. This group is led by the Executive Vice President, Refurbishment Project. The group is responsible for the detailed planning of the Project as well as overseeing the Execution Phase of the Project (when refurbishment work on the four nuclear reactor units will occur). Prerequisite project work (that OPG planned to complete before starting to refurbish the actual nuclear reactor units) continues to be overseen by another existing group, Projects & Modifications, which was established in 1999 to maintain and upgrade operational parts in OPG's nuclear generating stations and nuclear waste facility.
March 2010	OPG issues an expression of interest to seven contractors for the largest contract as part of the Project related to the replacement of some of the key components of the nuclear reactor units (such as the replacement of feeder pipes that carry coolant required in each nuclear reactor unit). This results in four contractor consortiums expressing interest in performing the work.
October 2010	Three of the four contractor consortiums interested in performing the work are invited to participate in a prequalification process.
October 2011	OPG submits its Integrated Safety Review (identifying areas where Darlington Station currently does not meet standards and practices, and also any areas that would limit the safe, long-term operation of a nuclear facility) to the Canadian Nuclear Safety Commission.
March 2012	OPG enters into a contract with a joint venture between SNC-Lavalin Nuclear Inc. and AECON Construction Group Inc. to begin planning the main refurbishment work on Darlington Station's four nuclear reactor units. Once this work is planned, OPG enters into a contract that will pay the joint venture over $2.7 billion to perform the work.
June 2012	OPG enters into a contract with Black & McDonald for the Heavy Water Storage project (one of the prerequisite projects, which will store radioactive water extracted from the operating nuclear reactor units while the units are being refurbished). See **Section 4.6.3**.
February 2013	OPG's Board of Directors retains an advisor to provide external oversight of the Project.
March 2013	Chief Nuclear Officer takes over as the senior corporate officer responsible for the Project after the Executive Vice President, Refurbishment Project, left OPG.
May 2013	Senior Vice President, Nuclear Projects takes over responsibility for the Project.
July 2013	Canadian Nuclear Safety Commission accepts OPG's Integrated Safety Review.
March 2014	OPG builds a nuclear reactor mock-up to help staff practise doing Project work in a replica of a nuclear reactor. The mock-up costs about $50 million to build.
May 2014	OPG appoints a new Senior Vice President, Nuclear Projects as the senior corporate officer responsible for the Project.

