ASSET MANAGEMENT PROCESS

1. OVERVIEW

Hydro Ottawa's 2026-2030 capital expenditure plan, as developed through the asset management process, demonstrates a comprehensive and forward-thinking approach to asset management. It is guided by the corporate Eight point strategy in Section 3.2 - Corporate Strategy Objectives, the plan aligns with the OEB's performance outcomes and prioritizes customer preferences identified through engagement as in Section 3.3 - Customer Preference and Priorities. Hydro Ottawa advances the corporate objectives and customer priorities through five core business strategies—Asset Management, Grid Modernization, Digital, Facilities, and Fleet—which provide a framework for the development of targeted investment plans. Notably, the Grid Modernization strategy effectively bridges Asset Management and Digital initiatives, ensuring a cohesive approach to technological advancement as described in Section 3.4 - Business Strategies.

This strategic framework is operationalized through Hydro Ottawa's ISO 55001-certified Asset Management System (AMS). The AMS employs a structured four-stage process (prepare, plan, optimize, execute) to ensure methodical asset management, aligning expenditures with the four Investment Priorities: Growth & Electrification, Renewing Deteriorating Infrastructure, Grid Modernization and Enhancing Resilience as described in Section 4.3 - Asset Management Process Overview. Hydro Ottawa's commitment to continuous improvement, as demonstrated by ongoing enhancements to the AMS, includes the implementation of predictive analysis, refined inspection programs, and comprehensive asset health indexing as in Section 4.4 - Asset Management Process Enhancements. This commitment extends beyond the AMS, encompassing a Decarbonization Study projecting future electricity demand, a Climate Study reaffirming the efficacy of existing adaptation measures, and a Resilience Assessment informing a multi-faceted resilience program as described in Section 4.4 - Asset Management Process Enhancements.

These initiatives are critical for managing the complexities of Hydro Ottawa's distribution system, a substantial network encompassing over 364,000 customers and facing diverse challenges, including geographic constraints, the evolving impacts of climate change, and escalating demand as described in Section 6 - Overview of Distribution System. Regional-based planning rigorously considers Ottawa's unique landscape, including its intricate river systems, the protected Greenbelt, and federal lands, while addressing the region's challenging soil conditions and seismic activity detailed in Section 6.3 - Geographic Planning Considerations. Within this context, the utility maintains a vigilant watch on climate change impacts, including temperature extremes and the increasing frequency of high wind events, proactively implementing adaptation measures to bolster grid resilience as in Section 6.4 - Historical and Future Climate. Furthermore, to effectively accommodate escalating demand-driven by residential expansion, the electrification of transportation, and the growing adoption of electric space heating - Hydro Ottawa is strategically augmenting system capacity as described in Section 6.5 - System Demand and Growth Planning Considerations.

Hydro Ottawa is committed to providing a sustainable and dependable electricity service by optimizing asset lifecycles and ensuring reliability and cost-effectiveness through informed asset management practices. A comprehensive analysis of managed assets provides detailed insights into their demographics, condition, failures, and risk profiles, highlighting the critical need for proactive replacement of deteriorating infrastructure, detailed in Section 7 - Overview of Assets Managed. To this end, Hydro Ottawa methodically optimizes asset lifecycles by establishing robust typical useful life (TUL) values, conducting thorough asset replacement and refurbishment analyses, and actively monitoring asset utilization through key performance indicators (KPIs) such as the Station Load Index (SLI) and Feeder Load Index (FLI), as described in Section 8 - Asset Lifecycle Optimization Policies and Practices. Stringent inspection and maintenance programs further ensure the continued safe and reliable operation of the electrical grid as in Section 8.2 - Asset Replacement and Refurbishment Policies.

Hydro Ottawa undertakes a comprehensive System Capacity Assessment, incorporating detailed load forecasting that considers customer growth and electrification, as shown in Section 9 - System Capacity Assessment. Immediate capacity constraints are strategically addressed through the construction of new stations, targeted upgrades, and the implementation of Non-Wires Solutions (NWSs), while medium and long-term needs are met through voltage conversions, strategic distribution transfers, and additional NWSs as described in Section 9.2 - Non-Wires Solutions to Address System Needs. Hydro Ottawa will actively leverage NWSs, including utility owned battery storage solutions and a comprehensive Non-Wires Customer Solutions Program, to proactively manage peak demand, enhance grid reliability, and seamlessly support the integration of distributed energy sources (DERs) as detailed in Section 9.4 - Planning Load Forecasting. Through this holistic and integrated planning process, Hydro Ottawa is strategically investing in its electricity grid to ensure its reliability, resilience, and customer-centricity for the long term.

Hydro Ottawa's asset management practices leverage forward-thinking strategies that anticipate the complexities of a future grid. By incorporating considerations for increased electrification, seamless DER integration, and the evolving impacts of climate change, alongside the asset renewal drivers, this comprehensive strategy enables Hydro Ottawa to not only meet the needs of its customers but also to ensure the long-term sustainability and resilience of its electricity distribution system.

2. INTRODUCTION

This document provides a comprehensive overview of Hydro Ottawa's Asset Management Process. It outlines the strategic framework that guides asset management and integrates decisions with core business strategies and customer preferences.

Hydro Ottawa's systematic approach encompasses lifecycle optimization, risk mitigation, and system capacity assessment. It enables the utility to effectively plan, prioritize, and optimize expenditures.

The planning processes result in a capital expenditure plan that delivers on four Investment Priorities: Growth & Electrification, Renewing Deteriorating Infrastructure, Grid Modernization, and Enhancing Grid Resilience.

The following sections detail Hydro Ottawa's asset management process and how the utility ensures the reliability, resilience, and customer-centricity of its electricity grid.

- **Section 3:** Describes Hydro Ottawa's integrated business planning process
- **Section 4:** Presents Hydro Ottawa's asset management system
- **Section 5:** Explains the detailed asset management process
- **Section 6:** Provides an overview of Hydro Ottawa’s distribution system
- **Section 7:** Details the assets managed by Hydro Ottawa
- **Section 8:** Describes the policies and practices for asset lifecycle optimization
- **Section 9:** Presents Hydro Ottawa's system capacity assessment

3. PLANNING PROCESS

This section provides a comprehensive overview of Hydro Ottawa's integrated business planning process, the foundation upon which the utility built its capital expenditure plan for the 2026-2030 period. As detailed in Section 3.1 - Business Planning Process, this plan is not developed in isolation; it is the direct result of a robust and iterative process that aligns strategic objectives, as detailed in Section 3.2 - Corporate Strategic Objectives, incorporates extensive customer engagement in Section 3.3 - Customer Preferences and Priorities, and addresses the specific needs of various asset categories.

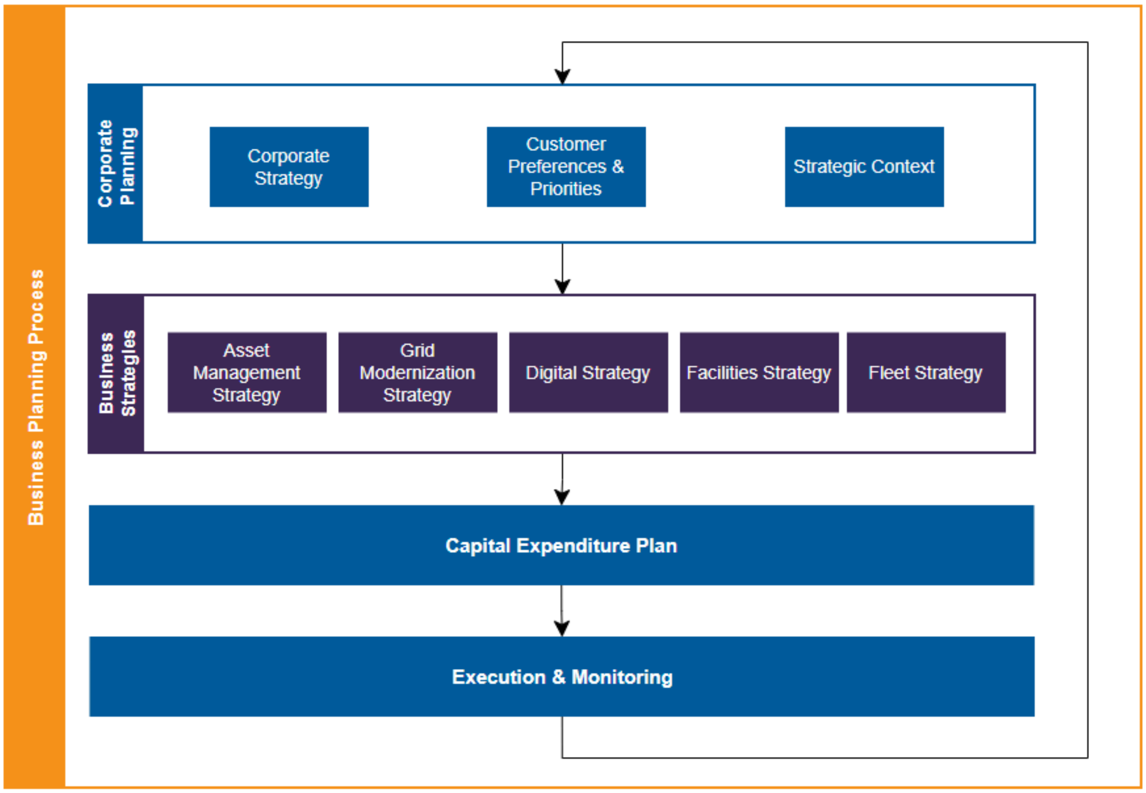
Hydro Ottawa's approach emphasizes a cascading structure, where high-level corporate planning informs specific business strategies, which in turn guide the development of detailed investment plans. This section will explore the key drivers behind Hydro Ottawa's 2021-2025 Strategic Direction, including the "5 Ds" (Decarbonization, Digitization, Decentralization, Diversification, and Demographics) and the utility's overarching Eight point plan (see Figure 2).

It will delve into the customer engagement process, as detailed in Section 3.3 - Customer Preferences and Priorities, highlighting how customer feedback shapes investment priorities and ensures that the plan reflects the needs and expectations of the community it serves. Furthermore, this section details the five core business strategies: Section 3.4.1 - Asset Management Strategy, Section 3.4.2 - Grid Modernization Strategy, Section 3.4.3 - Digital Strategy, Section 3.4.4 - Facilities Strategy, and Section 3.4.5 - Fleet Strategy. Finally, it will examine the capital expenditure planning process itself in Section 3.5 - Capital Expenditure Planning Process, from the development of individual investment plans to their consolidation and prioritization within the broader Capital Expenditure Plan as detailed in Schedule 2-5-5 - Capital Expenditure Plan. This section aims to provide a clear understanding of how Hydro Ottawa strategically plans for its future, ensuring a reliable, sustainable, and customer-centric electricity grid.

3.1. BUSINESS PLANNING PROCESS

Hydro Ottawa's capital expenditure plan is an output of the utility's integrated business planning process. Through this process, Hydro Ottawa advances its overall strategic objectives and provides value to customers by establishing goals and priorities, allocating resources, monitoring performance, identifying areas for improvement, and adapting to developments in the external business environment. Figure 1 outlines the top-level inputs and flows through the business planning process to ultimately deliver a final capital expenditure plan for the four investment categories: System Access, System Renewal, System Service, and General Plant. See Schedule 2-5-5 - Capital Expenditure Plan, for the 2026-2030 Capital Expenditure Plan.

Figure 1 - Business Planning Process



3.1.1. Corporate Planning

Attachment 1-2-3(A) - Corporate Memorandum - 2024-2030 Priorities and Budget Guidelines provides an overview of the business planning process employed by Hydro Ottawa to prepare for this application, including the capital expenditure plan.

The memorandum comprises a set of formal guidelines prepared by the Chief Financial Officer for five-year budgets covering the 2026-2030 rate period. This internal guidance was circulated more than one year in advance of the expected filing date of the rebasing application.

The document serves a number of purposes:

- laying out the timeline for the development of preliminary capital and operational budgets;
- finalizing spending plans based on customer feedback;
- outlining considerations for capital investments and operational expenditures;
- identifying constraints and expectations with respect to such matters as inflation, compensation and headcount;
- stipulating requirements related to productivity, continuous improvement and cost control; and
- directing the alignment of spending with customer interests and outcomes, see Section 3.3 - Customer Preferences and Priorities, the utility's strategic objectives, see Section 3.2 - Corporate Strategic Objectives, and OEB's policy and direction.

The process mapped out in this Corporate Memorandum attests to the rigour, discipline, and customer-oriented focus of Hydro Ottawa's business planning activities.

Affordability was a key consideration when preparing and evaluating preliminary capital and operational budgets. "Affordability" refers to both customer ability and willingness to pay, as well as Hydro Ottawa's financial ratios and capacity to deliver. Throughout the planning process, affordability was essential to optimize the proposed capital expenditure plan and balance rate impacts with the achievement of outcomes valued by customers.

3.1.2. Business Strategies

Hydro Ottawa's five business strategies — Asset Management, Grid Modernization, Digital, Facilities, and Fleet — guide the objectives of its expenditure plan. These strategies share a consistent framework, beginning with corporate planning and then incorporating specific objectives tailored to the scope of each strategy and the assets it oversees. This ensures resulting investment plans contribute to Hydro Ottawa's overall strategic objectives. Because the Grid Modernization Strategy's objectives are achieved through the Asset Management and Digital Strategies, rather than through distinct assets, it does not generate a separate, independent set of investment plans. Instead, it informs and shapes the investment plans developed within the Asset Management and Digital strategies. See Section 3.4 - Business Strategies of this schedule for details on each of the five business strategies.

3.1.3. Capital Expenditure Plan

The investment plans developed for each business strategy (except Grid Modernization, as described above) translate the Strategic Direction, customer insights, and asset-specific objectives into concrete investment needs. These needs are then consolidated through the expenditure planning process, which serves as the mechanism for prioritizing and coordinating the various investment needs identified for each asset category.

3.1.4. Execution & Monitoring

During the 2026-2030 rate period, Hydro Ottawa will continuously monitor and evaluate its execution of the capital expenditure plan, and will consider adjustments to the plan as part of the annual refresh of its business plan and budget. These adjustments may be required during a given calendar year based on a variety of factors (e.g. prior year results; macroeconomic pressures such as interest rates or inflation; and major shifts in the business or operating environment, including severe weather events). Hydro Ottawa is committed to ensuring effective execution of its capital expenditure plan and will continue to implement appropriate controls through annual business planning in support of this priority.

3.2. CORPORATE STRATEGIC OBJECTIVES

Hydro Ottawa's Strategic Direction sets the organization's overarching objectives, which, in turn, drive the planning practices.

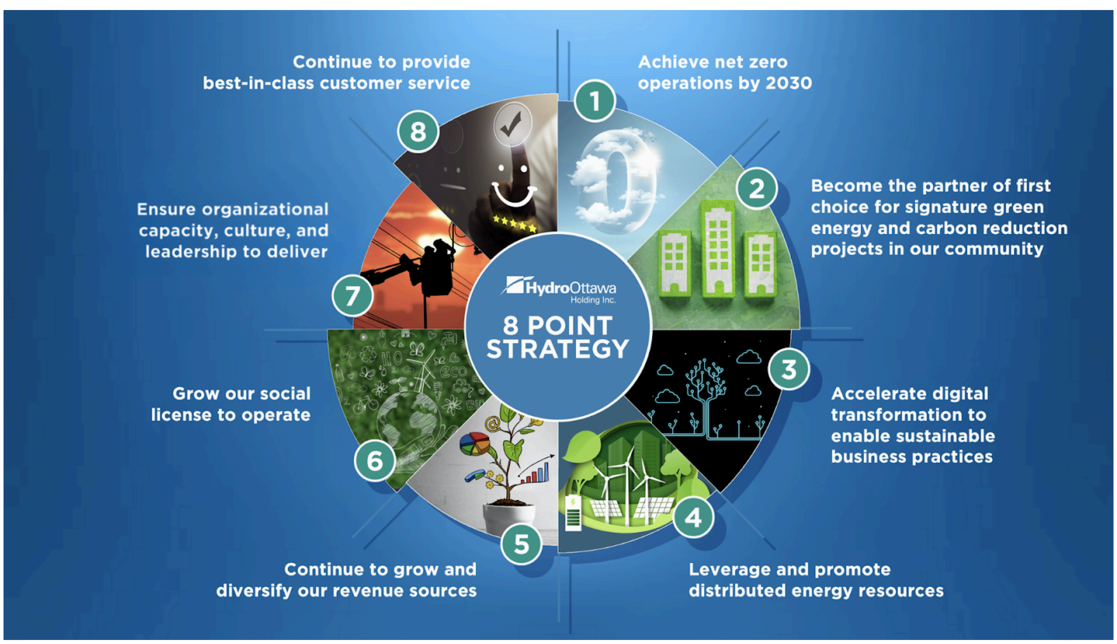
Hydro Ottawa's corporate strategy[1] was formulated, and continues to be implemented, against the backdrop of major shifts in the company's operational, business, and policy environments. These key change drivers are collectively referred to as the "5 Ds" and consist of the following:

[1] Hydro Ottawa Holding Inc., 2021-2025 Strategic Direction.

- **Decarbonization** - the removal or reduction of carbon dioxide emissions; the switch to usage of low-carbon energy sources;
- **Digitization** - the conversion of information and processes from analog to digital form;
- **Decentralization** - the transition from large, centralized production and networks to smaller, more distributed production and networks;
- **Diversification** - the process of enlarging a business or varying its range of assets, products, services, business lines, and operational fields; and
- **Demographics** - the 'people' side of the electricity business – customers, community, employees.

The utility's strategy is anchored in an Eight point plan for responding to these external change drivers, while providing value to customers, growing the business, and embedding sustainability into all areas of operations. These eight strategic objectives are outlined in Figure 2.

Figure 2 – Hydro Ottawa's Strategic Objectives



Hydro Ottawa's strategic objectives are aligned with the four core performance outcomes established by the OEB for electricity distributors under the Renewed Regulatory Framework (RRF). This mapping is shown in Table 1.

Table 1 – Alignment between Hydro Ottawa's Strategic Objectives and OEB RRF Performance Outcomes

RRF Performance Outcomes	Corporate Strategic Objectives
Financial Performance	Continue to grow and diversify our revenue sources
	Become the partner of first choice for signature green energy and carbon reduction projects in our community
Customer Focus	Continue to provide best-in-class customer service
	Leverage and promote distributed energy resources
Operational Effectiveness	Accelerate digital transformation to ensure sustainable business practices
	Ensure organizational capacity, culture and leadership to deliver
Public Policy Responsiveness	Achieve net-zero operations by 2030
	Grow our social license to operate

For additional information on Hydro Ottawa's corporate strategy, please see Schedule 1-2-3 - Business Plan.

3.3. CUSTOMER PREFERENCES AND PRIORITIES

As described in Schedule 1-4-2 - Customer Engagement on the 2026-2030 Application, Hydro Ottawa engaged Innovative Research Group (Innovative Research), a national consulting firm with expertise in public opinion research and experience in energy policy. They were hired to collaboratively design, test, and implement a strategy for engaging customers on Hydro Ottawa's 2026-2030 rate application proposals.

An iterative, two-phase customer engagement process was undertaken, with the following key principles adopted in order to maximize the effectiveness of the process:

- Ensure all Hydro Ottawa customers have an opportunity to be heard
- Ensure a representative sample of customers are engaged
- Create an open, voluntary process to allow any customer the opportunity to provide comment
- Focus on the key outcomes and customer preferences
- Inform customers about the distribution system and electricity industry

Phase I

Phase I of the Customer Engagement process surveyed Hydro Ottawa's residential customers, small business customers, Commercial & Industrial (C&I) customers, and key accounts. The purpose of this survey was to gather feedback and insights on priorities, preferences, and needs from these customers. The information collected through this survey helped inform the inputs used to develop the Focus Areas of the Distribution System Plan (DSP) and Business Plan, which were shared in draft with customers in Phase II.

For each customer class, Innovative Research conducted online surveys and focus groups in Phase I. Using these results, Innovative Research established baselines and developed weights that allowed a move to an online methodology for Phase II of the customer engagement program.

Engagement results and key findings from Phase I, in relation to satisfaction and general priorities, include:

- Customer satisfaction has improved relative to 2019 for residential and small business customers.

- Residential and small business customers prioritize very similar general outcomes, with both ranking “maintaining reliable electricity service” as their top priority.
- Commercial and industrial and key account customers have more distinctive prioritizations, with reliable service being important, but outranked by the related and more specific objective of hardening the grid to withstand severe weather. Capacity to meet future demand was also a high-ranked priority of these customer classes.

This feedback helped Hydro Ottawa develop the four themes around which its investment plan is organized for communication with customers:

- Aging Infrastructure
- Grid Resilience
- Growth & Electrification
- Grid Modernization

Phase II

Phase II of the Customer Engagement process focused on gathering customer feedback on Hydro Ottawa's proposed investment plan. This was achieved through an online survey that presented the plan's four key categories: Growth and Electrification, Aging Infrastructure, Grid Modernization, and Grid Resilience. The survey aimed to gauge customer investment preferences across these categories and assess the overall level of support for the proposed plan by outlining priority investment options with varying paces and cost impacts, enabling them to directly influence the final plan by providing feedback on their preferred balance of cost, timing, and system outcomes (reliability, resilience, renewable integration).

Key Findings:

- **Strong Support for the Plan:** The results demonstrated strong overall support for the plan, particularly among commercial customers who recognize the value of a reliable and modern electricity grid. An average of 87% of customers, across all rate classes, gave Hydro Ottawa social permission to proceed with its draft plan. These customers provided social permission by indicating either:

  - 16% think Hydro Ottawa should accelerate spending beyond the level in the draft plan to deliver better system outcomes.
  - 28% support the proposed rate increase that is reflected in the draft plan, or
  - 43% They feel that the proposed rate increase in the draft plan is necessary, even though they don't like the proposed rate increase.

- **Acceptance of Necessary Increases:** While many customers expressed a general dislike for bill increases, a majority within each customer category acknowledged the necessity of these increases to fund critical system investments.
- **Desire for Accelerated Investment:** A significant minority of respondents favoured an even faster pace of investment, indicating a willingness to absorb higher near-term costs to expedite system upgrades and realize their associated benefits sooner.

Phase II of the Customer Engagement process successfully gathered valuable customer feedback on Hydro Ottawa's proposed investment plan. The results demonstrated strong overall support for the plan, particularly among commercial customers, and provided insights into customer perspectives on affordability and the need for continued investment in a reliable and sustainable electricity system.

This feedback provided valuable insight into customer perspectives on the balance between affordability and the need for continued investment in a reliable and sustainable electricity system, which is outlined in Table 2.

Table 2 - Support for Proposed Investment Plan per Rate Class[2]

Support for Proposed Investment Plan	Residential	Small Business	C&I and Key Account (GS>50 kW)
I think Hydro Ottawa should accelerate spending beyond its proposed draft plan to deliver better system outcomes	19%	20%	8%
I support the proposed bill increase when it comes to preparing Hydro Ottawa's grid for the future	28%	25%	32%
I don't like the proposed bill increase, but I think it's necessary to maintain the grid to a reasonable standard and prepare for the future	37%	39%	54%
Total Social Permission for Investment Plan	**84%**	**83%**	**94%**
I oppose the bill increase and think Hydro Ottawa needs to scale back its plan	11%	13%	2%
I don't know	5%	4%	4%

3.4. BUSINESS STRATEGIES

This section outlines business strategies that oversee the key asset categories: Asset Management, Grid Modernization, Digital, Facilities, and Fleet. These strategies are grounded in a consistent framework that aligns corporate Strategic Direction and customer feedback with individual asset needs. The following sections detail the specific strategies for each category.

3.4.1. Asset Management Strategy

Hydro Ottawa's Asset Management Strategy, which covers distribution assets, creates the crucial link between the company's overarching strategic objectives and customer preferences and priorities down through to the Asset Management Objectives, as illustrated in Figure 5. These objectives then guide the development of individualized asset management plans

[2] Totals may not sum due to rounding.

(AMPs) that support the foundation of the capital investment planning process. See Section 4.2 - Asset Management Scope, Strategy and Objectives for further details on the strategy.

3.4.2. Grid Modernization Strategy

Hydro Ottawa's Grid Modernization Strategy is a comprehensive plan to address evolving challenges in the utility sector. Developed in response to deteriorating infrastructure, decarbonization, and changing customer expectations, the strategy aims to enhance grid reliability, flexibility, resilience, and customer engagement while promoting sustainability. The strategy promotes five grid modernization objectives, and aligns with the company's Eight point strategy, see Section 3.2 - Corporate Strategic Objectives, emphasizing data-driven and technologically-advanced grid management.

A reliable and modernized grid is at the core of Hydro Ottawa's Strategic Direction. To enable the company's Eight point strategy, the grid modernization plan outlines five grid modernization objectives:

1. **Enhanced Reliability**
   Improve grid reliability through advanced monitoring, proactive failure detection, fast fault detection, automated power control, automated system restoration, and reduced outage times.
2. **Adaptive Grid Flexibility**
   Enable the grid to adapt to the changing energy demand and incorporate diverse energy sources.
3. **Fortified Resilience & Robust Security**
   Improve the grid's ability to withstand disruptions caused by system faults or extreme weather and protect its assets from cyber threats.
4. **Strengthened Customer Engagement & Empowerment**
   Engage and empower customers by providing them with real-time data, efficient billing, and tools to manage their energy use.

5. Sustainable Decarbonization & Renewable Integration

Reduce carbon emissions and promote sustainability by optimizing grid planning and operations to support the integration of renewable energy sources.

Table 3 illustrates how each of the five objectives contribute to the Eight point strategy.

The Grid Modernization Strategy translates the corporate priorities into actionable objectives, which are then achieved through the Asset Management and Digital Strategies. This strategy informs the objectives of both the Asset Management and Digital Strategies, ensuring coordinated investment and avoiding duplicated effort or inefficiencies that could arise from shared asset accountabilities. Specifically, it allows for sole oversight and coordination of distribution assets under the Asset Management framework and information technology (IT) assets under the Digital framework.

The Grid Modernization Roadmap operationalizes the Grid Modernization Objectives in conjunction with the Capital Expenditure plan. The Strategy defines the needs, which are then translated through the Asset Management and Digital strategy processes into concrete investment plans. These plans are consolidated within the capital expenditure planning process and monitored through the Grid Modernization Roadmap to ensure the Grid Modernization Objectives are achieved.

Table 3 - Comparative Analysis of Grid Modernization Objectives and Eight Point Strategy

		Eight Point Strategy							
		Achieve net-zero operations by 2030	Become the partner of first choice for signature green energy and carbon reduction projects in our community	Accelerate digital transformation to enable sustainable business practices	Leverage and promote distributed energy resources	Continue to grow and diversify our revenue sources	Grow our social license to operate	Ensure organizational capacity, culture, and leadership to deliver in a post-pandemic environment	Continue to provide best-in-class customer service
Grid Modernization Objectives	1. Enhance Reliability			✓	✓		✓	✓	✓
	2. Adaptive Grid Flexibility	✓	✓	✓	✓			✓	✓
	3. Fortified Resilience & Robust Security			✓	✓		✓	✓	✓
	4. Strengthened Customer Engagement & Empowerment		✓	✓	✓	✓	✓	✓	✓
	5. Sustainable Decarbonization & Renewable Integration	✓	✓	✓	✓	✓	✓	✓	✓

3.4.3. Digital Strategy

The 2026-2030 Digital Strategy is built on the overarching Strategic Direction of Hydro Ottawa. There are five key themes of the digital strategy:

Customer Experience

Providing customers with the tools to understand their consumption patterns and costs, giving them more control over their usage. Generative AI will be able to assist customers 24/7, creating a faster and more convenient way for customers to get answers.

Employee Experience

Employees expect to be able to access the tools they need where they are, when they need them, in a secure manner. Touch-screen devices and modern applications, on web or mobile, augment workflow efficiency for employees in the field. HR and safety platforms will continue to be improved as a core aspect of the employee experience.

