

# Economic Analysis of a Proposed Hydroelectric Pumped Storage Project in Ontario

**Prepared for:**

**TC Energy**



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## QUALIFICATIONS

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## EXECUTIVE SUMMARY

### Introduction

TC Energy is planning the development of a large-scale hydroelectric pumped storage power project (“the project”) at the 4<sup>th</sup> Canadian Division Training Center in Meaford, Ontario. Pumped storage is a proven technology that involves pumping water from a low-lying reservoir during periods of low demand for electricity, typically at night, to a higher-elevation reservoir. When electricity demand is greater, operators release water back to the low-lying reservoir through turbines that generate electricity.<sup>1</sup>

The project is designed to draw up to 1,000 megawatts (MW) for pumping and to provide 1,000 MW of firm generation capacity for 8 hours, or 8,000 MWh of energy storage. It is also designed to operate over a range of outputs with high ramp speeds and fast start-up capabilities. The project site in Southern Ontario is located at a robust connection point to the electric grid.

TC Energy retained Navigant Consulting, Inc., n/k/a Guidehouse Inc. (“Navigant”) to perform an economic analysis of the project with two focus areas:

1. Assess the potential impact of the project on the cost of electricity for Ontario ratepayers.
2. Quantify the potential CO<sub>2</sub> emissions reductions for the electricity sector attributable to the project.

The analysis is summarized in this final report, which presents Navigant’s detailed methodology and key findings. Project impacts are evaluated both for a baseline market forecast and for potential alternative future scenarios that may affect the project economics, as described in further detail below.

### Methodology

The Navigant team completed a rigorous economic analysis using Navigant’s PROMOD simulation of the Ontario electricity market, calculating the ratepayer and CO<sub>2</sub> emissions impacts of the project by running simulations with and without the project. Additionally, the team used Navigant’s proprietary Electric Valuation Model (EVM) to calculate the avoided cost of operating reserve and regulation procurement to the Ontario Independent Electricity System Operator (IESO). EVM represents the project’s capabilities in greater detail and dispatches it against energy, operating reserve, and regulation prices to develop estimates of hourly operation.

Navigant developed a Base Case that represents our view of the most likely evolution of the Ontario power system over the next 40 years. The Base Case relies on the Navigant team’s subject matter experts who have specific knowledge and understanding of several fundamental power market characteristics, such as fuel pricing, generation development, asset operation, environmental regulations, and technology deployment. This case also utilizes publicly available data and forecasts from the IESO. The project is evaluated over a 40-year study period beginning in 2027, the project’s expected commercial operation date.

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<sup>1</sup> Proposed TC Energy Pumped Storage Project, TC Energy, accessed November 2019, <https://www.tcenergy.com/operations/power/pumped-storage-project/>.

Key modeling assumptions for the Base Case include:

- Peak demand will remain relatively flat through the late 2020s before increasing gradually at a 0.5% compound annual growth rate (CAGR) through 2040.
- There will be a supply gap of 2,000 to 3,000 MW during the mid-to-late 2020s and beyond, even as all existing resources continue to operate after their contracts expire.
- More than 3,000 MW of capacity at Pickering Generating Station will retire in the mid-2020s, and at its peak, more than 3,300 MW of nuclear capacity will be offline for refurbishment.
- Surplus Baseload Generation (SBG), a condition that occurs when electricity production from baseload and intermittent resources exceeds Ontario's demand, will persist into the late-2020s and 2030s, though at lower levels than today.
- Regulation requirements for the IESO triple (from +/- 100 MW to +/- 300 MW) by the early 2020s.
- IESO administers market changes as part of the Market Renewal public stakeholder consultation process, including switching to a single-schedule structure with locational marginal prices, adding a day-ahead energy market, and implementing a transitional capacity auction that gradually evolves into a full organized capacity market.

To verify the Ontario power system is accurately modeled for this study, Navigant then calibrated the model outputs with actual Ontario data for 2018, ensuring that the hourly energy price profiles, generation by fuel type, total interchange, and surplus baseload generation conditions were largely consistent with actual 2018 operation.

Finally, Navigant performed a scenario analysis for five alternate Ontario electricity system scenarios to investigate the impacts of demand growth, gas prices, environmental policy, technology costs, and nuclear refurbishment on project simulation results:

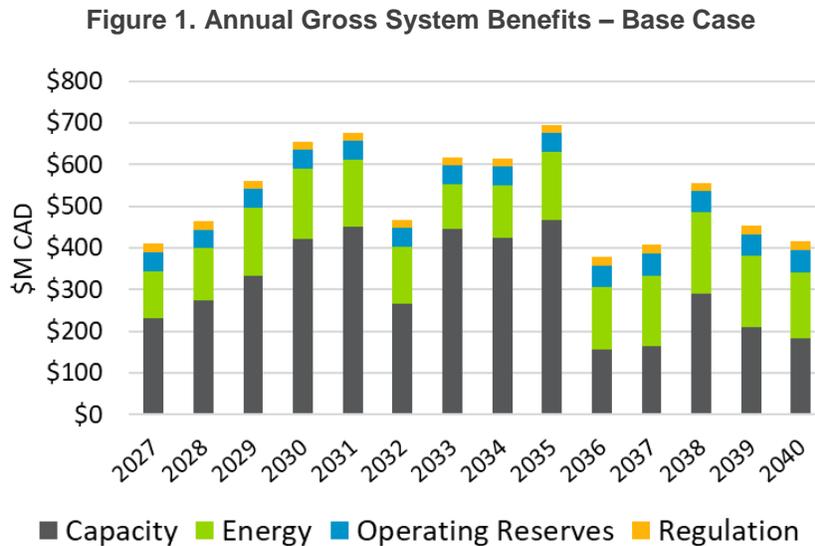
1. **Booming Economy Case:** A strong economy and electrification drive increased load and incremental supply.
2. **Clean Grid Case:** More aggressive decarbonization efforts drive additional load from increased electrification and higher carbon emissions prices.
3. **Challenging Supply Case:** The absence of new conservation programs causes peak demand to increase and major disruptions for nuclear refurbishments, resulting in larger supply gaps.
4. **Low Net Demand Case:** Slow growth and industrial economic restructuring drive a decrease in Ontario's electricity peak demand.
5. **No Market Case:** The absence of a competitive electricity market in Ontario.

## Key Findings

Results from Navigant's analysis show that the project has an overall positive impact on the power system, providing several key benefits to the IESO and Ontario ratepayers, including avoided costs and CO<sub>2</sub> emissions reductions.

The proposed project adds capacity that helps address the forecasted supply gap in the IESO market and reduces energy costs by facilitating the more efficient operation of Ontario’s natural gas fleet. The project would also support the IESO’s flexibility, reliability, and system resiliency needs driven by the transition to a more dynamic power system. The ability of the project to mitigate price spikes during peak periods also contributes to net savings to ratepayers.

Figure 1 below shows the annual gross benefits from the project under the Base Case scenario.



Source: Navigant

In addition to the capacity, energy, operating reserves, and system regulation benefits shown above, Navigant found that the project has the potential to reduce Ontario electricity system CO<sub>2</sub> emissions by approximately 490,000 tonnes per year on average, the equivalent to removing more than 150,000 cars from the road.<sup>2</sup> The project reduces CO<sub>2</sub> emissions by storing energy from zero-emission generation sources (nuclear, hydro, or renewables, depending on the time of day and year) and releasing it back to the grid during on-peak hours, typically replacing gas-fired generation.

At a high level, the project is also expected to provide local economic benefits. While this topic was not part of Navigant’s technical analysis, the project would be a large four-year construction project for Southern Ontario. Approximately 60% of the total capital cost is planned to utilize local building trades and local materials.

Table 1 summarizes the project’s capabilities and associated gross and net benefits under the Base Case scenario in one view. The total financial net ratepayer benefit of the project over a 40-year lifetime is estimated to be \$12.1B.

<sup>2</sup> Assuming a standard 2016 model sedan in Ontario driven 15,000 km/year. Vehicle Emission Comparison Tool v. 1-1-5, Natural Resources Canada, July 2016, <https://www.nrcan.gc.ca/energy/vehicle-emission-comparison-tool/18907>.

**Table 1. Gross and Net Ratepayer Benefits – Base Case**

Benefit	Project Capability	Value to Ontario Ratepayers, 2027 – 2066
Reducing CO <sub>2</sub> Emissions	The project can store excess baseload generation and use it to avoid gas generation during peak times. By providing quick-start operating and flexibility reserves, less gas generation must be online to meet spinning reserve requirements.	Average of 490,000 tonnes per year
Minimizing Costs for Energy	The project can shift energy from low cost off-peak generation (including exports sold or curtailed at a loss to the province) to replace higher cost on-peak generation. This also reduces price spikes and stabilizes prices. By providing quick-start operating reserves, gas plants can also operate more efficiently.	\$13.2B Gross Benefits \$8.5B Net Global Adjustment Feedback <sup>3</sup>
Minimizing Costs for Operating Reserves	The project can provide a large share of system operating reserve requirements.	\$2.6B Gross Benefits
Minimizing Costs for Ancillary Services	The project can provide a large share of system regulation requirements.	\$1.0B Gross Benefits
Providing Flexible Capacity	The project can provide capacity to meet reserve margin requirements and hence avoid the IESO having to procure other capacity.	\$10.9B Gross Benefits
Providing Local Economic Benefits	The project will be built in Ontario using locally-sourced components and local labour.	Locally-sourced materials and equipment Local jobs for construction and operation
Total Gross Benefit		\$23.1B
Project Revenue Requirement		\$11.0B
<b>Total Net Benefit</b>		<b>\$12.1B</b>

To determine the full range of potential project impacts, Navigant also conducted the scenario analysis for five alternative market outlooks as described in the study methodology. The results of the scenario analysis are summarized below in Table 2, illustrating a range of net ratepayer benefits from approximately \$8B to \$30B over the 40-year project lifetime.

<sup>3</sup> Under the assumption that capacity coming off-contract does not re-contract with the IESO.

**Table 2. Net Ratepayer Benefits – Scenario Analysis**

Scenario	CO <sub>2</sub> Emissions Reduction (Avg. Tonnes/Year)	Net Ratepayer Benefit (\$CAD)
<b>Base Case</b>	<b>490,000</b>	<b>\$12.1B</b>
Booming Economy	410,000	\$20.4B
Clean Grid	800,000	\$30.0B
Challenging Supply	690,000	\$19.2B
Low Net Demand	630,000	\$7.8B
No Market	490,000	\$10.0B

Navigant concludes that under a range of future scenarios, the project would result in net ratepayer savings and would significantly reduce CO<sub>2</sub> emissions associated with the Ontario electricity sector. The project could potentially achieve greater economic value and additional CO<sub>2</sub> emissions reductions through increased imports of zero-carbon hydroelectric power from neighbouring jurisdictions through existing transmission connections, beyond what was modeled in this analysis.

## 1. INTRODUCTION

TC Energy retained Navigant Consulting, Inc., n/k/a Guidehouse Inc. (“Navigant”) to perform an economic analysis of a proposed large-scale hydroelectric pumped storage power project (“the project”) in Meaford, Ontario. The analysis is a refresh of a prior Navigant study from 2017 and incorporates changes in the Ontario power market and electricity supply and demand forecasts over the past three years.

The current analysis has two focus areas:

1. Assess the potential impact of the project on the cost of electricity for Ontario ratepayers.
2. Quantify the potential CO<sub>2</sub> emissions reductions for the electricity sector attributable to the project.

This chapter provides an overview of the project and context for the current state of the Ontario power system, including generation capacity needs and other factors that affect the project’s financial and environmental impacts. Information from Navigant’s Base Case scenario is shown in the following sections to provide a foundation for the project analysis.

Chapter 2 describes Navigant’s modeling methodology and major assumptions that inform the Base Case, our approach to calculating the proposed project’s impacts, and the design of alternative market scenarios. Chapter 3 presents Navigant’s key findings for project impacts under the Base Case and alternative scenarios.

### 1.1 Project Overview

Pumped storage is a proven technology that involves pumping water from a low-lying reservoir during periods of low demand (and low cost) for electricity, typically at night, to a higher-elevation reservoir. When electricity demand is greater (and higher cost), operators release water back to the low-lying reservoir through turbines that generate electricity.<sup>4</sup> Pumped storage facilities are designed to switch from energy storage to generation several times per day as needed to take advantage of market price changes. In 2016, the US had more than 30 pumped storage facilities in operation, with a combined capacity of 22 gigawatts (GW). Ontario is already home to Ontario Power Generation’s 174-megawatt (MW) pumped storage facility, the Sir Adam Beck Pump Generating Station.<sup>5</sup>

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<sup>4</sup> Proposed TC Energy Pumped Storage Project, TC Energy, accessed November 2019, <https://www.tcenergy.com/operations/power/pumped-storage-project/>.

<sup>5</sup> “Market Snapshot: Pumped-storage hydro – the largest form of energy storage in Canada and a growing contributor to grid reliability,” Canada Energy Regulator, October 19, 2016, <https://www.cer-rec.gc.ca/nrg/ntgrtd/mrkt/snpshst/2016/10-03pmpdstgrghdr-eng.html>.

TC Energy designed the proposed project to draw up to 1,000 MW for pumping and to provide 1,000 MW of firm generation capacity for 8 hours, or 8,000 MWh of energy storage. It is also designed to operate over a range of outputs with high ramp speeds and fast start-up capabilities. As proposed by TC Energy, the project would:<sup>6</sup>

- Provide needed power capacity
- Reduce electricity costs and greenhouse gas emissions
- Drive local economic benefits and growth
- Provide storage for Ontario's excess baseload generation

Specifically, the project is configured to provide flexibility to IESO system operators and has the following planned capabilities:

- Three 333 MW units providing 1,000 MW of pumping and generation
- Fast start-up in less than 5 minutes to either pump or generate
- Complete ramp range (when online) within 40 seconds
- Ability to start and stop multiple times per hour without restriction and to switch from pumping to generation
- Two variable speed pumps to provide 100 MW of regulation services
- 72% round-trip efficiency (based on the specific elevation and topography of the project site)

The project would be sited at the 4<sup>th</sup> Canadian Division Training Center in Meaford, Ontario, at a robust connection point to the electric grid. The planned in-service date is in the 4<sup>th</sup> quarter of 2027. At the time of this report, the project is in early development stages with planned community engagement over the next several months (December 2019 – January 2020).

## 1.2 Power System Needs

Over the past two decades, Ontario's power system has undergone a significant energy resource transformation. In the early 2000s, Ontario began the process of eliminating its 8,800 MW coal fleet consisting of five coal-fired generating stations. Coal went from 25% of the supply mix in 2003 to 0% in 2014, helping to achieve the CO<sub>2</sub> emissions reduction target of 6% below 1990 levels in that year.<sup>7</sup> Overall, Ontario's electricity sector greenhouse gas emissions fell by 80% from 2005 to 2015.<sup>8</sup> As of September 2019, the total installed capacity on Ontario's transmission system is approximately 37,000 MW, including nuclear (35%), natural gas (27%), hydroelectric (24%), wind (12%), solar (1%), and biofuel (1%) generation resources.<sup>9</sup>

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<sup>6</sup> TC Energy, <https://www.tcenergy.com/operations/power/pumped-storage-project/What-Is-Pumped-Storage/>.

<sup>7</sup> "Achieved – The End of Coal," Ministry of Energy, Northern Development and Mines, archived, updated March 27, 2019, <https://www.ontario.ca/page/end-coal>.

<sup>8</sup> Ontario Planning Outlook, IESO, September 1, 2016, <http://www.ieso.ca/-/media/Files/IESO/Document-Library/planning-forecasts/Ontario-Planning-Outlook/Ontario-Planning-Outlook-September2016.pdf?la=en>.

<sup>9</sup> Ontario's Supply Mix, IESO, accessed December 2019, <http://www.ieso.ca/en/Learn/Ontario-Supply-Mix/Ontario-Energy-Capacity>.

Major changes to the energy supply mix also contribute to several key challenges. A more diverse power system comes with increased variability and volatility, greater forecasting risks, reduced ability to respond to changes in demand, and less supply flexibility.

Using available IESO information, the Navigant team verified three critical power system needs that Ontario will likely have to address in the next decade:

1. **Add new capacity** to meet Ontario's future electricity demand following the anticipated closure of the Pickering Nuclear Generating Station in 2024.<sup>10</sup> The IESO estimates between 2,000 and 3,000 MW of new supply will be required starting in 2025 to meet Ontario's future long-term demand.<sup>11</sup> Ontario also has an aging gas fleet, and it is likely that some gas-fired units will retire as contracts expire through the 2020s and 2030s. This may result in a larger supply gap than currently anticipated.
2. **Deploy flexible resources** that can start and stop quickly and change output rapidly (ramp) to help balance supply and demand. The addition of renewable generation and the elimination of coal-fired generation has left Ontario with fewer dispatchable power resources.
3. **Minimize excess generation** from periods when renewable resources produce more power than Ontario needs. Intermittent renewable resources do not generate in response to consumer demand for electricity, and wind in particular tends to generate at night when demand is low. Under these conditions, Ontario must export to adjacent markets or curtail its wind generators. This excess generation is called Surplus Baseload Generation (SBG) and represents an economic loss to the province, which typically has already paid for the power.

With these changes, Ontario ratepayers have also seen significant increases in the cost of electricity. Both time-of-use and tiered rates have more than doubled from 2005 to 2019, with a sharp increase just this year.<sup>12</sup> Managing ratepayer costs while deploying low-carbon energy resources poses an additional challenge for the power system.

The following sub-sections provide further detail on the three critical power system needs listed above.

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<sup>10</sup> The Future of Pickering Generating Station, Ontario Power Generation, accessed December 2019, <https://www.opg.com/powering-ontario/our-generation/nuclear/pickering-nuclear-generation-station/future-of-pickering/>.

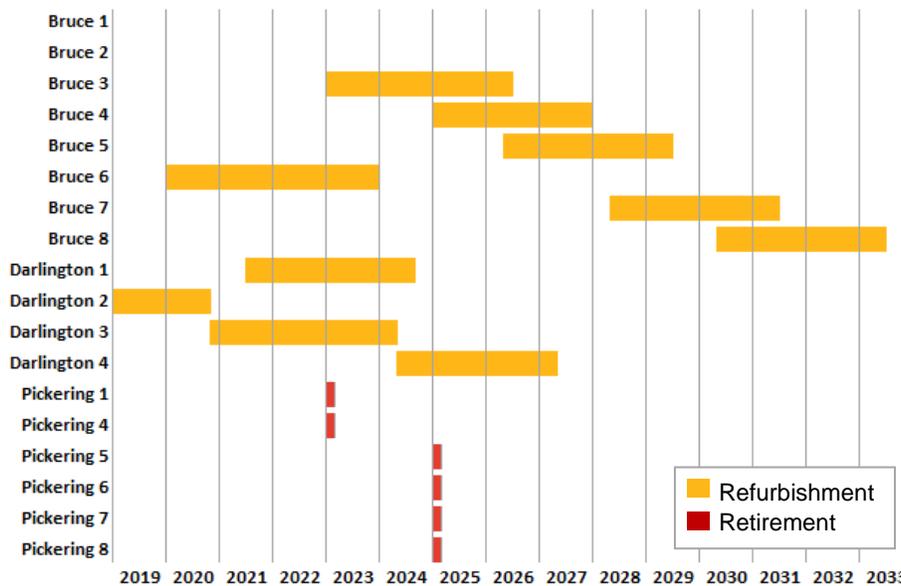
<sup>11</sup> 2018 Technical Planning Conference, IESO, September 13, 2018, <http://ieso.ca/en/sector-participants/planning-and-forecasting/technical-planning-conference>.