Date	Event
October 2014	OPG terminates its contract with Black & McDonald for the Heavy Water Storage project after OPG believes Black & McDonald's performance on the Project was poor. See **Section 4.6.3**.
April 2015	OPG submits its Integrated Implementation Plan (identifying the schedule and work needed to be done to address areas for improvement identified in its Environmental Assessment and Integrated Safety Plan) to the Canadian Nuclear Safety Commission.
July 2015	OPG's Board of Directors appoints a new President and Chief Executive Officer, effective August 21, 2015.
July 2015	OPG enters into a contract with a new contractor (the joint venture between SNC-Lavalin Nuclear Inc. and AECON Construction Group Inc.) to complete the Heavy Water Storage project.
November 2015	OPG's Board of Directors receive and approve the full business case to continue with the Project, including OPG's overall cost and time estimate (which is the basis for the public estimates OPG releases in January 2016). The Project is estimated to cost $12.8 billion, of which $2 billion is contingency for risks that may occur throughout the Project's duration. The Board releases $1 billion to help fund the start of the Execution Phase, including funding for the direct refurbishment work on nuclear reactor Unit 2.
December 2015	Ministry hires an advisor to provide Project oversight on their behalf and keep them informed on the status of the Project.
December 2015	Canadian Nuclear Safety Commission grants a 10-year operating licence to OPG to operate Darlington Station from January 1, 2016, to November 30, 2025.
Execution Phase	
January 2016	OPG publicly announces its decision (with Ministry support) to continue to pursue the Project, which is expected to cost $12.8 billion and be completed in 2026.
April 2016	OPG establishes a Refurbishment Construction Review Board made up of nuclear industry experts with megaproject experience. The board is expected to provide quarterly reports to OPG senior management to identify improvements that can be made in overseeing and executing the Project.
May 2016	OPG files its rate application with the Ontario Energy Board to determine the rate it can charge for the nuclear electricity it generates between 2017 and 2021. The rate application includes details on OPG's estimates for the cost and timeline of the Project.
October 2016	OPG starts its direct refurbishment work on the first nuclear reactor unit (Unit 2).
November 2017	The Financial Accountability Office of Ontario releases a report that reviews the Province's plan to refurbish nuclear reactors at the Bruce and Darlington Nuclear Generating Stations and to extend the life of the Pickering Nuclear Generating Station. The report discusses how the nuclear refurbishment plan will impact electricity ratepayers and the Province. Overall, the report concludes that the nuclear refurbishment plan is projected to provide electricity ratepayers with a long-term supply of relatively low-cost, low-emissions electricity.
November 2017	The joint venture of SNC-Lavalin Nuclear Inc. and AECON Construction Group Inc. decides to have its staff stop all work on the Project for two days after a safety incident. See **Section 4.4.2**.
November 2017	OPG senior management prepare a memorandum at the request of OPG's Board of Directors assessing areas where contractors performing Project work have not performed according to OPG's initial expectation, resulting in OPG incurring additional costs to assist the contractors to improve their performance on the Project. See **Section 4.3**.
December 2017	The Ontario Energy Board releases its decision approving OPG's rate application for the 2017–2021 period. Its decision approves $4.8 billion in costs related to refurbishment of nuclear reactor Unit 2 to be included in OPG's nuclear electricity rate. The decision approves OPG earning rates of 7.8 cents per kilowatt hour in 2017, increasing to 9.0 cents in 2021 on the nuclear energy it generates.
February 2018	The Ontario Government confirms its commitment to begin the refurbishment of Unit 3 at Darlington Station.
March 2018	OPG's Board of Directors releases $170 million to start detailed planning for the refurbishment of the next nuclear reactor (Unit 3).

Note: See **Figure 3** for the exact timeline and main activities involved in each of the three phases of the Project.

Appendix 4: Audit Criteria

Prepared by the Office of the Auditor General of Ontario

1.	Time and cost budgets of the Darlington Nuclear Generating Station Refurbishment Project (Project) should be established based on reliable information and reasonable assumptions with significant risks and issues being identified and addressed.
2.	A fair and transparent procurement process should be followed, documented and applied consistently in selecting appropriate and cost-effective contractors for the Project with due regard to economy.
3.	A clear accountability framework or structure should be in place to ensure that staff and contractors working on the Project deliver satisfactory services in adherence to contract terms and legislated safety and environmental standards, and that their performance is monitored and appropriately addressed in a timely manner.
4.	Timelines and costs of the Project should be managed, monitored and publicly reported on a regular basis to ensure that the intended outcomes are achieved, unforeseen situations are addressed, and corrective actions are taken on a timely basis when issues are identified.

Appendix 5: Description of Prerequisite Work on the Project and Explanations for Cost Overruns and Delays