Productivity & Operational Effectiveness

The new Enterprise Asset Management (EAM) System referred to in Attachment 4-1-1(A) - Transition to Cloud Computing will improve lifecycle management and optimize resource planning. Planned enhancements to the ERP system will streamline workflows.

Grid Automation

Increasing demand for electricity, combined with the increasing threat of severe weather events, require a reliable and responsive grid. Automation and the integration of technology like DERs, have the potential to meet these needs.

Cyber Security & Business Continuity

The risks from cyber threats are growing as the world becomes more interconnected. Hydro Ottawa, as a critical infrastructure company, must invest not only protection from these threats, but proactive detection and response.

For more details on the Digital Strategy, please see Attachment 1-3-4(B) - Digital Strategy.

3.4.4. Facilities Strategy

The facilities strategy is a key pillar of Hydro Ottawa's Eight point plan by supporting the organization's capacity to deliver its programs and moving toward its goal of achieving Net-Zero Operations. The overall facilities strategy is to maintain facilities in a suitable condition for their intended purpose and to achieve the lowest overall lifetime cost of ownership. The Facilities Program manages a portfolio of administration, operations, and substation building components needed to provide the environment necessary for employees to work safely, effectively and efficiently as well as to protect and store inventory and operating equipment. For clarity, the substation building components refer to the building shell and supporting systems such as fencing, ground surfaces - asphalt / concrete, roofing, and HVAC Systems. Facilities are strategically located throughout Hydro Ottawa's service territory to provide operational coverage and allow for a central location for administration and for training functions.

Hydro Ottawa invests in building improvements that are critical to the operation of the utility's electricity distribution system. Capital expenditures in the Facilities Program relate to structures, systems, and site work necessary for a facility to reach its operational service life or capital expenditures that extend service life enhance capacity or functionality of the facility. For example, expenditures on window and roof replacement help to ensure an ongoing safe and effective work environment and also avoid the potential cost of building structural damage or deterioration and future costly repairs.

Operations and maintenance costs for these facilities are included in the Facilities Program and discussed in Schedule 4-1-2 - Operations, Maintenance and Administration Program Costs.

Hydro Ottawa's Facilities strategy is focused on two main types of facilities, as outlined below.

Administration Facilities

Hydro Ottawa's two main Administration centres are located at 2711 Hunt Club Road and 4565 Bank Street. The primary function of investments in these facilities is to help ensure productivity by replacing poor-condition and end-of-life assets that may otherwise cause hazards or business interruptions. Expenditures also include investments that support the utility's strategic objectives and outcomes, such as providing suitable space for new staff additions.

Stations and Operations Facilities

Stations and Operations facility capital investments are to sustain and improve buildings that house Hydro Ottawa's distribution stations and operations and manage risks that may arise from any facility's assets deteriorating to the point of poor condition or end of life. The integrity and operating condition of stations buildings may significantly affect safety and the reliability of distribution equipment housed within these assets, which are critical to grid safety and performance.

The Facilities Strategy considers both the condition of all facility assets in the process to develop the capital work program and the imperative to comply with legislative and regulatory requirements, as described below:

Asset Condition Assessment

Hydro Ottawa undertakes an Asset Condition Assessment (ACA) process to determine both (a) the risks that may be present in respect of facilities assets, and (b) plans to mitigate these risks. The results of this assessment and risk management prioritization process were used to inform the planned scope of the Facilities Program capital work for the 2026-2030 rate period. Without sufficient funding to make these investments, Hydro Ottawa's facilities would be exposed to the risk of structural failures, significant hazards, and/or damage, e.g. due to flooding or leaking. If these risks were to materialize, they could endanger Hydro Ottawa's employees and public safety and cause severe disruption to the utility's business activities and potentially prolonged outages.

Legislative and Regulatory Requirements

It is essential that Hydro Ottawa be compliant with applicable legislative and regulatory requirements, such as the *Occupational Health and Safety Act*, the Ontario Building Code and the Fire Code. The Facilities Program supports this by:

- Providing safe and functioning facilities by addressing deficiencies that may cause hazards;
- Addressing stations-related deficiencies such as the absence of secondary exits, non-compliant stairs, and inaccessible doors along pathways;
- Improving internal lighting conditions and external damaged lighting in work areas;
- Installing enhanced safety systems to deter theft, vandalism and reduce the risk of unauthorized access into work centres and stations; and
- Installing and improving security systems and technology.

Hydro Ottawa identified required work over the 2026-2030 rate period based on inspections and management judgement with respect to sound asset management practices. Capital expenditure decisions were also informed by Hydro Ottawa's Net-Zero Strategy. This includes replacements and upgrades of equipment that is reaching end of life with electrically powered equipment that meet certain standards and reduce environmental impacts, where it is feasible and cost effective to do so. These expenditures include electrical service upgrades that are necessary to support green initiatives and equipment such as electric heat pumps and water heaters. Further details on Hydro Ottawa's Net-Zero Strategy can be found in Attachment 4-1-3(E) - Health, Safety and Environmental Compliance, Sustainability and Business Continuity Management, Section 5.2. All identified work was prioritized and only critical projects are included in this plan. Projects that were identified but not funded in this plan will be brought forward in the next rate application.

3.4.5. Fleet Strategy

The fleet strategy is a vital component of Hydro Ottawa's Eight point plan by providing the vehicles and equipment that support the organization's capacity to deliver its programs and contribute toward its goal of achieving Net-Zero from operations. Hydro Ottawa's fleet management practices are governed by established corporate policies and procedures related to fleet operations and asset lifecycle management. Vehicle purchases are made in accordance with standard Hydro Ottawa procurement policies and procedures.[3] Hydro Ottawa's fleet is categorized as Light-duty (pick-up trucks, vans) for staff transport and inspections; medium-duty (dump trucks, step vans) for materials and mobile workshops; heavy-duty (bucket trucks) for line work; and specialized equipment (trailers, forklifts) for support.

The utility has a multi-year capital plan to effectively manage, replace and add to its fleet assets. The objectives of the fleet replacement/addition plan are as follows:

- **Safety:** Provision of safe, reliable, and efficient vehicles and equipment to meet operational requirements.
- **Regulatory:** Compliance with all applicable legislation and regulations, as well as accepted industry norms and practices. For example, Fleet must perform annual vehicle inspections to make sure vehicles are compliant with its Commercial Vehicle Operators Registration.
- **Financial:** Management of assets to the lowest overall lifecycle cost, while ensuring asset reliability and employee and public safety.
- **Environmental:** Environmental considerations from the point of procurement through the life of the vehicle. This includes consideration of fuel economy, exhaust emissions, route optimization, reducing idle time (through education of vehicle operators), and reviewing environmentally friendly options where feasible.
- **Operational:** Provision of readily available and reliable vehicles and equipment to meet the requirements of an expanding workforce.

A key objective is that capital investments be made at a level and pace that allows overall costs to be minimized. An optimally-timed vehicle replacement and growth strategy helps to ensure that the appropriate number of vehicles are available to support system maintenance and capital investment

[3] Please see Attachment 4-2-2(A) - Procurement Policy.

plans. The planned pooling program as described in Schedule 2-5-9 - General Plant Investments will further minimize costs and optimize vehicle utilization.

Hydro Ottawa's fleet replacement plan reviews all current vehicles and proposes future replacement dates and cost. The replacement plan is based on a vehicle-by-vehicle assessment weighing the following criteria:

- Vehicle age
- Mileage
- Engine hours
- Power take off (PTO) hours
- Operating and maintenance costs
- Repair history
- Availability of repair parts
- Overall internal mechanic assessment of vehicle condition
- Utilization

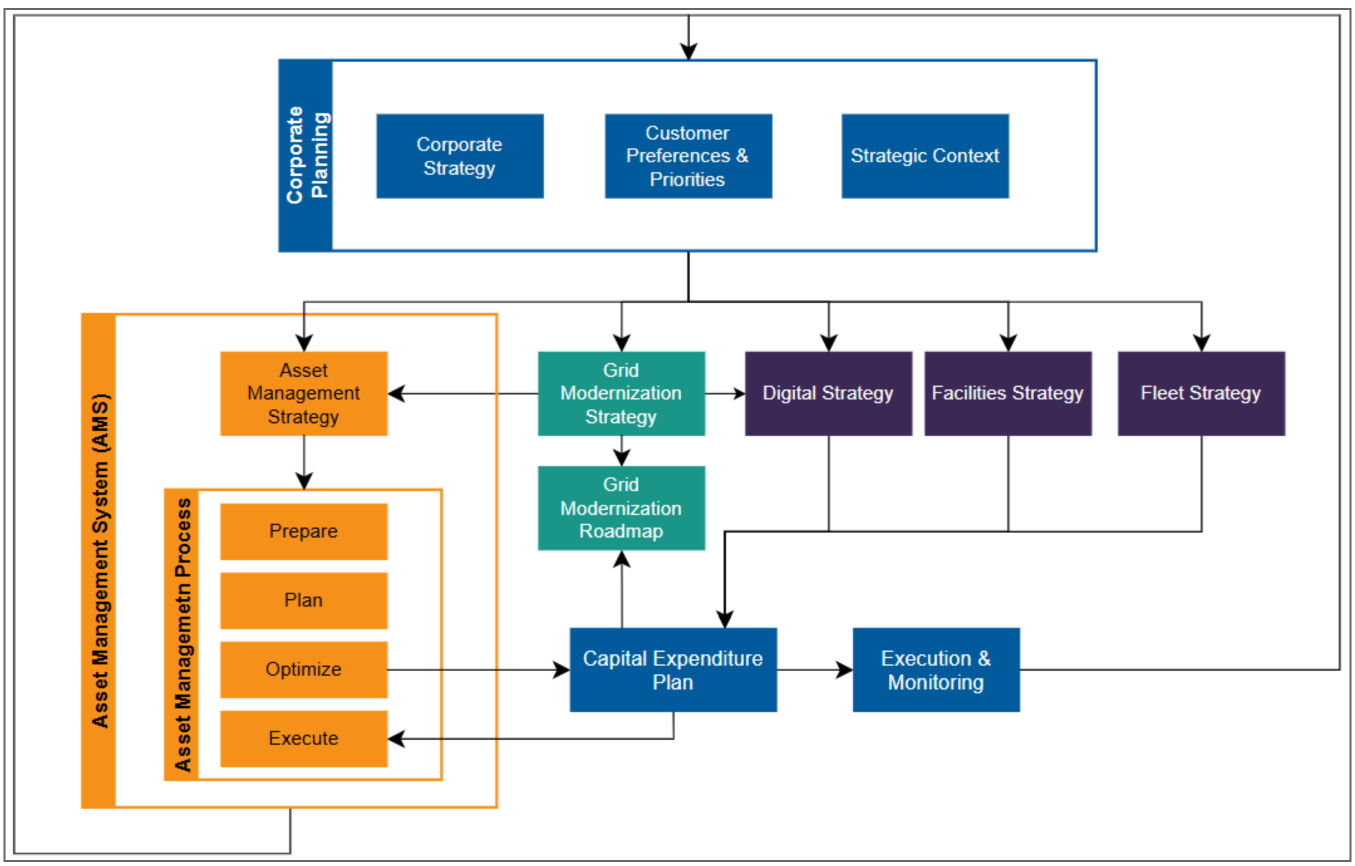
As a result of these assessments, vehicles may be retained longer due to being in better than average condition, while others may be replaced earlier due to being in poorer condition. Of note, Ottawa is subject to extremely hot and humid summers and harsh and cold winters. This has a direct effect on the life expectancy of engines and hydraulic equipment as well as on road conditions. Reactive repairs increase during the harsh months and vehicle condition can sometimes deteriorate ahead of projected schedules. Hydro Ottawa factors in conditions such as these, along with specific vehicle condition assessments, in order to determine which vehicles should be replaced and the appropriate year of replacement.

Hydro Ottawa continues to invest in green fleet vehicles and technology, where it is available for commercial fleets and cost effective. This includes replacing vehicles, as per the established fleet replacement schedule, with hybrid or more energy efficient vehicles, where available; hybrid technology to operate hydraulics for aerial devices, where it is effective; battery technology to eliminate idling for heating and lighting, while servicing underground cabling; and electric vehicles (EVs), where appropriate.

3.5. CAPITAL EXPENDITURE PLANNING PROCESS

Hydro Ottawa's business planning process uses a cascading structure: corporate objectives inform business strategies, which then guide investment plan development. These plans are then optimized and prioritized within the expenditure planning process, culminating in the Capital Expenditure Plan, as illustrated in Figure 3.

Figure 3 - Detailed Business Planning Process



Distribution asset management investment plans originate within the AMS and are also shaped by the Grid Modernization Strategy. These plans feed into the expenditure planning process, and approved plans are executed and monitored within the AMS through the core asset management process. Sections 4 through 9 of this Schedule details the AMS.

IT investment plans, governed by the Digital Strategy and aligned with the Grid Modernization Strategy, are combined with the Fleet, Facilities and Asset Management investment plans within the expenditure planning process. Selected plans are executed and monitored under their respective governance processes.

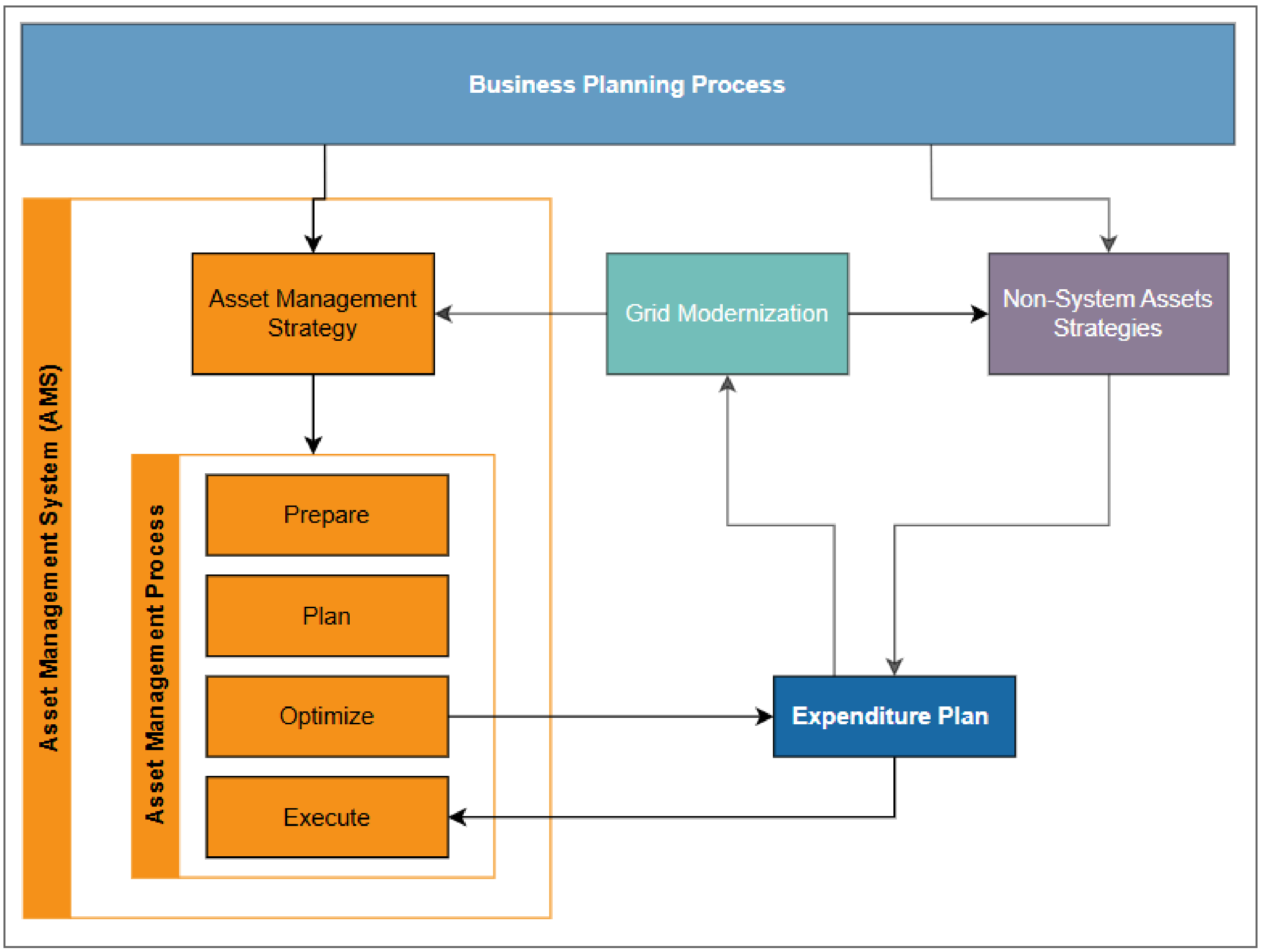
The Capital Expenditure Planning Process evaluates proposed investment plans and alternatives, balancing overall corporate risk to determine investment priorities for the Capital Expenditure Plan. This plan is handed back to the various areas of the business to implement through their asset management frameworks.

The remainder of this Schedule details the AMS, from the guiding Asset Management Strategy to the identification, execution, and monitoring of the capital expenditure plans for the distribution assets.

4. ASSET MANAGEMENT OVERVIEW

This section provides a comprehensive overview of Hydro Ottawa's AMS, outlining the strategic framework guiding the management of its distribution assets, which are critical to the utility's core operation. By effectively managing its assets, Hydro Ottawa ensures it can provide safe, reliable, and affordable electricity. Components of Hydro Ottawa's AMS are shown in Figure 4.

Figure 4 - Hydro Ottawa's Asset Management System



Hydro Ottawa's AMS, certified against ISO 55001, manages assets through a four-stage process: prepare, plan, optimize, and execute. The program-level output from the optimization stage is integrated with results from other non-system assets for optimization of the entire asset portfolio. This process, which is described in Section 3.5 - Capital Expenditure Planning Process, ensures that assets are used effectively and efficiently to provide value to customers and stakeholders and that non-system assets are planned to support the utility's core operations. Once the expenditure plan has been submitted and approved, it is used as a directive to develop a project-level list for annual execution.

Hydro Ottawa is committed to continuously improving its AMS to meet future challenges by leveraging data-driven insights and advanced technologies to optimize asset performance, enhance service reliability, and deliver long-term value.

The asset management processes culminate in a Capital Expenditure Plan that effectively delivers on the four Investment Priorities: Growth & Electrification, Renewing Deteriorating Infrastructure, Grid Modernization and Enhancing Grid Resilience. This is achieved through strategic mapping that aligns program-level decisions with the DSP Investment Priorities, see Section 2.3 of Schedule 2-5-1 - Distribution System Plan Overview, ensuring that all expenditures and activities contribute to achieving Hydro Ottawa's long-term goals for a reliable, resilient, and modern electricity grid.

This section provides a comprehensive overview of Hydro Ottawa's AMS, specifically tailored for the management of distribution assets. It is divided into the following key areas to provide a structured and detailed exploration of the AMS:

- **Section 4.1: Asset Management System Certification** delves into the processes and achievements related to the certification of Hydro Ottawa's AMS. It outlines the requirements and standards that the AMS has been certified against, as well as the benefits that certification brings to the organization and its asset management practices.
- **Section 4.2: Asset Management Scope, Strategy, and Objectives** defines the scope of Hydro Ottawa's AMS, outlining which asset classes and types are included within its purview. It articulates the overarching strategy that guides the AMS, including the goals and

objectives that the organization aims to achieve through effective asset management.

- **Section 4.3: Asset Management Overview** provides a holistic overview of the AMS, explaining its core components, processes, and how it integrates with other organizational systems and functions.
- **Section 4.4: Asset Management Process Enhancements** explores the ongoing efforts to improve and enhance Hydro Ottawa's AMS. It discusses new technologies, methodologies, or strategies that are being implemented to optimize asset performance, reduce costs, and improve overall asset management outcomes. It also includes information about lessons learned from past experiences and how they are being applied to future asset management initiatives.

4.1. ASSET MANAGEMENT SYSTEM CERTIFICATION - ISO55001

Hydro Ottawa's asset management process is certified against the ISO 55001 standard, as outlined in Section 4.2 - Asset Management Scope, Strategy, and Objectives. This international standard provides a framework for asset management systems, offering a structured approach for utilities to optimize the value and minimize the risks of their physical assets throughout their lifecycle.

This framework helps an organization manage the lifecycle of their assets, from acquisition to disposal. Hydro Ottawa’s certification against ISO 55001 demonstrates that its AMS:

- Ensures that assets are managed systematically and consistently.
- Improves the efficiency and effectiveness of asset management.
- Reduces risks associated with asset ownership.
- Improves decision-making about asset investments.
- Ensures that asset management objectives are achieved.
- Demonstrates a commitment to asset management best practices.

In 2023 Hydro Ottawa's AMS was re-certified against the ISO 55001 standard, demonstrating that it has been independently audited and meets all requirements. For details, see Attachment 2-5-4(A) -

ISO 55001 Hydro Ottawa Certificate of Conformance 2023. This achievement showcases Hydro Ottawa's ongoing commitment to excellence in asset management.

The ISO 55001 certification process includes a rigorous evaluation of the utility's asset management practices, including planning, implementation, monitoring, and improving asset performance. The standard requires utilities to establish clear asset management objectives, develop strategies to meet these objectives, and implement processes to ensure continuous improvement and risk management. To maintain this certification, Hydro Ottawa undergoes scheduled internal and external audits to ensure that the standard is met on an ongoing basis. These audits help to identify areas for improvement and ensure assets are effectively managed to deliver value to customers and stakeholders.

By attaining ISO 55001 certification, Hydro Ottawa has demonstrated strength in managing its assets responsibly and effectively. The certification demonstrates that Hydro Ottawa has a robust AMS that optimizes the performance and value of its assets, minimizes risks, and ensures long-term sustainability.

4.2. ASSET MANAGEMENT SCOPE, STRATEGY, AND OBJECTIVES

As outlined in Section 3.2 - Corporate Strategic Objectives, Hydro Ottawa's Eight point strategic objectives outline the company's business strategy, and provides all stakeholders with visibility into trends shaping the business environment and how the company plans to respond.

The Eight point plan establishes a balanced program for robust performance in existing operations as well as sustainable and profitable growth, with a focus on customer centricity, financial responsibility, and responsiveness to a changing environment. This alignment underscores Hydro Ottawa's commitment to adapting to evolving market conditions and customer needs, ensuring continued success and relevance in a dynamic industry.

The company's Eight point plan serves as the foundation for developing the Asset Management objectives and the outcomes used to evaluate the risk and performance of the AMS.

4.2.1. Asset Management Scope

Hydro Ottawa's AMS covers distribution assets, metering, and specified telecommunications assets. Distribution assets are further categorized into several asset classes:

- Station Assets
    - Station Transformers
    - Station Switchgear & Breakers
    - Station Batteries, Protection & Control Equipment
- Overhead Assets
    - Poles, Fixtures & Primary Overhead Conductors
    - Overhead Switches
    - Overhead Transformers
- Civil Structures
- Underground Assets
    - Underground Primary Cables
    - Distribution Underground Transformers
    - Distribution Underground Primary Switchgear
    - Vault Transformers
- Telecommunications
- Metering

This categorization allows for targeted management and maintenance practices, which help to ensure the reliability and efficiency of the electrical infrastructure and a focused and effective approach to asset management in aligning with its Eight point strategic objectives.

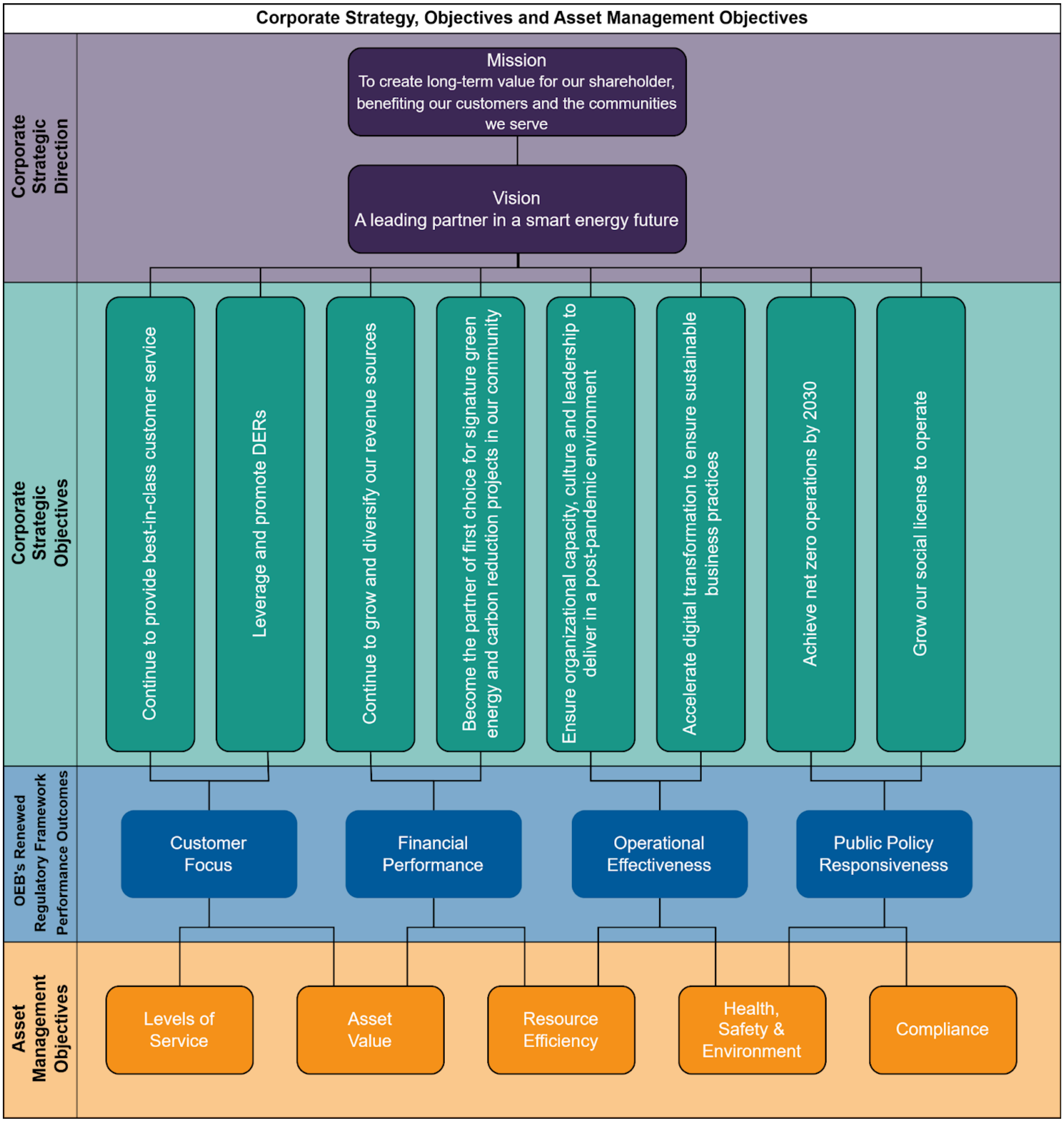
4.2.2. Asset Management Strategy

Hydro Ottawa's Asset Management Strategy provides a crucial link between the company's overarching strategic objectives and the focused goals of asset management. This strategy not only outlines the development of individualized AMPs but also emphasizes the critical role these plans play in achieving those objectives. A visual representation of this cascading hierarchy, from corporate Strategic Direction through to the asset management objectives, is illustrated in Figure 5. By establishing this framework, Hydro Ottawa ensures a cohesive and strategic approach, aligning all asset management endeavors with the company's broader vision and goals.