<sup>12</sup> Historical electricity rates, Ontario Energy Board, accessed December 2019, <https://www.oeb.ca/rates-and-your-bill/electricity-rates/historical-electricity-rates>.

### 1.2.1 System Supply and Demand

In 2017, Ontario began the process to refurbish or retire most of its nuclear generation fleet. In addition to the retirement of the Pickering Generating Station, 10 units in total are expected to be refurbished by 2033. This timeline is shown in Figure 2, below. Notably, the more than 3 GW of capacity at Pickering Generating Station is expected to retire in the mid-2020s, and at its peak, more than 3.3 GW of nuclear capacity is expected to be offline for refurbishment at one time, causing significant supply gaps.

**Figure 2. Expected Nuclear Refurbishment and Retirement Schedule**

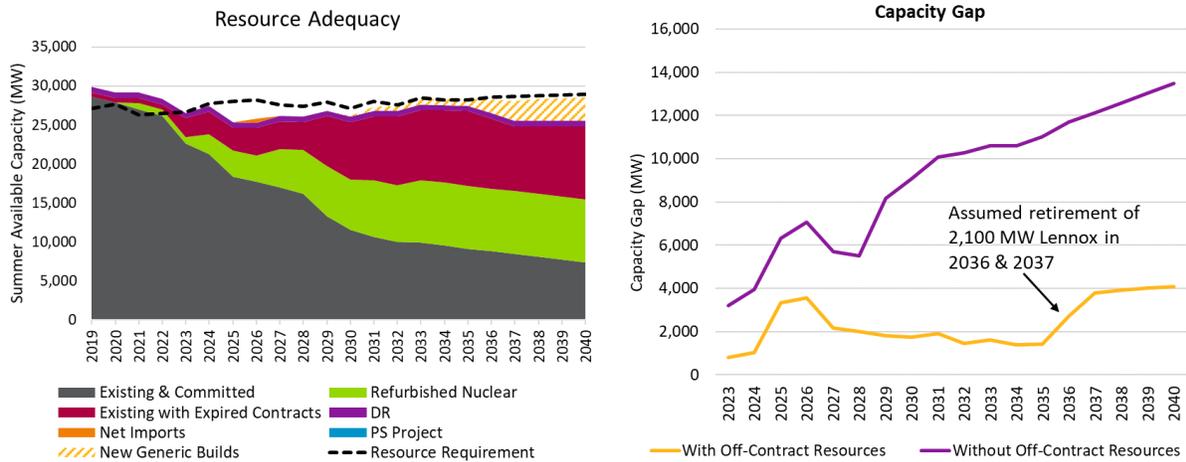


Source: Navigant

Navigant assumed some delays in refurbishment relative to the IESO's original schedule (eight months longer for Darlington Unit 2 and two months longer for Darlington Unit 3). Any further delays would result in greater supply gaps.

Even if all existing generation resources continue to operate after their contracts expire, the IESO forecasts that there will be a supply gap of 2,000 to 3,000 MW during the mid-to-late 2020s and beyond. Short-term resource alternatives, such as demand response (DR) and electricity imports, will be needed to meet reliability requirements during this period before new generation resources can be brought online.

**Figure 3. IESO Forecasted Resource Adequacy and Capacity Gap**



Source: Navigant Base Case; DR shown in chart assumes current levels moving forward

Additionally, it is likely that some of the gas-fired generation resources currently contracted with the IESO will not continue to operate after their contracts expire; for example, Lennox Generating Station shown in Figure 3 above. These are generally aging, relatively inflexible, inefficient, and expensive generation facilities. If these units go offline, there will be an even greater need for new capacity to meet system reliability requirements.

### 1.2.2 System Operability

In 2016, the IESO initiated two processes to address the operability issues associated with Ontario’s changing supply and demand characteristics. The first was a stakeholder engagement process to explore a range of potential solutions for enhanced flexibility in the electricity system. At the time, the IESO estimated that it would need up to 1,000 MW of flexible generation, defined as resources that can be called upon with less than 1-hour of notice.<sup>13</sup> In 2018, as a result of this stakeholder engagement process, the IESO started scheduling additional resources for flexibility by increasing the operating reserve requirement when there was an anticipated need for flexibility.

The second process the IESO initiated in 2016 was a procurement process for Incremental Regulation Capacity to maintain the instantaneous balance between Ontario system supply and demand. Through this initiative, the IESO planned on increasing the regulation capacity from +/-100 MW to +/-150-200 MW from 2017-2019. The IESO’s RFP in 2017 resulted in two awarded contracts, bringing the regulation

<sup>13</sup> 2016 IESO Operability Assessment – Summary, IESO, June 2016, <http://www.ieso.ca/-/media/Files/IESO/Document-Library/engage/esf/ESF-20161208-2016-IESO-Operability-Assessment-Summary.pdf?la=en>.

scheduled to approximately +/-150 MW.<sup>14</sup> The IESO also plans to have the ability to schedule up to 250 to 300 MW of regulation capacity on an as-needed basis by 2020.<sup>15</sup>

Additionally, since the IESO's 2016 Operability Assessment, the IESO has witnessed an influx of distributed energy resources (DERs), which are generation facilities or controllable load facilities connected to the local distribution company's system. DERs pose unique challenges to system reliability, and the loss of DERs could become the IESO's single largest contingency by 2025, further increasing the need for operating reserves.<sup>16</sup>

### **1.2.3 Surplus Baseload Generation**

Surplus Baseload Generation (SBG) is a condition that occurs when production from baseload and intermittent self-scheduling and non-dispatchable resources (including all wind and solar, nuclear and hydroelectric generation) exceeds Ontario's demand. Ontario's significant and frequent SBG issue is typically managed by a combination of 1) scheduling export transactions, 2) curtailing wind, 3) curtailing solar, 4) spilling water at hydroelectric facilities, and 5) curtailing nuclear generation through maneuvers or shutdowns. The IESO practice of curtailing wind and solar generation beyond what is strictly required to balance supply and demand in order to preserve system flexibility during ramp (demand and variable generation) hours also increases SBG; however, this increase is not included in the current analysis.

Figure 4 illustrates the typical operation of the Ontario power system over three days, showing the amount of SBG on the system. Exports and SBG occur in most hours, as total supply often exceeds provincial demand. It is also important to note that some gas generation is always operating – even when there is SBG – because it is needed for system reliability purposes.

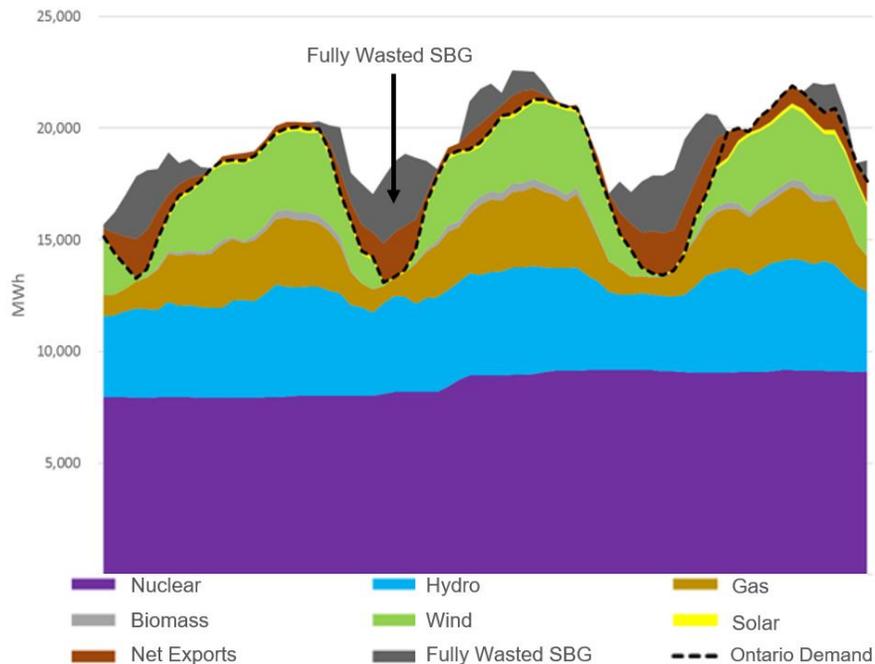
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<sup>14</sup> Regulation Service RFP, IESO, June 2017, <http://www.ieso.ca/en/Sector-Participants/Market-Operations/Markets-and-Related-Programs/Regulation-Service-RFP>.

<sup>15</sup> Ancillary Services Market, IESO, accessed December 2019, <http://www.ieso.ca/en/Sector-Participants/Market-Operations/Markets-and-Related-Programs/Ancillary-Services-Market>.

<sup>16</sup> Review of the IESO-Controlled Grid's Operability to 2025, IESO, June 2019, <http://www.ieso.ca/-/media/Files/IESO/Document-Library/system-reliability/2019-IESO-Operability-Assessment.pdf?la=en>.

**Figure 4. Typical Operation of Ontario Power System over 72 hours**



When SBG conditions are prevalent, as in Ontario, adding more renewable capacity has diminishing value to the power system and contributes to higher electricity rates. This is because the added energy is subject to an increasing probability of curtailment, but under existing renewable contracts, many of these generators are still paid for generation that is curtailed.

Neighboring markets are experiencing similar issues with SBG as they integrate increasing levels of renewable generation into their systems. Ontario's SBG challenges therefore cannot simply be solved by increased exports.

Although SBG levels in Ontario are forecasted to decline from current levels as nuclear units retire and other nuclear units go offline for refurbishment, the forecast remains uncertain due to many factors including electricity demand, weather, carbon prices, renewable generation development, and the nuclear refurbishment timeline. Adding more renewable generation to further decarbonize the power sector – without energy storage – will likely create more frequent SBG conditions. Incorporating grid-scale storage into the system to shift SBG to periods of demand is a promising option to optimize existing resources and enable additional renewable development.

### 1.3 IESO Market Outlook

The IESO manages Ontario's electricity marketplace, connecting generators that sell electricity to wholesale purchasers. The proposed project would participate in this market, and its economics depend on the IESO's market structures, avoided costs, and wholesale market prices. The following sub-sections provide further detail on the IESO market outlook as defined in Navigant's Base Case.

### 1.3.1 Market Renewal

The IESO is currently undertaking market reform under a stakeholder engagement process called the Market Renewal Program, which began in April 2016.<sup>17</sup> The program expects to make major changes to the structure of IESO-administered markets beginning in the 2020s. Although the program has been underway for several years, there is still uncertainty about the specific future market structures, particularly with regards to a capacity market.

MRP objectives as outlined by the IESO include:

1. Replace the two-schedule market with a single schedule market that will address current misalignments between price and dispatch, eliminating the need for unnecessary out-of-market payments.
2. Introduce a day-ahead market that will provide greater operational certainty to the IESO and greater financial certainty to market participants, which lowers the cost of producing electricity and ensures we commit only the resources required to meet system needs.
3. Reduce the cost of scheduling and dispatching resources to meet demand as it changes from the day-ahead to real-time through the enhanced real-time unit commitment initiative.
4. Though capacity auctions, secure capacity to meet Ontario's future resource adequacy needs transparently and at the lowest cost in the long run.

Over the course of the stakeholder engagement process, the IESO has altered its plans with respect to the incremental capacity market. The IESO had originally planned for an Incremental Capacity Auction (ICA) to take place beginning with the 2024/2025 delivery year.<sup>18,19</sup> In July 2019, the IESO announced that it is halting further work on the high-level design for the ICA. Instead, it will modify its existing demand response (DR) auction to allow participation by non-DR resources, including new capacity and existing resources whose long-term contracts have expired. This modified structure, referred to by the IESO as the Transitional Capacity Auction, is expected to have its first auction in June 2020.<sup>20</sup> The Transitional Capacity Auction is focused on meeting the IESO's capacity needs through imports, DR, generators that are coming off long-term contract, uprates, and energy efficiency, but will not procure new baseload resources.<sup>21</sup>

The IESO's decision to cease development of the ICA creates some uncertainty in the market and creates a greater possibility for future re-contracting of resources. However, Navigant still expects that new capacity needed to maintain reliability requirements and existing capacity that is coming off contract will receive a capacity payment through some market mechanism as opposed to re-contracting. Navigant

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<sup>17</sup> Market Renewal, IESO, accessed December 2019, <http://www.ieso.ca/en/Sector-Participants/Market-Renewal/Overview-of-Market-Renewal>.

<sup>18</sup> An Incremental Capacity Auction is market-based mechanism that would secure incremental capacity to help ensure Ontario's reliability needs are met in a cost-effective manner.

<sup>19</sup> Incremental Capacity Auction Engagement, IESO, accessed December 2019, <http://www.ieso.ca/en/Market-Renewal/Stakeholder-Engagements/Market-Renewal-Incremental-Capacity-Auction>.

<sup>20</sup> Active Engagements – Capacity Auction, IESO, accessed December 2019, <http://www.ieso.ca/en/Sector-Participants/Engagement-Initiatives/Engagements/Capacity-Auction>.

<sup>21</sup> Market Renewal Update, IESO, July 16, 2019, <http://www.ieso.ca/-/media/Files/IESO/Document-Library/engage/ica/2019/MRP-20190716-Communication.pdf?la=en>.

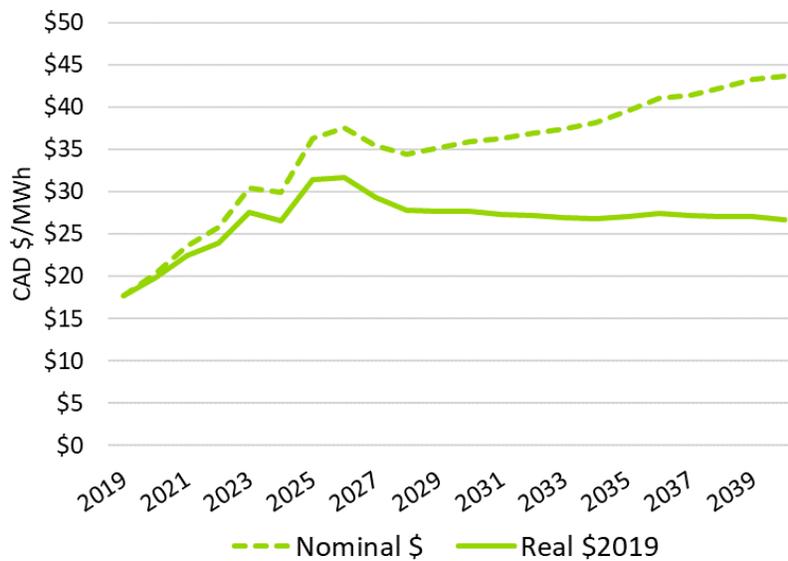
assumes that the Transitional Capacity Auction will gradually evolve over time into a fully organized capacity market.

Given the information released through the IESO’s Market Renewal public stakeholder consultation process, and Navigant’s experience with the IESO-administered market, Navigant also expects a real-time and day-ahead locational marginal price (LMP) market will be implemented by 2022.

### 1.3.2 Energy & Ancillary Services Market Outlook

Market energy prices are currently low due to an oversupply of generation and low natural gas prices. They are forecasted to increase in real-terms through the mid-2020s as nuclear units go offline for refurbishment, natural gas prices rise, and costs increase due to the federal carbon policy. The average all-hours annual energy price forecast for Ontario is shown in Figure 5.

**Figure 5. Annual Average Energy Prices**



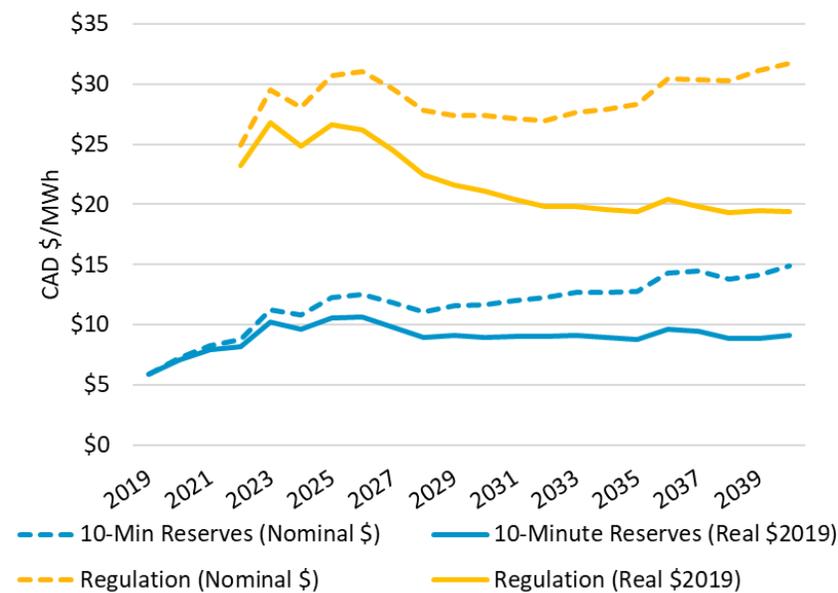
Source: Navigant 2019 Base Case

The energy price forecast assumes the implementation of the federal floor price on carbon, which began in January 2019. The floor price is expected to rise from CAD \$20/tonne in 2019 to CAD \$50/tonne by 2022 (in nominal dollars), after which it increases with inflation for the remainder of the forecast period. The program includes an Output-Based Standard (OBS), which sets an emissions threshold for existing gas plants; however, only emissions over the specified threshold are subject to the carbon price, so there is relatively little impact on energy prices. Energy prices are expected to stabilize in real-terms (and increase in nominal terms due to inflation<sup>22</sup>) in the late-2020s for the remainder of the forecast period as downward pressure from increasing nuclear and renewable generation offset the upward pressure on prices from modestly increasing load and natural gas prices.

<sup>22</sup> Navigant assumes 2.3% annual inflation.

The IESO administers an operating reserve market which ensures that additional supply is available to manage unexpected mismatches between generation and load. There is a premium on 10-minute spinning reserves relative to non-synchronized reserves, which typically benefits fast-responding, grid-connected resources. Although the IESO currently contracts for regulation, Navigant assumes that with the Market Renewal Program the scheduling of regulation is co-optimized with energy and operating reserves to ensure efficient market outcomes, similar to PJM (and other adjacent markets). As shown in Figure 6, both operating reserve and regulation prices tend to track with energy prices.

**Figure 6. Annual Average Operating Reserve & Regulation Prices**



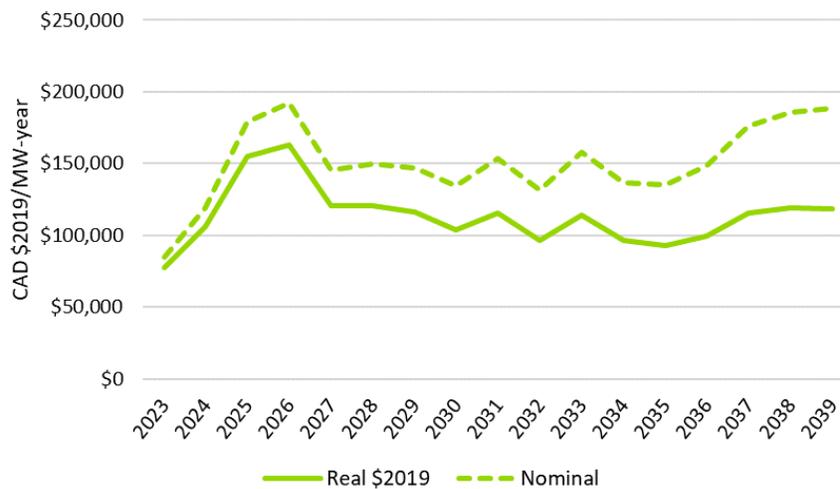
Source: Navigant 2019 Base Case

Thermal units have increased opportunity costs for participating in these markets rather than participating in the energy market. As nuclear capacity comes back online after refurbishment and renewables comprise a higher percentage of total load, there is more gas capacity operating at minimum generation levels. These plants can provide regulation, causing prices to decrease in real-terms in the late-2020s and early-2030s as shown above.