Source: Ontario Power Generation

Prerequisite Project	Description	Cost Above Original Estimate?	Completed Later than Original Estimate?	Reason for Overspending on Prerequisite Project
Thirteen Prerequisite Projects Included in Total Estimated Project Cost				
1. Additional (3rd) Emergency Power Generator (see **Section 4.6.2**)	To be used as a third emergency power generator that can withstand a higher-level seismic event (earthquake) than the station's two existing emergency power generators were designed to withstand	Yes	Yes	• Overreliance on initial cost estimate provided by contractor without obtaining adequate understanding of the Project's complexity and risks (such as soil contamination)
2. Containment Filtered Venting System (see **Section 4.6.1**)	To release steam in the event Darlington Station completely loses power in order to prevent a safety event from occurring	Yes	Yes	• Overreliance on initial cost estimate provided by contractor without obtaining adequate understanding of the Project's complexity
3. Darlington Energy Complex	To house the nuclear reactor unit mock-up, a public information centre, and general training area for new staff	No	Yes	• N/A – project work completed at lower cost than initially estimated
4. Heavy Water Storage and Drum Handling Facility (see **Section 4.6.3**)[1]	To store radioactive heavy water (also known as deuterium oxide or D_2O) extracted from each nuclear reactor unit safely while that unit is being refurbished	Yes	Yes	• Overreliance on initial cost estimate provided by contractor without obtaining adequate understanding of the Project's complexity and risks (such as soil contamination) • Change of contractors due to poor performance of the contractor initially contracted • Changes of the building design made by the new contractor
5. Island Support Annex (See **Section 4.6.2**)	To provide office and workshop space for OPG and contractor staff during prerequisite work and refurbishment of the four units	Yes	Yes	• Overreliance on initial cost estimate provided by contractor without obtaining adequate understanding of the Project's complexity and risks (such as soil contamination)
6. Power and Electrical Distribution	To supply electrical power to new buildings such as the Darlington Energy Complex and lighting in new parking lots	Yes	Yes	• Changes to the construction of the system based on unexpected issues with the existing power system

Prerequisite Project	Description	Cost Above Original Estimate?	Completed Later than Original Estimate?	Reason for Overspending on Prerequisite Project
Thirteen Prerequisite Projects Included in Total Estimated Project Cost				
7. Powerhouse Steam Venting System	To release steam from Darlington Station's powerhouse in the event of piping failure, minimizing the effect of harsh environment on the equipment located in the powerhouse	No	Yes	• N/A – project work completed at initially estimated cost
8. Refurbishment Project Office	To provide office space, a lunchroom, change rooms and additional parking spaces for additional OPG and contractor staff	Yes	No	• Overreliance on initial cost estimate provided by contractor without obtaining adequate understanding of the Project's complexity and risks (such as soil contamination) • Overtime and other schedule acceleration costs as a result of a decision to open the building earlier than initially estimated
9. Replacement of Buried Piping	To replace a deteriorated underground safety system that supplies cooling water when normal water supplies are unavailable	Yes	Yes	• Work was more challenging and took longer to perform than was initially estimated
10. Retube Waste Processing Building	To provide a place for processing removed reactor components, which are cut, crushed and placed in shielded storage containers	Yes	Yes	• Increased project scope due to changes (not initially planned) to the building based on lessons learned from previous nuclear generating station refurbishments
11. Shield Tank Overpressure Protection[1]	To provide additional overpressure protection in each reactor unit installed in order to prevent potential shield tank failure under a severe event	Yes	Yes	• Work took longer to perform than initially estimated partially as a result of OPG prioritizing other projects over this
12. Vehicle Screening Facility	To provide additional space for screening the increased volume of vehicles before entering and exiting restricted areas during prerequisite work and refurbishment of the nuclear reactor four units	Yes	Yes	• Changes of the building design to deal with issues related to the ground where the building was built that were not identified during planning
13. Water and Sewer	To replace existing on-site water and sewer system	Yes	No	• Overreliance on initial cost estimate provided by contractor without obtaining adequate understanding of the Project's complexity and risks (such as poor soil conditions)

Prerequisite Project	Description	Cost Above Original Estimate?	Completed Later than Original Estimate?	Reason for Overspending on Prerequisite Project
Five Prerequisite Projects Not Included in Total Estimated Project Cost[2]				
14. Auxiliary Heating System (see **Section 4.6.1**)	To be used as a back-up to the main heating system for safety reasons in case all four nuclear reactor units are shut down in the winter months	Yes	Yes	• Overreliance on initial cost estimate provided by contractor without obtaining adequate understanding of the Project's complexity and risks (such as soil contamination)
15. Holt Road Interchange Upgrade	To improve the main road from the highway close to Darlington Station to minimize traffic delays and support the increase in vehicular traffic (funded by OPG and executed by the Ontario Ministry of Transportation)	No	No	• N/A – project work completed at lower cost than initially estimated
16. Operations Support Building Refurbishment	To renovate an existing building that houses maintenance and administrative support, including site security and information technology	Yes	No	• Work was more challenging and took longer to perform than was initially estimated
17. Retube Waste Storage Building	To build a new storage facility to house removed reactor components	Yes	Yes	• Construction costs greater than initially estimated partially due to performing execution work in winter rather than during warmer months as the estimates assumed
18. Used Fuel Storage Building	To expand storage space for used fuel from continued operation and also store material waste from execution of the Project	Yes	Yes	• Costs greater than initially estimated due to materials costing more than estimated and a 10-week delay in the completion of work due to extreme cold weather
Total		**15[3]**	**14[3]**	
Cost Above Original Estimate (as of June 30, 2018)[2]			**$727 million[3]**	