Hydro Ottawa's asset management strategy is based on data and a portfolio approach that balances risk reduction with level investments. The strategy gives priority to the following:

- **System Risk Mitigation:** Addressing assets that pose the greatest risk to reliability, environment and safety, in a proactive manner.
- **Maintaining Asset Performance:** Extending the life and value of assets through targeted renewals and upgrades, timely repairs, and proactive maintenance. Proactive maintenance includes making investments to improve data collection, quality, and condition assessments for critical assets, which prevents minor issues from becoming major problems.
- **Portfolio Investment Optimization:** Balancing program investments across the portfolio to achieve a level investment strategy for effective asset replacement and renewal targets.

1 **Figure 5 - Corporate Strategic Direction & Asset Management Objectives**



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4.2.3. Asset Management Objectives

Hydro Ottawa's AMS is built upon a foundation of five Asset Management Objectives, ensuring that investments and activities directly support both the company's Eight point plan and the four OEB Performance Outcomes. These five Asset Management Objectives, as detailed in Table 4, act as guiding principles for all asset-related decisions. They ensure a focus on maintaining high **Levels of Service**, maximizing **Asset Value**, driving **Resource Efficiency**, prioritizing **Health, Safety & Environment**, and maintaining **Compliance**. These objectives are not just abstract goals; they are actively pursued through Hydro Ottawa's established asset management processes and translated into tangible capital, operational, and maintenance programs.

Table 4 - Asset Management Objectives

Asset Management Objective	Description
Levels of Service	To maintain and enhance the leading performance of the distribution system through improving electrical service and alignment with customers' expectations.
Asset Value	To maximize the realization of value from distribution assets over their entire lifecycle through managing risks and opportunities.
Resource Efficiency	To maximize economic efficiency by minimizing costs associated with maintaining and operating the distribution system.
Health, Safety & Environment	To minimize employee and public health and safety risks and environmental risks from distribution system activities.
Compliance	To maintain compliance with all internal and external requirements while managing the distribution system.

The connection between overarching objectives and practical execution becomes even clearer when examining Hydro Ottawa's four strategic Investment Priorities for the 2026-2030 DSP. These priorities—Growth & Electrification, Renewing Deteriorating Infrastructure, Grid Modernization, and Enhancing Grid Resilience—are the direct result of a comprehensive analysis that considered customer feedback, system needs, historical performance, and future trends.

The four Investment Priorities serve as the practical application of the five Asset Management Objectives.

1. **Growth & Electrification - Powering a Growing Community:** This priority, focused on expanding grid capacity, relies on all five Asset Management Objectives. Levels of Service ensures the expanded grid meets growing demand reliably. Asset Value guides strategic investments in new infrastructure with long-term value. Resource Efficiency ensures cost-effective expansion. Health, Safety & Environment prioritizes safety and environmental responsibility during expansion. Compliance ensures all expansion activities meet regulatory requirements.

2. **Renewing Deteriorating Infrastructure:** This priority, focused on upgrading deteriorating infrastructure, is heavily driven by Asset Value, as the core goal is to maximize the remaining value of existing assets through strategic replacements and upgrades. Levels of Service is also crucial, as these upgrades aim to improve reliability and prevent service disruptions. Resource Efficiency plays a role in selecting replacements that are more efficient. Health, Safety & Environment is paramount, as older infrastructure may pose safety or environmental risks. Compliance ensures all upgrades meet current standards.

3. **Grid Modernization - Enabling the Energy Transition:** This priority, focused on technology adoption and infrastructure upgrades for the energy transition, relies heavily on Levels of Service, as modernization aims to improve grid capabilities and customer experience. Asset Value guides the selection of modern technologies with long-term value. Resource Efficiency is often a key driver, as modern grids can optimize energy flow and reduce losses. Health, Safety & Environment is essential, as new technologies must be implemented safely and with environmental considerations. Compliance ensures all modernization efforts adhere to regulations.

4. **Enhancing Resilience** This priority, focused on protecting against severe weather and cyber threats, is strongly linked to Levels of Service, as resilience measures aim to maintain service during disruptions. Asset Value informs investments in resilient infrastructure. Resource Efficiency guides cost-effective resilience measures. Health, Safety & Environment is crucial, as resilience efforts must consider safety and environmental impacts. Compliance ensures all resilience measures follow regulations and best practices.

In essence, the four Investment Priorities are the "how" – the concrete actions – that will enable Hydro Ottawa to achieve its "what" – the five overarching Asset Management Objectives. This strategic alignment ensures that every investment contributes to a more reliable, resilient, and future-ready electricity system for the community.

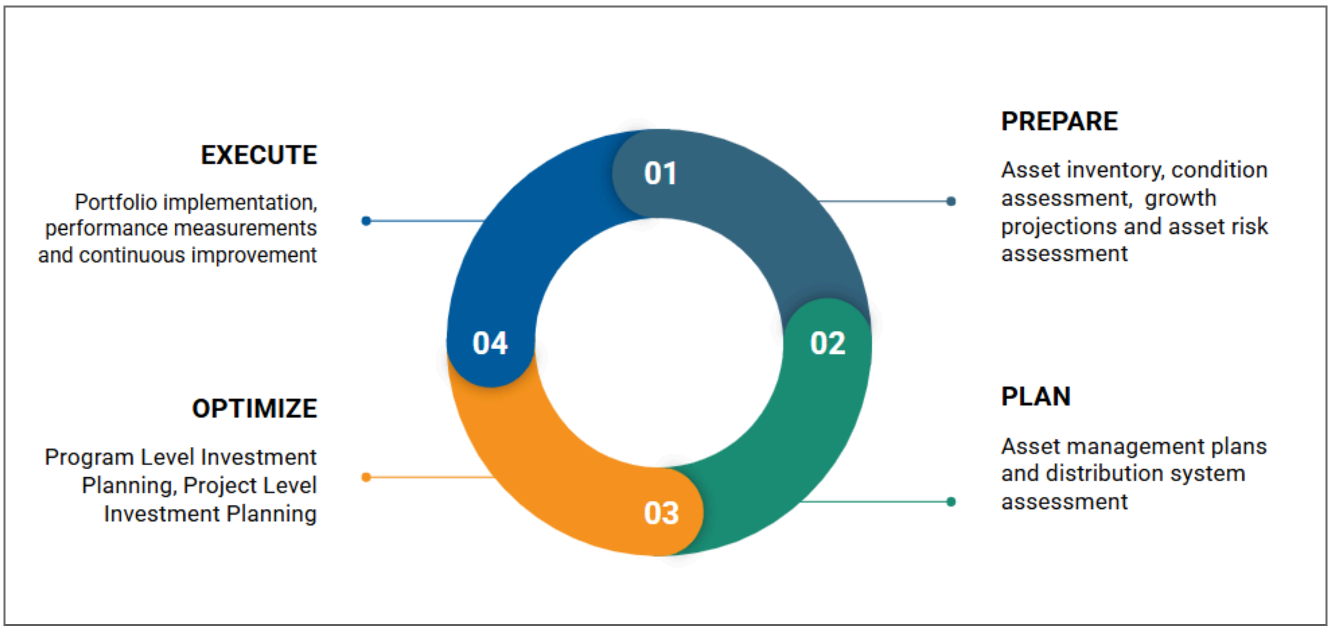
The Asset Management Objectives consider stakeholder expectations, business drivers, and compliance with relevant legislation, codes, licenses, and technical standards. Hydro Ottawa's commitment to delivering safe, reliable, and sustainable electricity to support community growth and prosperity is reflected in its approach to asset management. The AMS is revisited annually to ensure that it incorporates evolving industry best practices and maintains alignment with Hydro Ottawa’s Strategic Direction, regulatory changes, and emerging technologies. This process ensures that Hydro Ottawa's asset management practices effectively support the company's objectives, driving strong performance, sustainable growth, and value creation for stakeholders.

4.3. ASSET MANAGEMENT PROCESS OVERVIEW

Hydro Ottawa's asset management process for distribution assets, certified against the ISO 55001 standard, utilizes a risk-based approach to optimize the value and resource efficiency of its assets while ensuring compliance and effective risk management. This process is guided by asset management objectives outlined in Section 4.2 - Asset Management Overview, which covers the Scope, Strategy, and Objectives of Asset Management.

The asset management process at Hydro Ottawa consists of four main stages: prepare, plan, optimize, and execute, as illustrated in Figure 6.

Figure 6 - Hydro Ottawa's Asset Management Process



The **prepare** stage involves establishing the context of asset management by identifying assets and associated risks, reviewing results from testing and maintenance, analyzing assets condition, identifying regional growth, and analyzing performance metrics.

The **plan** stage encompasses the development of comprehensive AMPs that directly address the identified risks and objectives. This involves a strategic alignment of asset plans with the overarching system needs, ensuring that capacity constraints, reliability, resilience, and grid modernization requirements are all taken into account. A key component of this stage is the identification of both capital and operations, maintenance, and administration (OM&A) investments required to support the asset management strategy and achieve the desired outcomes.

The **optimize** stage consists of two parts: program-level assessment and project-level assessment. During program-level assessment, plans to address asset and system needs are allocated under specific investment categories and programs based on primary drivers. In addition, plan alternatives are evaluated in material investment plans (MIP) for evaluation and selection of the preferred alternative. Project-level assessment involves evaluating and scoring identified projects. This stage utilizes a portfolio optimization tool to further refine and optimize project selection.

The **execute** stage includes implementing the plan, tracking performance for ongoing improvement, and making necessary adjustments to ensure that the AMPs achieve their objectives. Additionally, any insights gained during this phase are integrated into the development of the subsequent plan.

Hydro Ottawa's asset management process is designed to align asset management practices with both organizational objectives and customer expectations, ultimately ensuring the safe, reliable, and cost-effective delivery of electricity. This risk-based approach enables the utility to maximize asset value, enhance operational efficiency, and bolster service reliability. Furthermore, it supports compliance with regulatory requirements and facilitates sound financial risk management. A more detailed exploration of the Asset Management process can be found in Section 5.

4.4. ASSET MANAGEMENT PROCESS ENHANCEMENTS

Hydro Ottawa continuously reviews its asset management process to identify opportunities for enhancements that would help to navigate the changing electrical distribution network landscape. In this regard, some of the asset management process enhancements introduced by Hydro Ottawa since the 2021-2025 DSP include:

4.4.1. Implementation of Predictive Analysis

In 2024, Hydro Ottawa enhanced its asset management framework by incorporating Predictive Analytics (PA) into its System Renewal investment planning. This involved creating a comprehensive distribution asset model within the Copperleaf Asset PA module. Copperleaf is an Asset Investment Planning and Management software solution that provides evidence-based support for strategic asset planning and budgeting decisions. This integrated, enterprise-wide solution connects and streamlines asset analytics, risk, financial and performance modeling, investment portfolio optimization, budgeting, and variance analysis, ultimately supporting a risk-informed approach to asset management.

In order to manage assets effectively, PA was required as a tool to predict the effects of asset degradation over time and the required spending on the remediation of the deteriorated assets. The PA module within Copperleaf forecasts system renewal investment needs for Hydro Ottawa's asset population and generates the risk and cost profiles of various sustainment levels. The output of Copperleaf PA can then be input into Copperleaf Portfolio, Hydro Ottawa's investment optimization software (refer to section 5.3.2 for more details) as investments. The information generated by Copperleaf PA will grow and be refined over time as there are improvements to asset risk information.

Copperleaf PA leverages age/Health Index information or condition assessments to determine the probability of failure and the risks associated with each asset. Based on the risk information at the individual asset level, Copperleaf PA can create an optimal strategic plan for the entire asset population.

Copperleaf PA utilizes various information such as asset nomenclature, condition data, probability of failure curves, risk consequences, and intervention data, to compute risk at an individual asset level. Key risk measures, such as those related to reliability, safety, environmental impact, financial implications, and compliance, are calculated by the model.

Deployed across Hydro Ottawa's major asset classes, this model forecasts the impact of asset degradation over time. This enables risk assessment and optimized replacement scheduling by evaluating the overall value of various intervention strategies, ultimately leading to more informed investment decisions. The PA module helps to determine the optimal timing for asset interventions like replacements or upgrades. It considers factors such as risk mitigation, cost-effectiveness, and resource constraints to guide investment decisions. By considering a comprehensive range of risk factors and optimizing intervention strategies, PA has enabled Hydro Ottawa to make more informed system renewal investment decisions for this application. Further details are available in Section 5.1.4 - Asset Risk Assessment of this Schedule.

4.4.2. Inspection Enhancements

Through 2024, Hydro Ottawa further improved its testing, inspection, and maintenance programs to capture additional inspection parameters down to the asset component level such as insulators, elbows, barriers, etc. As a result, Hydro Ottawa is gathering more granular visual inspection and infrared scanning data on its distribution equipment. Specifically, the overhead asset inspection program now captures information on pole-mounted transformers, switches, and related hardware at every pole inspected rather than only when an issue was found, though currently only from the ground level, as noted in Schedule 4-1-2 Operations, Maintenance and Administration Program Costs, a drone pilot program is planned for 2025.

For underground infrastructure, Hydro Ottawa enhanced its cable testing methodology by including advanced testing methods such as Very Low Frequency Tan-Delta, Partial Discharge, and Time Domain Reflectometry. These advanced techniques provide a deeper understanding of the condition of cable components, facilitating targeted remediation efforts, compared to the initial cable testing technique employed by Hydro Ottawa, which was solely based on the detection of water trees in the cable insulation. Furthermore, Hydro Ottawa has expanded its vault inspection program to include visual and infrared assessments of vault equipment, in addition to the civil inspection.

These improvements in data collection and analysis empower Hydro Ottawa to conduct more accurate condition assessments. This enhanced accuracy is essential for effective risk-based investment planning through PA and the proactive maintenance of Hydro Ottawa's critical asset infrastructure. Further details regarding Hydro Ottawa's 2026-2030 preventative maintenance programs are available in Schedule 4-1-2 - Operations, Maintenance and Administration Program Costs.

4.4.3. Comprehensive Asset Health Indexing

In 2023, Hydro Ottawa started to enhance its ACA framework by incorporating parameters captured through existing testing, inspection and maintenance programs into the calculation of asset health index scores. This change was driven by a need for more precise condition assessments to inform risk-based investment planning to effectively maintain assets, based on information already captured through inspections, but not utilized in health indexing.

Previously, Hydro Ottawa's condition assessments relied on less granular data, focusing on reporting on exceptions or major issues identified during inspections. The new framework includes asset-specific parameters for calculating the health index score, based on data already being gathered through inspections. These parameters are tailored to reflect the specific degradation mechanisms and failure modes relevant to each asset class. These enhancements ensure that the relevant data required for calculating the updated health index is collected for each individual asset. This shift from exception-based reporting to individual asset assessment provides a much richer dataset.

Some other key improvements implemented to the asset health indexing process include:

- Reducing the heavy reliance on age as a major contributor to health index through two ways:
    - Decreasing the weighting assigned to age as a part of the health indexing process.
    - Translating age to condition based on the linear piecewise relationship established between age and condition through the failure curve development exercise outlined in Section 4.4.4 - Failure Curves and Typical Useful Life Update. This approach was used to determine the equivalent condition value for assets that had a known age, but lacked a valid health index.
- Implementing validity to the health index process to ensure that at least 70% of the condition information is available to define a health index value.

With improved condition data, Hydro Ottawa will make more informed, risk-based investment decisions through the use of PA. This means prioritizing System Renewal investments by the assets that pose the greatest risk to system reliability, safety, and performance. A third-party assessment of Hydro Ottawa's ACA implementation, completed in 2024, confirmed the robustness of its framework. The assessment, conducted by Hatch, found that Hydro Ottawa's ACA framework used best-practice formulations and was well-integrated with its broader asset management processes, procedures, and outcomes. For further information, please refer to Attachment 2-5-4(C) - Asset Condition Assessment Third Party Review. While Hatch identified minor calculation gaps with minimal portfolio impact, Hydro Ottawa has already implemented updates to address them. Hatch also provided recommendations for ACA methodological enhancements, and Hydro Ottawa is currently gathering additional data and exploring solutions to support advanced analytics and meet evolving data needs, through improvements to OM&A programs as outlined in Schedule 4-1-2 - Operations, Maintenance and Administration Program Costs.

4.4.4. Failure Curves and Typical Useful Life Update

In 2024, concurrent with the PA implementation, Hydro Ottawa engaged Hatch to enhance asset failure curve knowledge and insights, aiming to refine the utility's risk-based and value-based asset management framework. This initiative involved:

- A thorough review of existing failure curves.
- The development of new, data-driven failure curves.
- Augmentation of existing age-condition curves using asset registry data to improve accuracy.
- Establishing the TUL values of the various asset types.

As the first step of the data-driven failure curve development process, Hydro Ottawa provided Hatch with the asset registry information for all major asset classes, including:

- All asset-related information such as the voltage class, current rating, insulation type, installation date, health index, etc.
- Existing asset failure curves and TUL information
- Number of assets replaced each year (since 2016) within each asset class under the different OEB investment programs (System Renewal - Planned and Corrective, System Service, and System Access)

Hatch employed statistical techniques to analyze and interpret the data provided by Hydro Ottawa to create a simulated asset population to align with Hydro Ottawa's actual asset registry. This analysis focused on deriving the best representative Weibull curve parameters (a matrix of shape and scale values), a common industry practice for failure curve development. The simulation results, including the TUL values obtained during this first phase, closely matched Hydro Ottawa's asset registry, and were identified as Data Driven Results.

Hatch identified that it is common in the utility sector that converging at an absolute steady state or the exact asset registry is a challenge, primarily due to variations in asset information maturity and quality. Hatch's model encountered this challenge with certain asset classes, which showed deviations from typical industry TULs. To refine the results, Hatch produced TUL Adjusted Results. This involved selecting the top 10% of matches that most closely aligned with Hydro Ottawa's asset registry, while still utilizing Hydro Ottawa data. These selected results were then used to generate adjusted failure curves and TUL values. Following this, Hatch conducted a workshop with Hydro Ottawa to review both the initial Data Driven Results and the TUL Adjusted Results.

Hydro Ottawa updated existing TUL values for asset classes exhibiting substantial variations (exceeding five years) between the Data Driven Results, TUL Adjusted Results, and the current TUL values. This resulted in changes to the TUL values for underground transformers, electronic relays, maintenance holes (manholes/cable chambers), and station VLA batteries.

For the remaining asset classes, the Data Driven or the TUL Adjusted Values were found to be either identical or very similar (within a few years) to Hydro Ottawa's current TUL values. During the workshop, Hydro Ottawa and Hatch subject matter experts agreed to retain the existing TUL values for these asset classes. This decision stemmed from Hydro Ottawa's high maturity asset survival records and less developed failure records. To confidently adjust the TUL values by a few years, it is necessary for Hydro Ottawa's asset failure records to mature further.

To enable future TUL value refinements, a workshop recommendation was for Hydro Ottawa to strengthen its asset tracking by consistently recording annual failures and renewals, including age, health index at failure, and replacement details. Hydro Ottawa has already begun this process, tracking age and condition at failure since 2023. The accumulation of this data over the next few years will support further TUL adjustments (even by a few years) for the relevant asset classes.

Section 8.1 - Asset Typical Useful Life outlines the TUL values finalized for the different asset classes. A segmented linear piecewise relationship was also developed to establish the relationship between Health Index and age across all asset types. A detailed report on this asset failure curve analysis is available in Attachment 2-5-4(D) - Failure Curves Review. The Copperleaf PA module uses the failure curves developed in this study to forecast asset degradation and determine future asset risk levels.

4.4.5. ISO 55001 - Asset Management System Recertification

Hydro Ottawa’s mature AMS is a robust framework that effectively directs, coordinates, and controls asset management activities. It incorporates interrelated and interacting elements to establish an asset management policy, asset management objectives, and the overarching processes necessary to achieve those directives. This framework strengthens the strategic asset decision-making processes by effectively balancing the weighting of cost, risk, and asset performance. It is designed to meet or exceed the service level expectations of customers; comply with applicable acts, licenses, and codes; improve asset value and resource efficiency; and minimize health, safety, and environmental impacts.

Hydro Ottawa's dedication to advancing asset management practices culminated in the adoption of the ISO 55001 Asset Management Standard in preparation for this application. Achieving initial certification in 2020, the organization further solidified its commitment through successful recertification in 2023. This achievement serves as a testament to the ongoing advancements and maturity of Hydro Ottawa's AMS, a fundamental element in the recertification process.

During the recertification process, Hydro Ottawa demonstrated enhancements to its AMS. These enhancements include:

- Utilization of a comprehensive risk register to proactively identify and mitigate potential issues.
- Implementation of a defective equipment tracker to facilitate efficient monitoring and resolution of equipment deficiencies.
- Development and execution of targeted mitigation plans for specific asset-related risks, exemplified by the comprehensive strategy for managing SF_6 switchgear leaks.

Furthermore, Hydro Ottawa maintains a commitment to continuous improvement through structured ongoing operational practices focused on assessing risks and mitigations, adherence to standards, consideration of emerging technologies and evolving industry standards, and other opportunities for enhancement.

4.4.6. Decarbonization Study

To gain an understanding of the evolving energy landscape and strategically navigate its associated complexities, Hydro Ottawa commissioned Black & Veatch in 2023 to conduct a Decarbonization Study. This study evaluated the potential impacts of societal electrification trends on the Hydro Ottawa distribution system, projecting outcomes in five-year increments through 2050 with a scenario based approach. Five scenarios with varying assumptions of decarbonization initiatives on the distribution system were assessed.

Completed in 2024, the study provides:

- Projections of electricity demand driven by the decarbonization-related electrification of buildings and transportation for 5 different scenarios.
- Rough-order-of-magnitude capital cost estimations.
- Strategic insights to inform future infrastructure investments.

Hydro Ottawa's capacity investment planning and forecasting initiatives leverage the insights from this study for the medium to long-term outlook (beyond 2030). Decarbonization and the subsequent electrification of key sectors necessitate a shift from traditional to scenario-based electricity demand forecasting. Hydro Ottawa is utilizing the Decarbonization Study's Reference Scenario, see details in Section 9.4.2.1 - Decarbonization Study, to inform its Integrated Regional Resource Plan (IRRP) forecast (details in 9.4.2. IRRP Forecast). This alignment is crucial for long-term regional transmission planning, given the extended lead times of transmission grid investments. This approach ensures that immediate capacity investments, guided by Hydro Ottawa's planning forecast, see details in Section 9.4.1 - Hydro Ottawa Planning Forecast, are strategically aligned with long-term regional transmission needs, thereby optimizing capital allocation and asset utilization.

Recognizing the uncertainties of government policies and technological advancements, Hydro Ottawa leveraged the IRRP forecast derived from the Decarbonization Study's reference scenario to augment investment decisions for the mid- to long-term. Hydro Ottawa prioritized investments in areas with existing capacity constraints and immediate, confirmed, and committed load requirements (as per the planning forecast) necessary to meet customer service obligations. These investments include upsizing new stations to align to a consistent 100 Mega Volt Ampere (MVA) design, converting voltage levels to 13kV when replacing deteriorated 4kV station assets to support intensification and other known large projects, utilizing NWSs, and implementing grid modernization initiatives. Hydro Ottawa will continuously monitor the impact of electrification to minimize disruptions and ensure the ability to connect new customers. This strategic approach also emphasizes driving efficiencies across investment programs by leveraging technological advancements and enhancing grid reliability, resilience, and adaptability. By strategically phasing investments, Hydro Ottawa ensures that immediate customer needs are met without compromising its ability to support future growth.

Further details are available in:

- Schedule 2-5-4 - Asset Management Process, Section 9 - System Capacity Assessment
- Schedule 2-5-4 - Asset Management Process, Attachment 2-5-4(F) - Decarbonization Study

4.4.7. Climate Study Reaffirmation

In 2023, Hydro Ottawa commissioned Stantec Consulting Ltd. (Stantec) to conduct a study to update the 2019 climate risk assessment,[4] incorporating the latest climate projection data and factoring in recent extreme weather events, including the 2022 Derecho.

[4] See Hydro Ottawa Limited, *2021-2025 Custom Incentive Rate-Setting Distribution Rate Application*, EB-2019-0261 (February 10, 2020); and in this Applicaton, Attachment 2-5-4(B) - Addendum Report to Distribution System Climate Vulnerability Risk Assessment and Climate Change Adaptation Plan.

This comprehensive assessment utilized updated climate models and regional projections to refine the probability estimations of extreme weather events. Notably, two new wind speed thresholds, exceeding 130 km/h and 180 km/h, were introduced based on updated criteria and empirical observations from the 2022 Derecho storm. This led to a reassessment of potential high-wind impacts on infrastructure, resulting in elevated consequence ratings.

Despite the increased risk scores associated with severe wind events, the overall risk level for the majority of Hydro Ottawa's infrastructure remained unchanged. This finding indicates that the adaptation and mitigation measures outlined in the 2019 plan retain their efficacy. Consequently, the primary areas of vulnerability within Hydro Ottawa's system, namely overhead assets, remain consistent with previous assessments.

As a result, Hydro Ottawa commissioned a further study, conducted by 1898 & Co., to explore strategic opportunities for undergrounding vulnerable sections of overhead lines to enhance the overall resilience of the electricity distribution system. Further details on the study's findings can be found below in Section 4.4.8 - Resilience Assessment.

4.4.8. Resilience Assessment

Following a series of severe weather events and recognizing that grid resilience is a priority for its customers, Hydro Ottawa engaged 1898 & Co. to conduct a comprehensive assessment and develop a Resilience Investment Business Case. This initiative aimed to enhance grid resilience by strategically burying vulnerable sections of the overhead distribution system. The resulting report underscored the escalating importance of grid resilience in the face of increasingly frequent major weather events and society's growing reliance on a stable power supply. Employing a data-driven model, the study identified and prioritized resilience investments, focusing on the strategic conversion of overhead lines to underground systems.

Hydro Ottawa integrated the study's findings with empirical evidence from recent storm events to proactively incorporate resilience investments into the capital plan. The resulting Distribution System Resilience program encompasses a multi-faceted approach, including:

- Strategic undergrounding of vulnerable overhead lines
- Reinforcement of existing overhead infrastructure
- Feeder reconfiguration
- Undergrounding of station egress points
- Relocation of lines

These investments are designed to mitigate system disruptions caused by severe weather events, ultimately minimizing restoration costs, customer outage durations, and overall system recovery time.

Hydro Ottawa's Distribution System Resilience program closely aligns with the OEB's ongoing consultation of a Vulnerability Assessment and System Hardening (VASH) framework[5] by using climate projections, conducting asset-based vulnerability assessments, employing quantitative analysis to prioritize investments, and focusing on maximizing customer value. This data-driven approach allows Hydro Ottawa to align with the VASH framework in order to strategically improve the grid's ability to withstand extreme weather while minimizing customer impacts.

A detailed description of the Distribution System Resilience program is provided in Section 3 of Schedule 2-5-8 - System Service Investments.

4.4.9. Capture Implementation

Hydro Ottawa utilizes Copperleaf Portfolio, Hydro Ottawa's investment optimization software, to optimize its decision-making processes and ensure the long-term sustainability of its infrastructure

[5] OEB, *Decision and Order*, EB-2024-0199 - Vulnerability Assessment and System Hardening Project (December 17, 2024).

assets. Further details can be found in Section 5.3.2 - Project Level Investment Planning. In 2022, Copperleaf significantly enhanced its software suite by introducing the Capture module. This module streamlines and optimizes the input of investment ideas and potential system risks from various stakeholders. By empowering stakeholders to directly submit these ideas or risks into the Copperleaf Investment Planning software through an intuitive and user-friendly form, the Capture module effectively simplifies and accelerates the initial stages of both project and risk management.

The form's intelligent design automates the creation of a draft project or risk, which can then be subjected to a thorough review and refinement process. This automation not only yields substantial time savings but also ensures that all submissions adhere to a standardized format, thereby making the subsequent review and approval processes significantly more efficient. Moreover, the Capture module fosters a culture of transparency and accountability by enabling the meticulous tracking of project and risk lifecycles throughout their various stages, from inception to completion. This comprehensive tracking functionality plays a pivotal role in ensuring that all projects and risks receive the requisite approvals and are managed in a manner that is both consistent and compliant with prevailing regulations and internal policies.