### 1.3.3 Cost of Capacity

One of the key drivers of capacity prices in Ontario is the nuclear refurbishment schedule and the subsequent supply gaps it creates. Contracted nuclear power will not directly participate in the capacity market, but as refurbishment causes nuclear capacity to become unavailable, there are forecasted spikes in the prices as other resources such as DR and imports must be procured to fill supply gaps. Navigant’s capacity price forecast is shown in Figure 7.

**Figure 7. Capacity Price Forecast**



Source: Navigant 2019 Base Case

There are practical limits to the amount of DR that can be used to meet resource adequacy, and neither DR nor long-term reliance on imports address other system needs. Studies have shown that the effective load carrying capability (ELCC) of DR decreases considerably as its percentage of peak demand increases.<sup>23</sup> Even if all existing resources continue to operate post-contract expiry, there will still be a considerable supply gap during the mid-to-late 2020s as shown previously in Figure 3.

The supply gap peaks in the mid-2020s at around 3,500 MW, resulting in a subsequent spike in capacity prices shown above. By the early 2030s, most nuclear retirements and upgrades are expected to be completed, and capacity price begins to stabilize and converge near net Cost of New Entry (CONE)<sup>24</sup> with inflation driving much of the increase in nominal prices. In the later years of the capacity price forecast, the assumed retirement of the 2,100 MW Lennox Generating Station in 2036 and 2037 and the subsequent need for replacement capacity causes prices to once again increase.

<sup>23</sup> Earle, et. al. "Measuring the Capacity Impacts of Demand Response." The Electricity Journal 22(6):47-58. July 2009

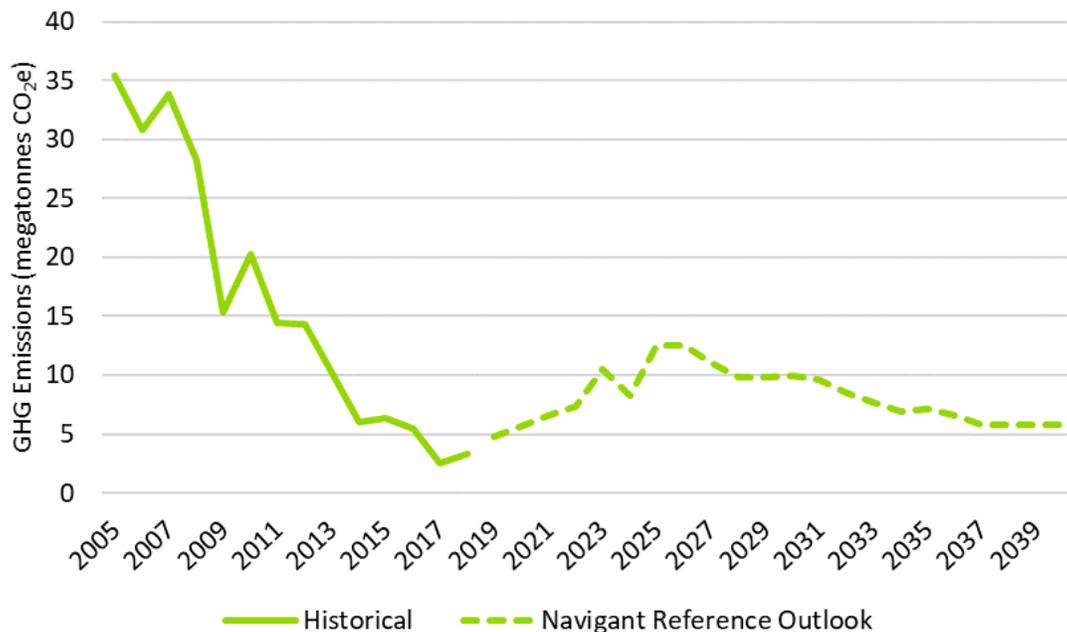
<sup>24</sup> Net CONE referenced here is Navigant’s estimate of the true Net CONE to build capacity in the province and does not assume costs associated with firm gas. It is developed from our assumptions around the CONE less our forecast of energy and ancillary services revenue. This differs from administratively determined Net CONE that is a capacity market parameter and is often much higher. The IESO currently intends to use an administrative Net CONE of approximately \$570/MW-day (single-cycle gas CT with firm gas) for the first transitional capacity auction to take place in June 2020.

## 1.4 Greenhouse Gas Emissions

To transition to a low-carbon economy, the previous Ontario government enacted several environmental policies including the *Green Energy Act* and *Green Economy Act*, which enabled the proliferation of renewable energy facilities in Ontario.<sup>25</sup> The growth in renewable energy and energy conservation, along with the retirement of domestic coal generating units, has resulted in reductions to provincial power sector greenhouse gas emissions by 80% since 2005, along with significant reductions in conventional pollutants such as NO<sub>x</sub>, SO<sub>2</sub>, particulate matter, and unburned hydrocarbons (UHCs). In 2015, carbon emissions from the power sector made up just 4% of Ontario's total emissions.<sup>26</sup>

Figure 8 shows forecasted greenhouse gas (CO<sub>2</sub> equivalent) emissions from the Ontario power sector over time. The CO<sub>2</sub>e emissions forecast profile largely mirrors the nuclear refurbishment schedule, as gas-fired generation increases to compensate for reduced nuclear generation going offline. CO<sub>2</sub>e emissions are projected to rise in the near term as nuclear retirements and refurbishments require Ontario to rely more heavily on its natural gas-fired generation fleet, before stabilizing at around 5-6 megatonnes CO<sub>2</sub>e per year. The extent to which emissions increase will depend on demand growth and how much energy production from natural gas generators is displaced by renewables, and on how much natural gas generation is required to be online to meet reserves requirements.

**Figure 8. Ontario Power Sector CO<sub>2</sub> Emissions**



Source: Historical: IESO 2018 Technical Planning Conference; Forecast: Navigant Base Case

<sup>25</sup> Green Energy and Green Economy Act, 2009, S.O. 2009, c. 12 – Bill 150, <https://www.ontario.ca/laws/statute/s09012>.

<sup>26</sup> Ontario Planning Outlook, IESO, September 1, 2016, <http://www.ieso.ca/-/media/Files/IESO/Document-Library/planning-forecasts/Ontario-Planning-Outlook/Ontario-Planning-Outlook-September2016.pdf?la=en>.

## 2. METHODOLOGY

This chapter describes Navigant's approach to calculating the proposed project's impacts, our modeling methodology and major assumptions, and the design of the five alternative market scenarios.

### 2.1 Approach Summary

The Navigant team completed a rigorous economic analysis using Navigant's PROMOD simulation of the Ontario electricity market, calculating the system, ratepayer, and CO<sub>2</sub> emissions impacts of the project by running simulations with and without the project. PROMOD is an industry-standard, detailed energy production cost model that simulates hourly chronological operation of generation and transmission resources on a nodal basis in wholesale electric markets.

Additionally, the team used Navigant's proprietary Electric Valuation Model (EVM) to calculate the avoided cost of operating reserve and regulation procurement to the IESO. EVM represents the project's capabilities in greater detail and dispatches it against energy, operating reserve, and regulation prices to develop estimates of hourly operation. More information about Navigant's models may be found in Appendix A.

Using these tools, the Navigant team considered the following potential benefits of the proposed project:

- Providing energy arbitrage (pumping during low priced periods, generating during high priced periods)
- Reducing market volatility and overall IESO energy costs
- Providing firm capacity to Ontario (based on an assumption of ICA qualified capacity) and capacity avoided costs
- Providing operating reserves and regulation services
- Reducing surplus baseload generation and CO<sub>2</sub> emissions

After modeling the operation of the project and its market revenues, the Navigant team calculated project impacts as gross financial values. The team then calculated net financial values after accounting for project costs provided by TC Energy. Results of the analysis are aggregated into overall gross and net ratepayer values for the Base Case and five alternative market scenarios in Chapter 3.2. Navigant also performed a brief comparison of the value of pumped storage technology to other resource alternatives, described in Chapter 3.3.

The following sub-sections provide further detail on modeling the Base Case, calibrating Navigant's model, developing the alternative scenarios, and the proposed project costs.

## 2.2 Base Case Development

Navigant developed the Base Case that represents our view of the most likely evolution of the Ontario power system over the next 40 years. The Base Case relies on the Navigant team's subject matter experts who have specific knowledge and understanding of several fundamental power market characteristics, such as fuel pricing, generation development, asset operation, environmental regulations, and technology deployment. This case also utilizes publicly available data and forecasts from the IESO. The project is evaluated over a 40-year study period beginning in 2027, the project's expected commercial operation date.

Key modeling assumptions for the Base Case include:

- Peak demand will remain relatively flat through the late 2020s before increasing gradually at a 0.5% compound annual growth rate (CAGR) through 2040.
- There will be a supply gap of 2,000 to 3,000 MW during the mid-to-late 2020s and beyond, even as all existing resources continue to operate after their contracts expire.
- More than 3,000 MW of capacity at Pickering Generating Station will retire in the mid-2020s, and at its peak, more than 3,300 MW of nuclear capacity will be offline for refurbishment.
- Surplus Baseload Generation (SBG), a condition that occurs when electricity production from baseload and intermittent resources exceeds Ontario's demand, will persist into the late-2020s and 2030s, though at lower levels than today.
- Regulation requirements for the IESO triple (from +/- 100 MW to +/- 300 MW) by the early 2020s.
- IESO administers market changes as part of the Market Renewal public stakeholder consultation process, including switching to a single-schedule structure with locational marginal prices, adding a day-ahead energy market, and implementing a transitional capacity auction that gradually evolves into a full organized capacity market.

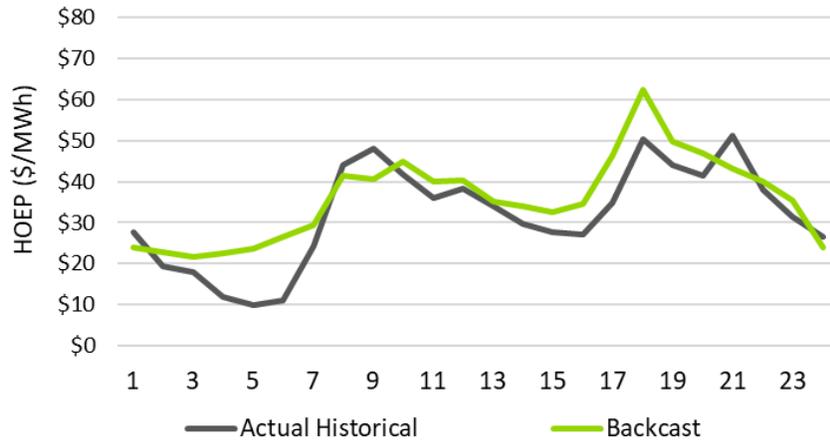
These assumptions were incorporated into the previous chapter to represent Navigant's view of the power system and the IESO market conditions in which the proposed project would operate.

## 2.3 Model Calibration

To verify that the Ontario power system was being accurately modeled, Navigant performed a 2018 "backcast" on the Base Case to compare results with the actual historical operation of the Ontario power system in that year. The process of calibrating the model included accurately representing Ontario's operating reserve needs, benchmarking trading friction with neighboring regions, and fine-tuning unit characteristics. The backcast also accounted for actual historical nuclear outage schedules, renewable capacity factors, renewable generation shapes, and zonal load.

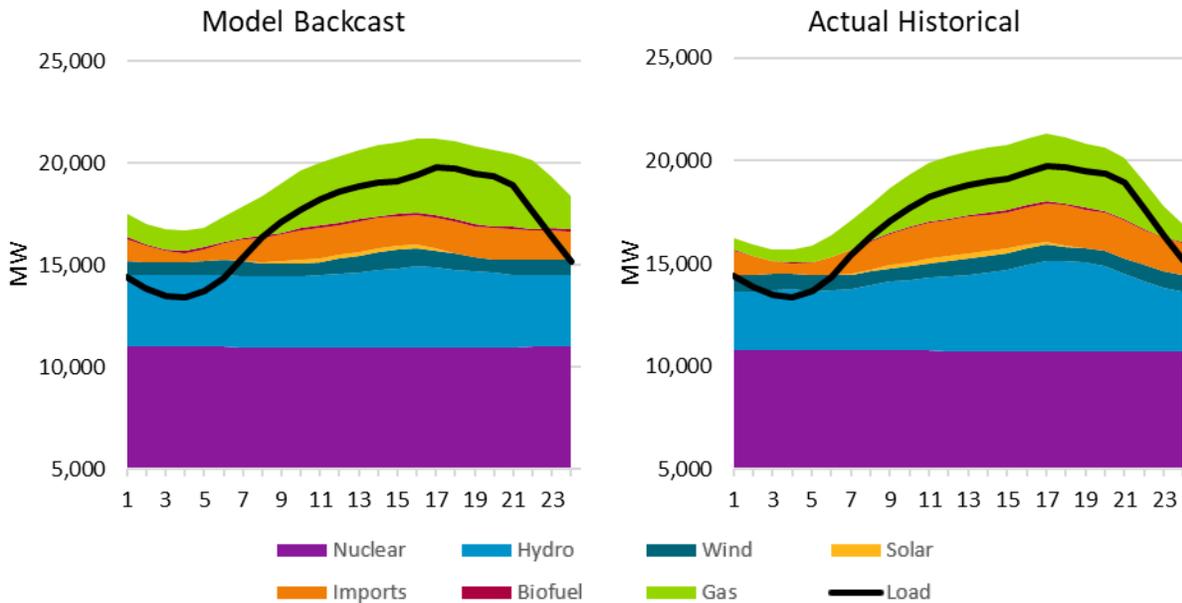
Navigant considered the model to be appropriately benchmarked once hourly energy price profiles, generation by fuel type, total interchange, and surplus baseload generation conditions were largely consistent with actual 2018 operation. Figure 9 and Figure 10 show that the model backcast aligns well with actual historical data, verifying the model accurately captures Ontario's power system dynamics.

**Figure 9. Average Hourly Energy Price – January 2018**



*Navigant 2019 Base Case Backcast*

**Figure 10. Average Hourly Generation Profiles – August 2018**



*Navigant 2019 Base Case Backcast*

## 2.4 Scenario Development

Navigant performed a scenario analysis for five alternate Ontario electricity system scenarios to investigate the impact of various market outlooks (demand growth, gas prices, environmental policy, technology costs, and nuclear refurbishment) on the value of the project. The team evaluated the following five cases:

- **Booming Economy:** A strong economy and electrification drive increased load and incremental supply. This demand outlook assumes peak demand grows at a 1.4% CAGR through 2040. In the absence of a strong carbon price and a more gradual decline in renewable costs, it is more economic to build gas capacity to meet supply gaps, although more renewables and storage are added relative to the Base Case. Increased natural gas demand and lower supply causes natural gas prices to increase.
- **Clean Grid:** Efforts to decarbonize the economy result in greater electrification and subsequently higher demand, with peak demand growing at a 1.4% CAGR through 2040. Lower costs for renewables and storage along with a strong carbon price tied to the NYISO social cost of carbon result in a much larger build-out of renewables and storage to meet higher energy and peak demand. Some of the older and less efficient gas capacity that comes off contract also retires.
- **Challenging Supply:** The absence of new conservation programs causes peak demand to increase at a 0.8% CAGR through 2040. Due to issues with nuclear refurbishment projects, several are cancelled resulting in the retirement of an additional 2,400 MW nuclear capacity, increasing the supply gap. To fill the supply gap, it is more economic to build gas capacity; however, some renewables and storage are added relative to the Base Case. Like the Booming Economy Case, increased natural gas demand and lower supply causes natural gas prices to increase.
- **Low Net Demand:** The Ontario market experiences lower than expected load growth, caused by industrial economic restructuring and a faster transition to a service-oriented economy. In this demand outlook, peak demand decreases through the early 2030s, dropping 5% below 2019 levels by 2032. Demand rebounds in the second half of the forecast at a CAGR of 0.4% through 2040. There is a lesser need to add new resources throughout the forecast, assuming all resources are available post-contract expiration.
- **No Market:** The IESO does not move forward with an incremental capacity market, and all capacity is re-contracted after current contracts expire. The IESO also continues to re-contract for regulation service instead of transitioning to a market-based co-optimization with energy and operating reserves. Energy price suppression impacts of the project are not considered a benefit to ratepayers in this case.

## 2.5 Project Costs

The Navigant team used project costs provided by TC Energy to calculate net project values. The project is estimated to cost \$3.3 billion (in nominal dollars) in total, with most costs incurred between 2022 and 2026 associated with construction and a new transmission line to connect the project to the grid. For the purpose of calculating the net benefits to Ontario ratepayers for this study, the costs for the project are defined based on a regulated rate cost of service structure consistent with the Ontario Energy Board 2020 Cost of Capital Parameters, and with an equity thickness of 50%.<sup>27</sup> Including financing costs, the estimated capital cost results in a 40-year cost of service toll starting at \$357 million in the first year and

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<sup>27</sup> Final rate determination for this project is assumed to result from an Ontario Energy Board hearing process that would consider cost and risk allocation and then-current cost of capital and debt assumptions.

declining over time with regulatory depreciation. This revenue requirement includes administration, operating and maintenance costs which are estimated to be \$22 million per year escalating at inflation.

The project is expected to register with the Ontario Ministry of Finance and pay taxes and charges on the gross project revenue to the Minister of Finance and Ontario Electricity Financial Corporation. Similarly, the project is expected to pay water rental rates under the Dominion Water Power Act to Crown Indigenous and Northern Affairs Canada (CIRNA) based upon the horsepower-year of electrical output and the annual load factor. Neither of these charges have been delineated in this study. They do not change the overall net project benefit but rather simply represent a re-allocation of some of the net ratepayer benefit to provincial taxpayers (in the case of the gross revenue charge) and to the Federal Government (CIRNA) through the water rental rates.

In a similar matter, demand charges and energy charges have not been included in the toll. Demand charges do not change the overall net project benefit, but rather represent a reallocation of demand charges between loads all within the Global Adjustment. The project will pay for energy during charging and receive revenues when generating, but it has been assumed that these would represent flow-through amounts. Generation revenues are expected to be in excess of the charging costs, and it is assumed that these net revenues will flow through to ratepayers, as modified by impacts of Global Adjustment charges. Table 3 shows the financial assumptions used to develop the cost estimate.