1. Since two prerequisite projects have not been completed as of June 30, 2018 (Heavy Water Storage and Drum Handling Facility and Shield Tank Overpressure Protection), the actual total costs and completion dates compared to original estimates are not known. Amounts and completion dates are based on OPG's estimates for each prerequisite project as of June 30, 2018.
2. OPG only included 13 of these 18 prerequisite projects in the total estimated Project cost of $12.8 billion that it publicly announced in January 2016. This is because OPG reclassified three projects as work not related to the Project prior to its public announcement (Auxiliary Heating System, Operations Support Building Refurbishment and Holt Road Interchange Upgrade) and two projects were funded through segregated funds for waste management (Retube Waste Storage Building and Used Fuel Dry Storage Building). We included these five projects in our review of OPG's prerequisite work because they are required for the continued operation of Darlington Station.
3. These totals are for all 18 prerequisite projects. Eleven of the 13 prerequisite projects included in OPG's total estimated Project cost are now expected to cost more and take longer to complete than was originally estimated. These 13 projects are currently expected to cost $640 million more than was originally estimated.

Appendix 6: Bid Evaluation Scorecards for Five Project Contracts

Source of data: Ontario Power Generation

	Scorecard[1]								
	Winning Contractor				Losing Contractor				
Project #	Bid Price[2] ($ million)	Score for Bid Price[2]	Score for Technical Criteria[3]	Total Score	Bid Price[2] ($ million)	Score for Bid Price[2]	Score for Technical Criteria[3]	Total Score	Increase in Project Costs Compared to OPG's Initial Estimate ($ million)[4]
1[5]	66	**50/50**	32/50	82/100	93	25/50	**49/50**	74/100	400
2	4	**45/50**	41/50	86/100	5	35/50	**45.5/50**	80.5/100	8
3	20	**38/40**	56/60	94/100	34	11/40	**57/60**	68/100	15
4	42	**40/40**	30.4/60	70.4/100	50	12.9/40	**51/60**	63.9/100	61
5	5	**40/40**	46/60	86/100	8	19/40	**59/60**	78/100	22
Total									**505**

1. OPG uses a scorecard to evaluate each contractor's bid for Project work. The maximum score is 100. The scorecard uses two general categories: a contractor's bid price and a contractor's technical ability to perform the work being contracted out. OPG determines the weighting of scores related to each category; for example, if OPG allocates 40 marks (or 40% of the score) to the contractor's bid price, the remaining 60 marks (or 60% of the score) will be allocated to the contractor's technical ability to perform the project work. In all cases, OPG selects and awards the contract to the contractor with the highest overall score. **Bolded** scores identify the category in which the contractor received the highest score.
2. Bid price is one of the criteria that OPG uses to evaluate proposals submitted by contractors. In some cases, this was the full cost of the project being bid on/evaluated. In other cases, this was just the performance fee (or profit) the contractors were expecting to receive if they were contracted to perform the project.
3. Technical criteria represents OPG's assessment of each contractor's technical expertise, risk management plans and overall quality of proposal.
4. Projects 2, 3 and 4 have been completed; therefore, cost increases are final. Projects 1 and 5 are still ongoing; therefore, cost increases are based on OPG's estimates as of June 30, 2018—the actual cost increases may be more or less than currently identified.
5. Project 1 is related to work on the Heavy Water Storage and Drum Handling Facility.