The Capture module's capacity to facilitate the seamless integration of stakeholder input directly into the Copperleaf Planning software holds the potential to catalyze a more collaborative and inclusive approach to decision-making. By breaking down traditional barriers to participation and affording stakeholders a direct and accessible channel for contributing their insights and perspectives, the module can foster a sense of shared ownership and commitment to the success of projects and the mitigation of risks. This, in turn, can lead to more informed and robust decision-making, as well as enhanced organizational agility and responsiveness to emerging opportunities and challenges.

4.4.10. Portfolio Management Enhancement

To enhance financial reporting and control over distribution sustainment projects, Hydro Ottawa implemented process improvements during 2021-2025. Benefits included enhanced reporting and oversight, improved project tracking, strategic alignment, contingency planning, and increased rigor in project and program delivery.

Budget Programs, as identified in Schedule 2-5-5 - Capital Expenditure Plan, were categorized into four Programs: Corrective Renewal, Distribution Construction & Maintenance, Stations, and Maintenance, and further grouped into a Portfolio. Hydro Ottawa uses a multi-stakeholder model composed of Distribution Design, Program Management, Asset Planning, Contractor Management, Maintenance & Reliability, Supply Chain, and Operations to oversee the execution of the programs/portfolios on a monthly basis. This group considers key issues and risks impacting execution, such as inflation, supply chain, impactful weather events, labour disruptions, safety, third-party coordination, and third party service availability. The core focus of this team is to proactively monitor and adjust the execution of the plan as needed to achieve project and program objectives in light of evolving conditions and circumstances on the ground.

Key topics impacting expenditures in the historical 2021-2025 period include inflation, unprecedented supply chain disruptions, customer connections (volume, complexity and cost), unforeseen externally-driven projects, increased emergency renewal work due to major storms such as the 2022 Derecho, equipment failure and new stations investments to address growing electricity demand. To mitigate these pressures, Hydro Ottawa implemented proactive financial management strategies, notably deferring planned projects such as Major Station Rebuilds, Voltage Conversions, ERP Upgrades, and Underground Switchgear Renewals. Please refer to variances in Section 4 of Schedule 2-5-5 - Capital Expenditure Plan.

Hydro Ottawa will leverage this framework and model through 2026-2030, continuing to refine financial reporting and control across investment categories.

4.4.11. Asset Management Technology

In addition to the aforementioned enhancements, Hydro Ottawa has recognized that many of its asset management processes are restricted by existing technology and disparate systems, with limited interoperability, unable to scale effectively to meet asset growth and customer demands. As a result, Hydro Ottawa is seeking an EAM platform as outlined in Section 3 of Attachment 4-1-1(A) - Transition to Cloud Computing, to address these challenges and further transform asset management processes over the 2026-2030 rate period.

5. ASSET MANAGEMENT PROCESS

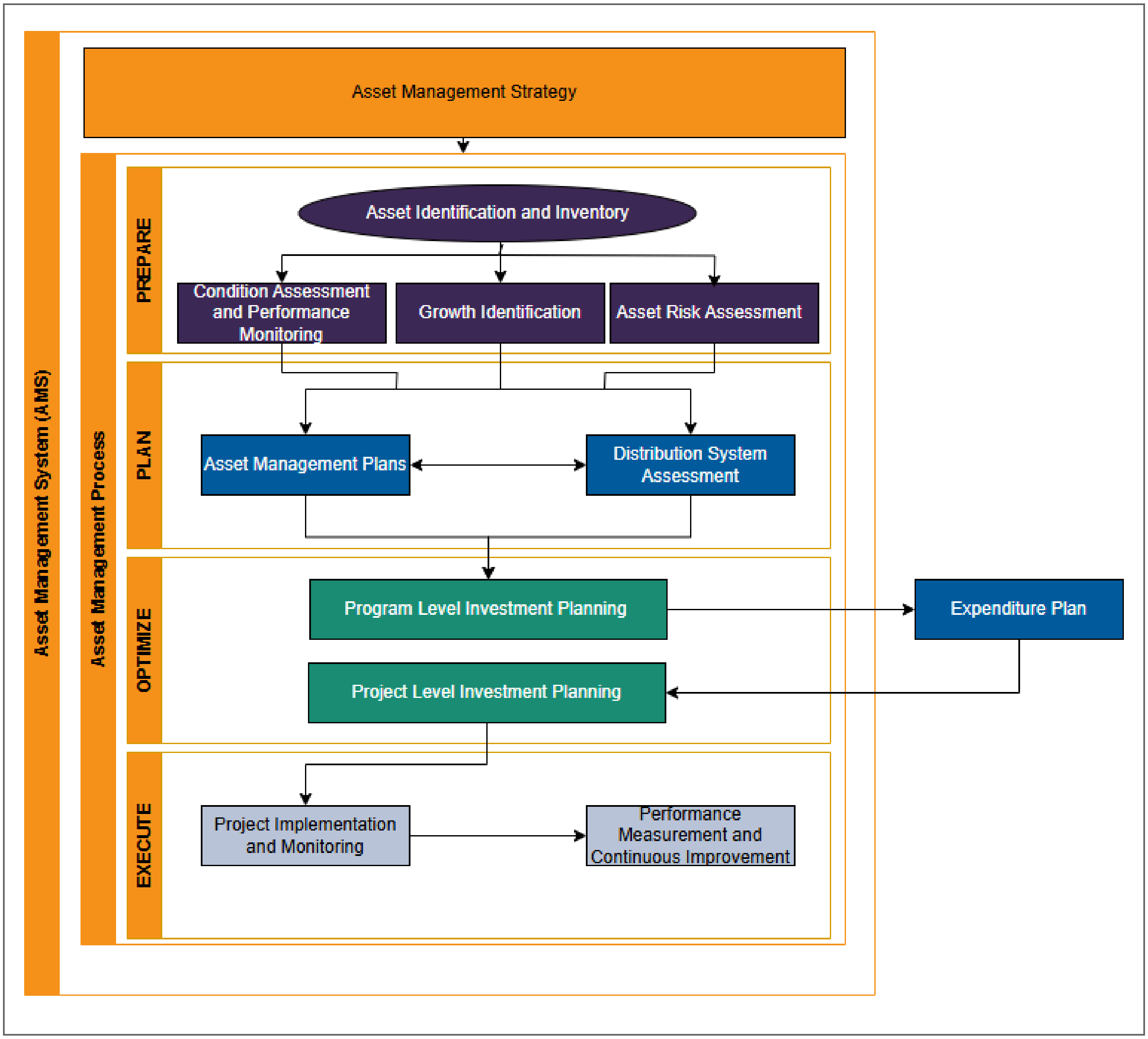
Section 5 describes the process used to plan, prioritize, and optimize expenditures related to distribution assets. This section speaks to the components of Hydro Ottawa's asset management process used to satisfy asset and system needs, in alignment with the asset management objectives described in Section 4.2 - Asset Management Scope, Strategy and Objectives. For each process, details are provided on the tools and methods used, inputs and outputs of information, and how opportunities are identified to coordinate for cost effectiveness.

The process involves several crucial stages that collectively contribute to the development of the investment plan for both Capital and OM&A activities. Each of these stages is described in the following sections:

- **Section 5.1: Prepare**
- **Section 5.2: Plan**
- **Section 5.3: Optimize**
- **Section 5.4: Execute**

Hydro Ottawa's asset management process is shown in Figure 7.

1 **Figure 7 - Asset Management Process Details**



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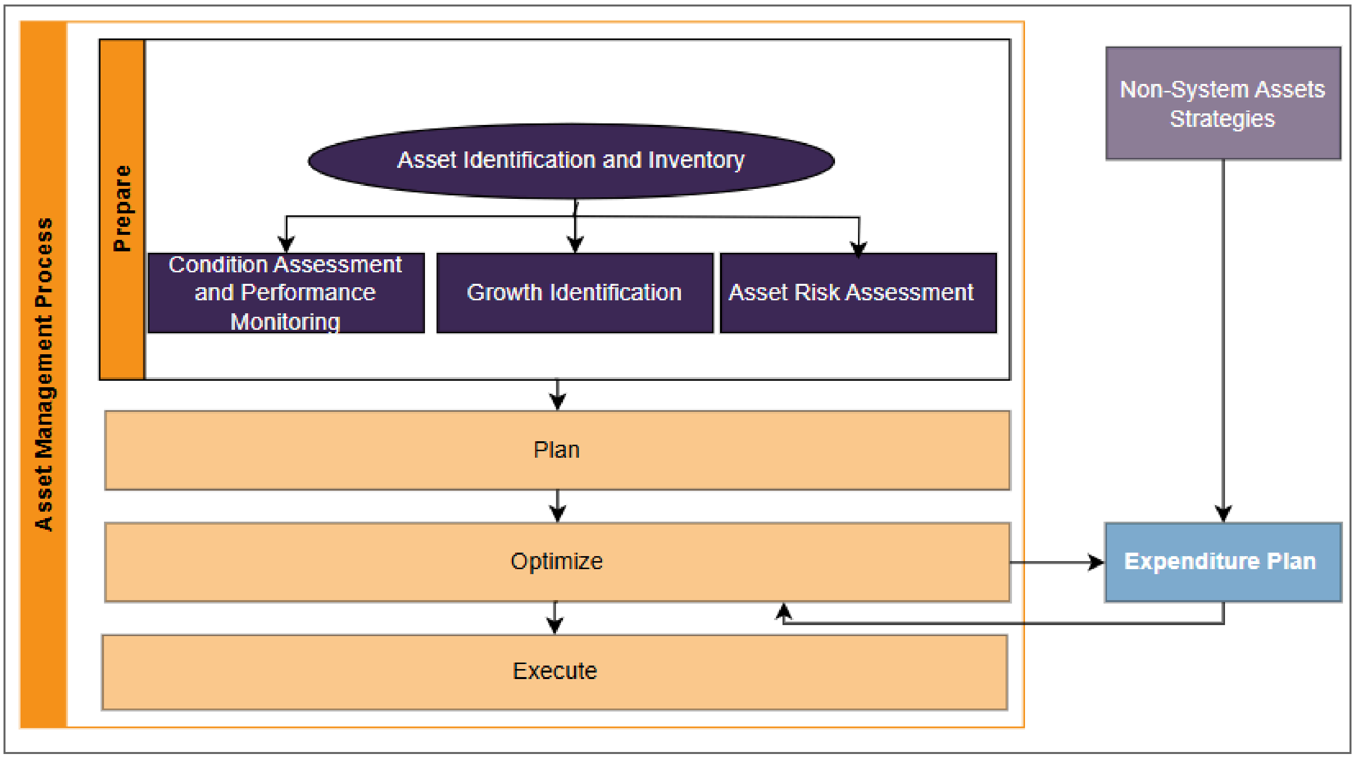
5.1. PREPARE

The preparation stage of asset management is a multifaceted process that lays the groundwork for effective and strategic decision-making. Figure 8 shows the components of this stage of the asset management process. It commences with a comprehensive identification of distribution assets, followed by a meticulous assessment of the risks associated with each asset, considering factors such as operational, financial, and environmental risks.

Figure 8 - Asset Management Process: Prepare Stage



Furthermore, the preparation stage entails a thorough review of the results gleaned from testing and maintenance activities. This involves scrutinizing maintenance records, analyzing test data, and identifying trends or patterns that may indicate potential asset degradation or failure. Additionally, the condition of each asset is evaluated, taking into account factors such as age, usage, and wear and tear.

Another crucial aspect of the preparation stage is the identification of regional growth patterns. This involves analyzing demographic trends, economic indicators, and infrastructure development plans to anticipate future demands and ensure that asset management strategies are aligned with regional growth objectives.

Finally, the preparation stage encompasses a rigorous analysis of performance metrics. This involves tracking KPIs such as reliability, asset condition, asset utilization and efficiency to assess the effectiveness of asset management practices and identify areas for improvement. By diligently executing these tasks, the preparation stage ensures that asset management is rooted in a comprehensive understanding of the organization's asset landscape, risks, and performance, enabling informed and proactive decision-making.

5.1.1. Asset Identification and Inventory

In this phase, Hydro Ottawa focuses on establishing and maintaining an inventory of all distribution assets under its ownership or management. The inventory process involves meticulously gathering detailed information about each asset, including its type, precise location, current condition, and criticality. This comprehensive inventory serves as the cornerstone for subsequent asset management activities.

Asset Register

The asset register is the system of tools used to capture, organize, and disseminate data pertaining to Hydro Ottawa's distribution assets. Hydro Ottawa maintains electronic repositories to store its technical, testing, inspection, and maintenance information, and geographic data for most of its distribution assets (buildings and other non-power delivery assets are excluded). These repositories allow the data to be collected, reported, and queried in a manner that enables efficient dissemination and reporting of information.

The system of record for Hydro Ottawa’s power delivery assets is the Geographical Information System (GIS), based on Intergraph’s G/Technology platform. With minor exceptions (i.e. secondary conductors in the downtown core), it forms a complete repository of Hydro Ottawa's assets used within its stations and distribution system. These minor exceptions do not reduce the effectiveness or usability of GIS as they are few in number and typically do not bring additional clarity during analysis. The missing data can be readily retrieved elsewhere if the need arises.

Hydro Ottawa's GIS is used to store, query, and provide reports to enable the analysis and development of investment plans. The data kept in the system is continuously improved through feedback from field staff and data collected through inspection programs. Using a graphical interface, it enables users to view distribution assets on a geo-referenced map showing location, technical nameplate data, and assess their relationship to other nearby assets, including electrical connectivity and relation to civil structures. Further, this system is used by resources in the field while collecting asset condition data, exclusive of station assets, before storing it within the same repository.

For Hydro Ottawa's Station assets, the PowerDB system is used for the collection of testing, inspection, and maintenance data as it allows for more complex collection forms. Technical data is stored through customized forms for each asset class and maintenance activity. This technical data can then be exported for further analysis, and is used as input into the health index formulation for specific assets described in Section 5.1.2 - Condition Assessment and Performance Monitoring. Each station's geographic information is stored in GIS.

To satisfy the increased inspection data demands for well-informed investment choices and the shift towards condition-based maintenance, a more effective tool for gathering asset data is necessary. The adoption of an EAM solution over the 2026-2030 rate period will facilitate this, among other key benefits. The resulting robust network model and automated field data collection will allow for sophisticated analytics, anomaly identification, and enhanced health assessments. For further information on the EAM project, please refer to Attachment 4-1-1(A) - Transition to Cloud Computing.

5.1.2. Condition Assessment and Performance Monitoring

Regular condition assessments are conducted to evaluate the current state of assets. These assessments involve inspections, testing, and data analysis to determine the physical condition, remaining useful life, and potential risks associated with each asset. Performance monitoring systems track asset performance indicators, enabling early identification of issues and proactive maintenance or replacement.

5.1.2.1. Asset Condition Assessment

Hydro Ottawa uses health index scores for its assets to rate their condition and understand the requirements for intervention. Hydro Ottawa engaged a third-party expert (METSCO) to develop its asset health indexing and condition assessment framework in 2015, which is a weighted addition of a number of degradation factors to determine an overall health index score. This framework has since been reviewed twice, once for the 2021-2025 DSP and again for the 2026-2030 DSP. The most recent review by Hatch, which is filed in Attachment 2-5-4(C) - Asset Condition Assessment Third Party Review, concluded that (i) Hydro Ottawa's ACA framework is comprehensive and that (ii) the calculations are aligned with methodologies that generally reflect industry best practices.

The health index is an indicator of an asset's condition and remaining life and is assigned a score from 100% to 0%. A new asset will have a health index of 100%, while an asset in very poor condition would have a health index below 30%. Table 5 presents the health index ranges, corresponding asset condition, and the required action generally associated with each health index band.

Table 5 – Asset Condition Based on Health Index

Health Index (%)	Condition	Description	Requirements
85-100	Very Good	Some aging or minor deterioration of a limited number of components	Normal maintenance
70-85	Good	Significant deterioration of some components	Normal maintenance
50-70	Fair	Widespread significant deterioration or serious deterioration of specific components	Increase diagnostic testing; possible remedial work or replacement needed depending on criticality and degradation pattern
30-50	Poor	Widespread serious deterioration	Replace or rehabilitate considering risk and consequences of failure
0-30	Very Poor	Extensive serious deterioration	Asset has reached its end-of-life; immediately assess risk; replace or refurbish based on assessment

To determine the health index for a given asset, an assessment specific to the asset under consideration is used to convert various condition parameters (such as visual inspection, electrical test results, infrared scan information, etc.) that describe the asset's condition down to a single value. These values are then used to prioritize asset replacement, when warranted, and are used to determine the probability of failure associated with each individual asset, alongside the related baseline risk as established by the PA process, see Section 5.1.4 - Asset Risk Assessment for more details.

As a part of the failure curve calibration exercise for the various asset classes, Hydro Ottawa engaged a consultant, Hatch, to review its existing asset failure curves and develop data-driven failure curves where applicable. Please refer to Attachment 2-5-4(D) - Failures Curves Review and Section 4.4.4 Failure Curves and Typical Useful Life Update of this Schedule. Statistical analysis leveraging Hydro Ottawa's asset registry and replacement information was instrumental in arriving at the best synthetic registry (aligned with Hydro Ottawa's asset population) and the corresponding Weibull curves. For the asset classes where the simulation model did not converge, recommended failure curves were developed based on ensuring an alignment with industry consensus and Hydro Ottawa's data maturity/asset registry demographics. Hatch categorized Hydro Ottawa as a utility with slightly low maturity specific to historical failure records but having robust asset survival information. Even prior to this exercise (from 2023), Hydro Ottawa started compiling detailed asset failure information, relating any asset failure to the nomenclature, age, and condition at the time of failure (apart from establishing the probable root cause). Also, the historical asset failure curves used by Hydro Ottawa were largely found to be in alignment with best industry estimates. As an output of the failure curve calibration initiative, Hatch recommended Hydro Ottawa to continue to improve the tracking of asset failure information and ensure continued health indexing across its asset fleet.

The failure curve results obtained through this exercise greatly aided in improving Hydro Ottawa's risk assessment process for system renewal investment planning by utilizing them in the Copperleaf PA module for forecasting asset degradation patterns and establishing the optimal time of intervention for each individual asset in the system. Also, the typical useful lives of all asset classes were established to highlight the expected duration an asset can reliably operate before it requires replacement or refurbishment.

Hydro Ottawa has made several key improvements to its condition assessment process since 2014. The health indexing framework now includes additional condition parameters captured from existing inspection and maintenance programs, and age is no longer as heavily weighted. Age is now translated to condition using the linear piecewise/linear relationship established between age and condition through the failure curve development exercise with Hatch. This approach was used to determine the equivalent condition value for assets that had a known age, but lacked a valid health index to be used in Copperleaf PA. Additionally, a validity measure was implemented to ensure that at least 70% of the condition information is available to define a health index value.

Hydro Ottawa has also assessed the maturity of its ACA implementation by a third party. The summary of this assessment can be found in Attachment 2-5-4(C) - Asset Condition Assessment Third Party Review. Overall, the third party, Hatch, found that Hydro Ottawa's ACA framework utilized robust formulations that are in alignment with best practices, and that it was tightly integrated with Hydro Ottawa's broader Asset Management related processes, procedures, and outcomes. Hatch identified minor calculation gaps with minimal impact to the overall asset portfolio and Hydro Ottawa found mitigation solutions, ultimately resulting in addressing all the calculation gaps as a result of the project. Hatch also provided suggestions for enhancing the methodologies, with Hydro Ottawa being in the process of gathering additional data and exploring solutions to support advanced analytics and meet evolving data requirements. The potential opportunities for improvement highlighted by Hatch as a part of this exercise include:

- Enhanced coding/modeling practice for asset health indexing, see Section 4.4.11 - Asset Management Technology
- Integrated analytics and/or EAM and/or Asset Performance Management solution, see Section 4.4.11 - Asset Management Technology
- Non-linear modeling to better reflect asset management philosophy
- Considering additional criteria for certain asset classes, if feasible (e.g. including short circuit/fault level information)

Hydro Ottawa has targeted plans to further advance its ACA process as a part of the 2026-2030 rate period, inclusive of enhancements in data collection and analysis (based on OM&A programs), exploring an EAM solution and investments in ADMS to have better visibility into system level information.

5.1.2.2. Testing, Inspection, & Maintenance Programs

Hydro Ottawa's planned testing, inspection, and maintenance programs are the utility's primary means of collecting condition data used to calculate the health index of assets and to identify corrective actions to ensure continued reliable operation.

Hydro Ottawa's planned programs can be divided into three groups:

1. Predictive: Assessing the condition of the asset
2. Preventative: Maintaining the condition of the asset
3. Corrective: Improving the condition of the asset

Predictive programs: Collect technical details, testing, and inspection data used to identify assets in need of corrective actions while determining the asset's overall condition. These programs use a combination of inspection techniques depending on the asset type being considered and the failure mode(s) that pose an increased risk to safety, reliability, or the environment. The deployment of communication and sensors on certain new or upgraded assets provides the ability to monitor the condition of assets and collect operational data in real-time. This can reduce or eliminate the need for predictive programs to physically collect asset data. Furthermore, the ongoing monitoring can support the eventual transition from time-based to condition-based maintenance.

Preventative programs: Maintain the existing condition of the asset. Some asset types require regular maintenance activities that are time-based, while other assets are maintained after a certain number of operations to ensure that they will continue to operate as designed. These include visual inspection/mechanical activities such as cleaning, tensioning, tightening, calibrating, and realigning various components, aside from electrical testing.

Corrective programs: Improve the condition of the assets by repairing, replacing, or refurbishing various defective or degraded components. This activity aims to ensure the asset maintains performance, particularly when premature degradation occurs, and may also extend the asset's TUL.

More information on Hydro Ottawa's testing, inspection, and maintenance programs can be found in Schedule 4-1-2 - Operations, Maintenance and Administration Program Costs.

5.1.2.3. Performance Metrics

Hydro Ottawa monitors the performance of its assets and systems to ensure the successful delivery of its Asset Management Objectives. Continuous improvement is achieved through the use of KPIs. Schedule 2-5-3 - Performance Measurement for Continuous Improvement outlines Hydro Ottawa's DSP performance measurement framework and associated KPIs.

5.1.3. Growth Identification

To power a growing community, Hydro Ottawa needs to expand grid capacity while ensuring the reliability and efficiency of its electrical network. Growth identification for Hydro Ottawa's service territory is informed by two types of forecasts — Hydro Ottawa Planning forecast and IRRP forecast.

Hydro Ottawa's planning forecast uses available information of known developments to predict future load increases at the station level, excluding systemic electrification impacts but including known large load requests, see Section 9.4.1 - Hydro Ottawa Planning Forecast for more details. These large load requests, ranging from 5 MVA to 57 MVA, are primarily driven by electrification of heating and transportation in large institutions and companies. The forecast also includes initial-stage customer requests to anticipate future load impacts, providing the foundation for capacity investment needs in the near term (until 2030) primarily driven by existing capacity constraints and committed load requests. However, this forecast, relying on historical consumption patterns and projected growth based on known and observable trends, fails to capture the impacts of decarbonization goals and the resulting electrification of space heating, water heating, and transportation.

Hydro Ottawa's IRRP forecast incorporates the Decarbonization Study's hourly system coincident peak forecasts to reflect the impact of electrification on future energy demands, see Section 9.4.2 IRRP Forecast for more details. This strategic shift is essential for medium to long-term (beyond 2030) transmission planning, as investments in the provincial grid require lead times exceeding five years. By aligning with the Decarbonization Reference Scenario, Hydro Ottawa ensures that immediate capacity investments are consistent with anticipated long-term needs, optimizing asset utilization and enabling efficient capital deployment. This approach facilitates a more robust and forward-looking planning process, critical for navigating the evolving energy landscape driven by decarbonization goals.

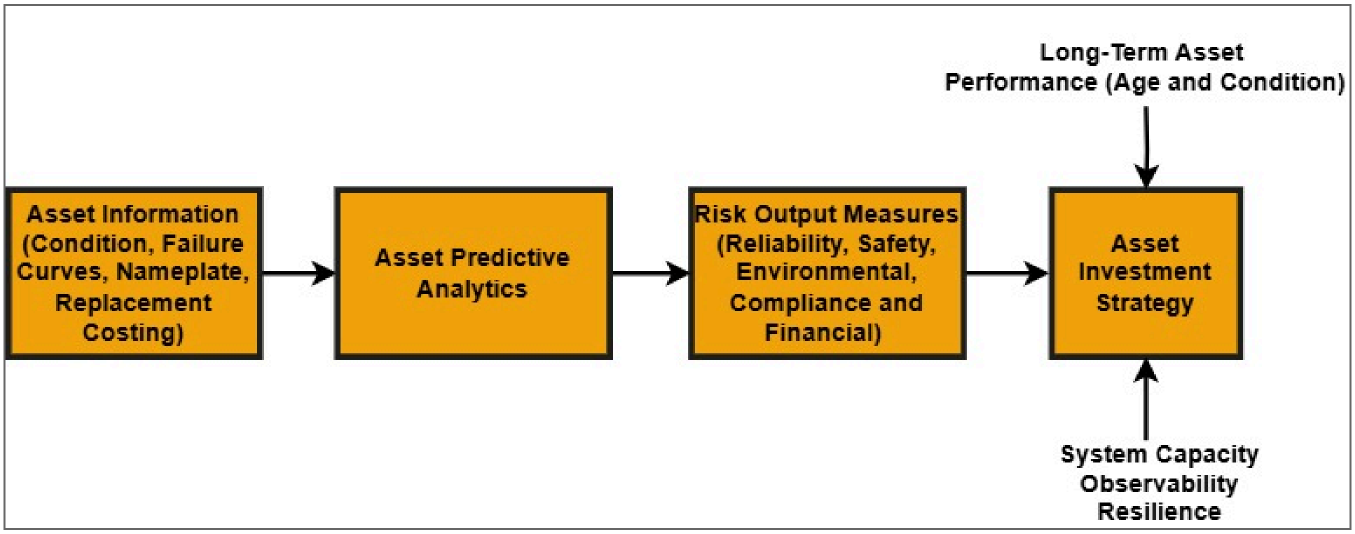
More details on the load forecasting approach are available in Section 9.4 - Planning Load Forecasting and details on capacity assessment in Section 9.1 - Capacity Needs Assessment.

5.1.4. Asset Risk Assessment

Risk assessments are performed to identify and evaluate the risks associated with asset failures. Factors such as asset criticality, failure consequences, and likelihood of failure are considered. Risk assessments help to prioritize assets requiring intervention based on their potential impact on service reliability, public safety, and financial implications.

Hydro Ottawa systematically follows the asset management process to ensure that its physical assets are managed proactively, risks are mitigated, and capital investments are made strategically to maintain a reliable and efficient electricity distribution system for its customers. Hydro Ottawa utilized the PA module within Copperleaf Asset to perform a comprehensive risk assessment considering various risk measures for capital investment planning, as shown in Figure 9.

Figure 9 - Asset Risk Assessment Framework



Hydro Ottawa's risk assessment framework is two-fold:

- **Part One: Asset Risk Evaluation**
  The initial stage of the framework focuses on evaluating the risk associated with each asset. This is achieved through the application of the PA module within Copperleaf Asset.
  - **Asset Information (Condition, Failure Curves, Nameplate, Replacement Costing):** PA considers various factors such as the asset condition, failure curves, nameplate information, and replacement costing.
  - **Asset Predictive Analytics:** By quantifying the likelihood and consequence of asset failure in addition to the asset's criticality to the system, PA provides a risk score for each asset, enabling a comparative analysis and prioritization based on risk levels.
- **Part Two: Asset Investment Strategy Development**
  The second stage builds upon the risk assessment conducted in the first part. It involves formulating an asset investment strategy that aligns with Hydro Ottawa's overarching asset management objectives.
  - **Risk Output Measures (Reliability, Safety, Environmental, Compliance and Financial):** The PA module calculates the overall value of intervening on an asset

based on key risk output measures - reliability, safety, environmental, compliance and financial.