**Table 3. Project Financial Assumptions**

Financial Parameter	Assumption
Project Lifespan (years)	40
Project Size (MW)	1,000
Overnight Cost (\$/kW)	3,300/kW (including transmission)
Statutory Tax Rate (%)	25%
Regulatory Return on Equity (%)	8.52%
Regulatory Cost of Debt (%)	3.21%
Equity Thickness (%)	50%
Total Rate Base (\$Millions)	\$3,767 million at COD in 2027
Annual A&G + O&M Expenses	\$22mm/year (\$2027) escalating at inflation
Power Expenses	Wholesale costs only for pumping
Provincial Gross Revenue Tax	No taxes on water use
Water rental rates under Dominion Water Power Act	No rental charges on water use
Energy / Demand Charges	Not included in toll
<b>Year 1 Cost of Service Toll inclusive of A&amp;G, O&amp;M (\$/kW)</b>	<b>\$357</b>

### 3. KEY FINDINGS

#### 3.1 Base Case Project Impacts

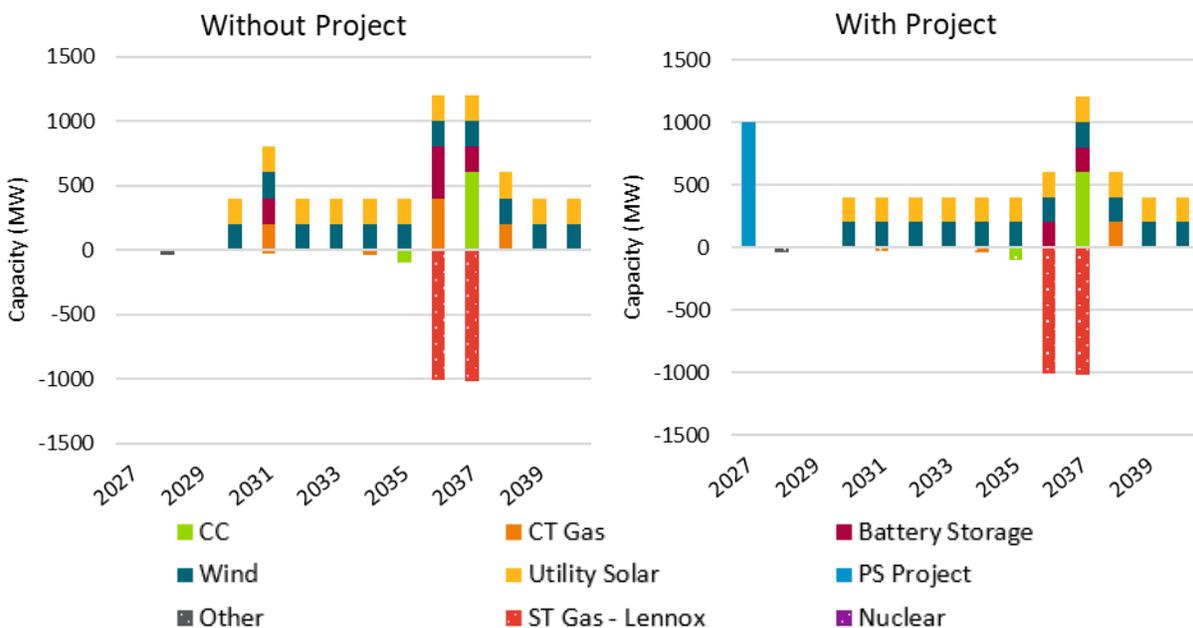
Navigant evaluated the impacts of the proposed project on the Ontario power system and on ratepayer costs and CO<sub>2</sub> emissions by running the Base Case electricity market simulation with and without the project, as described in the previous chapter. The results of Navigant’s analysis show how the project can both reduce CO<sub>2</sub> emissions and lower system costs in the Base Case scenario. The results are presented as gross benefits in this section.

##### 3.1.1 Capacity Avoided Costs

Even if all existing generation resources continue to operate post-contract expiration, there will still be a capacity supply gap during the mid-to-late 2020s. Either new capacity build-out or short-term alternatives, such as DR or imports, or the deferral of the Pickering nuclear unit retirements, will be needed to meet reliability requirements during this period.

Figure 11 shows the power system capacity build-out (excluding nuclear refurbishments, DR, and imports), with and without the project. If the project is completed as planned in 2027, Navigant assumes that 1,000 MW less generic capacity will be built in subsequent years. For the purposes of this study, the generic capacity is represented as 600 MW of simple cycle natural gas-fired combustion turbines and 400 MW of 4-hour battery storage.

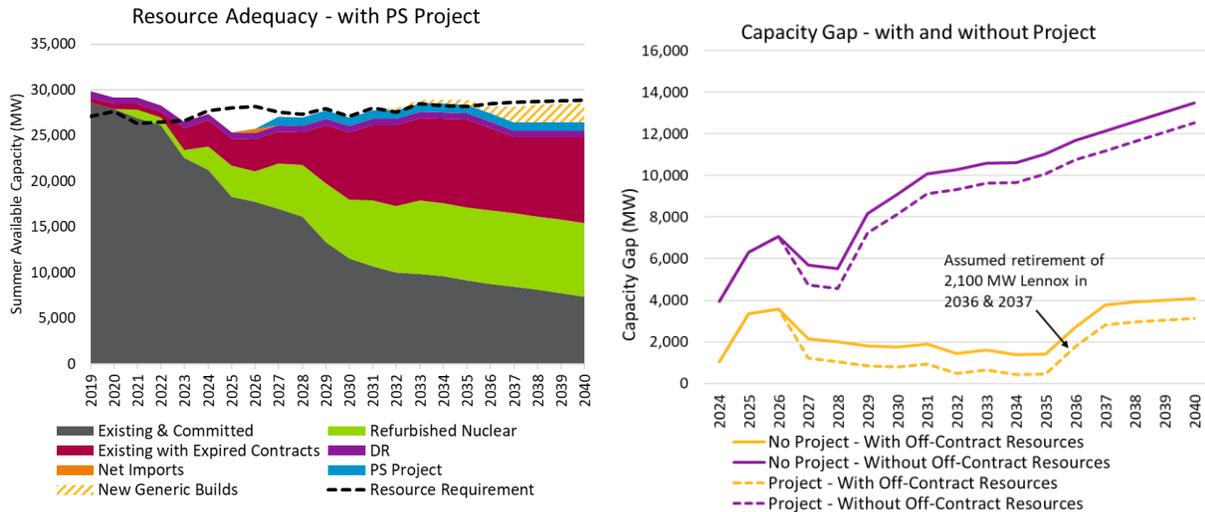
Figure 11. Incremental Capacity Additions & Retirements – Base Case



Source: Navigant

The proposed project would close the supply gap in the late 2020s, decreasing the need to procure short-term alternatives and delaying the need for other new capacity build-out in the long-term, as shown in Figure 12.

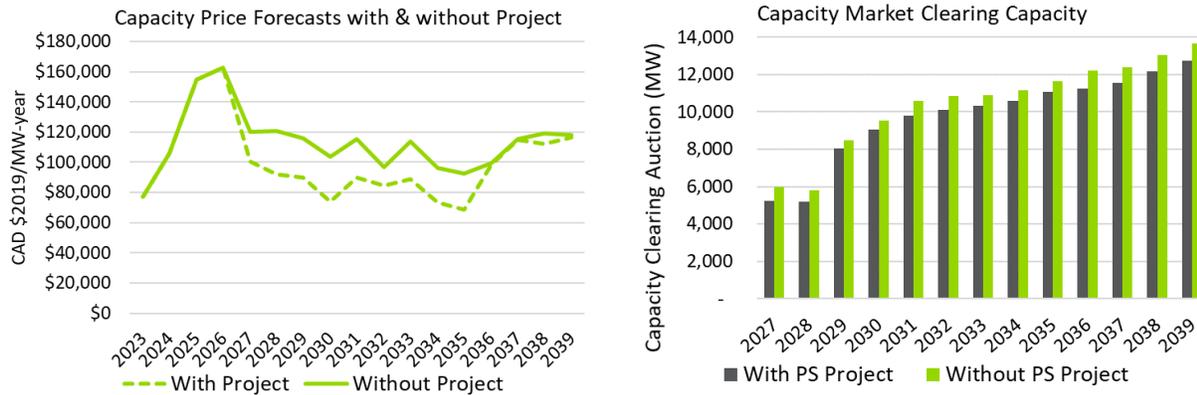
**Figure 12. Capacity Gap Plot – Base Case**



Source: Navigant

Adding the proposed project's capacity has the effect of lowering capacity prices, as shown in Figure 13. The amount of MW that clear the market with and without the project is also shown in this figure. This includes short term resources such as DR and imports, and capacity coming off-contract and new build-outs needed to meet reliability requirements.

**Figure 13. Capacity Price Forecasts and Market Clearing Capacity – Base Case**



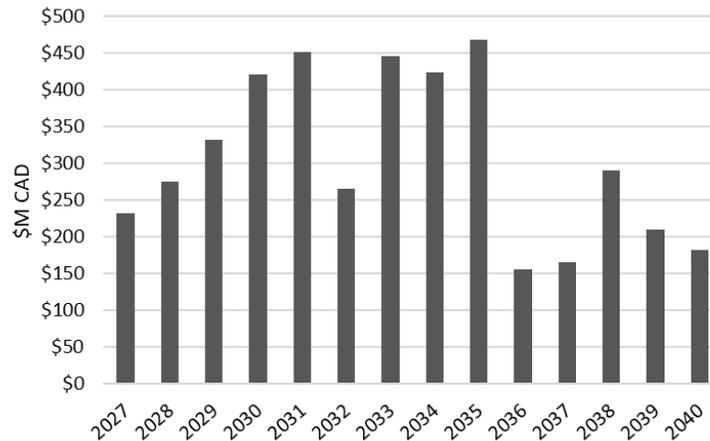
Source: Navigant

Figure 14 below shows the avoided capacity costs that result from both a need to procure less capacity at the market prices and the market price suppression impacts of the project. The market clearing price of capacity is paid to all incremental capacity that clears the market, so the total capacity payment to generators is equal to the product of the clearing price and the amount of capacity clearing the market. The gross avoided capacity costs shown in Figure 14 are calculated using the values shown in Figure 13:

*Gross Avoided Capacity Cost*

$$= (\text{Capacity Price Without Project} \times \text{Market Clearing Capacity Without Project}) - (\text{Capacity Price With Project} \times \text{Market Clearing Capacity With Project})$$

**Figure 14. Gross Avoided Capacity Costs – Base Case**



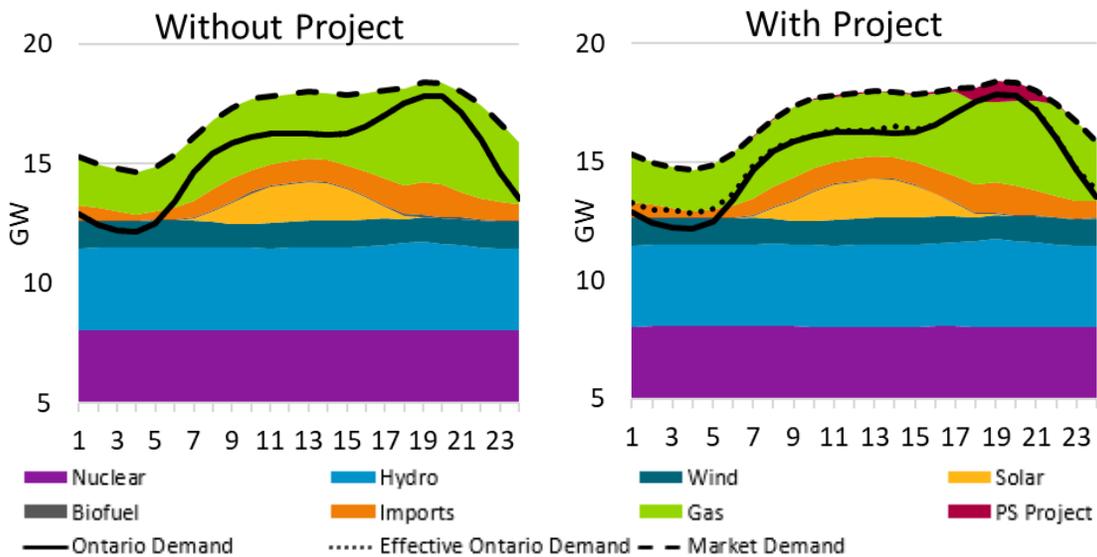
Source: Navigant

While the avoided capacity cost benefits vary from year to year, they are generally higher in the first 9 years of the forecast due to the capacity price suppression impacts of the project. In the long-run, reserve margins with and without the project converge as new capacity must be built for reliability purposes, eliminating the price suppression benefit. Although the capacity prices converge, there are still avoided capacity costs through 2040, as less capacity is needed if the proposed project is built.

### 3.1.2 Energy Cost Reduction

Pumped storage facilities generally draw power for pumping in low price periods and then use that energy to reduce the amount of generation needed from higher cost resources during peak times. This has the effect of reducing energy prices in peak hours, which subsequently decreases energy payments to generators and reduces ratepayer costs. To illustrate this effect, Figure 15 below shows the Base Case daily average generation profiles with and without the project for September 2029.

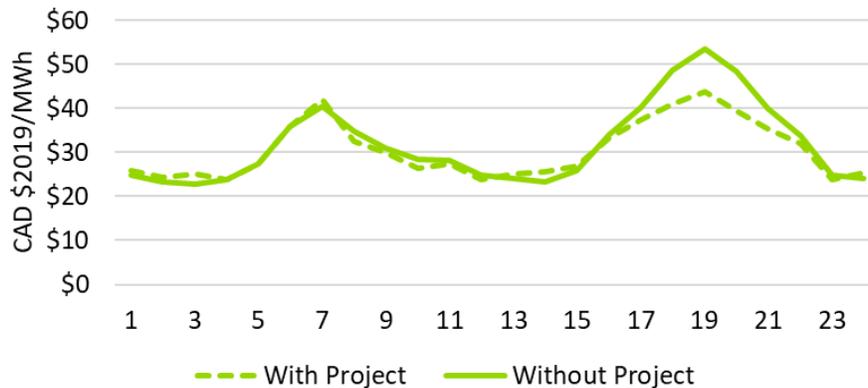
**Figure 15. Average September 2029 Daily Generation Profiles – Base Case**



Source: Navigant

Under this dispatch schedule, the project suppresses evening prices. The average daily energy price impacts of the project in September 2029 are shown in Figure 16.

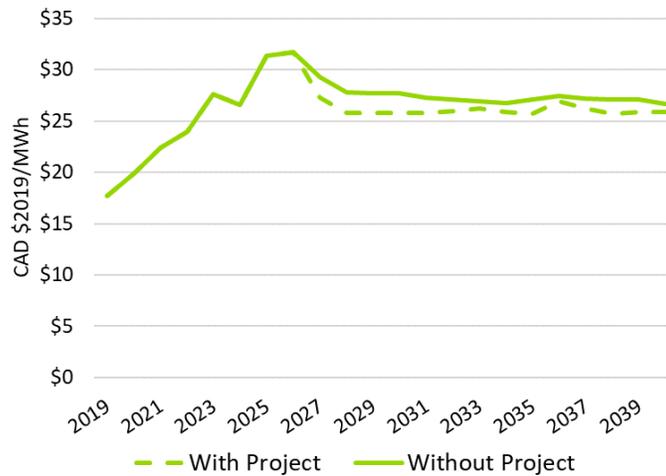
**Figure 16. Average September 2029 Daily Energy Price Suppression – Base Case**



Source: Navigant

The amount of price suppression on any given day depends on the operating costs of the marginal generating units which are displaced by the project. During times the project is pumping and adding load to the system, energy prices typically increase slightly; however, this depends on the energy mix during those hours. The energy price suppression impacts of the project on an annual basis for the Base Case are shown in Figure 17.

**Figure 17. Energy Price Suppression of the Project**



Source: Navigant

The project also reduces energy costs by facilitating more efficient operation of Ontario’s natural gas fleet. The project provides operating reserve with excess capacity when it is generating or the ability to turn down its pumps quickly when it is in pumping mode. By providing quick-start operating reserves, less gas generation needs to be online at inefficient minimum generation levels to meet spinning reserve requirements. A summary of annual generation and pumping for the project is provided in Table 4.

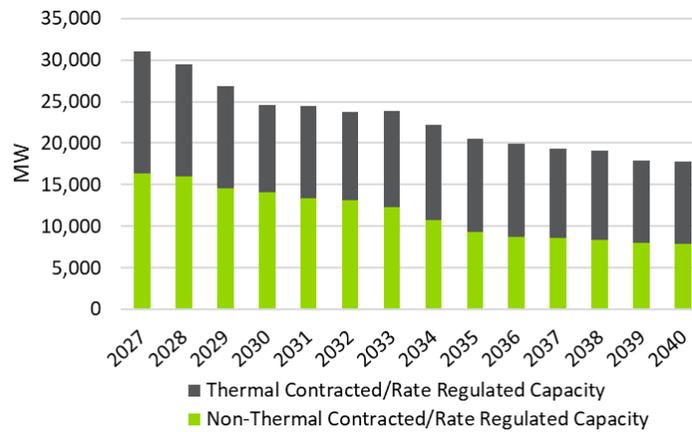
**Table 4. PROMOD Project Dispatch Summary**

Year	Generation (GWh)	Pumping (GWh)	Year	Generation (GWh)	Pumping (GWh)
2027	1,290	1,788	2034	1,526	2,116
2028	1,349	1,870	2035	1,553	2,153
2029	1,319	1,829	2036	1,570	2,176
2030	1,422	1,971	2037	1,547	2,144
2031	1,360	1,886	2038	1,553	2,153
2032	1,446	2,004	2039	1,574	2,182
2033	1,501	2,081	2040	1,627	2,256

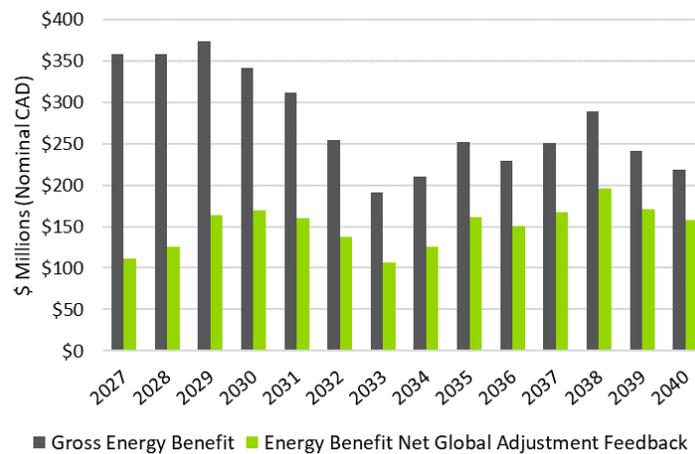
To calculate overall avoided energy costs for ratepayers, the Navigant team had to account for Ontario’s unique hybrid electricity market structure. Under the hybrid market structure, generation supply costs are recovered from electricity ratepayers through two mechanisms: the IESO-administered market in the form of the Hourly Ontario Electricity Price (HOEP) and the Global Adjustment. The Global Adjustment is

Ontario’s mechanism through which the out-of-market costs for 1) generation under contract or regulation, 2) CDM programs, and 3) other IESO initiatives are passed through to electricity ratepayers. Any revenue shortfalls from the IESO-administered market are wholly or partially compensated by increases in payments to these generators by the IESO and recovered through the Global Adjustment. Thus, the savings to the ratepayer in energy market costs that might be achieved through the implementation of the proposed project are partially offset by compensation paid to generators out of the Global Adjustment (global adjustment feedback). The offset is not 100%, and it decreases over time as the amount of contracted generation in Ontario declines as contracts end, shown below in Figure 18. The results for gross avoided energy costs, including the effects of the global adjustment feedback, are shown in Figure 19.

**Figure 18. IESO Rate Regulated & Contracted Capacity**



**Figure 19. Avoided Energy Costs (\$M) – Base Case**



Source: Navigant

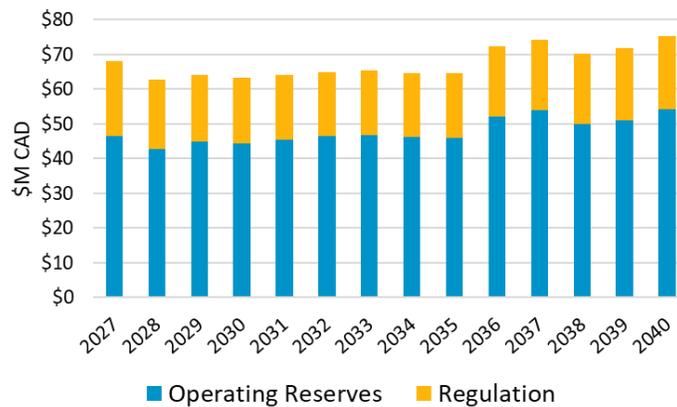
As shown, the gross energy benefit is highest for the first five years the project is online. During this time, Ontario will rely more heavily on its natural gas fleet as considerable nuclear capacity is still offline for refurbishment, causing less efficient, higher-cost resources to set the market energy price in peak hours.

The project can therefore displace the higher-cost gas-fired generation, suppressing prices and reducing ratepayer costs. As nuclear units come back online from refurbishment, gross energy benefits decrease; however, net benefits remain largely constant. This is due to the decreasing global adjustment feedback as more resources come off-contract and participate in the market as merchant generators.

### 3.1.3 Operating Reserves & Regulation Avoided Costs

To calculate the avoided cost of operating reserve and regulation procurement for the IESO, the project dispatch was simulated with Navigant’s proprietary Electric Valuation Model (EVM). EVM represents the project’s capabilities in greater detail and dispatches it against the energy, operating reserve, and regulation prices previously discussed in Chapter 1.3. This project is assumed to provide 500 MW of the IESO’s operating reserve needs and 100 MW of the IESO’s anticipated regulation needs due to the flexibility of the generation and the variable speed pumps. Results are shown in Figure 20.

**Figure 20. Operating Reserves & Regulation Avoided Costs – Base Case**



Source: Navigant

Over the life of the project, the EVM simulation shows that the project provides operating reserves and/or regulation services in approximately 85% of hours, resulting in average annual avoided costs between \$60-\$75M CAD. A summary of the project’s ancillary service dispatch is shown below in Table 5.

**Table 5. EVM Ancillary Service Project Dispatch Details**

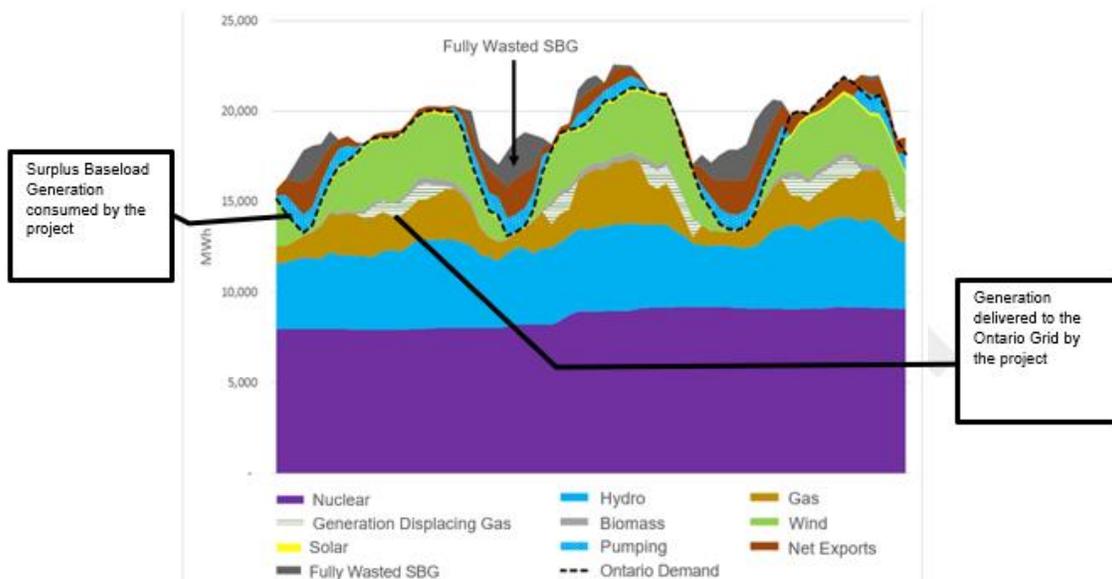
Year	Total Regulation Provided (MWh)	Total 10-Minute Reserves Provided (MWh)	Year	Total Regulation Provided (MWh)	Total 10-Minute Reserves Provided (MWh)
2027	690,149	3,858,431	2034	578,565	3,576,900
2028	661,495	3,826,982	2035	575,696	3,579,355
2029	647,758	3,790,953	2036	588,050	3,598,779
2030	629,018	3,744,389	2037	597,159	3,619,077
2031	623,756	3,707,752	2038	582,056	3,585,910
2032	604,558	3,730,021	2039	584,212	3,566,479
2033	589,396	3,639,066	2040	575,667	3,569,885

### 3.1.4 Environmental Benefits

The same operating pattern for the proposed project that results in IESO avoided costs also reduces CO<sub>2</sub> emissions. Annual average CO<sub>2</sub> emissions reductions are estimated at 490,000 tonnes, if the project focuses on flexible operation (optimizing operability) and minimizing ratepayer costs. This is equivalent to removing more than 150,000 cars from the road.<sup>28</sup>

During low price periods in Ontario, when the project will use electricity to pump water, the marginal generating units are often zero-carbon nuclear, hydro, or renewable resources (depending on the time of day and year). During these times, the province is typically either exporting this zero-carbon energy at a low price or curtailing (or maneuvering) the generating units, contributing to SBG and losing the CO<sub>2</sub> emissions benefits. The project would instead store this zero-carbon energy via pumped storage (reducing SBG) and use it during peak times when marginal gas units would otherwise operate and emit CO<sub>2</sub>, as illustrated in Figure 21.

**Figure 21. Ontario System Operation Over 72 hours with Project – Base Case**



Source: Navigant

The IESO's estimation of SBG assuming flat load growth is provided in Table 6. For 2029, Navigant determined SBG based on the PROMOD simulation without the project and it was consistent with the IESO's 2029 forecast. The PROMOD simulation with the project showed that roughly 33% of that SBG could be mitigated by the project. Based on the IESO's annual SBG forecast and assuming the project can reduce 33% of SBG in the other years as well, SBG reductions for the project are estimated to average around 0.5 TWh per year as shown in Table 6. This is comparable to the annual net energy consumed by the project due to efficiency losses. If the project was operated to maximize environmental

<sup>28</sup> Assuming a standard 2016 model sedan in Ontario driven 15,000 km/year. Vehicle Emission Comparison Tool v. 1-1-5, Natural Resources Canada, July 2016, <https://www.nrcan.gc.ca/energy/vehicle-emission-comparison-tool/18907>.

benefits rather than optimize system flexibility and ratepayer benefit, the project could reduce SBG by approximately 50%.

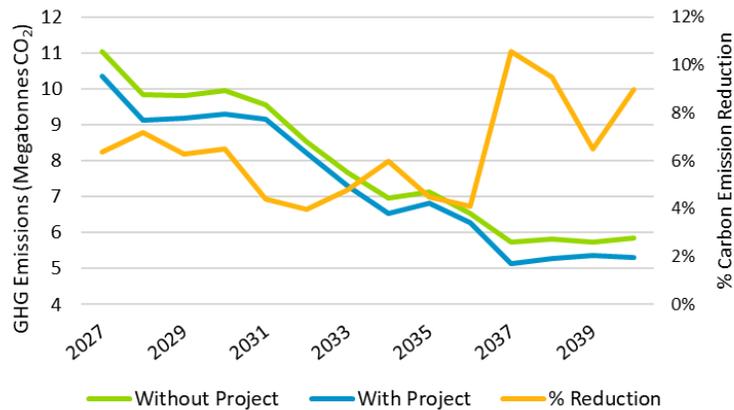
**Table 6. Ontario Forecast SBG and Project SBG Reductions**

Year	IESO SBG Forecast (TWh)	Estimated SBG Reductions from Project Optimized for System Flexibility (TWh)	Estimated SBG Reductions from Project Optimized for Environmental Benefits (TWh)
2027	1.1	0.4	0.6
2028	1.3	0.4	0.7
2029	1.7	0.5	0.9
2030	1.3	0.4	0.7
2031	0.6	0.2	0.3
2032	1.4	0.5	0.7
2033	1.6	0.5	0.8
2034	2.1	0.7	1.1
2035	1.5	0.5	0.8

Source: IESO 2018 Technical Planning Conference and Navigant Base Case

Figure 22 shows the annual Ontario CO<sub>2</sub> emissions assuming the project is focused on flexible operation and minimum ratepayer costs.

**Figure 22. Annual Ontario Power Sector CO<sub>2</sub> Emissions – Base Case**



Source: Navigant

If the project operates to maximize CO<sub>2</sub> emission reductions within the capability of existing Ontario resources, the annual average CO<sub>2</sub> emission reductions could increase another 100,000 tonnes.<sup>29</sup> If the project is co-operated with off-peak hydro imports from Quebec and used to maximize offsetting of gas generation, annual CO<sub>2</sub> emission reductions from the project could be even higher.

<sup>29</sup> Assuming the additional SBG reductions shown in Table 6 are replacing generation with a 370 tonnes/GWh emission intensity.

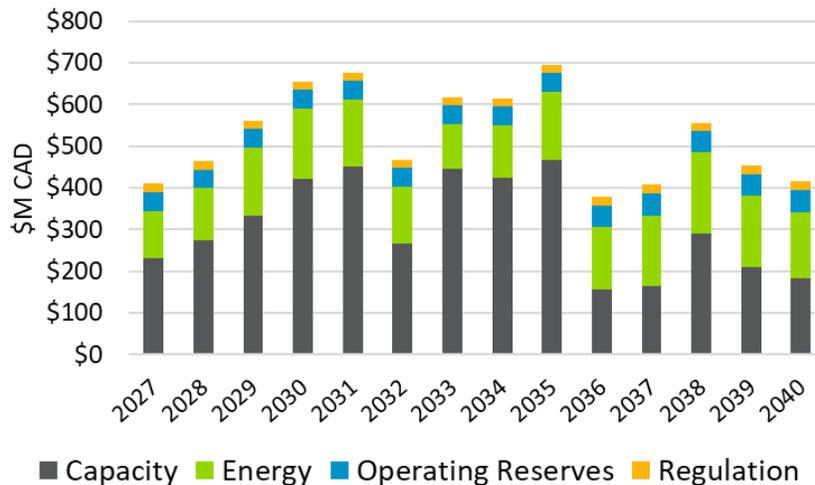
### 3.1.5 Base Case Summary

Results from Navigant’s analysis show that the Base Case project has an overall positive impact on the power system, providing several key benefits to the IESO and Ontario ratepayers, including avoided costs and CO<sub>2</sub> emissions reductions.

The proposed project adds capacity that helps address the forecasted supply gap in the IESO market and reduces energy costs by facilitating the more efficient operation of Ontario’s natural gas fleet. The project would also support the IESO’s flexibility, reliability, and system resiliency needs driven by the transition to a more dynamic power system. The ability of the project to mitigate price spikes during peak periods also contributes to net savings to ratepayers.

Figure 23 shows the annual gross benefits from the project under the Base Case scenario.

**Figure 23. Annual Gross System Benefits – Base Case**



Source: Navigant

Table 7 below summarizes the project’s capabilities and associated gross and net benefits under the Base Case scenario in one view. The total financial net ratepayer benefit of the project over a 40-year lifetime is estimated to be \$12.1B.

**Table 7. Gross and Net Ratepayer Benefits – Base Case**

Benefit	Project Capability	Value to Ontario Ratepayers, 2027 – 2066
Reducing CO <sub>2</sub> Emissions	The project can store excess baseload generation and use it to avoid gas generation during peak times. By providing quick-start operating and flexibility reserves, less gas generation must be online to meet spinning reserve requirements.	Average of 490,000 tonnes per year
Minimizing Costs for Energy	The project can shift energy from low cost off-peak generation (including exports sold or curtailed at a loss to the province) to replace higher cost on-peak generation. This also reduces price spikes and stabilizes prices. By providing quick-start operating reserves, gas plants can also operate more efficiently.	\$13.2B Gross Benefits \$8.5B Net Global Adjustment Feedback <sup>30</sup>
Minimizing Costs for Operating Reserves	The project can provide a large share of system operating reserve requirements.	\$2.6B Gross Benefits
Minimizing Costs for Ancillary Services	The project can provide a large share of system regulation requirements.	\$1.0B Gross Benefits
Providing Flexible Capacity	The project can provide capacity to meet reserve margin requirements and hence avoid the IESO having to procure other capacity.	\$10.9B Gross Benefits
Providing Local Economic Benefits	The project will be built in Ontario using locally-sourced components and local labour.	Locally-sourced materials and equipment Local jobs for construction and operation
Total Gross Benefit		\$23.1B
Project Revenue Requirement		\$11.0B
<b>Total Net Benefit</b>		<b>\$12.1B</b>

While it was not part of Navigant’s technical analysis, the table also includes a high-level view of local economic benefits, since the project would be a large four-year construction project for the Southern Ontario region. Approximately 60% of the total capital cost is planned to utilize local building trades and local materials.

<sup>30</sup> Under the assumption that capacity coming off-contract does not re-contract with the IESO.

## 3.2 Scenario Analysis

Navigant performed a scenario analysis for five alternate Ontario electricity system scenarios to investigate the impacts of demand growth, gas prices, environmental policy, technology costs, and nuclear refurbishment on project simulation results:

1. **Booming Economy Case:** A strong economy and electrification drive increased load and incremental supply.
2. **Clean Grid Case:** More aggressive decarbonization efforts drive additional load from increased electrification and higher carbon emissions prices.
3. **Challenging Supply Case:** The absence of new conservation programs causes peak demand to increase and major disruptions for nuclear refurbishments, resulting in larger supply gaps.
4. **Low Net Demand Case:** Slow growth and industrial economic restructuring drive a decrease in Ontario's electricity peak demand.
5. **No Market Case:** The absence of a competitive electricity market in Ontario.

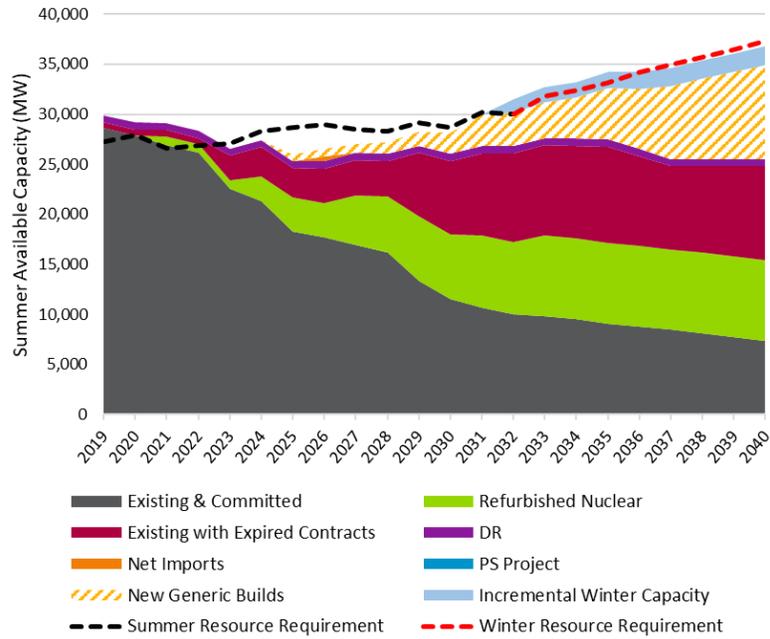
The following sub-sections detail the gross energy, capacity, ancillary service, and environmental benefits of the project under each of these scenarios.

### 3.2.1 Booming Economy Case

In the Booming Economy scenario, a strong economy and electrification drive increased load and incremental supply. This demand outlook assumes peak demand grows at a 1.4% CAGR through 2040. In the absence of a strong carbon price and a more gradual decline in renewable costs, it is more economic to build gas capacity to meet supply gaps, although more renewables and storage are also added relative to the Base Case. Increased natural gas demand and lower supply causes natural gas prices to increase as well. As increased electrification drives higher demand growth under this scenario, Navigant found that the project provides greater cost benefits than the Base Case overall.

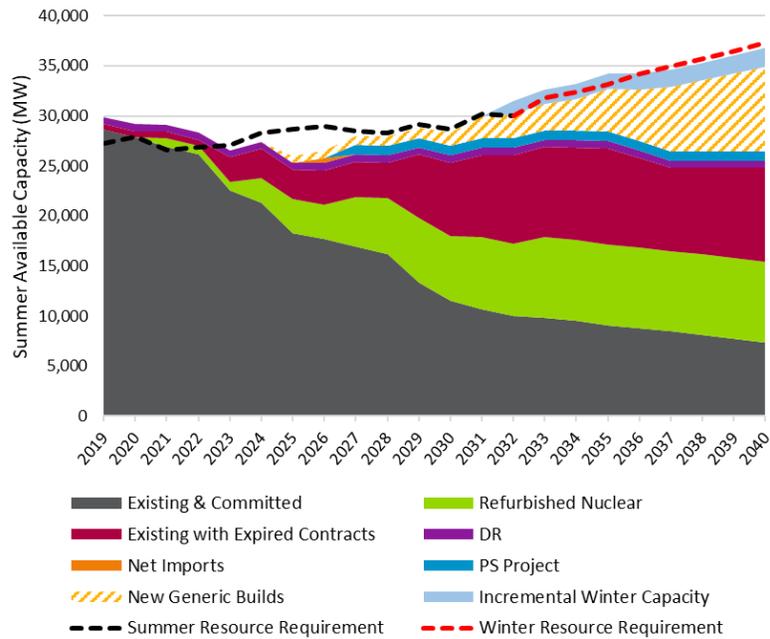
In this case, there is a greater need for new capacity to meet reliability requirements, as demonstrated by the increased generic capacity builds (combination of combined-cycles, simple-cycle CTs and renewables) in Figure 24. Like the Base Case, there will be a supply gap during the mid-to-late 2020s that will require the IESO to procure new capacity or short-term alternatives, such as demand response or imports, to meet reliability requirements during this period. The project would close the supply gap in the late 2020s, decreasing the need to procure other resource alternatives and delaying the need for new capacity in the mid-term, as shown in Figure 25.

**Figure 24. Capacity Gap Plot Without the Project – Booming Economy**



Source: Navigant; DR shown in chart assumes current levels moving forward

**Figure 25. Capacity Gap Plot with the Project – Booming Economy**



Source: Navigant; DR shown in chart assumes current levels moving forward

Because the project would decrease the need to procure other resource alternatives and delay the need for new capacity in the mid-term, it would also have the impact of depressing capacity prices, as shown in Figure 26.