- ○ **Long-Term Asset Performance (Age and Condition):** Long-term asset performance, in terms of the age and condition projections by PA into 2040 is a key consideration in defining underlying system renewal investment alternatives, to decide on the most optimal investment strategy.
- ○ **Asset Investment Strategy:** The most optimal investment alternative or strategy is finalized based on the objective of balancing long-term affordability and minimizing the failure risk associated with assets in degraded condition.

In addition to risk mitigation, the asset investment strategy considers other crucial factors that influence asset management decisions. These factors include:

- **System Capacity**: Ensuring that the system has sufficient capacity to meet current and future demand, while considering potential expansion and upgrades.
- **Observability:** Implementing monitoring and control systems that provide real-time visibility into asset performance, enabling proactive maintenance and issue detection.
- **Resilience:** Evaluating the ability to enhance the resilience of distribution assets (specifically OH infrastructure), in response to the increasing impact of extreme weather events such as ice storms, Derechos, and tornadoes.

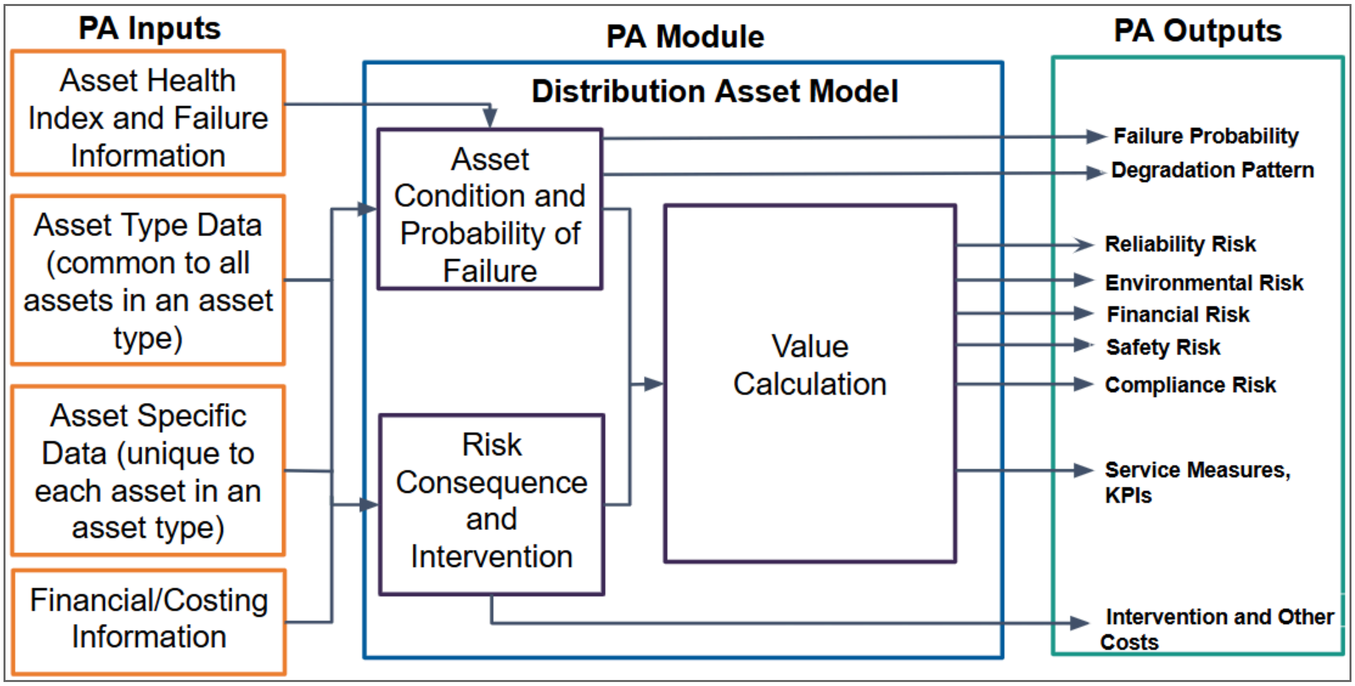
Table 6 provides the assets that are integrated into the PA module for each of the asset classes - Stations, Distribution Overhead, and Distribution Underground:

Table 6 - Assets Integrated with Predictive Analytics

Stations	Distribution Overhead	Distribution Underground
Batteries	Composite Poles	EPR Cables
Circuit Switchers	Concrete Poles	PILC Cables
HV SF_6 Breakers	Metal Poles	XLPE Cables
Metalclad Air Breakers	Wood Poles	Manholes
Metalclad Oil Breakers	Polemount Transformers	Underground Primary Pedestals
Metalclad SF_6 Breakers	Manual Loadbreak Switches	Padmount Switchgear (Air)
Metalclad Vacuum Breakers	SCADA Loadbreak Switches	Padmount Switchgear (Gas)
Station Outdoor Reclosers	Overhead Reclosers	Padmount Transformers
Station Transformers		Vault Switchgears
Station Transformer Tap Changers		Vault Transformers

Hydro Ottawa developed a distribution asset model within the PA module to determine its asset renewal needs, as shown in Figure 10. Asset information (including financial/costing), condition, probability of failure curves, risk consequences, and intervention data gets used in the distribution asset model towards calculating an overall value for risk assessment. Based on the calculated value, the distribution asset model determines the optimal replacement date for a given asset. This is achieved by balancing value maximization with risk and cost minimization, to establish the recommended asset replacement timeline. Utilizing the distribution asset model developed within PA allows Hydro Ottawa to minimize impact to customers by factoring in key risk measures as a part of asset renewal decision-making.

Figure 10 - Distribution Asset Model Architecture



The following sections describe in detail the inputs that feed into PA, the PA module, and the resulting outputs.

5.1.4.1. PA Inputs

Diverse inputs enable the distribution asset model within the PA Module to generate a comprehensive assessment of the asset's condition, risks, and associated costs. These inputs are described below:

a) **Asset Health Index and Failure Information:** PA considers the health index of an asset to establish the baseline condition. It further requires the probability of failure curves unique to each asset type to forecast the degradation pattern and future risk values. In the absence of health index information, it translates the age of an asset to its equivalent condition, based on the established age-condition curves.

b) **Asset Type and Asset Specific Data:** PA considers data pertaining to all asset types (e.g. age, condition, manufacturer, voltage, etc.) in addition to asset-specific data (e.g. oil quantity of oil-filled equipment, SF_6 quantity related to gas-filled equipment etc.).

c) **Financial & Costing Information:** PA considers the replacement cost of an asset between planned and corrective renewals (critical/emergency replacements) for like-for-like or like-for-better scenarios. It also considers the maintenance cost of an asset, to recommend the relevant intervention strategy that derives the maximum value.

5.1.4.2. PA Module

a) **Asset Condition and Probability of Failure:** PA uses the asset health index information/age of an asset to establish the failure probability/degradation pattern, unique to each individual asset in the system.

b) **Risk Consequence and Intervention:** Within PA, the risk consequence calculations are performed unique to each individual risk being considered (reliability, safety, environmental, financial, and compliance). The relevant intervention strategy can also be defined in PA based on constraints and the nature of replacement required (like-for-like or like-for-better).

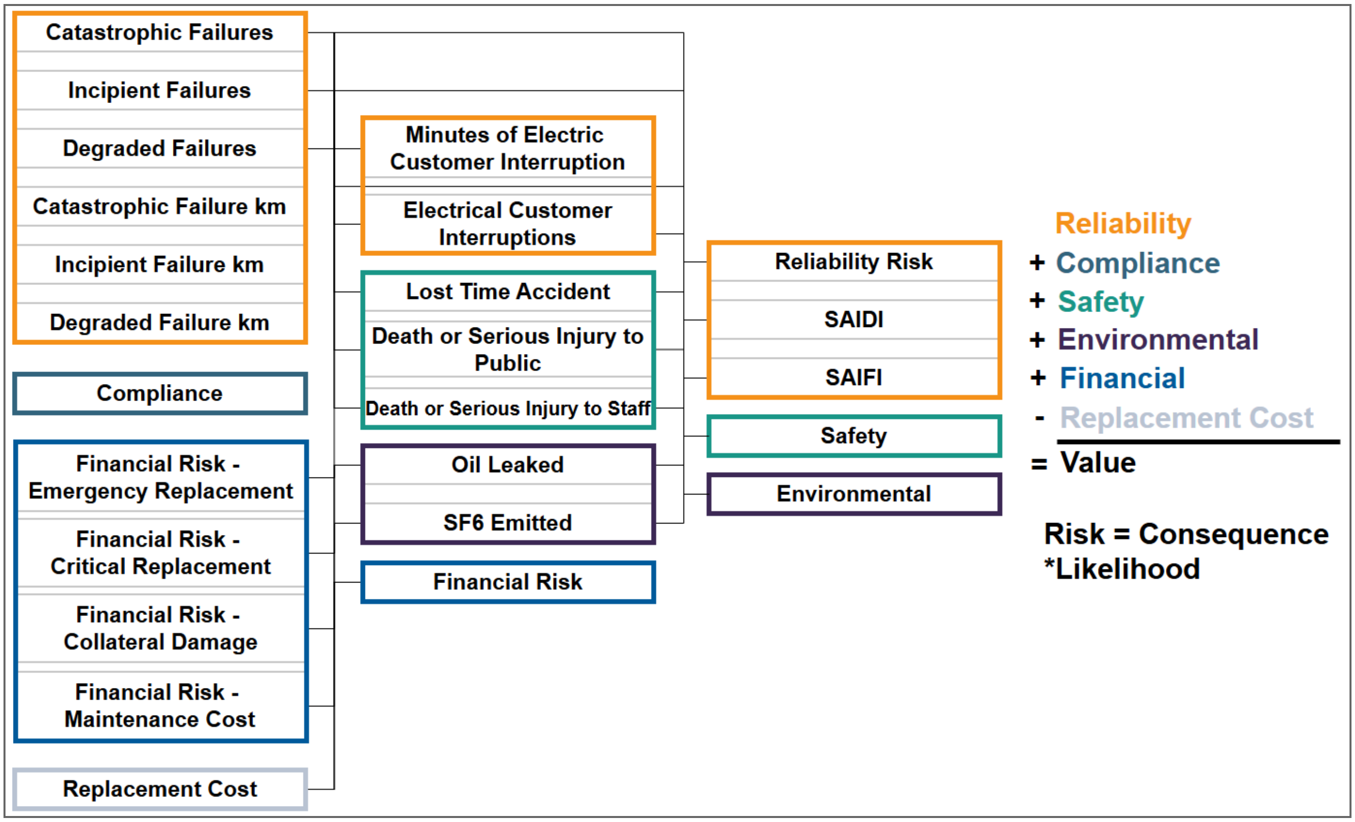
c) **Value Calculation:** PA calculates the overall value of intervening on an asset at a given point in time based on the probability and consequence of the risk measures considered (reliability, safety, environmental, financial, and compliance).

5.1.4.3. PA Outputs

a) **Asset Failure Probability and Degradation Pattern:** Based on the asset condition and probability of failure curve, PA provides an output of the asset failure probability and the expected degradation pattern over time.

b) **Value Measures:** The value measures determined by PA are shown in Figure 11. These value measures are used to calculate the overall value of asset replacement at a given point in time and also support relevant asset renewal decisions.

Figure 11 - PA Module Value Measures



i) **Risk Measures:** The key risk measures (calculated by the PA module) used to compare the relative value of replacing different assets are shown below:

- **Reliability Risk** is the risk associated with the asset's ability to perform its intended function. It is calculated based on the consequences of failure (outage duration, lost redundancy duration, number and type of customers affected, peak load, and worst performing feeder) and the likelihood of failure (based on individual asset failure curves and the probability of emergency, critical, or expected failures).
- **Compliance Risk** is the risk associated with the asset not complying with regulations. The consequence is calculated based on the financial penalty for non-compliance and

the likelihood that the asset will need to be replaced to maintain compliance by a certain date.

- **Safety Risk** is the risk associated with the asset causing harm to the public or Hydro Ottawa crews. It is calculated based on the consequences of an incident (number of lost time accidents, deaths, or serious injuries to Hydro Ottawa staff and the public that occur per incident) and the likelihood of an incident (based on asset location, individual asset failure curves and the probability of emergency, critical, or expected failures).
- **Environmental Risk** is the risk associated with the asset causing environmental contamination or damage. It is calculated based on the consequences of an environmental incident (oil leaked, SF_6 emitted and oil containment present or not) and the likelihood of an incident (based on individual asset failure curves and the probability of emergency, critical, or expected failures).
- **Financial Risk** is the risk associated with the cost of replacing or repairing a given asset. It is calculated based on the consequences of different types of replacement (Planned Renewal, Emergency Renewal, Critical Renewal, Collateral Damage (tied to other widespread damages not limited to the asset failure alone) and Planned Maintenance Costs) and the likelihood of those replacements (based on individual asset failure curves and the probability of emergency, critical, or expected failures).

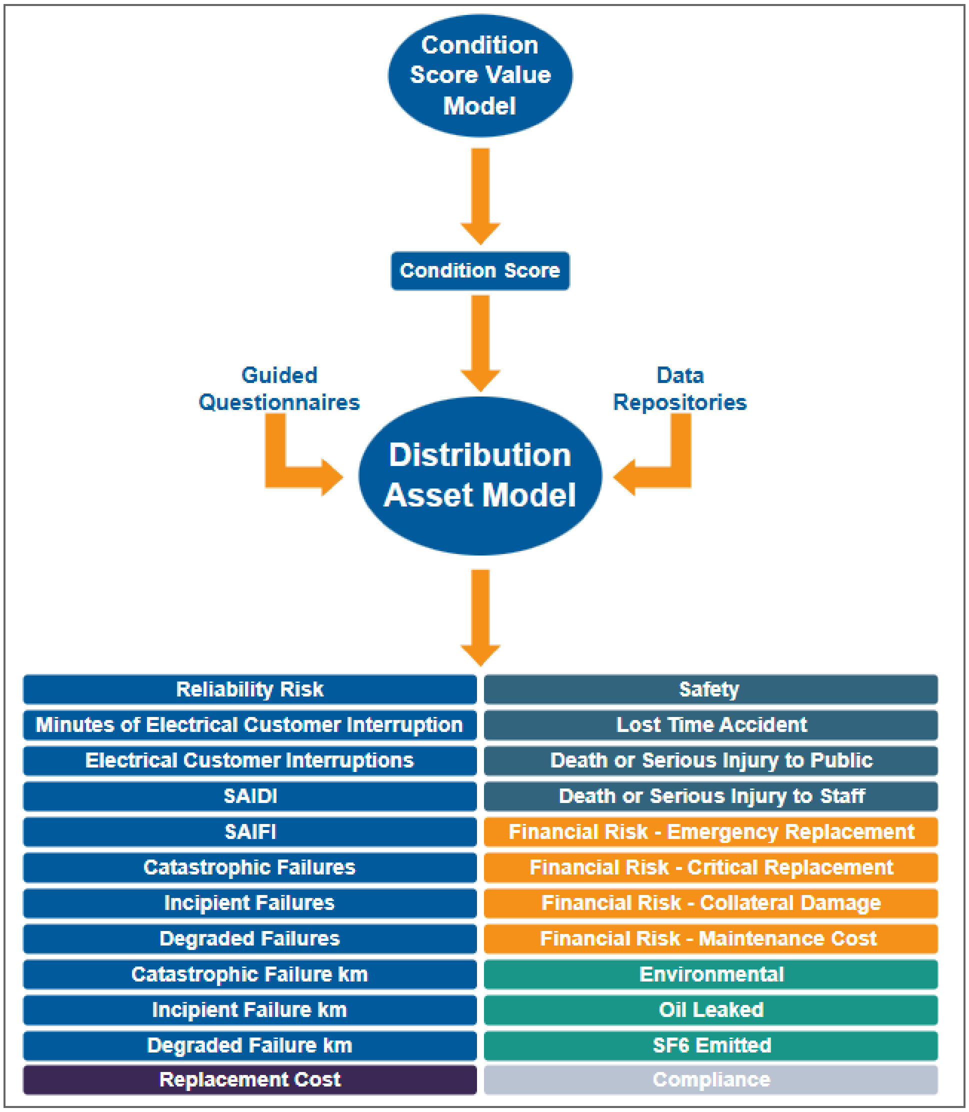
ii) Replacement Cost: PA considers the cost of replacing an asset under normal (planned) or emergency/critical conditions based on the desired nature of replacement (like-for-like or like-for-better).

c) **Service Measures:** Based on the distribution asset model calculation within PA, service measures such as SAIDI, SAIFI, Customer Minutes of Interruption or CMI, Customer Interruptions, forecasted number of failures, lost time accident, death or serious injury to staff/public, amount of oil leak, and amount of SF_6 emitted can be obtained. These service measures can be used as constraints within the distribution asset model to further optimize an investment scenario (e.g. defining SAIDI, SAIFI thresholds to establish the investment level required each year).

d) **Intervention and Other Costs:** PA forecasts the risk impact of asset deterioration over time. It optimizes asset remediation timing by evaluating the overall value of intervention strategies, guiding investment decisions. It shows the optimal and recommended intervention date for each individual asset in the system and the related costs.

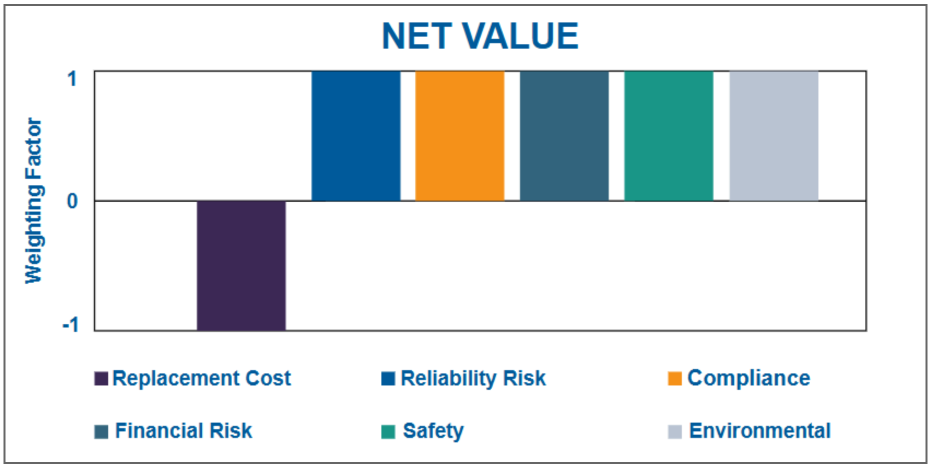
The distribution asset model within the PA module, including inputs and output measures, is illustrated in Figure 12 and details the specific inputs and calculations used to determine these output measures.

Figure 12 - Distribution Asset Model in Copperleaf PA Value Measures



Based on the distribution asset model implemented in Copperleaf Asset, the net value of intervening on any given asset is computed as a function of the various risk measures: reliability, safety, environmental, financial and compliance compared against the replacement cost. Figure 13 shows the weighting factors that are applied to the six value measures that contribute to the value function.

Figure 13 - Weighting Factors of Value Measures that Contribute to the Value Function



PA aligns Hydro Ottawa's investment plans with strategic goals, improves efficiency, integrates planning, and manages deteriorating infrastructure risk. This leads to higher-value decisions, improved business performance, and optimized resource allocation.

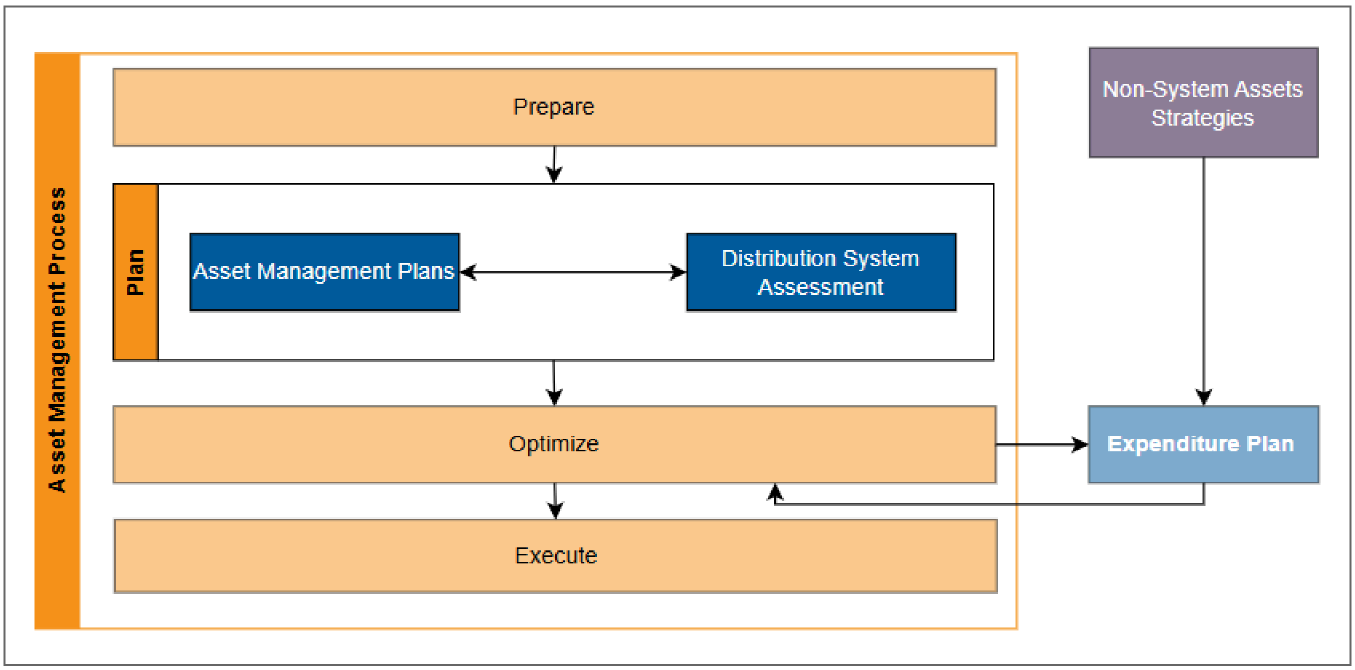
Hydro Ottawa's asset intervention assessment process in Copperleaf PA is centered around three primary alternatives at the program level: Cost Containment, Short Term Risk Mitigation, and Long Term Risk Mitigation. The alternatives undergo a thorough evaluation to review the ability to balance long term affordability and minimize the failure risk associated with assets in a degraded condition.

5.2. PLAN

This stage encompasses the creation of detailed AMPs that strategically align with the overarching system requirements while effectively addressing identified risks and objectives as shown in Figure 14. These plans take into account a multitude of factors such as capacity constraints, reliability requirements, resilience needs, and grid modernization initiatives. Furthermore, this stage includes a thorough analysis and identification of the necessary capital investments and OM&A expenditures that are essential to support the proposed asset management strategy and ultimately achieve the desired outcomes.

By meticulously considering these various aspects, the AMPs developed in this phase will provide a comprehensive roadmap for optimizing the performance, reliability, and longevity of assets while ensuring they are aligned with the broader system needs and objectives. This approach to asset management will not only mitigate risks but also enhance the overall efficiency and effectiveness of the system, leading to improved operational outcomes and long-term sustainability.

Figure 14 - Asset Management Process: Plan Stage



5.2.1. Asset Management Plans

Hydro Ottawa prepares AMPs for each asset group or class. An AMP is a comprehensive, multi-year plan designed to guide Hydro Ottawa in achieving its asset management objectives, outlined in Section 4.2 - Asset Management Scope, Strategy and Objectives. An AMP outlines the necessary activities, strategies, and timeframes, drawing upon principles stated in Section 4.2 - Asset Management Scope, Strategy and Objectives. AMPs incorporate insights from internal stakeholders, ensuring a thorough understanding of specific asset needs and management requirements.

AMPs focus on defining the required level of service for assets and ensuring alignment with the broader asset management objectives and performance measures. AMPs also include a detailed assessment of the current condition and performance of assets, enabling the identification of areas where improvements can be made. By pinpointing these gaps, the AMPs help to identify remedial actions to enhance asset performance and reliability.

AMPs are also forward looking and consider future demand and various drivers that may influence asset management practices. This forward-looking perspective allows Hydro Ottawa to anticipate changes and adapt its strategies accordingly. Finally, AMPs outline the lifecycle strategies and activities associated with managing assets effectively. They identify the resources needed to execute these strategies and present a financial plan that supports the overall asset management approach. AMPs serve as roadmaps for Hydro Ottawa to optimize asset performance, mitigate risks, and ensure the long-term sustainability of its infrastructure.

Hydro Ottawa has developed AMPs categorized as follows:

1. Underground Transformers
2. Underground Switchgear
3. Station Transformers
4. Station Switchgear and Breakers
5. Poles, Fixtures and Overhead Conductors
6. Overhead Switches
7. Overhead Transformers
8. Civil Structures
9. Underground Cables
10. Station Batteries, Protection and Control Equipment

11. Vault Transformers
12. Telecommunications
13. Revenue Meters

5.2.1.1. Program Planning Approach

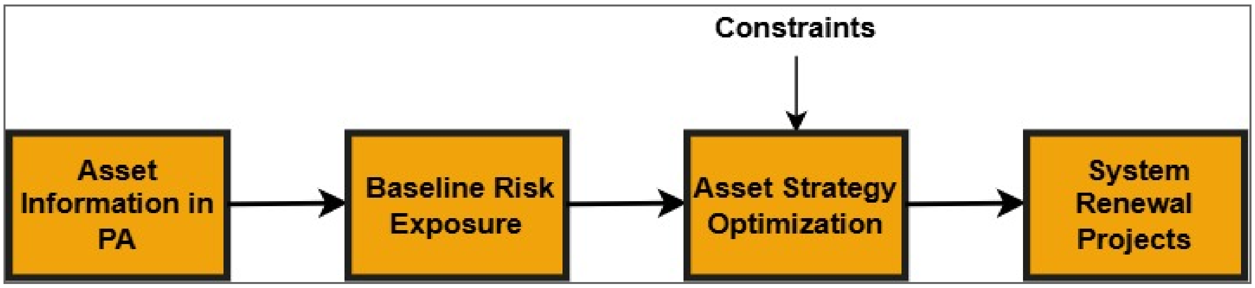
The AMPs are strategically aligned with the overall system requirements while proactively addressing identified risks and objectives. They serve as a comprehensive and actionable roadmap for optimizing asset performance, reliability, and longevity. Furthermore, they encompass a detailed analysis of the capital expenditures necessary to effectively support the overarching asset management strategy. Hydro Ottawa's DSP is informed by the AMPs, which also ensure that the resulting capital programs are monitored, implemented, and reported on annually through relevant AMP updates. Hydro Ottawa monitors the asset demographics (in terms of age/condition) and other impacts/risks to an asset type through the AMPs, which are key factors that drive the program planning process, in addition to the risk-based assessment outlined below for system renewal investments.

Hydro Ottawa leveraged the Copperleaf PA module to facilitate and enhance the decision-making process surrounding the allocation of financial resources towards system renewal program-level expenditures. As described in Section 5.1.4 - Asset Risk Assessment, Hydro Ottawa developed a distribution asset model by utilizing asset condition to forecast the degradation pattern based on the probability of failure. Asset-specific consequences and exposure factors were also established based on asset criticality with higher granularity.