**Figure 26. Capacity Price Forecasts With & Without the Project – Booming Economy**

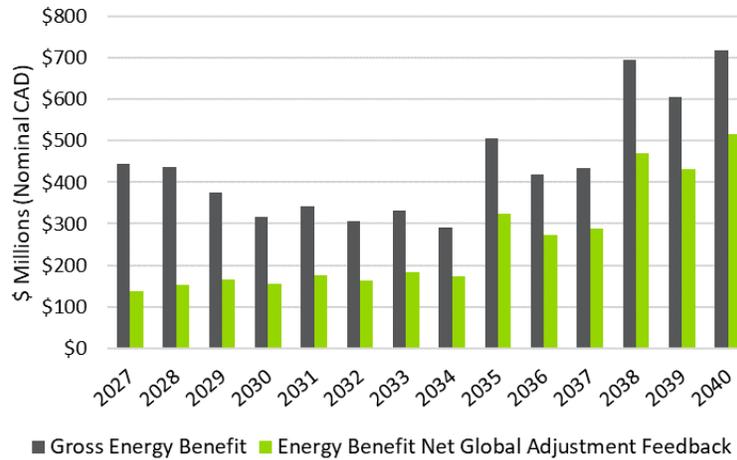


Source: Navigant

Compared to the Base Case, the capacity price suppression is a shorter-term effect and the magnitude is smaller. The effect is shorter-lived because reserve margins in the simulations with the project and without the project converge sooner, as faster demand growth requires new capacity to be built sooner to meet reliability requirements. The magnitude of the price suppression is smaller due to feedback between the energy and capacity markets. The project decreases energy revenues for other plants, causing them to bid higher in capacity markets and eroding some of the avoided capacity costs. Overall, the avoided capacity costs in the Booming Economy Case are approximately 30% lower than in the Base Case.

For energy costs, additional load and higher gas prices result in increased marginal cost of energy during the periods when gas generation is on the margin and increases the difference between on-peak and off-peak prices. Because the project's pumped storage displaces even more costly peak generation in the evening, the energy price suppression impacts are greater than in the Base Case. Relative to the Base Case, this leads to more than double the energy cost benefit (net global adjustment feedback) over the lifetime of the project, shown in Figure 27.

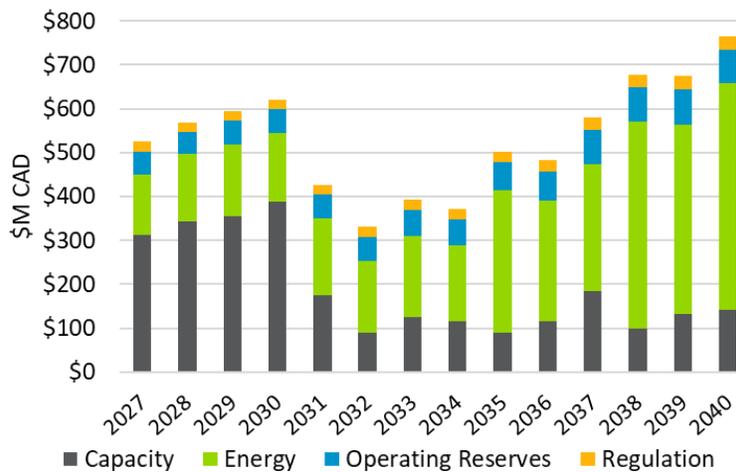
**Figure 27. Avoided Energy Costs (\$M) – Booming Economy**



Source: Navigant

With higher energy prices, the opportunity cost for units providing operating reserves and regulation is higher. This results in nearly 40% higher avoided costs to the IESO for these services from the project as shown in Figure 28.

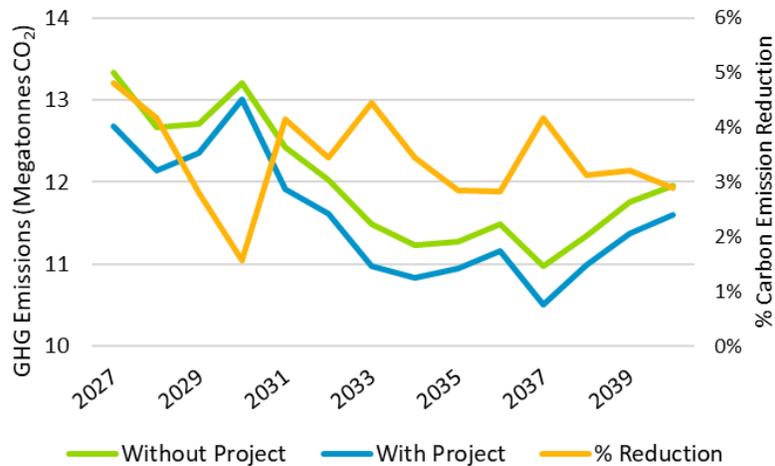
**Figure 28. Annual Gross System Benefits – Booming Economy**



Source: Navigant Booming Economy Case

The same operating pattern that results in reduced IESO costs to procure energy and operating reserve also helps to reduce CO<sub>2</sub> emissions. Compared to the Base Case, the emissions reductions are slightly lower, with an annual average reduction of 410,000 tonnes per year. With higher demand growth, there is less surplus baseload generation to shift from off-peak to on-peak times, eroding some of the environmental benefits of the project. This is somewhat offset, however, by the fact that the on-peak gas generation that the project is displacing in the Booming Economy Case is being produced by less efficient plants. The annual carbon emissions with and without the project are shown in Figure 29.

**Figure 29. Annual Ontario Power Sector CO<sub>2</sub> Emissions – Booming Economy**



Source: Navigant

Overall, Navigant’s analysis of the Booming Economy Case shows that the project has the potential to reduce Ontario electricity system CO<sub>2</sub> emissions by approximately 410,000 tonnes per year on average while providing a net-benefit of \$20.4 billion (nearly 70% higher than in the Base Case) to Ontario ratepayers between 2027 and 2066.

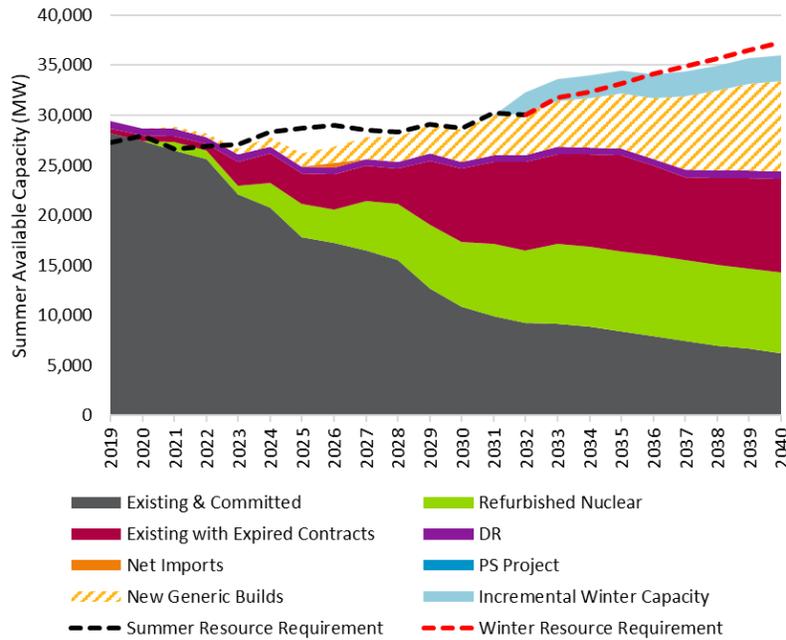
### 3.2.2 Clean Grid Case

In the Clean Grid scenario, efforts to decarbonize the economy result in greater electrification and subsequently higher demand, with peak demand growing at a 1.4% CAGR through 2040. Lower costs for renewables and storage, along with a strong carbon price tied to the NYISO social cost of carbon, result in a much larger build-out of renewables and storage to meet higher energy and peak demand. Some of the older and less efficient gas capacity that comes off contract also retires. If there are aggressive efforts to decarbonize the economy under this scenario, Navigant found that the project would provide the greatest system cost benefits.

In the Clean Grid Case, there is a greater need for new flexible and green capacity to meet reliability requirements, as can be seen by the increased generic capacity builds (combination of primarily battery storage, simple-cycle CTs and renewables) in Figure 30. Like the Base Case, there will be a supply gap during the mid-to-late 2020s that will require the IESO to procure new capacity or short-term alternatives, such as demand response or imports, to meet reliability requirements during this period. The project

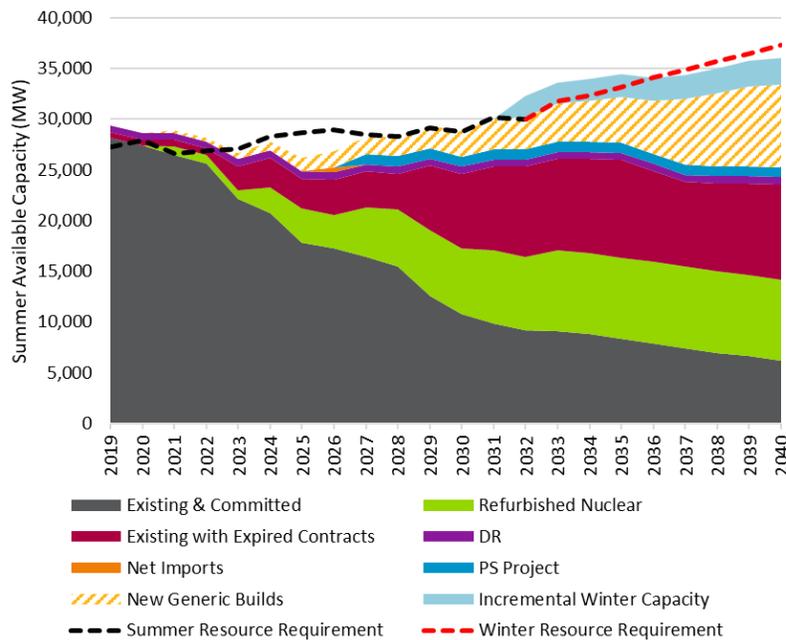
would close the supply gap in the late 2020s, decreasing the need to procure other resource alternatives and delaying the need for new builds in the mid-term as shown in Figure 31.

**Figure 30. Capacity Gap Plot Without the Project – Clean Grid**



Source: Navigant; DR shown in chart assumes current levels moving forward

**Figure 31. Capacity Gap Plot with the Project – Clean Grid**



Source: Navigant; DR shown in chart assumes current levels moving forward

Because the project would close the supply gap in the late 2020s, decreasing the need to procure other resource alternatives and delaying the need for new builds in the mid-term, it would also have the impact of depressing capacity prices as shown in Figure 32.

**Figure 32. Capacity Price Forecasts With & Without the Project – Clean Grid**

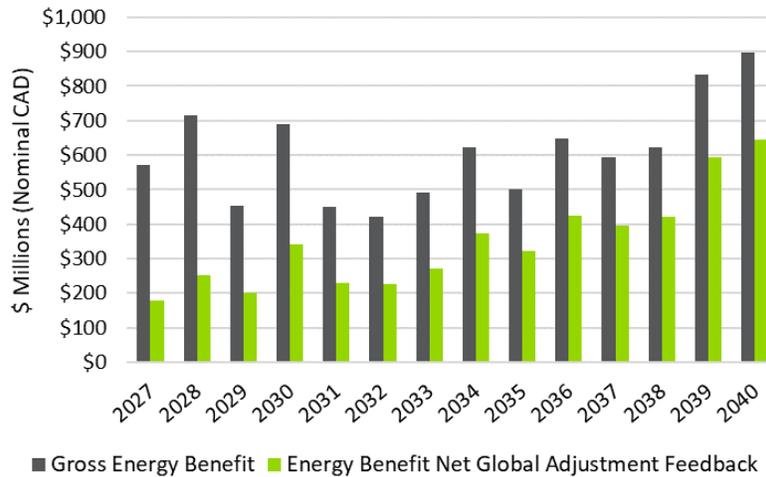


Source: Navigant

Like the Booming Economy Case, the capacity price suppression in the Clean Grid Case does not persist for as long and the magnitude is smaller than in the Base Case. This is because reserve margins between the with project and without project cases converge sooner, as faster demand growth requires new capacity to be built sooner to meet reliability requirements. The magnitude of the price suppression is smaller due to the same feedback between the energy and capacity markets. Overall, capacity prices are slightly higher than those in the Base Case as the markets need to incentivize slightly higher cost battery storage. Since avoided capacity costs result in part from a need to procure less capacity at the market price for capacity, the higher capacity prices lead to greater gross capacity benefits. The overall impact of these dynamics is a gross capacity benefit slightly lower than that in the Base Case

For energy costs, additional load from increased electrification and higher carbon emissions prices result in increased marginal cost of energy during the periods when gas generation is on the margin and increases the difference between on-peak and off-peak prices. Also, increased ramping needs due to more intermittent generation on the system results in peakier prices in the evening. Because the project's pumped storage displaces even more costly peak generation in the evening, the energy suppression impacts are greater than in the Base Case. Relative to the Base Case, this results in 2.5 to 3 times the energy benefits (net global adjustment feedback) over the lifetime of the project, shown in Figure 33.

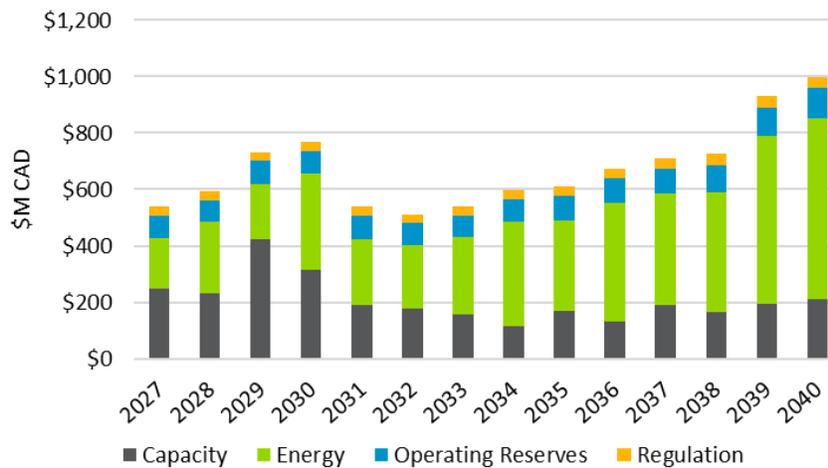
**Figure 33. Avoided Energy Costs (\$M) – Clean Grid**



Source: Navigant

With higher energy prices and increased ancillary service needs, the cost of providing operating reserves and regulation services is higher than in the Base Case. This results in nearly double the avoided costs to the IESO for these services from the project, as shown in Figure 34.

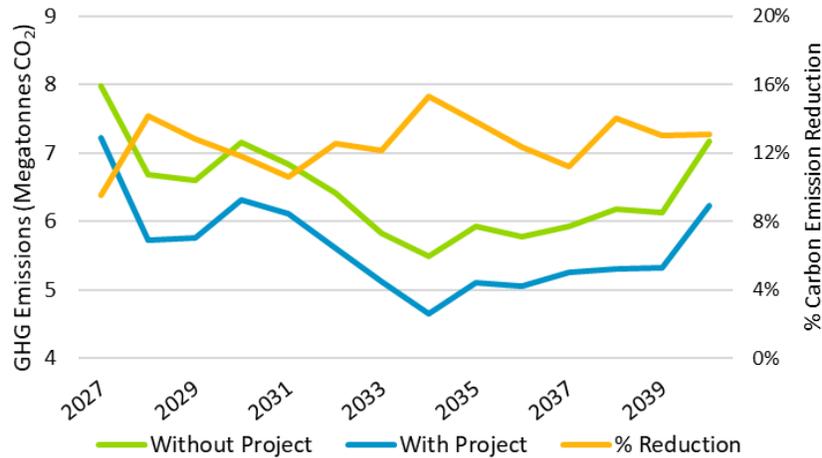
**Figure 34. Annual Gross System Benefits – Clean Grid**



Source: Navigant

The same operating pattern that results in reduced IESO costs to procure energy and operating reserves also helps to reduce CO<sub>2</sub> emissions. The emissions reductions benefits are significantly higher than the Base Case and all other scenarios, with an annual average reduction of 800,000 tonnes per year. With significantly more renewable generation on the system, there is more surplus baseload generation to shift from off-peak to on-peak times, increasing the environmental benefits of the project. The annual carbon emissions with and without the project are shown in Figure 35.

**Figure 35. Annual Ontario Power Sector CO<sub>2</sub> Emissions – Clean Grid**



Source: Navigant

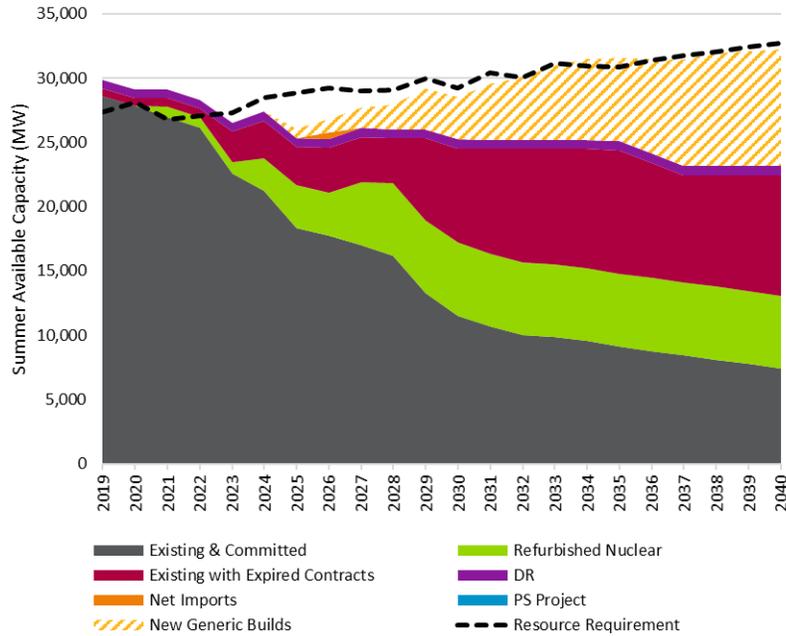
Overall, Navigant’s analysis of the Clean Grid Case shows that the project has the potential to reduce Ontario electricity system CO<sub>2</sub> emissions by approximately 800,000 tonnes per year on average, while providing a net-benefit of \$30 billion to Ontario ratepayers between 2027 and 2066 (nearly 2.5 times that in the Base Case).

### 3.2.3 Challenging Supply Case

In the Challenging Supply scenario, the absence of new conservation programs causes peak demand to increase at a 0.8% CAGR through 2040. Due to issues with preceding nuclear refurbishments, several are cancelled resulting in the retirement of nearly 2,400 MW more nuclear capacity, increasing the supply gap. To fill the supply gap, it is more economic to build gas capacity, however, some renewables and storage are added relative to the Base Case. Like the Booming Economy Case, increased natural gas demand and lower supply causes natural gas prices to increase. If the absence of new conservation programs causes peak demand to increase and major disruptions with preceding nuclear refurbishments result in larger supply gaps, Navigant found that the project would provide greater system cost benefits than the Base Case.

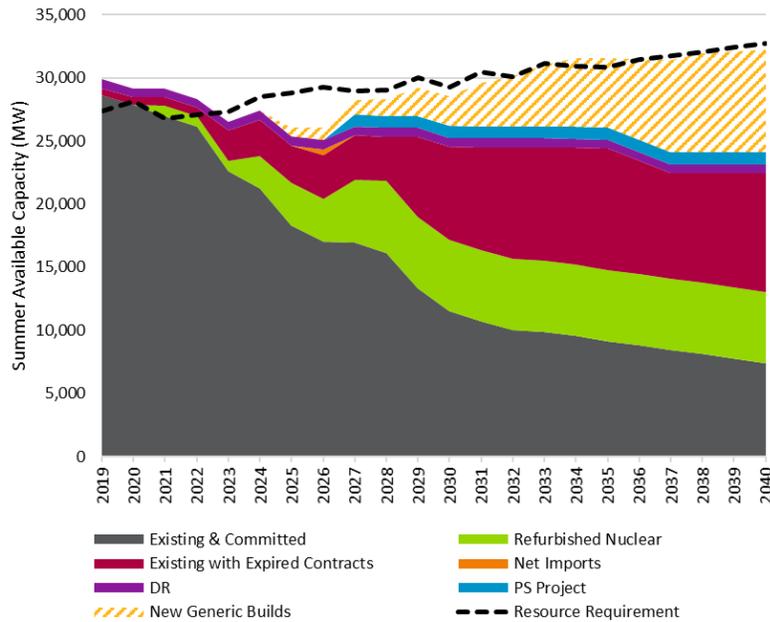
In this case, there is a greater need for new capacity to meet reliability requirements due to the assumption that several nuclear refurbishments are cancelled. The greater need for new capacity and energy can be seen by the increased generic capacity builds (combination of combined-cycles, simple-cycle CTs and renewables) in Figure 36. Like the Base Case, there will be a supply gap during the mid-to-late 2020s that will require the IESO to procure new capacity or short-term alternatives, such as demand response or imports, to meet reliability requirements during this period. The project would close the supply gap in the late 2020s, decreasing the need to procure other resource alternatives and delaying the need for new builds in the mid-term as shown in Figure 37.

**Figure 36. Capacity Gap Plot Without the Project – Challenging Supply**



Source: Navigant; DR shown in chart assumes current levels moving forward

**Figure 37. Capacity Gap Plot with the Project – Challenging Supply**



Source: Navigant; DR shown in chart assumes current levels moving forward

Because the project would close the supply gap in the late 2020s, decreasing the need to procure other resource alternatives and delaying the need for new builds in the mid-term, it would also have the impact of depressing capacity prices as shown in Figure 38.

**Figure 38. Capacity Price Forecasts With & Without the Project – Challenging Supply**

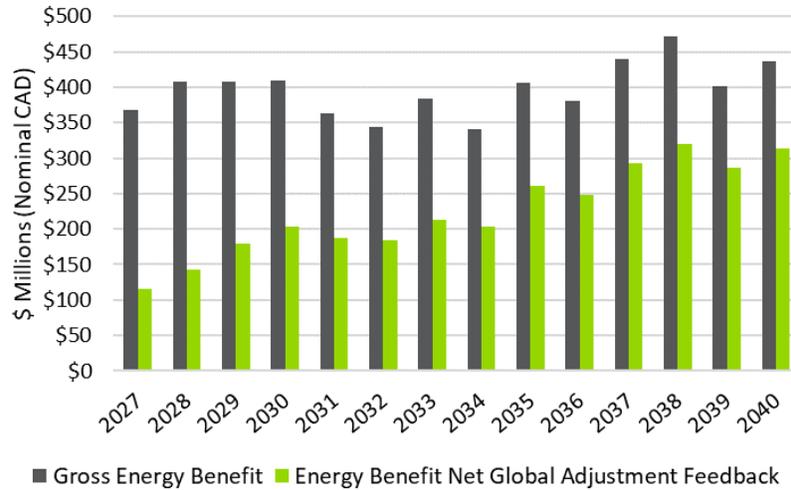


Source: Navigant

While capacity prices are considerably higher in the Challenging Supply Case than in the Base Case due to larger supply gaps, the capacity price suppression is shorter-lived. This is because reserve margins between the with project and without project cases converge sooner, as faster demand growth requires new capacity to be built sooner to meet reliability requirements. Although the capacity prices converge, there are still gross avoided capacity costs as less capacity is paid the market clearing price if the proposed project is built. Overall, the gross avoided capacity costs in the Challenging Supply Case are very similar to those in the Base Case.

For energy costs, additional load, higher gas prices, and less low-cost nuclear energy result in an increased marginal cost of energy during the periods when gas generation is on the margin and increases the difference between on-peak and off-peak prices. Since the project's pumped storage is displacing even more costly peak generation in the evening, the energy suppression impacts are greater than in the Base Case. Compared to the Base Case, this scenario results in nearly 70% more energy benefits (net global adjustment feedback) over the lifetime of the project.

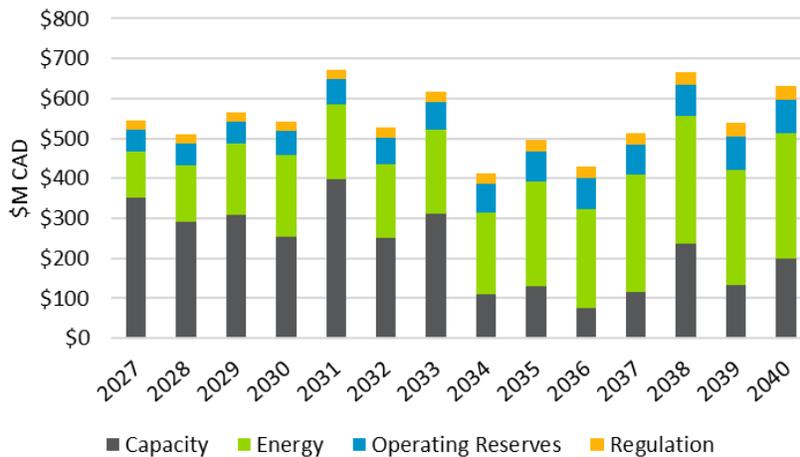
**Figure 39. Avoided Energy Costs (\$M) – Challenging Supply**



Source: Navigant C

With higher energy prices, the opportunity cost for units providing operating reserves and regulation is also higher. This results in nearly 60% higher avoided costs to the IESO for these services from the project, as shown in Figure 40.

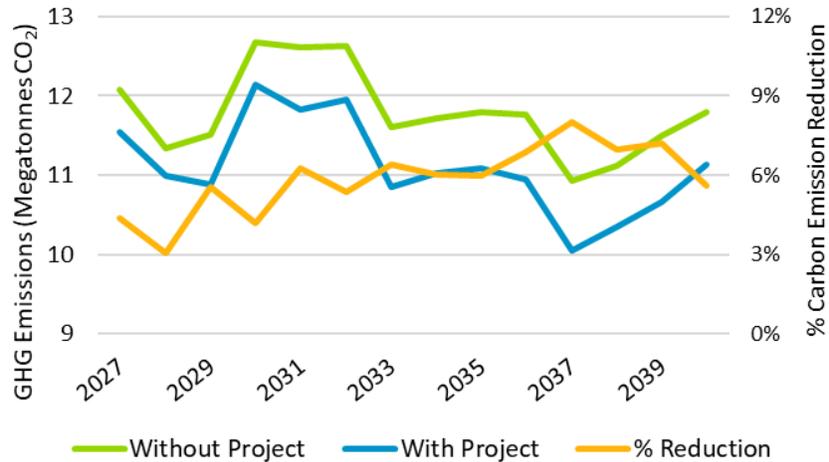
**Figure 40. Annual Gross Benefits from the Project – Challenging Supply**



Source: Navigant

The same operating pattern that results in reduced IESO costs to procure energy and operating reserve also helps to reduce CO<sub>2</sub> emissions. Compared to the Base Case, the emissions reductions are higher, with an annual average reduction of 690,000 tonnes per year. The on-peak gas generation that the project is displacing in the Challenging Supply Case is being produced by less efficient plants, resulting in more carbon reductions. The annual carbon emissions with and without the project are shown in Figure 41.

**Figure 41. Annual Ontario Power Sector CO<sub>2</sub> Emissions – Challenging Supply**



Source: Navigant

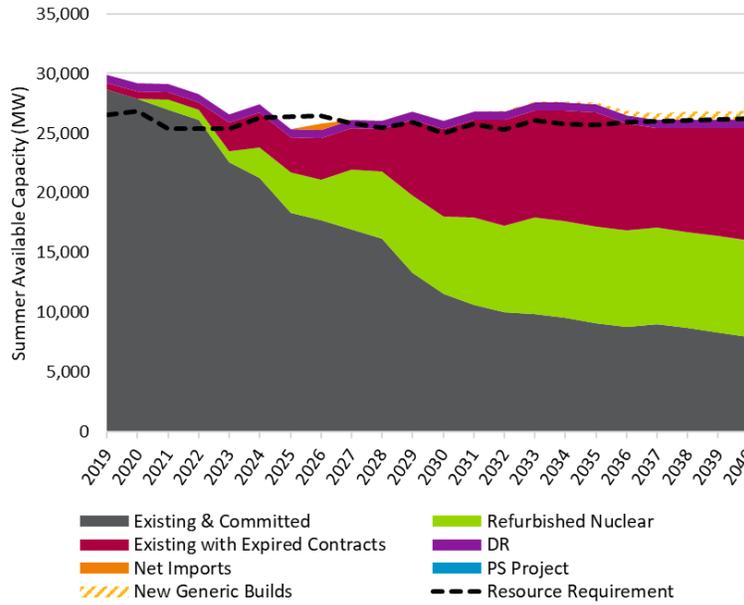
Overall, Navigant’s analysis of the Challenging Supply Case shows that the project has the potential to reduce Ontario electricity system CO<sub>2</sub> emissions by approximately 690,000 tonnes per year on average, while providing a net-benefit of \$19.2 billion to Ontario ratepayers between 2027 and 2066 (nearly 60% higher than in the Base Case).

### 3.2.4 Low Net Demand Case

In the Low Net Demand scenario, the Ontario market experiences lower than expected load growth, marked by industrial economic restructuring and a faster transition to a service-oriented economy. In this demand outlook, peak demand decreases through the early 2030s, with peak demand dropping 5% below 2019 levels by 2032. Demand rebounds in the second half of the forecast at a CAGR of 0.4% through 2040. There is a lesser need to add new resources throughout the forecast assuming all resources are available post-contract expiration. If Ontario’s electricity peak demand declines as described by this scenario, Navigant found that the project would provide relatively lower system cost benefits.

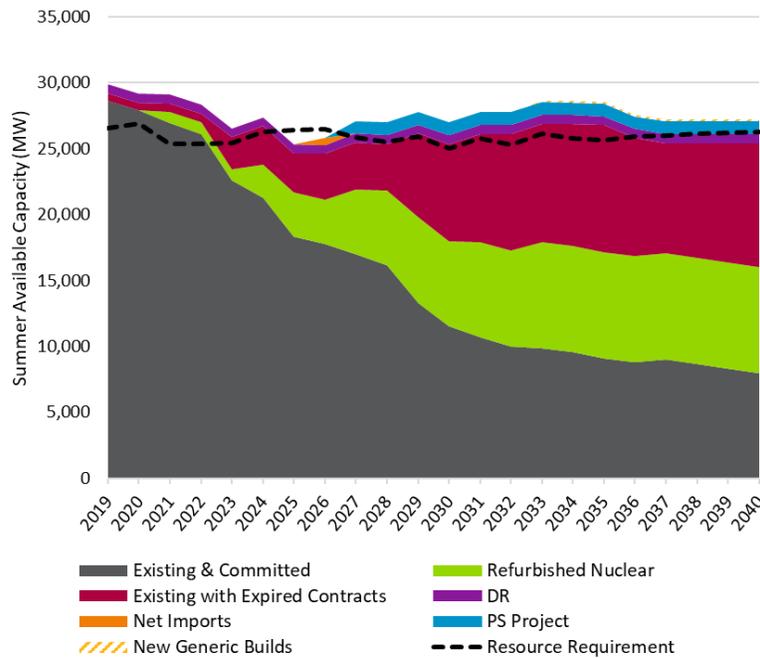
In this case, there is very little need for new capacity to meet reliability requirements, as shown in Figure 42. While there would still be a small supply gap during the mid-2020s, it is much smaller than in previous scenarios and does not extend as far into the forecast. The project would cause the IESO to have capacity in excess of its reliability requirement and would delay the need for new capacity in the long-term, as shown in Figure 43.

**Figure 42. Capacity Gap Plot Without the Project – Low Net Demand**



Source: Navigant; DR shown in chart assumes current levels moving forward

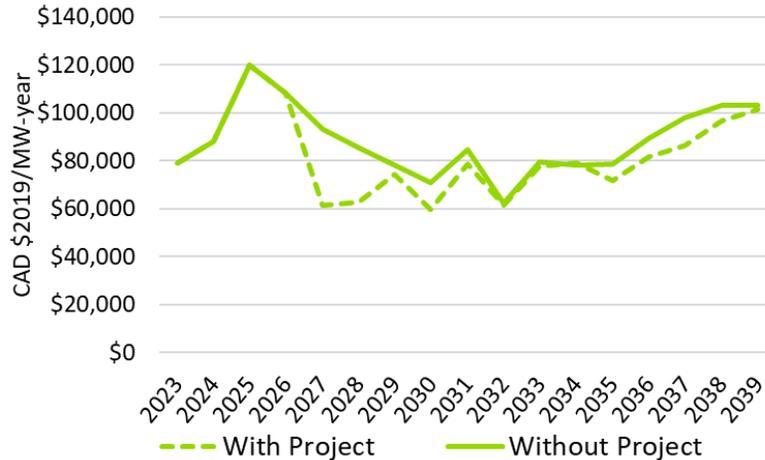
**Figure 43. Capacity Gap Plot with the Project – Low Net Demand**



Source: Navigant; DR shown in chart assumes current levels moving forward

Because the project would cause the IESO to have capacity in excess of its reliability requirement and delay the need for new capacity in the long-term, it would depress capacity prices as shown in Figure 44.

**Figure 44. Capacity Price Forecasts With & Without the Project – Low Net Demand**

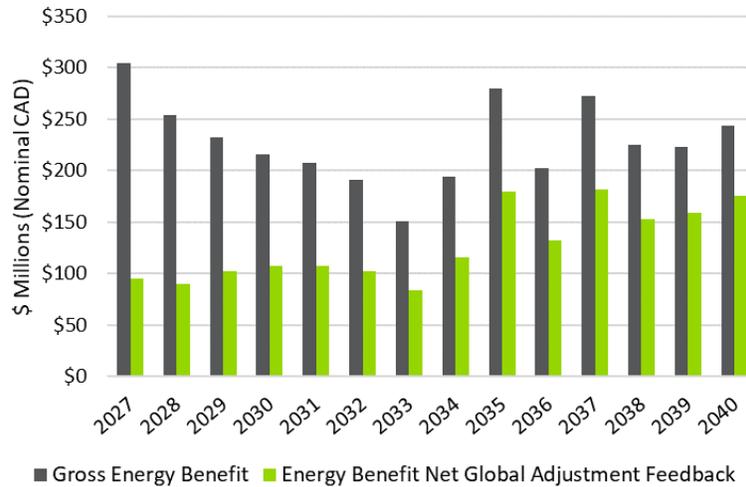


Source: Navigant

While capacity prices are considerably lower in the Low Net Demand Case than in the Base Case, the capacity price suppression as a result of the project is not as significant. The magnitude of the price suppression is smaller because there was already enough capacity on the system to meet reliability requirements. In the Base Case, the project decreased the IESO's need to procure more costly resource alternatives to close supply gaps. This is not the case, however, in the Low Net Demand Case. As a result, the avoided capacity costs in the Low Net Demand Case are approximately 28% lower than those in the Base Case.

Lower load also decreases the marginal cost of energy during the periods when gas generation is on the margin and decreases the difference between on-peak and off-peak prices. Since the project's pumped storage is displacing less costly peak generation in the evening, the energy price suppression impacts are less than in the Base Case. This dynamic is more notable, however, during the nuclear refurbishment period when the IESO is more reliant on its natural gas fleet. As nuclear comes back online and load begins to grow after a sustained period of negative load growth, the difference in energy benefits between the two cases diminishes. Compared to the Base Case, Low Net Demand Case has 8% lower energy benefits (net global adjustment feedback) over the lifetime of the project.

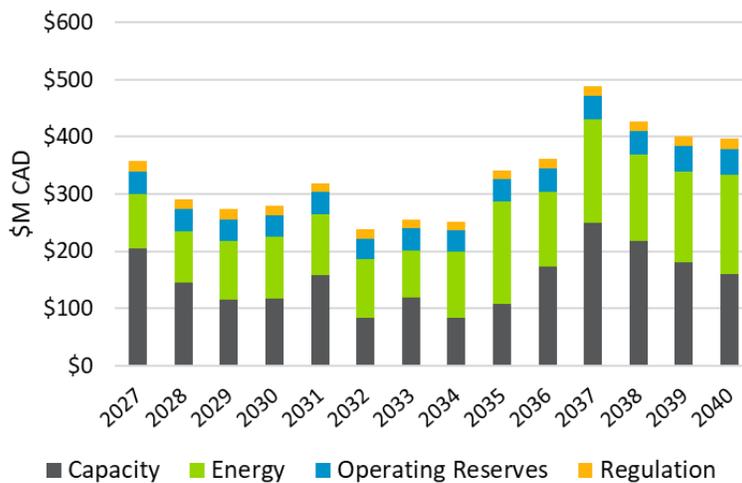
**Figure 45. Avoided Energy Costs (\$M) – Low Net Demand**



Source: Navigant

With lower energy prices, the opportunity cost for units providing operating reserves and regulation is also lower. This results in nearly 17% lower avoided costs to the IESO for these services from the proposed project, as shown in Figure 46.

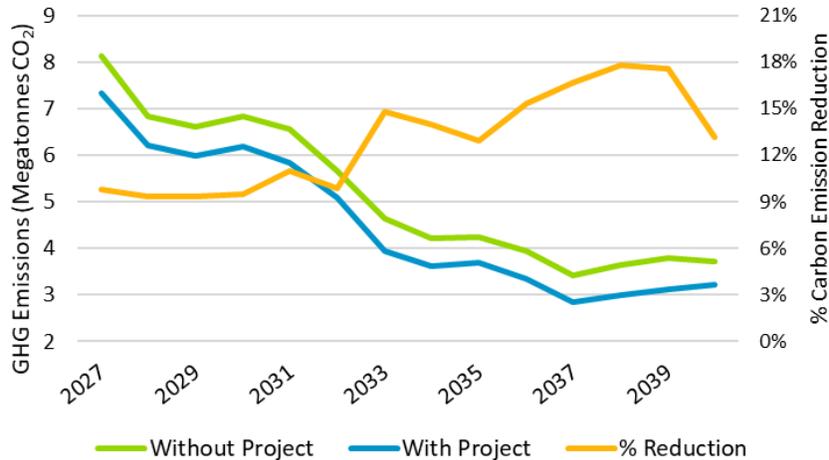
**Figure 46. Annual Gross Benefits from the Project – Low Net Demand**



Source: Navigant

The same operating pattern that results in reduced IESO costs to procure energy and operating reserve also helps to reduce CO<sub>2</sub> emissions. Relative to the Base Case, the emissions reductions are significantly higher, with an annual average reduction of 630,000 tonnes per year, similar to the Challenging Supply Case. With lower demand growth, there is considerably more surplus baseload generation to shift from off-peak to on-peak times, increasing the environmental benefits of the project. The annual carbon emissions with and without the project are shown in Figure 47.