Figure 15 below shows the system renewal planning process with Copperleaf PA. Hydro Ottawa loads asset information in PA, and the asset data is automatically run through the established distribution asset model. The PA module computes the baseline risk for all assets and establishes the risk exposure for Hydro Ottawa if no intervention were to be executed. PA also determines the most effective sustainment strategy to mitigate baseline risk exposure while considering constraints such as financial budgets, risk, resources, and service levels/measures. Copperleaf PA allows

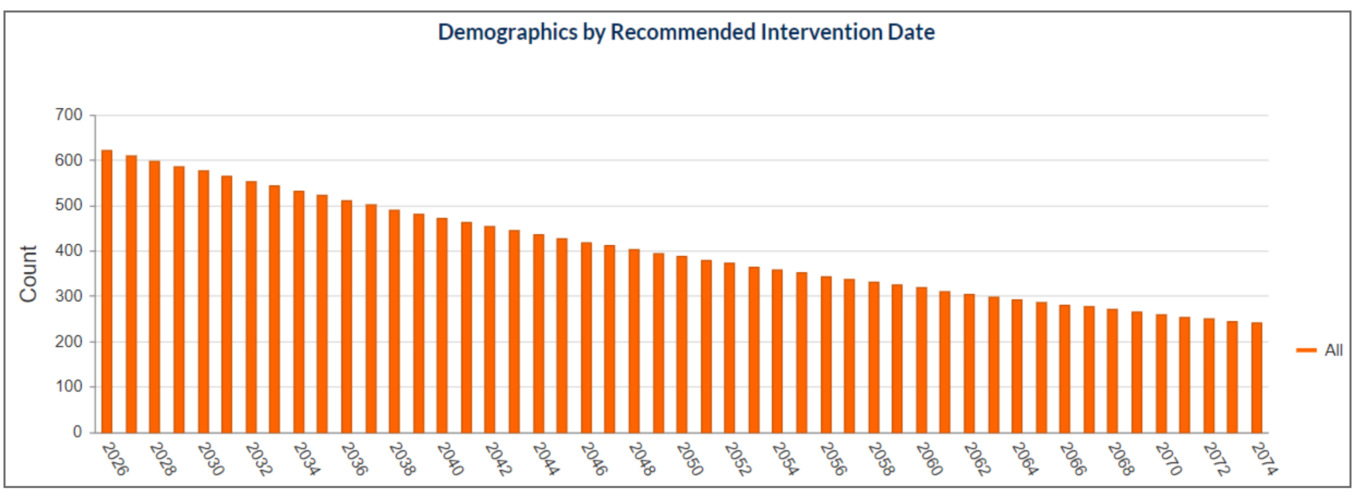
Hydro Ottawa to evaluate multiple scenarios, looking at various interventions and constraint levels on the asset sustainment strategy.

Figure 15 - System Renewal Planning Process with Copperleaf PA



Only direct asset replacement costs are considered in Copperleaf PA as a part of system renewal investment planning and establishing the recommended number of units to be replaced per year. Copperleaf PA determines an optimized spending level based on the underlying constraints in order to realize maximum value. Based on the example shown in Figure 16, for a given asset type, PA recommends more replacements in the initial years (driven by asset condition and risk), so the investment required tapers down in the future, as a part of the most optimal investment strategy.

Figure 16 - Yearly Recommended Interventions with Copperleaf PA



As a part of the optimization process in Copperleaf PA, Hydro Ottawa primarily considered the age and condition demographic projections into 2040, to develop three main alternatives with varying replacement levels. The major objective behind developing these alternatives was to balance long-term cost impacts to customers with the failure risk of assets in a degraded condition.

The following three alternatives were considered to plan the system renewal investments across the major distribution asset renewal programs:

1. **Cost Containment:** Cost impacts are minimized during the 2026-2030 period, however replacement rates will not allow Hydro Ottawa to balance long-term affordability or effectively manage risk associated with assets in degraded condition
2. **Short Term Risk Mitigation:** Cost impacts are more significant and replacement rates will allow Hydro Ottawa to mitigate only short term risk associated with assets in degraded condition
3. **Long Term Risk Mitigation:** Cost impacts are highest however replacement rates will allow Hydro Ottawa to most effectively balance long-term affordability and risk associated with assets in degraded condition

The aforementioned alternatives are evaluated against the corresponding evaluation criteria considered (such as safety, reliability, financial, system observability, resilience, etc.), to finalize an optimal investment alternative for a given asset type.

For additional details regarding investments planned for asset replacements for 2026-2030, refer to Schedule 2-5-7 - Asset Renewal Investments, Sections 1 through 5. The information from the Distribution System Assessment phase described in Section 5.2.2 - Distribution System Assessment is also considered to determine final investment asset renewal needs.

5.2.2. Distribution System Assessment

The distribution system assessment phase involves analyzing system constraints using the planning forecast from the growth identification phase to determine the need for capacity upgrades or reinforcements. The identification of system constraints is determined through evaluating the existing distribution system's capacity to meet the forecasted planning demand to identify bottlenecks and areas where upgrades or reinforcements may be needed. The assessments also aim to improve the reliability and resilience of the system. Hydro Ottawa's resilience assessment aligns with the OEB's future VASH framework by taking an asset-based approach that relies on data derived from climate forecast models developed by a third-party consultant. A quantitative analysis comparing asset threshold criteria to the probability of extreme weather events within the project evaluation stage ensures investments improve climate resilience within the distribution system. Section 5.2.2.4 - Resilience Assessment provides more detail on the resilience assessment.

5.2.2.1. Grid Modernization

Hydro Ottawa routinely reviews the existing system to identify opportunities for Distribution Enhancement projects that reduce operational constraints and improve system operability, through observability and controllability. Efficiency-driven projects are designed to reduce restoration times and reduce the number of personnel required for switching. As per Section 3.4.2 - Grid Modernization Strategy, the operability of the distribution system will be enhanced through advanced monitoring, rapid fault detection and localization, improved overload detectability, and automated/remote system restoration. System operability will also benefit from resilience measures that strengthen the distribution system and reduce the impact of outages from weather events.

The following criteria are used to identify areas that will benefit from projects related to operability:

- Asset Vulnerability
  - Areas prone to weather impacts
  - Areas with deteriorating infrastructure
  - Areas which are difficult to access or patrol
- Asset Criticality
  - Frequency of historical switching operations

    - Criticality of connected load
    - Number of customers connected and/or customer density
- Regional Considerations
    - Areas with loading constraints
    - Historical reliability performance
    - Density of DERs
    - Areas with high growth projections

These criteria are assessed within the grid modernization and resilience strategies for the purpose of increasing system observability and controllability where applicable. The aim of these initiatives is to bring greater real-time awareness of system performance to support both daily operations and inform system planning.

The following are the results of the system operability review process; these projects are further described in Section 3 of Schedule 2-5-8 - System Service Investment and Schedule 2-5-7 - System Renewal Investments:

- Critical switches identified for upgrades to remote operable units
- Decommissioning redundant/unused legacy equipment from the system upon renewal
- Relocation of equipment or normal-open points
- Installation of Fault Current Indicators (FCIs) to localize faults on long feeders and to optimize the use of remote switches

In addition to the immediate benefits around system operability, the installation of intelligent observation and control devices in the system will set the stage for future grid modernization, laying the foundation for future improvements and functionality contributing to further system operability improvements.

5.2.2.2. System Constraints

Transmission

The distribution system is designed and planned to supply existing and future customers reliably while conforming to system design constraints. These constraints include equipment thermal and short-circuit limitations, power quality, and restoration capability standards. System constraints must be considered in the design of the transmission supply network, station equipment, and distribution feeder configuration. Due to the large load and number of customers impacted by transmission system failures, the transmission system is constrained by standards designed to ensure a high level of reliability. To ensure the reliability of the bulk power system, transmission planning must consider both the adequacy and the security of wires and resources, as well as the supply mix requirements set out in the government's Powering Ontario's Growth plan. Planning and operation of the bulk power system must comply with all applicable standards and criteria established by IESO Ontario Resource and Transmission Assessment Criteria (ORTAC), North American Electric Reliability Corporation (NERC), Northeast Power Coordinating Council (NPCC) and the IESO Market Rules. Projects to address transmission system constraints are often driven by growth within the distribution system. Hydro Ottawa provides the IESO with updated growth forecasts for the distribution system to help identify and address transmission capacity and ORTAC constraints as part of the regional planning process. Details regarding the regional planning process can be found in Section 4 of Schedule 2-5-2 - Coordinated Planning with Third Parties.

Station

Hydro Ottawa's station planning criteria are based on the worst-case N-1 contingency scenario, which ensures the grid can continue operating after the failure of any single major component. The loading limit in this scenario is calculated by summing the capabilities of the remaining transformers after the largest one fails. For planning purposes, the 10-day limited time ratings (LTR) are used when available, which represent the load a transformer can handle for 10 days under peak conditions with less than 1% life loss. If the LTR isn't provided, the highest fan rating is used. Hydro Ottawa designs stations to ensure that transformers - rather than cables, buses, or breakers - set the limit on capacity. In stations with only one transformer, the load is transferred to nearby stations through feeder lines.

Feeder

At the feeder level, the system is constrained by conductor thermal limitations and voltage drop. Each feeder is planned to supply connected customers and/or back up other connected feeders in an N-1 contingency while remaining under the thermal limitation of the conductor. On the 4kV system, this is achieved by having a dedicated backup feeder available at the station, while for all other systems, this is achieved through feeder ties. Additionally, conductor properties, size of loads, and location of loads may lead to voltage drop concerns. Feeders must be configured to deliver voltage levels within the limits stated in Canadian Standards Association Standard (CSA) CAN3-C235-83 - Preferred Voltage Levels for AC Systems, 0 to 50 000 V.

Constraints of various equipment types are determined by the equipment properties information stored in Hydro Ottawa's Asset Register. Projects and operation guidelines are created to address equipment forecasted to exceed their constraints. Current capacity limitations of Hydro Ottawa's electrical infrastructure are monitored through SLI and FLI calculations, see more details in Section 8.4 - Asset Utilization Policies and Practices. The system capacity assessment and the resulting needs for each planning region are described in Section 9 - System Capacity Assessment. Alternatives to mitigate capacity needs are evaluated in Material Investment Plans (MIPs), Section 2 of Schedule 2-5-8 - System Service Investments.

The following key variables inform the capacity planning process:

- Historical station transformer loading from the system-wide annual peak day (weather-normalized and adjusted to a one-in-ten-year peak for forecasting)
- Historical feeder loading from the system-wide annual peak day (weather-normalized and adjusted to a one-in-ten-year peak for forecasting)
- Station, station transformer, and feeder planning capacity and ratings

- Asset condition
- System configuration and operating characteristics (and restrictions)
- Number of Hydro Ottawa customers
- Historical energy purchased and delivered
- Summer and winter peak load
- City of Ottawa Official Plans and Community Development Plans
- Land use designation and population and employment projections
- Known developments through conversations with developers and City of Ottawa
- Forecasted load growth triggered by decarbonization driven electrification
- DER connections and capacity
- Station capacity to connect generation and plans in place to address any restrictions
- Details and plans resulting from the IRRP process with the IESO and Hydro One Networks Inc. (Hydro One)
- Details relating to Connection Cost Recovery Agreements (CCRAs) with Hydro One for station or transmission projects

For more detail, refer to Section 9 – System Capacity Assessment.

5.2.2.3. Reliability Assessment

Distribution system assessments also aim at bolstering the overall performance and reliability of the distribution system. These initiatives include strategic endeavors to augment system reliability, elevate system observability through advanced monitoring and control technologies, and foster technological innovations. By strategically investing in these multifaceted initiatives, Hydro Ottawa aims to proactively address existing challenges, such as feeders exceeding planning limits, feeder phase imbalances, and neutral ties in the 13.2kV delta subtransmission system. The lack of 13.2kV neutral ties on the subtransmission system causes reliability concerns when connecting pad mount transformers without a delta primary as there is no return path for current, potentially causing an imbalance on phase voltage and subsequent overvoltage or undervoltage. Through these targeted investments, Hydro Ottawa seeks to not only enhance the reliability of the electrical grid but also to improve operational efficiency, reduce energy losses, and ensure the overall longevity and sustainability of the distribution system. These assessments feed into investment planning and provide input to System Service Investments.

Reliability-driven projects are those designed to reduce outage frequency or duration. In general, work considered as part of the system reliability plan includes the following:

- Feeder reconfiguration and addition of feeder ties for feeders experiencing poor reliability and/or capacity constraints
- Phase balancing of feeders with high phase imbalance
- Deployment of remote sensors
- Deployment of remotely operable and autonomous devices
- Deployment of field devices to provide fault indications locally
- Supporting technologies for automation (e.g., communication & SCADA)
- Modifications of existing installations to address specific interference (e.g., animal guards, circuit spacing)

The reliability assessment process may also identify required asset replacements. Successful lifecycle management of Hydro Ottawa's assets has a direct impact on system reliability. These activities focus on assets that are optimally maintained throughout their life, asset replacement before failure, and system planning to increase operability and reduce downtime.

The following key variables inform the reliability planning process:

- Historical outage statistics (primary cause, secondary cause, duration, number of customers affected, circuit affected, station affected, date of interruption, number of momentary interruptions)
- Worst Feeder evaluation

The following are the results of the reliability assessment process; these projects are further described in Section 2 of Schedule 2-5-8 - System Service Investment:

- Projects to improve the Worst Feeders' reliability performance
- Initiatives to improve overall reliability (specifically targeting the top three causes of interruption from the previous year)
- Details on automation plans and how they will impact reliability

5.2.2.4. Resilience Assessment

Ottawa has become the weather-alert capital of Canada.[6] Extreme weather events such as high heat, high winds, flooding, and ice storms are increasingly straining and damaging the electricity grid. Due to this, focusing on enhancing grid resilience through proactive measures and infrastructure upgrades is essential to protect against the increasing frequency and intensity of severe weather events.

Hydro Ottawa's service territory has been impacted by adverse weather events in recent years as described in Section 4.4 of Schedule 2-5-3 - Performance Measurement for Continuous Improvement. In 2019, Hydro Ottawa commissioned Stantec to complete a Distribution System Climate Risk and Vulnerability Assessment, as well as a Climate Change Adaptation Plan due to the increasing number of extreme weather events. Stantec reaffirmed the results from these reports in 2023 to include more recent weather events and updated climate models, refer to Section 6.4.2 - Future Climate.

Leveraging the findings from the 2023 Stantec report, Hydro Ottawa engaged Burns & McDonnell's subsidiary, 1898 & Co, to complete a Resilience Investment Business Case Assessment to identify investments that would increase grid resilience focusing on strategic undergrounding. These reports were used to establish resilience criteria that align with the OEB's VASH framework and ensure the greatest value from resilience investments. The criteria were used to create a new resilience risk

[6] Environment and Climate Change Canada.

value measure to quantify the risk associated with the frequency and intensity of major weather events on the distribution system, calculated based on a storm's impact on the reliability of a given section of feeder. This feeds into the Project Evaluation process detailed in Section 5.3.2.2 - Project Evaluation. The orientation, configuration, vegetation encroachment, and historical outage information for a given section was assessed against the ability of those assets to withstand major weather events such as high winds, winter storms, and tornadoes. The impact of a major weather event was quantified using a climate change forecast correlated against historical customer outage times. Reliability risks such as types of customers, average number of customers impacted, expected peak lost load, worst performing feeders, number of failures per year, duration of outages, and redundancy lost were referenced to assess the project value. Investments identified by the Resilience Business Case report were evaluated using this new resilience value measure to prioritize projects with the greatest resilience benefit.

Attachment 2-5-4(E) - Resilience Investment Business Case Report underscores the escalating significance of grid resilience. This emphasis was made in light of the increasing frequency of major weather events, with the report documenting the findings of the assessment. It emphasizes that resilience is not just a technical issue, but a societal one, as the modern customer and integrated society are increasingly reliant on a consistent power supply. The impact of power outages today is far greater than in the past, necessitating proactive investment in grid resilience. The report provides a conceptual framework for understanding resilience, breaking it down into three components: stressors (major events), the state of the system (vulnerabilities), and utility actions (prepare, mitigate, respond, recover). It underscores the importance of a future-focused approach to resilience, considering the 'universe' of potential events and system vulnerabilities.

The core of the report lies in its Resilience Investment Model, a data-centric approach to identify, prioritize, and justify resilience investments. The model focuses on converting overhead lines to underground systems and considers factors like vegetation density, asset age, and customer type to identify projects with the highest potential benefits. The analysis presents the results of a resilience evaluation for Hydro Ottawa, focusing on overhead to underground resilience investments. The benefits of these investments are quantified in reduced storm recovery costs and reduced customer outages, measured in Customer Minutes Interrupted (CMI). The results highlight the potential for significant customer benefits through strategic resilience investments.

Hydro Ottawa has adopted a proactive and comprehensive approach to resilience investment. Inputs from the Resilience Investment Business Case Report were considered to frame Hydro Ottawa's resilience strategy.

The report identifies 1,743 projects to underground lines, with 57 projects having a Benefit to Cost Ratio (BCR) greater than 0.8. Projects with a BCR >1 offer a positive business case, with benefits outweighing the costs, and are therefore recommended to undergo a scope evaluation. To have a larger pool of projects for scope evaluation, and consideration for other resilience measures for inclusion under the Resilience program, Hydro Ottawa considered projects with a BCR threshold greater than 0.8. These projects significantly reduce both storm restoration costs and CMI. The projects proposed have been reviewed by Hydro Ottawa and used as a starting point to frame resilience investments. Adjustments to the investments proposed by the consultant were mainly based on Hydro Ottawa's knowledge of the distribution system, such as updating project costs based on unique site conditions, and to drive efficiencies by collating project scope where it provides greater benefit.

In addition, while the report focuses on undergrounding, it acknowledges that other resilience investment options could be considered as part of a larger resilience plan such as stronger pole structures, enhanced switching, and improved access to deep right of ways. Hydro Ottawa adopted this approach to build resilience criteria that not only look at undergrounding but an overarching strategy to make the grid more resilient. Based on this, the resilience investments plans cover:

- Strategic Undergrounding - Based on Undergrounding Study results, BCR larger than 0.8 and passing of Hydro Ottawa screening
- Line Reinforcement - strong structure poles, guying and anchoring

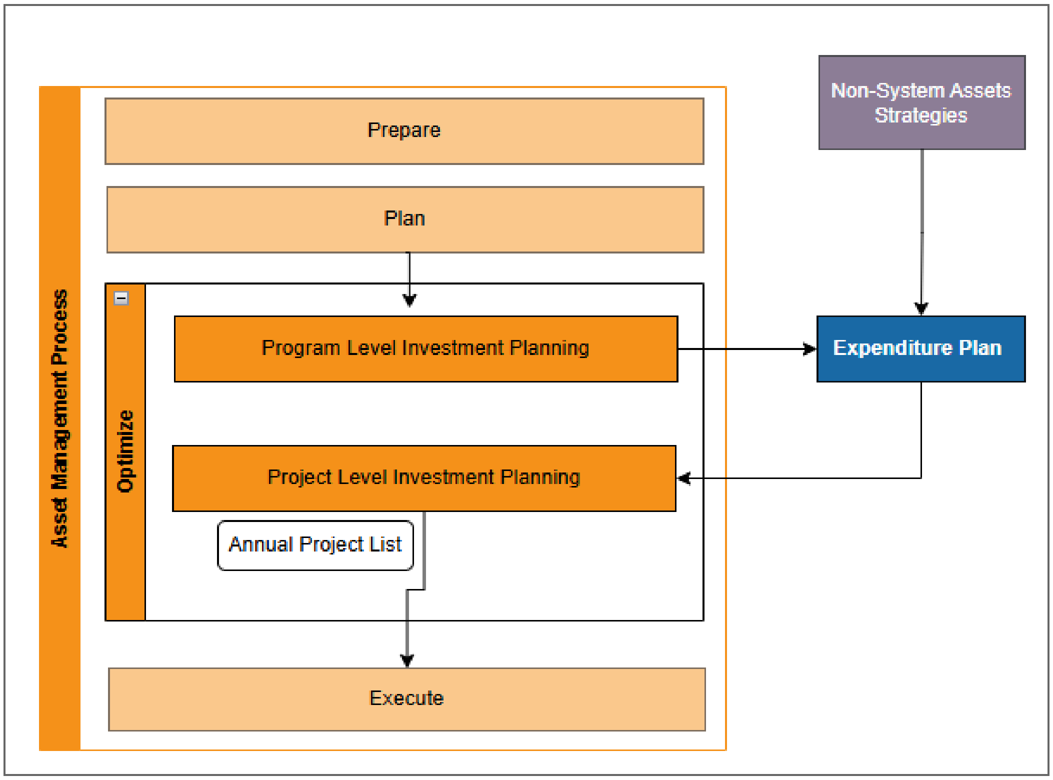
- Feeder Reconfiguration - reduce customer count on feeders heavily impacted by adverse weather conditions (radially fed customers, north-south arterials)
- Station Egress Undergrounding - undergrounding of overhead egress with more than two circuits up to a point where system flexibility increases
- Line Relocation - relocate lines with high vegetation and/or improve access to deep right of way.

More details on resilience investments can be found in Section 3 of Schedule 2-5-8 - System Service Investments.

5.3. OPTIMIZE

Hydro Ottawa organizes its Capital Expenditure Plan into four investment categories: System Access, System Renewal, System Service, and General Plant. Each category is divided into Capital Programs based on primary drivers, and then further subdivided into Budget Programs based on specific asset type or system need. Individual projects are created under Budget Programs for assets at specific geographic locations that require intervention or for specific initiatives. The investment planning process, which includes assessments at both the program and project levels, is part of the optimization stage. Figure 17 shows the components of the optimize stage for investment planning.

Figure 17 - Components of the Optimize Stage



During the program level assessment phase, the needs identified in the AMPs and the distribution system assessment during the planning stage are assigned to investment categories. Then, alternative solutions to address program needs are evaluated to select the solution that best meets asset management objectives. Selected programs are evaluated along with other non-system asset needs (IT, Facilities, and Fleet) through the Capital Expenditure Planning Process, described in Section 3.5, to create a balanced expenditure plan for rate application submission. After the Capital Expenditure Plan is finalized and approved, identified projects within each program are evaluated and scored for annual assessment during the project-level investment planning phase. A portfolio optimization tool is used to refine and optimize project selection using approved program-level constraints.

The optimization stage ensures a balanced and optimized investment approach that addresses system and asset needs identified through the distribution asset management process. This results in a Capital Expenditure Plan that prioritizes system capacity enhancements, renewal of deteriorating infrastructure, grid modernization, and increased overall resilience.

5.3.1. Program Level Investment Planning

The program-level investment planning phase involves a comprehensive integration of asset and system requirements that have been identified through the asset management process planning stage. This phase takes into account a multitude of factors, including but not limited to: investment priorities, risk mitigation strategies, regulatory compliance mandates, resource availability, and financial viability. Furthermore, the plan extends its purview to encompass requirements emanating from other non-system assets, ensuring a holistic alignment with the overarching needs of the distribution system.

The first step of this process, program definition, involves a thorough examination of the primary factors that influence each program within every investment category. This comprehensive analysis serves two key purposes:

- Ensuring that the budget is allocated appropriately and effectively to achieve the desired outcomes.
- Identifying areas where programs can be streamlined or optimized to enhance efficiency. These improvements in efficiency may also have the added benefit of addressing secondary drivers.

The second step of this process, program portfolio optimization, involves a comprehensive evaluation of how well identified programs align with the overarching investment priorities. These priorities, which include Growth and Electrification, Renewing Deteriorating Infrastructure, Grid Modernization, and Enhancing Resilience, serve as the guiding principles for investment decisions. Each of these priorities is further supported by underlying focus areas, such as Managing Rising

Costs and Investing in the Workforce, which highlight specific areas of concern within the broader strategic framework.

To facilitate the optimization process, MIPs are developed for each program. These plans provide a detailed breakdown of the financial resources required to implement the program to enable the assessment of the feasibility of different alternatives and their ability to meet the identified priorities. The assessment process involves a rigorous evaluation of the potential costs and benefits associated with each program, as well as its potential contribution to the overall strategic objectives. The evaluation criteria used to determine the preferred alternative differ depending on the program under consideration, but all follow components of the themes outlined in Table 7 below.

1 **Table 7 – Alternative Evaluation Criteria**

Evaluation Theme	Description
Regulatory and Legal Compliance	Adherence to all applicable laws, regulations, and industry standards, including specific acts, codes, and board requirements. Ensures legal operation and fulfills obligations to provide safe and reliable services.
Economic and Community Impact	Contribution to the city's growth and sustainability, supporting development projects, business expansion, and enhancing community well-being through reliable infrastructure and sustainable initiatives.
Environmental Sustainability	Promotion of environmental sustainability by supporting electrification, renewable energy integration, and energy efficiency initiatives. Aims to minimize environmental footprint, reduce greenhouse gas emissions, and promote clean energy sources.
Customer Experience and Empowerment	Enhancement of customer satisfaction through accurate billing, personalized service, transparent energy management, and providing direct control over energy usage and billing, fostering energy awareness.
Operational Efficiency and System Performance	Impact on operational processes and system capacity, focusing on optimizing power flow and ensuring the system can handle increasing loads without compromising service quality.
System Reliability	Management of asset performance to reduce the risk of failure and ensure consistent power delivery. Focuses on minimizing the frequency and duration of outages.
System Resilience	Evaluating the systems ability to withstand disruptions and quickly recover from extreme weather or unexpected events.
System Observability	Enhancement of the monitoring and diagnosis of system conditions to support grid modernization initiatives, real-time monitoring, and fault detection, enabling informed decision-making.
Financial Viability and Cost-Effectiveness	Financial implications, including upfront costs, ongoing maintenance, and risk mitigation, balancing infrastructure enhancements with minimizing rate impacts.
Safety and Public/Employee Protection	Mitigation of risks to employees and public safety, prioritizing the protection of both from electrical hazards and other potential dangers.
Asset Management and Renewal	Management of asset performance, including renewal, maintenance, and addressing aging infrastructure to ensure reliability and prevent failures.
Resource and Material Procurement	Ability to achieve successful project execution through optimized resource management and timely procurement of materials.
Cyber Security and Data Protection	Protection of customer data and safeguarding the grid from cyber threats through adherence to high industry standards for data security and privacy.

The results of the program-level investment planning assessment for the 2026-2030 rate period, which are detailed in Schedules 2-5-6 through 2-5-9, provide valuable insights into the effectiveness of the current program portfolio and its alignment with the strategic investment priorities.

5.3.1.1. Program Definition

Hydro Ottawa's Capital Expenditure Plan is broken into four Investment Categories, which are summarized in Table 8. These investment categories and definitions are in alignment with OEB Chapter 5 filing requirements.

Table 8 – Capital Investment Categories

Investment Category	Description
System Access	Modifications (including asset relocation) to a distributor's system to provide customers (including generator customers) with access to electricity services via the distribution system.
System Renewal	Replacing and/or refurbishing system assets to extend their original service life, maintaining the ability of the distribution system to provide customers with reliable and safe electricity services.
System Service	Modifications to the distribution system to ensure that it continues to meet the distributor's operational objectives while addressing anticipated future customer electricity demand and service requirements.
General Plant	Modifications, replacements, or additions to a distributor's assets that are not part of its distribution power delivery system, including land and buildings; tools and equipment; rolling stock, and electronic devices and software used to support day-to-day business and operations activities.

Table 9 outlines the description of the drivers by Investment Category. The Program Definition process assigns programs to appropriate investment categories based on the program's primary driver.

Table 9 – Driver Description

Investment Category	Driver	Description
System Access	Customer Service Request	Customer request for new connection (load or generation)
	Third Party Requirements	Request by a third party for plant relocation
	Mandated Service Obligation	Regulatory requirement to maintain distribution license under the OEB's Distribution System Code or requirement as per Hydro Ottawa's Conditions of Service
System Renewal	Failure	Asset no longer meets functional requirement
	Failure Risk	Asset is at risk to no longer meet functional requirements
	High Performance Risk	Asset is at risk of failure in a way that can cause harm or damage to other equipment or assets or would put the distribution system in a detrimental state
	Functional Obsolescence	Asset is functionally obsolete with no spare parts, tools, and/or software to continue operation
System Service	Capacity Constraints	Requirement for additional capacity (station transformation or circuit) due to planned or realized load increases
	Reliability	Requirements driven by poor distribution system performance such as abnormally high duration or frequency of interruptions
	System Efficiency	Requirements to improve both resource efficiency and power delivery reliability through strategic automation that minimizes manual intervention and streamlines data workflows.
	Observability	Requirements for improved system operability and visibility
	Resilience	Requirements for improved system resilience during major events.
General Plant	System Investment Support	Capital contributions to Hydro One for connection projects Requirement for fleet/vehicle acquisition
	Business Operations Support	Requirements for IT software and systems

5.3.1.1.1. System Access

System Access investments are obligatory activities. For this reason, they are not prioritized through the Capital Investment Planning Process, but rather based on available resources and in collaboration with the requesting party.