**Figure 47. Annual Ontario Power Sector CO<sub>2</sub> Emissions – Low Net Demand**



Source: Navigant

Overall, Navigant’s analysis of the Low Net Demand Case shows that the project has the potential to reduce Ontario’s electricity system CO<sub>2</sub> emissions by approximately 630,000 tonnes per year on average, while providing a net-benefit of \$7.8 billion to Ontario ratepayers between 2027 and 2066 (35% lower than in the Base Case).

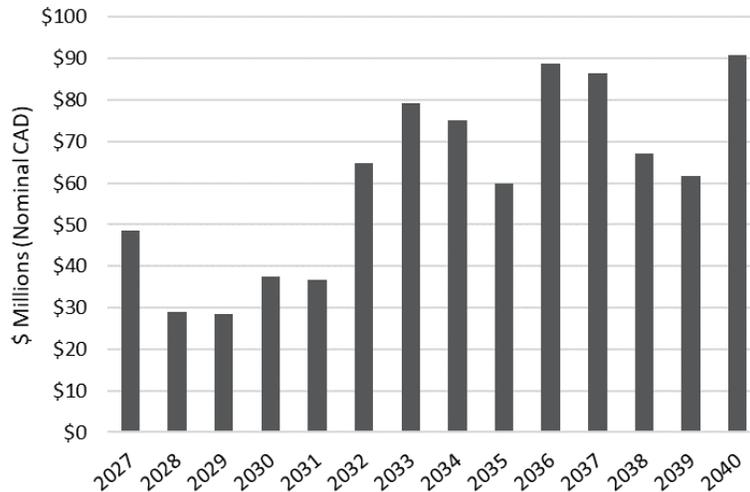
### 3.2.5 No Market Case

In the No Market scenario, the IESO does not move forward with a capacity market, and all capacity is re-contracted after their current contracts expire. The IESO also continues to recontract for regulation service instead of transitioning toward a market-based co-optimization with energy and operating reserves. Even in the absence of a competitive electricity market in Ontario, Navigant found that the project still provides ratepayer benefits.

Assuming Base Case levels of demand growth, even if all existing resources continue to operate post-contract expiration, there would still be a supply gap during the mid-to-late 2020s as a considerable amount of nuclear capacity is offline for refurbishment. Extending the life of existing assets beyond the expiry of their contracts also may prove inefficient and uneconomical, and some of these aging resources, such as the Lennox Generating Station, may not be in a condition to continue operations without significant investment. Given these potential risks to Ontario’s supply and demand outlook and the need for capacity revenues to be sufficient to maintain all existing capacity, capacity resources will have significant value in the mid-to-late 2020s and beyond.

Pumped storage provides operating reserves which allows the natural gas fleet to operate more efficiently and displaces gas fired generation by storing SBG and generating in the evening – both of which lead to decreased system production costs, as shown in Figure 48. Energy price suppression benefits from the storage project are not considered in the No Market Case analysis. The adjusted production cost savings (production costs adjusted for net interchange) attributed to the project over its lifetime are \$3.9 billion.

**Figure 48. Adjusted Production Cost Savings Attributable to the Project**



Source: Navigant

In addition to adjusted production cost savings, this project could provide a third, or 100 MW, of the IESO’s anticipated regulation needs and 500 MW of quick-start operating reserves. In the absence of competitive markets, the IESO would continue to contract for regulation services. In the IESO’s 2017 Regulation RFP, the average weighted average price of all awarded facilities was less than \$200,000/MW-year (CAD \$2017). Assuming the IESO can contract for regulation at this price (adjusted for inflation), the avoided regulation costs of the project would be \$1.7 billion over its lifetime. This is a conservative outlook for the cost of a regulation contract given that the 2017 RFP was ultimately unsuccessful as none of the contracted resources were actually built. The avoided operating reserve costs of the project would be \$2.6 billion over its lifetime. While a peaker could also provide both regulation and operating reserves, it would need to be operating at a less efficient generation level to do so, which would add to total system production costs.

There is also a need for increased flexibility, which cannot be provided by any of the existing units on the system. The project can provide flexible, zero-carbon peaking capacity that would allow the IESO to avoid the cost of procuring alternate capacity resources. The IESO recently released updated design proposals for the Transitional Capacity Auction to take place in June 2020. The IESO proposed that the reference technology be based on the all-in cost of a single cycle gas CT plant with firm-gas. The estimated all-in levelized cost (net of energy and ancillary margins) is estimated to be approximately \$570/MW-day on a UCAP basis<sup>31</sup>. Based on the IESO value and adjusted for inflation, the revenue requirement of a 1,000 MW simple-cycle gas turbine would be approximately \$246 million/year in 2026, resulting in a total cost of \$12.8B<sup>32</sup> over 40 years (lifetime of the project).

<sup>31</sup> IESO. *Proposed December 2020 Capacity Auction Design Features*. December 6, 2019

<sup>32</sup> Assuming 20-year economic life

Another option for new capacity would be an 8-hour battery. While an 8-hour battery could address some system needs, such as shifting SBG or providing reserves, it comes at a much higher cost. The 2026 levelized cost of a 1,000 MW 8-hour battery is estimated to be approximately \$425 million/year.<sup>33</sup> Over 40 years, this results in a total cost of \$17.0B.

Even in the absence of a competitive electricity market in Ontario, Navigant estimates that the project would still deliver \$10.0B in ratepayer benefits over the project's lifetime. By providing operating reserve, regulation services, and firm capacity to the IESO, the project offsets the costs of procuring these separately. Also, the project's ability to shift SBG to displace higher cost generation and to facilitate more efficient operation of the system results in significant adjusted production cost savings (production costs adjusted for net interchange) over its lifetime.

### 3.3 Comparison to Resource Alternatives

The proposed project's capabilities make it well suited to meet many of Ontario's power system needs, as described in the previous sections. While there are other resource alternatives that may be considered to meet these needs, pumped storage technology has several advantages. Table 8 shows a comparison of pumped storage capabilities and characteristics with other resource alternatives.

**Table 8. Comparison of Pumped Storage with Resource Alternatives**

Capability	Pumped Storage	Battery Storage (Capacity)	Battery Storage (Regulation)	Frame Gas Turbine	Demand Response
Capacity Resource	✓	✓	✗	✓	✓
Bulk Storage	✓	✓	✗	✗	✗
System Life (years)	40-100	10-15	10	40	-
Frequency Regulation	✓	✗	✓	✓	✗
10-Minute Reserves	✓	✓	✓	✓	✗ <sup>34</sup>
30-Minute Reserves	✓	✓	✓	✓	✓
Real-Time Price Stabilization	✓	✓	✓ <sup>35</sup>	✓	✓
Gas Price Hedge	✓	✓	✓	✗	✓

Source: Navigant

The 8-hour energy storage that the project can provide has significant advantages over 4-hour or shorter duration storage. If Ontario is to further decarbonize its economy, significant renewable capacity backed by storage will need to be added to displace thermal generation. If those storage resources are limited to a duration of 4 hours, however, there are diminishing returns as more storage is added. While prior system reliability needs were dictated by the ability to provide capacity during 3-hour events, in a carbon constrained future, the events that cause reliability challenges could be considerably longer, exceeding the capability of these energy limited resources.

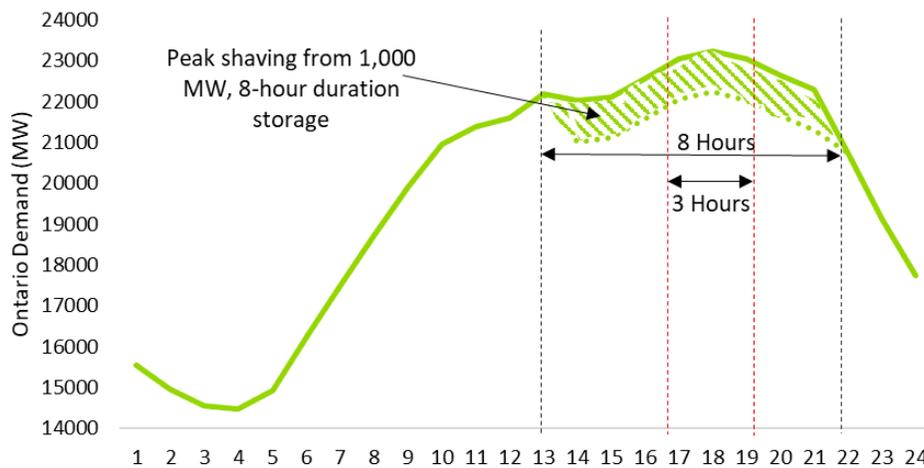
<sup>33</sup> Levelized cost assumes a 40-year life with all necessary battery cell maintenance and replacements.

<sup>34</sup> While not currently the case in Ontario, in other jurisdictions DR can provide 10-minute operating reserves.

<sup>35</sup> Assuming that the battery is not restricted to only providing regulation service.

To illustrate this challenge, Figure 49 below shows the demand profile for Ontario on the peak demand day in 2018. If the peak shape flattens due to increased renewable penetration or further peak shaving demand conservation measures, extending peak hours, the 8-hour storage provided by the project becomes much more valuable than shorter duration storage.

**Figure 49. 2018 Peak Ontario Demand Day**



Source: IESO Data Directory

Pumped storage has other advantages compared to battery technology. Batteries are typically designed for more specific use cases, allowing a battery storage project to meet some, but not all, of Ontario’s system needs. For example, a large grid-scale battery with 4-hour or even 8-hour storage serving as a capacity resource is unlikely to also provide a significant amount of regulation service, because excessive cycling would cause the battery to degrade and diminish its capacity value. In comparison, pumped storage can provide regulation service without material degradation.

Additionally, the levelized cost of capacity for an 8-hour battery is currently relatively high. Although Navigant expects it to decline to approximately \$425,000/MW-year in 2026,<sup>36</sup> and by an additional 25% in real terms by 2040, the IESO will need to fill their anticipated supply gaps before those cost decreases are fully realized.

Other resource alternatives, such as natural gas-fired peaking generation (peakers) and DR, would be similarly challenged to meet all of Ontario’s system needs. While a simple cycle gas turbine could theoretically provide both regulation and spinning reserves, it would need to be operated at lower efficiencies, which would add to total system production costs. While DR can serve as a capacity resource and provide operating reserves, there are practical limits to the amount of DR that can be used to meet resource adequacy needs, and DR cannot provide regulation services.

<sup>36</sup> Levelized cost assumes a 40-year life with all necessary battery cell maintenance and replacements.

### 3.4 Ratepayer Benefits Summary

Under the Base Case and all alternative scenarios, Navigant found that the project would provide significant benefits to the IESO and to Ontario ratepayers. The scenario analysis shows that the project value is robust across various market outlooks, with several outlooks (Booming Economy, Clean Grid, and Challenging Supply) resulting in considerable economic and environmental upsides relative to the Base Case. Net ratepayer benefits range from approximately \$8B to \$30B over the 40-year project lifetime, as shown in Table 9 below.

**Table 9. Net Ratepayer Benefits**

Scenario	CO <sub>2</sub> Emissions Reduction (Avg. Tonnes/Year)	Net Ratepayer Benefit (\$CAD)
<b>Base Case</b>	<b>490,000</b>	<b>\$12.1B</b>
Booming Economy	410,000	\$20.4B
Clean Grid	800,000	\$30.0B
Challenging Supply	690,000	\$19.2B
Low Net Demand	630,000	\$7.8B
No Market	490,000	\$10.0B

Table 10 summarizes the gross energy, capacity, ancillary service, and emissions reduction value to Ontario ratepayers for the Base Case and each of the alternate scenarios from 2027 – 2066.

Navigant concludes that under a range of future scenarios, the project would result in net ratepayer savings and would significantly reduce CO<sub>2</sub> emissions associated with the Ontario electricity sector. The project could potentially achieve greater economic value and additional CO<sub>2</sub> emissions reductions through increased imports of zero-carbon hydroelectric power from neighbouring jurisdictions through existing transmission connections, beyond what was modeled in this analysis.

**Table 10. Capabilities and Gross and Net Value to Ratepayers of the Project**

Benefit	Value to Ontario Ratepayers, 2027 – 2066					
	Base	Booming Economy	Clean Grid	Challenging Supply	Low Net Demand	No Market
Reducing CO <sub>2</sub> Emissions	Average of 490,000 tonnes per year	Average of 410,000 tonnes per year	Average of 800,000 tonnes per year	Average of 690,000 tonnes per year	Average of 630,000 tonnes per year	Average of 490,000 tonnes per year
Minimizing Costs for Energy	\$13.2B Gross \$8.5B Net GA Feedback <sup>37</sup>	\$27.8B Gross \$18.5B Net GA Feedback	\$35.6B Gross \$23.6B Net GA Feedback	\$21.7B Gross \$14.2B Net GA Feedback	\$12.0B Gross \$7.8B Net GA Feedback	\$3.9B
Minimizing Costs for Operating Reserves	\$2.6B	\$3.6B	\$5.1B	\$4.1B	\$2.1B	\$2.6B
Minimizing Costs for Ancillary Services	\$1.0B	\$1.5B	\$1.9B	\$1.6B	\$0.9B	\$1.7B
Providing Flexible Capacity	\$10.9B	\$7.8B	\$10.5B	\$10.3B	\$7.9B	\$12.8B
Local Economic Benefits	Locally-sourced materials and generators; local jobs for construction and operation					
Total Gross Benefit	\$23.1B	\$31.4B	\$41.0B	\$30.2B	\$18.7B	<b>\$21.0B</b>
Project Revenue Requirement	\$11.0B					
<b>Total Net Benefit</b>	<b>\$12.1B</b>	<b>\$20.4B</b>	<b>\$30.0B</b>	<b>\$19.2B</b>	<b>\$7.8B</b>	<b>\$10.0B</b>

<sup>37</sup> This value assumes that capacity coming off-contract does not recontract with the IESO.

## APPENDIX A. MARKET MODELING PROCESS

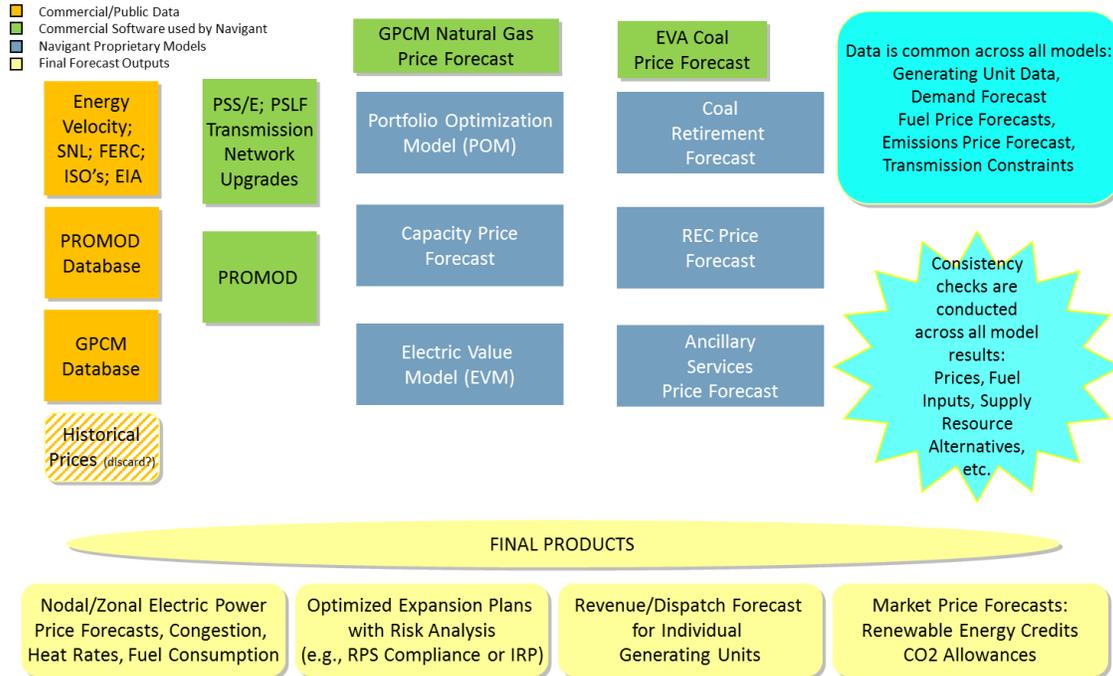
Navigant's market modeling approach relies on a multifaceted approach for simulating the proposed project in the Ontario energy market. The base forecast for the Ontario market relies on the involvement of numerous subject matter experts with specific knowledge and understanding of several fundamental assumptions, such as fuel pricing, generation development, transmission infrastructure expansion, asset operation, environmental regulations, and technology deployment. From our involvement in the industry, Navigant has specific and independent views on many of these fundamental assumptions based on our knowledge and understanding of the issues. Provided below is an overview of the modeling process and the methodology for evaluating the ratepayer costs and CO<sub>2</sub> emission reductions associated with the project.

Navigant uses PROMOD, a commercially-available software, to develop its wholesale energy market price and plant performance forecasts. PROMOD is an industry-standard, detailed energy production cost model that simulates hourly chronological operation of generation and transmission resources on a nodal basis in wholesale electric markets. PROMOD dispatches generating resources to match hourly electricity demand, dispatching the least expensive generation first. The choice of generation is determined by the generator's total variable cost given operating constraints such as ramp rates (for fossil resources) or water availability (for hydraulic resources), and transmission constraints. The total variable cost of the marginally dispatched unit in each hour sets the hourly market clearing price. All generators in the same market area that are selected to run receive the same hourly market clearing price adjusted for losses and congestion, regardless of their actual costs. The Hourly Ontario Energy Prices (HOEPs) produced by PROMOD compose Navigant's structural market price forecasts. PROMOD also outputs system CO<sub>2</sub> emissions.

Navigant's proprietary Electric Valuation Model (EVM) can provide deeper capabilities in greater detail and dispatches it against energy, operating reserve, and regulation prices to develop estimates of hourly operation. to calculate the avoided cost of operating reserve and regulation procurement to the Ontario Independent Electricity System Operator (IESO).

A diagram depicting the models used to support the PROMOD forecast in Navigant’s market modelling can be seen in Figure 50.

**Figure 50. Navigant’s Market Simulation Modelling Process**



Source: Navigant

## APPENDIX B. LIST OF ABBREVIATIONS

Abbreviation	Definition
CDM	conservation and demand management
CO <sub>2</sub>	carbon dioxide
DR	demand response
FAO	Financial Accountability Office of Ontario
MMBTU	millions of British thermal units
GA	Global Adjustment
GW	Gigawatt (1,000 MW)
HOEP	hourly Ontario energy price
IESO	Independent Electricity System Operator
ISO	Independent system operator
kV	kilovolts
kW	kilowatt (1,000 Watts)
MW	Megawatt (1,000 kW)
MWh	electrical energy produced by 1 MW of energy for one hour
MT	one million tonnes
OEB	Ontario Energy Board
OEM	original equipment manufacturer
OPG	Ontario Power Generation Inc.
PSP	pumped storage project
SBG	surplus baseload generation
TCE	TC Energy Energy Ltd.
TJ	Terajoule
TWh	one terawatt hour of electrical generation (1,000,000MWh)
VG	variable generation