The main drivers for programs under System Access are:

- **Customer Service Requests:** Customer Service Requests arise from the needs of load or generation customers for new connections. This category includes servicing for new commercial buildings, residential subdivisions, or generators, and encompasses any system expansion required to supply the development site.
- **Third Party Requirements:** Third Party Requirements are initiated from requests received for the relocation or upgrade (modifications) of assets or infrastructure (e.g., pole relocation for road widening).
- **Mandated Service Obligations:** Mandated Service Obligations are requirements of a distributor as defined by the Distribution System Code (DSC), as well as any additional obligations outlined in Hydro Ottawa's Conditions of Service.

The System Access investment category is further broken down into Capital Programs and subsequent Budget Program. Table 10 shows the allocation of System Access drivers to programs.

Table 10 – System Access Programs

Capital Program	Budget Program	Primary Driver
Plant Relocation & Upgrade	Plant Relocation & Upgrade	Third Party Requirements
Customer Connections	Residential Subdivision	Customer Service Request
	New Commercial Development	Customer Service Request
	Infill (Res & Small Com)	Third Party Requirements
System Expansion	System Expansion Demand	Customer Service Request
	Asset Transfer	Third Party Requirements
Generation Connections	Embedded Generation	Customer Service Request
Metering	Suite Metering	Customer Service Request

5.3.1.1.2. System Renewal

System Renewal investments are identified through the distribution system assessment process described in Section 5.2.1 - Asset Management Plans. The objective of the comprehensive risk assessment is to confirm that the assets deliver the required functions at the desired level of performance, and that this level of performance is sustainable for the foreseeable future while operating within acceptable risk levels.

The System Renewal program is driven by a number of primary factors related to asset risk levels, each indicating a need for intervention to maintain the integrity and functionality of distribution assets. A description of Hydro Ottawa's methodology to determine asset risk is provided in Section 5.1.4 - Asset Risk Assessment. These factors include:

- **Failure:** This refers to an asset that has ceased to operate or function as intended. This may be due to a variety of reasons such as age, condition, or damage.
- **Failure Risk:** This indicates an asset that is at risk of imminent failure. This may be due to observed signs of deterioration, performance issues, or the results of predictive maintenance analysis.

- **High Performance Risk:** This refers to an asset that, while currently functional, poses a significant risk of failure that could have severe consequences. This may include damage to other equipment or assets, disruption of the distribution system, or safety hazards.
- **Functional Obsolescence:** This refers to an asset that, while still operational, is no longer considered efficient or effective. This may be due to technological advancements, the unavailability of spare parts or supporting software, or changes in operational requirements.

These factors are used to identify assets that require attention under the System Renewal program, ensuring the continued reliability, safety, and efficiency of the system.

The System Renewal investment category is further broken down into Capital Programs and subsequent Budget Program. Table 11 shows the allocation of System Renewal drivers to programs.

Table 11 – System Renewal Programs

Capital Program	Budget Program	Primary Driver
Stations and Buildings Infrastructure Renewal	Station Transformer Renewal	Failure Risk
	Station Switchgear Renewal	Failure Risk
	Station Major Rebuild	Failure Risk
	Station P&C Renewal	Failure Risk
	Station Battery Renewal	Failure Risk
	Station & Building Minor Asset Renewal	Failure Risk
	EOL Voltage Conversion	Failure Risk
OH Distribution Assets Renewal	Pole Renewal	Failure Risk
	OH Switch/Recloser Renewal	Failure Risk
UG Distribution Assets Renewal	Vault Renewal	Failure Risk
	Civil Renewal	Failure Risk
	Cable Replacement	Failure Risk
	UG Switchgear Renewal	Failure Risk
	UG Transformer Renewal	Failure Risk
Corrective Renewal	Damage to Plant	Failure
	Emergency Renewal	Failure
	Critical Renewal	Failure
Metering Renewal	Metering Upgrades	Functional Obsolescence

5.3.1.1.3. System Service

System Service investments are identified through the asset management plan process described in Section 5.2 - Plan. The main drivers for programs under System Service are:

- **Capacity Constraints:** The capability and reliability of the distribution system is regularly evaluated to ensure a stable and dependable power supply for customers. When gaps are found, the utility develops plans for system upgrades or expansions, ensuring compliance with regulatory standards and considering safety, environmental impact, costs, and the reliability and security of the power supply. The results of this process are outlined in Section 9 - System Capacity Assessment, which identifies both short and long-term capacity needs.

To maintain adequate system capacity, Hydro Ottawa evaluates the current and future supply demands in its service area. The system is divided into subsystems based on voltage levels and geographic boundaries for capacity planning purposes. The process factors in projected growth, asset replacement schedules, reliability, and modernization technologies to develop both short-term and long-term solutions.

- **Reliability:** Hydro Ottawa continuously assesses the distribution system's service reliability. When issues are identified, appropriate actions are taken. Service reliability is integral to all work undertaken as part of system planning and asset management. The reliability assessment process described in Section 5.2.2 - Distribution System Assessment provides a platform for a thorough review of system reliability and identifies planned work designed to directly impact system reliability.
- **System Observability:** As per Section 3.4.2 - Grid Modernization Strategy, the observability and controllability of the distribution system will be enhanced through advanced monitoring, rapid fault detection and localization, improved overload detectability, and automated/remote system restoration. The aim of this driver is to bring greater real-time awareness of system performance to support both daily operations and inform system planning.

The System Service investment category is further broken down into Capital Programs and subsequent Budget Program. Table 12 shows the allocation of System Service drivers to programs.

Table 12 – System Service Programs

Capital Program	Budget Program	Primary Driver
Capacity Upgrades	Stations Capacity Upgrades	Capacity Constraints
	Distribution Capacity Upgrades	Capacity Constraints
	Non-Wire Upgrades	Capacity Constraints
Distribution Enhancements	Distribution System Reliability	Reliability
	Capacity Voltage Conversion	Capacity Constraints
	Distribution Enhancements	Reliability
	Distribution System Observability	Observability
	Distribution System Resilience	Resilience
Station Enhancements	Stations Enhancements	Reliability
Grid Technologies	SCADA Upgrades	System Efficiency
	RTU Upgrades	N/A
	Communication Infrastructure	System Efficiency
Control and Optimization	Control and Optimization	Observability
Field Area Network	Physical Fiber Extension	System Efficiency
	Wireless Communication	System Efficiency
	Management of Grid-Edge Device	System Efficiency
	SCADA Network Cyber Security	System Efficiency

5.3.1.1.4. General Plant

The General Plant category encompasses a diverse set of capital programs essential for maintaining and advancing Hydro Ottawa's infrastructure, operational capabilities, and customer service excellence. These investments address areas such as critical infrastructure reliability, fleet renewal, IT and cyber security infrastructure, and customer engagement.

The main drivers for programs under General Plant are:

- **System Investment Support:** Capital contributions to Hydro One for transmission upgrades required to service new and upgraded stations, in addition to requirements for fleet/vehicle acquisition.
- **Business Operations Support**: Requirements for IT software and systems

Table 13 lists the programs and primary drivers within General Plant.

Table 13 – General Plant Programs

Capital Program	Budget Program	Primary Driver
CCRA	CCRA	System Investment Support
Fleet Replacement	Fleet Replacement	System Investment Support
Tools Replacement	Tools Replacement	System Investment Support
Buildings - Facilities	Buildings -Facilities	System Investment Support
Grid Technology	Grid Technology	Business Operations Support
Meter to Cash	Meter to Cash	Business Operations Support
Customer Engagement Platform	Customer Engagement Platform	Business Operations Support
Enterprise Solutions	Enterprise Solutions	Business Operations Support
Infrastructure and Cyber Security	Infrastructure and Cyber Security	Business Operations Support
Data and System Integrations	Data and System Integrations	Business Operations Support

5.3.1.2. Program Optimization

Strategic planning involves optimizing the program portfolio by evaluating how well the identified programs align with key investment priorities. These priorities, including Growth and Electrification, Renewing Deteriorating Infrastructure, Grid Modernization, and Enhancing Resilience, guide investment decisions, supported by the focus areas of Managing Rising Costs and Investing in the Workforce.

MIPs are developed for each program to facilitate optimization, detailing financial resources required for implementation and enabling decision-makers to assess feasibility and alignment with priorities. The assessment process rigorously evaluates potential costs, benefits, and contributions to strategic objectives.

Results from the program level investment planning for 2026-2030, detailed in Schedules 2-5-6 through 2-5-9, provide insights into the current program portfolio effectiveness and alignment with strategic investment priorities.

5.3.1.2.1. System Access

Investments under System Access are necessary to support growth and electrification. This investment category includes programs like Customer Connections to facilitate new residential and commercial developments, System Expansion to address major infrastructure projects like new stations, and Generation Connections to enable the connection of customer-owned DERs.

MIP are developed for each Capital Program and included in Schedule 2-5-6 - System Access Investments. Program drivers under this category are mainly impacted by the growing number and complexity of customer connections, reflected in expenditures for the Customer Connections and System Expansion Capital programs. These programs are defined by assessing historical spending, historical connections and projects, and industry trends as well as known upcoming committed projects for the 2026-2030 rate period.

5.3.1.2.2. System Renewal

System Renewal investments are required to support the renewal of deteriorating infrastructure. This investment category includes programs like Station and Buildings Infrastructure Renewal, Overhead Distribution Asset Renewal, Underground Asset Renewal, Corrective Renewal, and Metering Renewal.

MIPs are developed for each Capital Program and included in Schedule 2-5-7 - System Renewal Investments. Hydro Ottawa's System Renewal investment planning uses a strategic, forward-looking approach with levelized spending to mitigate the long-term impacts of asset degradation or failure. While safety, financial, environmental, and compliance risks are considered, reliability is the primary driver of the overall risk value (based on actual data available). System Renewal investments have been scaled to reduce the corresponding risk values and maintain overall system reliability. Hydro Ottawa's asset renewal strategy is to mitigate and manage asset risks, considering long-term impacts, through strategic replacement of deteriorating infrastructure, and therefore not to outright replace all aged or deteriorated assets.

Programs for each asset type are defined through the AMPs, as described in Section 5.2.1 - Asset Management Plans and then evaluated at the asset class level (Stations, Overhead, Underground, and Metering assets) through MIPs. Similar alternatives to the asset-type level are used: cost containment, short-term risk mitigation, and long-term risk mitigation as described in Section 5.2.1.1 Program Planning Approach.

5.3.1.2.3. System Service

System Service investments are required to support growth and electrification and grid modernization to enable the energy transition as well as enhancing resilience. This investment category includes programs like Capacity Upgrades, Distribution Enhancements, Station Enhancements, Grid Technologies, Control and Optimization, and Field Area Network.

The System Service investment category focuses on strategic spending to enhance the overall functionality and capability of the distribution system. Key areas of investment include:

- **Expanding Distribution System Capacity:** This involves upgrading and expanding the existing infrastructure to accommodate increased demand and future growth.
- **Improving System Reliability and Resilience:** Investments are made to minimize outages, reduce downtime, and ensure the system can withstand and recover quickly from disruptions caused by natural events or other unforeseen circumstances.

- **Grid Modernization:** This encompasses the integration of advanced technologies and intelligent systems to optimize grid performance, enable better demand management, and support the integration of renewable energy sources.

The allocation of spending within the System Service category is guided by MIPs. These plans are developed for each Capital Program and are detailed in Schedule 2-5-8 - System Service Investments. They provide a structured framework for prioritizing and implementing projects that align with overall investment priorities.

A key component of the System Service investment strategy is the selection of specific station capacity projects for capacity upgrade programs based on capacity system needs described in Section 9 - System Capacity Assessment. These projects are carefully chosen based on several factors, including recommendations from the IRRP and aligned with supporting distribution and NWSs programs. This ensures that capacity upgrades are implemented strategically and in a way that maximizes benefits for the overall system.

5.3.1.2.4. General Plant

MIPs guide the allocation of spending within the General Plant category. These plans, which are detailed in Schedule 2-5-9 - General Plant Investments, are developed for each Capital Program and provide a structured framework for prioritizing and implementing projects that align with overall investment priorities.

Investments in CCRAs with Hydro One are included in the System Service planning process and are thus evaluated using the same criteria. See Section 5.3.1.2.3 - System Service for more details.

General Plant investments in IT, Fleet, and Facilities follow a similar approach to the distribution asset management processes. These investments are typically large replacement or enhancement initiatives for assets reaching the end of their useful life. As such, they generally span several years. Therefore, they are initiated and justified with detailed business cases.

Information Technology

All new IT requirements must be communicated to the IT team prior to purchase and/or implementation. The IT Engagement model outlines the appropriate contact for IT services when the nature of the request is not obvious or lacks an established communication channel. This process is designed to promote optimal use of technology assets, track and plan project demand, and to ensure objectives align with company priorities and the IT strategy.

Facilities

Hydro Ottawa engages consultants to complete building condition assessments for all its office buildings every five years. The building condition assessments include information about asset age and condition and represent the main component of Hydro Ottawa's five-year facility renewal plan. Hydro Ottawa performs alternating roofing and building envelope inspections on its substations in five-year cycles as well as monthly field inspections and safety checks to ensure its facilities assets remain in good working condition. Any defects found are catalogued and repaired or replaced as needed. To align with Hydro Ottawa's sustainability goals and level of organizational growth, the Facilities program will focus on maintaining and upgrading office and operational facilities to support workforce needs, improving energy efficiency, and providing a safe working environment.

Fleet

Every five years, a plan is devised for replacements and additions. Replacement decisions and timing are assessed unit-by-unit using a set of quantitative replacement criteria combined, a physical assessment, and judgement. See Schedule 2-5-9 - General Plant Investments for more details on evaluation criteria. Planned additions are informed by the operational needs of the business and ultimately determined through an iterative process with multiple stakeholders. Operation requirements inform projected staffing levels which are used to create an initial estimate of vehicles with preliminary specifications. The initial estimate is reviewed with operational staff to refine requirements and identify opportunities for efficiencies. Ultimately, the required number of vehicles by category are aligned and agreed between the business and operations.

5.3.2. Project Level Investment Planning

Following the approval of the overall Capital Expenditure Plan, Hydro Ottawa conducts an annual project-level assessment to refine and optimize the selection of individual projects within each program. Using Hydro Ottawa's investment optimization software (Copperleaf Portfolio), projects are prioritized based on their value, and constraints like budget limitations are applied to create a realistic and achievable project list. This process generates preliminary and final project lists, with the latter containing more refined cost estimates. The final project list is then presented for approval, marking the final step before project execution can begin. Essentially, this stage focuses on determining which specific projects will be funded within the already-approved budget allocations, maximizing the return on investment for Hydro Ottawa and its customers.

It is noteworthy that projects under the System Renewal and System Service investment categories only go through the capital investment planning process completed in Hydro Ottawa's investment optimization software (Copperleaf Portfolio) and as detailed in Sections 5.3.2.1 - Project Concept Definition to 5.3.2.4 - Portfolio Optimization below. Projects under the System Access investment category are obligatory in nature and hence not prioritized through Copperleaf Portfolio, but rather based on available resources and in collaboration with the requesting party. Similarly, projects under the General Plant investment category are also not evaluated within the Copperleaf Portfolio. These investments are typically large replacement or enhancement initiatives for assets reaching the end of their useful life. As such, they generally span several years. Therefore, they are initiated and justified with detailed business cases.

5.3.2.1. Project Concept Definition

Two distinct processes drive System Renewal and System Service project creation within Copperleaf Portfolio. These processes differ in their origin, data utilization, and scope definition. System Renewal projects leverage the power of data and PA for proactive asset management. They originate from insights derived from Copperleaf Assets and PA. The process begins with ACA information, which is used to identify assets that need intervention. The focus is on proactively minimizing risk based on predicted asset failure.

System Renewal projects born out of Copperleaf Assets and PA move to Copperleaf Portfolio, where they are reviewed to identify opportunities for synergy. For example, a pole renewal project might be expanded to include capacity upgrades in the same area, maximizing efficiency and minimizing disruption. System Renewal projects are then evaluated based on their contribution to system resilience. This includes comparing alternatives for "like-for-like" replacements with storm hardening upgrades or undergrounding assets, allowing for informed decisions regarding long-term resilience.

System Service projects, in contrast, are created on an individual basis within Copperleaf Portfolio. These projects address specific needs as they arise from capacity assessments detailed in Section 9 - System Capacity Assessment. Information for these projects is gathered on a case-by-case basis, and supporting documentation is manually entered into Copperleaf Portfolio. Value measures are assigned across various risk categories (capacity, reliability, compliance, resilience, etc.) to quantify the project's potential benefits. Where applicable, alternative solutions are identified and documented within Copperleaf Portfolio, enabling a comparative assessment of different approaches to mitigate the identified risk.

These two distinct processes contribute to a well-rounded and optimized project portfolio with System Renewal projects providing a proactive, data-driven approach to long-term asset management, ensuring system reliability and resilience while maximizing efficiency through synergy identification. Conversely, System Service projects address specific needs, ensuring responsiveness to emerging challenges. Their focus on individual project value allows for prioritization based on risk and potential impact.

By integrating both System Renewal and System Service projects within Copperleaf, Hydro Ottawa achieves a balanced portfolio. This approach allows for proactive asset management and timely problem-solving, ultimately leading to improved system performance, reduced risk, and optimized resource allocation. The ability to score projects across consistent metrics, regardless of origin from either Copperleaf Asset or Copperleaf Portfolio, allows for a holistic view and facilitates data-driven decision-making.

5.3.2.2. Project Evaluation

The Project Evaluation phase creates business cases supporting the project alternatives. Each alternative is valued based on Hydro Ottawa's Asset Management Objectives using the Value Framework Model to assess the project's alternatives. The evaluation of project alternatives is completed within the Copperleaf Portfolio.

For System Renewal investments, Copperleaf Assets' predictive asset analytics plays a critical role in investment planning for the system renewal portfolio as it identifies the assets that require intervention in a given year. The process begins with PA that assesses the condition and performance of assets, helping to forecast when they might fail or underperform. When an asset is flagged as requiring intervention, an investment proposal is created within Copperleaf Assets and pushed to Copperleaf Portfolio through the Capture Module in Copperleaf. For more details on Predictive Analytics see Section 5.1.4 - Asset Risk Assessment.

The value of the proposed investment is determined by evaluating the risk that would be mitigated by the intervention. This risk value reflects the potential consequences of asset failure, including financial, safety, and operational impacts. The benefits of the intervention are assessed against the replacement or repair costs. The combination of risk mitigation and benefits realization forms the basis for justifying and prioritizing the investment within the broader asset management strategy. This ensures that resources are allocated efficiently, focusing on projects that offer the most value in terms of risk reduction and cost-effectiveness.

For System Service investments, project concepts and their alternatives are conceptualized. Project alternatives are then scored by identifying their risk and/or benefit value measures as it relates to Hydro Ottawa's Asset Management Objectives through the use of the Copperleaf Value Model. The evaluation Value Model comprises twelve Value Measures grouped into three Value Categories, as shown in the Table 14 below.

Table 14 – Copperleaf Value Model

Asset Management Objective	Value Measure	Value Category
Resource Efficiency	Financial Benefits & Costs	Benefit Value Measures
Levels of Service	Program Effects	
Levels of Service	Distributed Generation	
Asset Value	Technological Innovation	
Levels of Service	Capacity Risk	Risk Value Measures
Compliance	Compliance Risk	
Health, Safety & Environment	Environmental Risk	
Resource Efficiency	Financial Risk	
Levels of Service	Reliability Risk	
Levels of Service	Resilience Risk	
Health, Safety & Environment	Safety Risk	
Resource Efficiency	Total Investment Cost	Cost Value Measure

Benefit Value Measures

- **Financial Benefits & Costs**: measures the financial benefits or costs to the organization in the form of annual Capital and OM&A cost savings/increases, cost avoidance or revenue increase (i.e. would result in a budget decrease/increase).
- **Program Effects**: captures the value of all programs not otherwise tracked in Copperleaf.
- **Distributed Generation**: measures the impact of whether a project enables distributed generation. Projects that enable distributed generation are given an additional 30 value units.
- **Technological Innovation**: measures the impact of whether a project introduces technological innovation to the corporation. Projects that introduce technological innovation are given an additional 10 value units.

Risk Value Measures

- **Capacity Risk**: measures the societal cost associated with an interrupted electrical supply and assigns a positive value to projects that help mitigate a proportion of this risk.
- **Compliance Risk**: measures the mitigation of the risk of non-compliance with federal regulations, namely the risk of annual fines, additional compliance costs, or the subsequent cost of operating restrictions.
- **Environmental Risk**: measures the mitigation of incidents that can lead to environmental damage.
- **Financial Risk**: measures the mitigation of financial risk due to damage to equipment, loss of company assets, financial errors, or other factors resulting in monetary loss.
- **Reliability Risk**: measures the mitigation of risk due to customer outages on the distribution system. The reliability value is based on the maximum of three computations: cost of outage duration, cost of outage frequency, and customer minutes of interruption. This Value Model also differentiates between residential, commercial, industrial, and mixed customers and between redundant & non-redundant equipment.
- **Resilience Risk**: measures the improved ability of distribution assets to resist damage due to inclement weather and the corresponding reduction in customer interruptions. This may be added to investments that move equipment underground or improve weather resistance in any way.
- **Safety Risk**: measures the mitigation of the risk of public safety incidents. This risk is intended for use in a Value Function and the avoided risk is a positive contributor to project value.

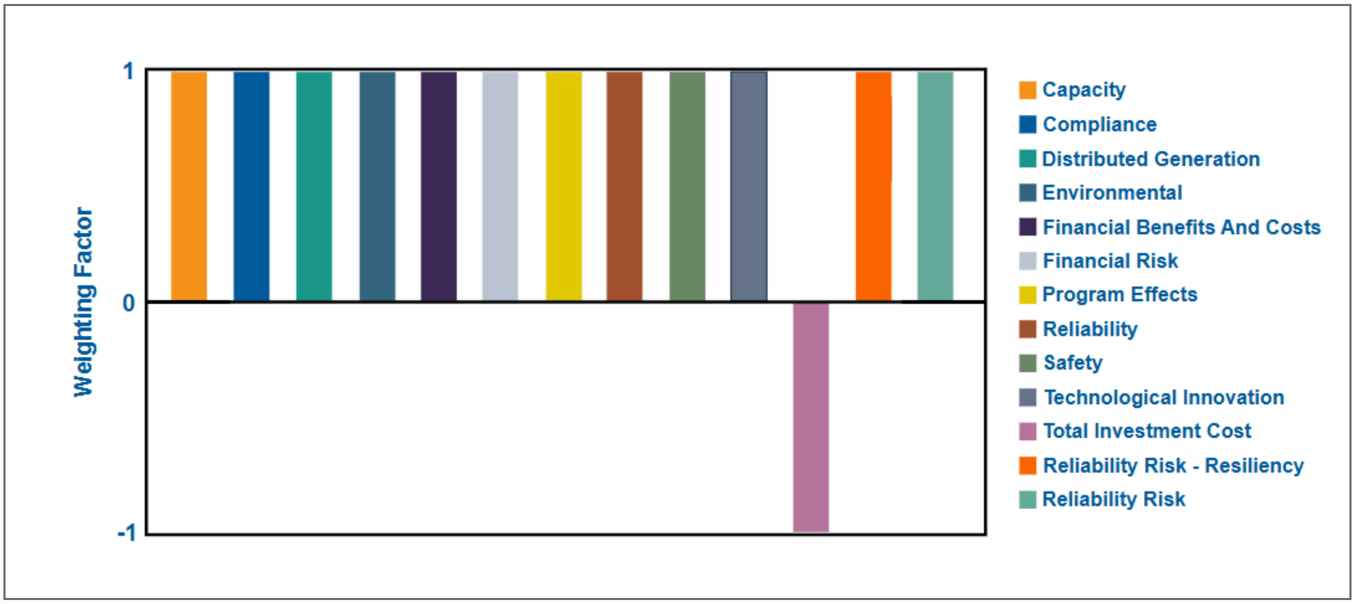
Cost Value Measure

- **Total Investment Cost**: measures the total spending from year to year on proposed projects.

In Figure 18, each Value Measure is normalized to the same scale, where one value point equals approximately $1,000. This means that within the Value Function, each Value Measure (except

Investment Cost) is weighted with the same value of +1. Investment Cost is a negative contributor to the Value Measure and, as such, is weighted with a value of -1.

Figure 18 - Value Category Weighting



The Value Measures for each project are computed for each year (the benefits or risks in one year can be different than the next – for example, the risk of a poor-condition asset failing increases with time). They are then converted into a single number by taking the present value back to the current fiscal year using the system-defined discount rate. This means that if a project has a negative value, the cost of the project outweighs its benefits.

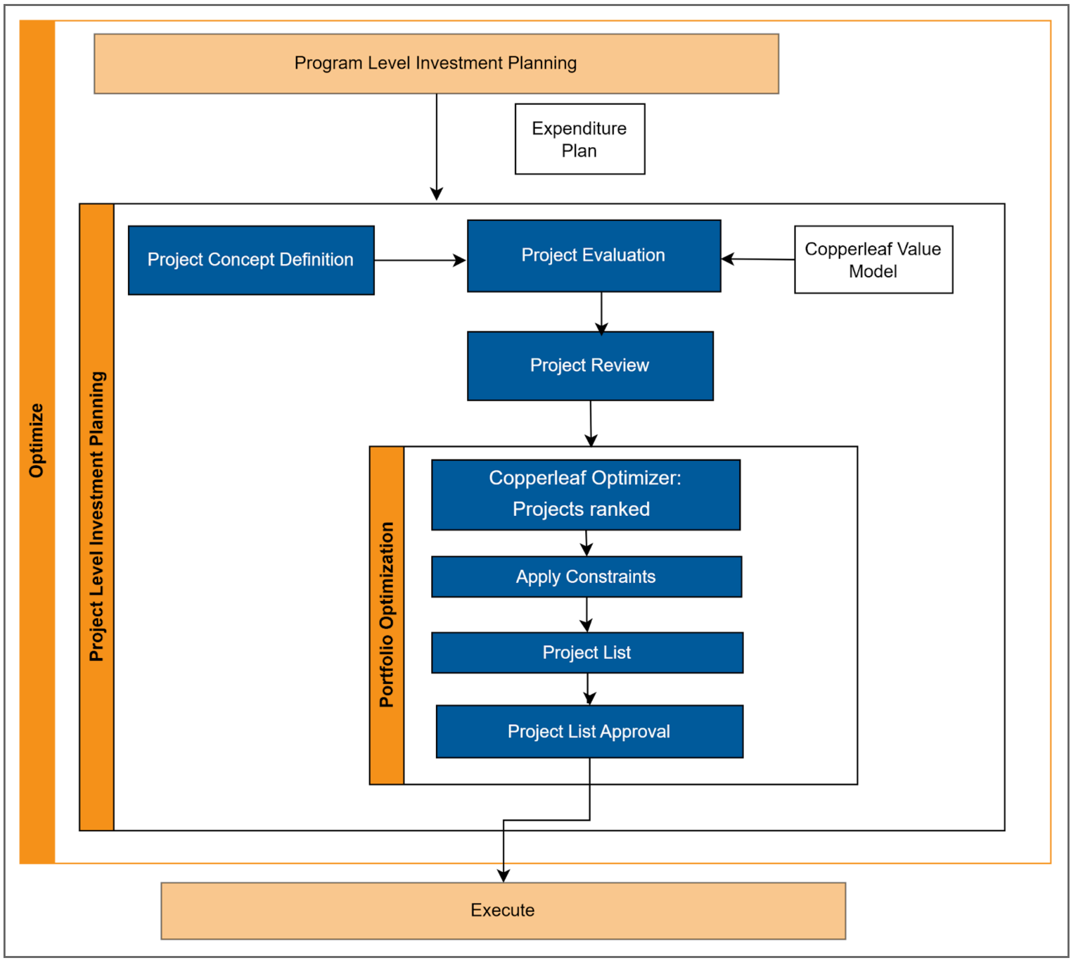
5.3.2.3. Project Review

During the project review phase, the valuation of each project is reviewed and compared to similar projects before the projects are optimized to ensure a consistent approach.

5.3.2.4. Portfolio Optimization

The portfolio optimization phase, depicted in Figure 19, uses Copperleaf to prioritize projects based on their value. Project Prioritization Procedure ensures consistent prioritization of projects to deliver on Asset Management Objectives. This phase utilizes the Copperleaf Portfolio module to rank projects based on their value, calculated through the Project Evaluation phase. The Optimizer algorithm within Copperleaf selects the optimal project portfolio based on value and constraints applied. This leads to the creation of a preliminary project list. Cost estimates are refined for projects in the preliminary list and a second phase of optimization is completed in Copperleaf Portfolio to produce the final project list with refined cost estimates. This final list is presented to Hydro Ottawa's Executive Management Team and Board of Directors for approval before project execution begins.

Figure 19 - Portfolio Optimization



5.4. EXECUTE

5.4.1. Portfolio Implementation and Monitoring

The Execution phase follows Hydro Ottawa's internal project management methodology called "Project Coach," which defines the core lifecycle for projects. Project Coach is based on the internationally accepted standard for project management: Project Management Body of Knowledge (PMBOK) issued by the Project Management Institute.[7] An ongoing effort titled "Project X" is in

[7] Project Management Institute, "PMBOK(R) Guide," https://www.pmi.org/standards/pmbok.

progress, with the goal of updating Hydro Ottawa's project delivery methodology. Further detail regarding "Project X" can be found in Section 3.1.1 of Schedule 1-3-4 - Facilitating Innovation and Continuous Improvement.

Project Coach, and Project X, provide specific guidelines, procedures, work instructions, and industry best practices that allow Hydro Ottawa personnel to perform project work efficiently, effectively, and with high quality. Processes described in Project Coach are intended to be scalable and applicable to all projects, regardless of complexity. By standardizing on a project delivery model, a consistent approach to planning, scheduling, and execution of projects can be implemented.

Project Coach describes six steps in the execution of the project:

1. Planning & Project Initiation (Plan): The project charter, scope, and objectives are created. Key players take steps to initiate the project and engage any needed authorization.
2. Design: The project charter, scope, and objectives are reviewed and approved. Preliminary and detailed project design and estimates are created.
3. Procurement & Circulation (Procure): The project design is approved. Material and services are procured.
4. Scheduling (Schedule): The project is scheduled with key milestones and deliverable dates.
5. Construction (Construct): The project is executed with a continuous review of progress and risk to completion.
6. Closure (Close): The project documentation, financials, and reviewed lessons learned are completed. Feedback and lessons learned are registered and communicated for continuous improvement.

Project X will serve to streamline the six steps in the project delivery methodology. More specifically, Project X aims to improve the Distribution Design team's project management expertise, improve organizational efficiency and capacity, update the delivery model (with enhanced reporting), and ensure smooth adoption of new processes through a change management plan.

Key activities include defining the strategy, establishing a project delivery model with stage gates, standardizing artifacts, reviewing tools and infrastructure, establishing clear roles, responsibilities and organizational structure to support the updated project delivery model, comprehensive reporting, and creating training and change management plans.

5.4.2. Performance Measurement and Continuous Improvement

Hydro Ottawa prioritizes continuous improvement in its asset management practices to ensure reliable and resilient electricity service. Recognizing the challenges posed by deteriorating infrastructure, climate change, and increasing demand, the company utilizes performance measurements to regularly evaluate the effectiveness of its asset management process. A key focus is on mitigating the risks associated with infrastructure nearing or exceeding its TUL. For the 2026-2030 DSP, Hydro Ottawa has implemented a refined set of performance outcomes specifically designed to evaluate plan performance at the MIP level. This targeted approach, combined with strategic investments in data analytics, enables a more precise assessment of network assets and facilitates data-driven decision-making. The performance framework for the 2026-2030 DSP, detailed in Schedule 2-5-3 - Performance Measurement for Continuous Improvement, will drive continuous improvement and ensure alignment with Hydro Ottawa's evolving operational context, ultimately supporting the company's commitment to delivering reliable service to its customers.

6. OVERVIEW OF DISTRIBUTION SYSTEM

Section 6 provides an overview of Hydro Ottawa's distribution system, including information such as characteristics of the service area. The subsections are organized as follows:

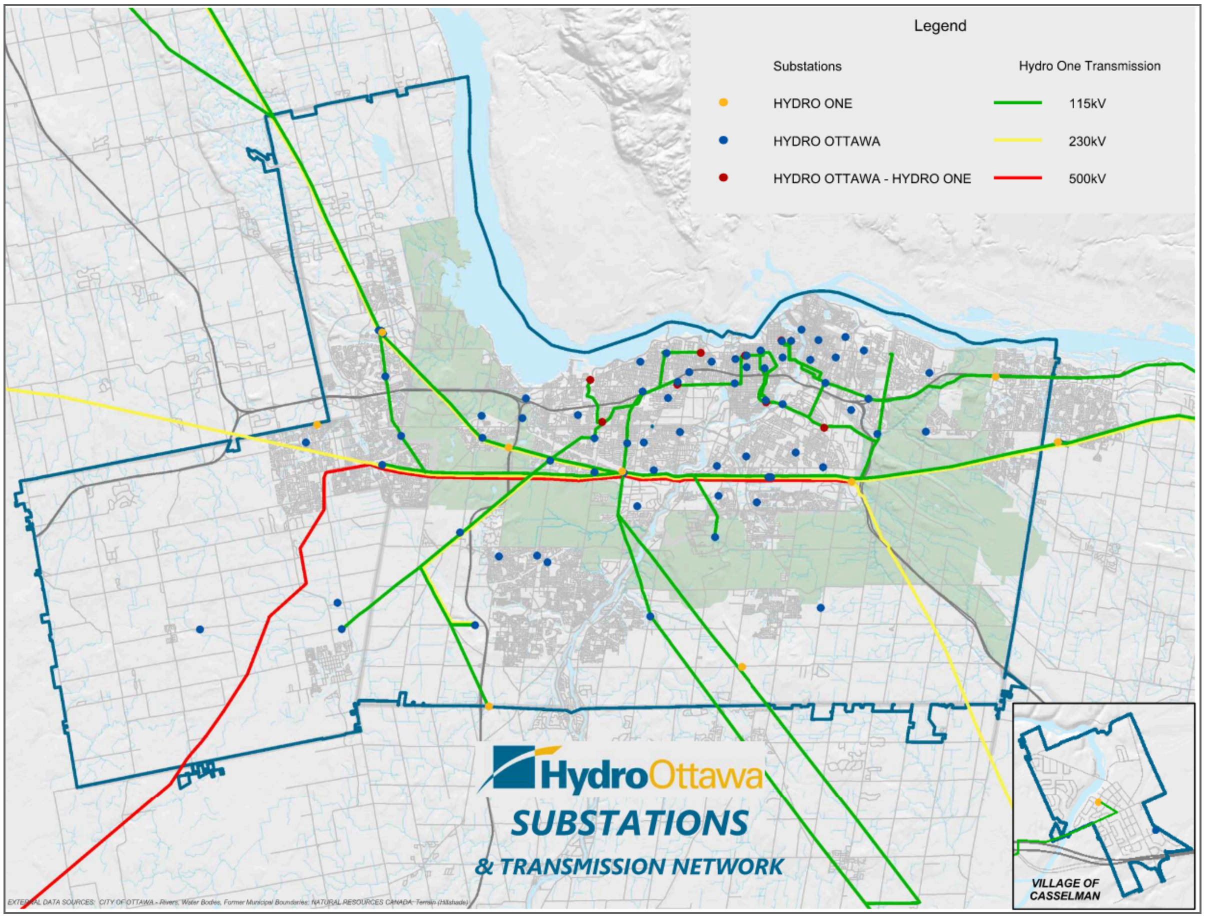
- 6.1 - Overview of Distribution System: provides a high-level description and a map of the Hydro Ottawa service territory.

- 6.2 - System Configuration: describes how the system is configured, including voltages and ownership of stations and transformers.
- 6.3 - Geographic Planning Considerations: looks at the geographic and physical characteristics of the Hydro Ottawa service area.
- 6.4 - Historical and Future Climate: provides historical weather details, including recent extreme weather events, as well as climate change impacts.
- 6.5 - System Demand and Growth Planning Considerations: discusses historical system peaks and details on anticipated customer growth within the service areas.

6.1. OVERVIEW OF DISTRIBUTION SYSTEM

Hydro Ottawa is one of the five largest electric distribution utilities in Ontario and, as of the end of 2023, distributes electricity to approximately 364,000 metered customers within the City of Ottawa and the Municipality of Casselman. The service area covers 1,116 square kilometers and is supplied by an even mix of overhead and underground distribution lines. Figure 20 illustrates Hydro Ottawa's service territory boundaries and its connection to the Hydro One transmission network.

Figure 20 - Hydro Ottawa Service Territory



6.2. SYSTEM CONFIGURATION

6.2.1. Asset Overview

Hydro Ottawa's formation in 2000 resulted from the amalgamation of five municipally owned electric utilities: Gloucester Hydro, Goulbourn Hydro, Kanata Hydro, Nepean Hydro, and Ottawa Hydro. This consolidation stemmed from the restructuring of Ontario's electricity sector, driven by the *Electricity Act, 1998*. The integration of utilities from the former region of Ottawa-Carleton. Casselman Hydro was subsequently acquired in 2002, further expanding Hydro Ottawa's service area. This amalgamation of six distinct utilities created a diverse distribution system characterized by six different operating voltages and a mix of overhead and underground infrastructure. The underground systems are predominantly located in urban areas. Table 15 details the length of overhead and underground lines within Hydro Ottawa's distribution system.

Table 15 - Length of Underground & Overhead Lines[8]

Orientation	Total Length (km)	Total Length (%)
Underground	3,515	55.9%
Overhead	2,768	44.1%
TOTAL	**6,283**	**100%**

Table 16 presents the number of circuits and length of overhead and underground cables by voltage level in Hydro Ottawa's distribution system.

[8] The km shown in this section pertain to primary circuits only, for information on the calculation of secondary lines, refer to Attachment 1-3-3 (A) - PEG Benchmarking Analysis, the total km including both primary and secondary are approximately 7,900 km of underground cable and 4,800 km of overhead lines

Table 16 - Number & Length of Circuits by Voltage Level

Orientation	Number of Circuits	Total Overhead (km)	Total Underground (km)
4 kV	310	609	288
8 kV	119	672	565
12 kV	6	456	943
13 kV	334		
28 kV	66	838	1,711
44 kV	16	193	8
TOTAL	**851**	**2,768**	**3,515**

The service area is supplied by a combination of stations and transformers owned by both Hydro Ottawa and Hydro One. Table 17 details the number of station transformers serving Hydro Ottawa customers, categorized by secondary voltage level and ownership.

Table 17 - Number of Stations and Transformers Owned by Hydro Ottawa and Hydro One

Secondary Voltage	Number of Stations	Number of Hydro Ottawa Owned Transformers	Number of Hydro One Owned Transformers
4 kV	35	95	0
8 kV	23	42	1
12 kV	2	3	0
13 kV	12	2	23
28 kV	17	28	5
44 kV	3	0	6
TOTAL	**92**	**170**	**35**

6.2.2. Embedded Feeders

Embedded feeders within Hydro Ottawa's distribution network are sections of Hydro One infrastructure that, upon entering Hydro Ottawa's service territory, transition to Hydro Ottawa ownership. Table 18 provides details on embedded feeders, including the connecting Hydro One Station, the corresponding Hydro Ottawa feeder name, and their respective voltages. Of the 13 embedded feeders listed, five serve Hydro Ottawa customers under normal operating conditions, while the remaining eight are reserved for abnormal or contingency situations.

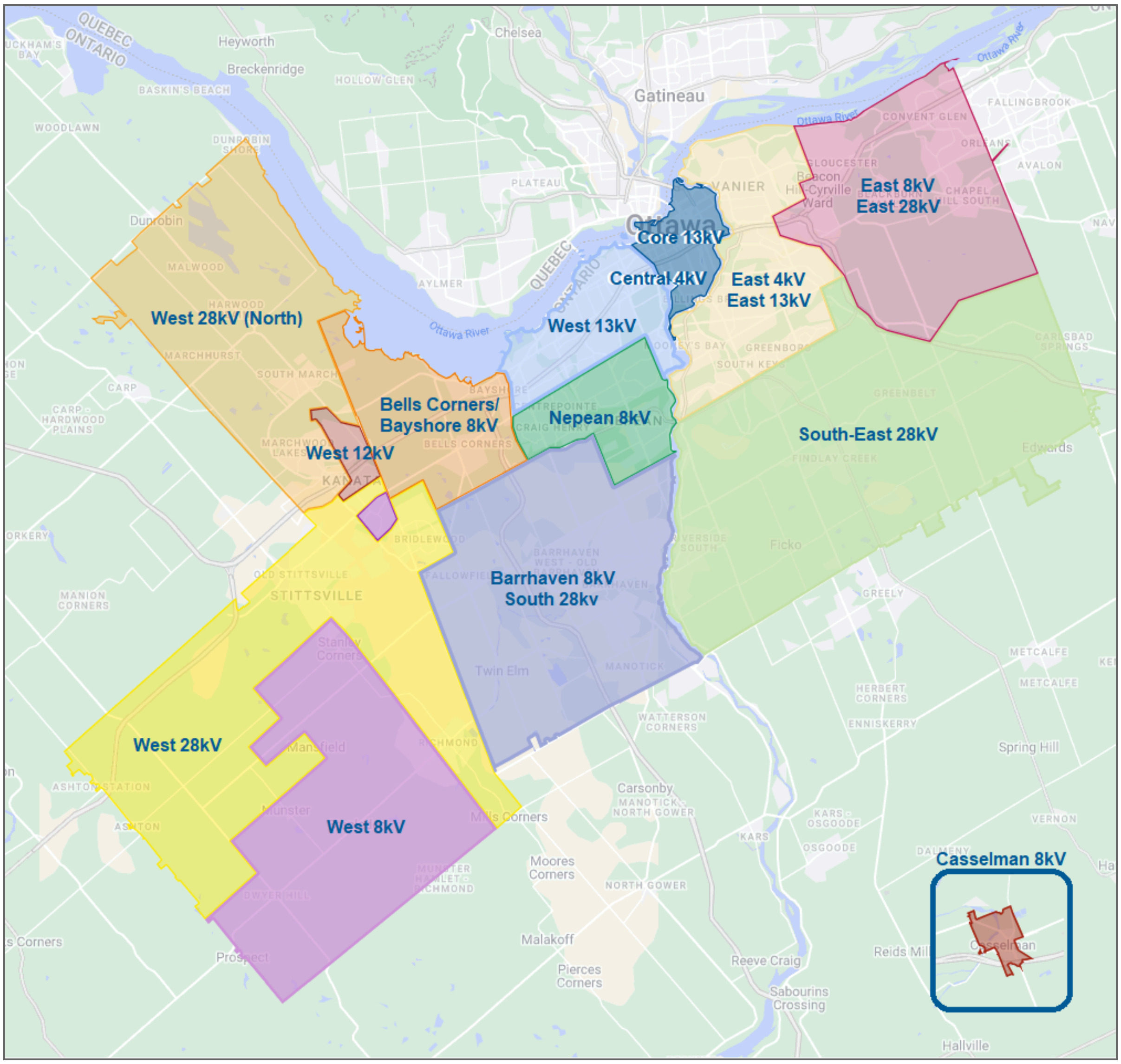
Table 18 - List of Distribution Supply Points

Hydro One Station	Feeder	Voltage	Type
Bilberry TS	77M3	28 kV	Back-up Supply
Bilberry TS	77M4	28 kV	Back-up Supply
South March TS	A9M3	44 kV	Nominal Supply
South March TS	A9M5	44 kV	Nominal Supply
St. Isidore TS	62M2	44 kV	Nominal Supply to Casselman - 62M2
Beckwith DS	BECKF2	28 kV	Nominal Supply
Casselman DS	36F1	8 kV	Back-up Supply
Casselman DS	36F2	8 kV	Back-up Supply
Manotick DS	81F5	8 kV	Back-up Supply
South Gloucester DS	56F3	8 kV	Nominal Supply
South Gloucester DS	56F2	8 kV	Nominal Supply
Alexander DS	ALEXF1	28 kV	Back-up Supply
Alexander DS	ALEXF2	28 kV	Back-up Supply

6.2.3. Planning Regions

Hydro Ottawa's distribution system consists of distinct subsystems, delineated by operating voltage, system interconnections and geographical boundaries, as seen in Figure 21. These subsystem characteristics have informed the definition of planning regions, which are essential for effective infrastructure management, resource allocation, service enhancement, and addressing the diverse needs of customers throughout the service territory. This regional approach facilitates more targeted, efficient, and responsive utility planning and operations.

Figure 21 - Hydro Ottawa Planning Regions



6.3. GEOGRAPHIC PLANNING CONSIDERATIONS

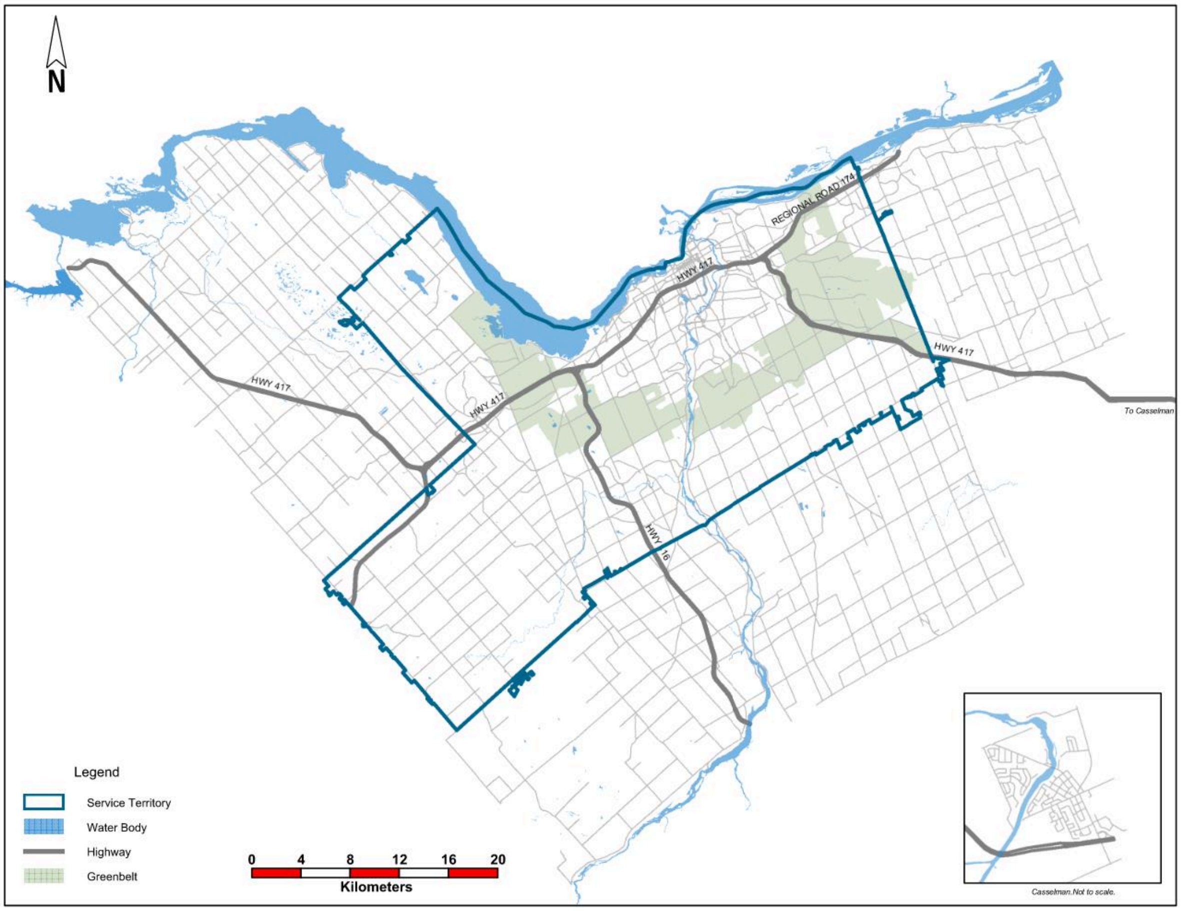
Distribution system planning within Ottawa requires careful consideration of the geographic and physical characteristics of Hydro Ottawa's service territory. The following sections detail key planning considerations and constraints that influence the planning process.

6.3.1. Geographic and Jurisdictional Influences

Hydro Ottawa's service territory encompasses the area surrounding the confluence of the Ottawa and Rideau Rivers. The Ottawa River forms the northern boundary, with the province of Quebec across the river. Hydro One's service territory completely surrounds Hydro Ottawa's remaining boundaries, as illustrated in Figure 22 below. Within the service area, the Rideau River and the Rideau Canal (which bypasses unnavigable sections of the river) traverse the landscape. This creates unique challenges, as certain neighborhoods, such as Old Ottawa, are effectively islanded by both the river and the canal, complicating both service provision and infrastructure maintenance.

The City of Ottawa's main urban area is encircled by a substantial Greenbelt, consisting primarily of forests, farmlands, and marshlands. Beyond the Greenbelt, numerous suburban communities are experiencing rapid growth. Furthermore, constructed barriers such as divided highways (Highways 417, 416, and 174) further segment Hydro Ottawa's service territory.

Figure 22 - Geographic and Jurisdictional Boundaries in Hydro Ottawa's Service Territory



As the Nation's Capital, the service territory also includes numerous federal lands managed by various government agencies. These federal land holdings can create administrative barriers due to the time and effort required to obtain environmental, land access, and encroachment permits, as well as to establish access agreements. These requirements create both technical and administrative challenges for the construction and maintenance of distribution interconnections, often resulting in increased cost and time for creating or augmenting such interconnections within the service territory.

6.3.2. Geotechnical Consideration

Soil Conditions

Hydro Ottawa's service territory faces unique geotechnical challenges due to the prevalence of problematic soil conditions. The dominant soil type, Champlain Sea clay, is inherently unstable, susceptible to liquefaction, and exhibits significant volume changes with varying moisture and temperature. These characteristics create poor foundation conditions and necessitate specialized construction techniques. Furthermore, extensive bog areas with compressible organic soils and the presence of shallow bedrock add complexity and cost to infrastructure development. These challenging conditions impact all aspects of electric distribution planning, from pole installations and underground cabling to station construction. Mitigation strategies, such as engineered fill replacement, specialized foundation designs, and robust pole hole standards, are essential for ensuring the long-term stability and reliability of the electrical grid. Careful geotechnical investigations and tailored engineering solutions are implemented on a project-by-project basis to navigate these challenges and deliver a resilient and dependable power supply to the Ottawa region.

Seismic Zone

Hydro Ottawa's service territory lies within the Western Quebec Seismic Zone,[9] requiring specialized engineering to ensure infrastructure resilience against potential seismic events. Through detailed seismic investigations and project-specific engineering solutions, Hydro Ottawa mitigates these risks. These solutions may include enhanced foundation and footing designs with increased reinforcing steel, concrete, and excavation, along with the incorporation of supplementary steel cross bracing. This approach enables Hydro Ottawa to deliver a dependable power supply to the Ottawa region, even in seismically-active conditions.

[9] Natural Resources Canada. (n.d.). *Earthquakes in Eastern Canada*. Retrieved from https://www.seismescanada.rncan.gc.ca/zones/eastcan-en.php#WQSZ

6.4. HISTORICAL AND FUTURE CLIMATE

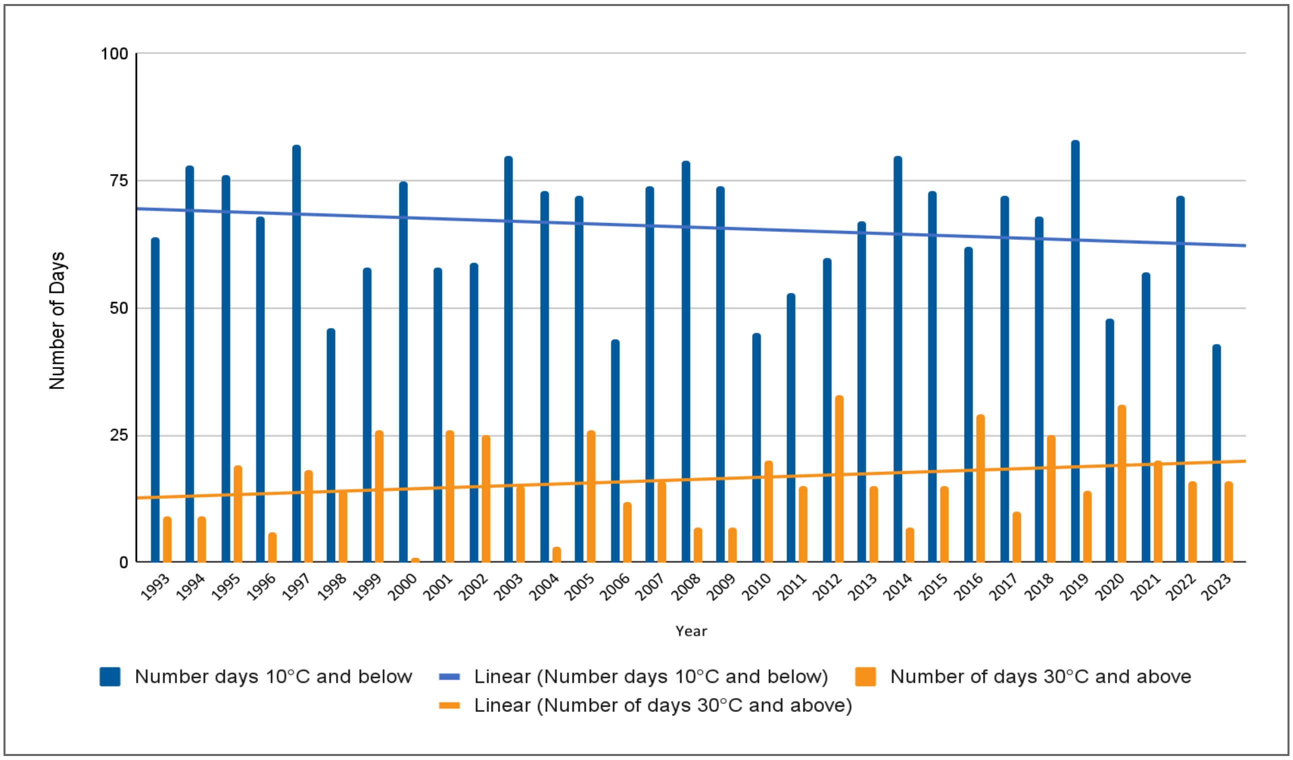
6.4.1. Historical Climate

Climate and weather significantly impact Hydro Ottawa's operations, particularly in planning and managing electricity demand and supply. Temperature variations directly influence consumption, with increased cooling loads in summer and growing heating loads in winter due to electrification trends. Monitoring temperature extremes, such as the increasing frequency of days above 30°C and below -10°C, is crucial for operational planning. Wind speed is another key factor, with high wind events posing challenges to grid stability. Recent severe storms have underscored the vulnerability of the electricity grid to extreme weather. Therefore, Hydro Ottawa's planning process incorporates these climatic considerations to ensure a reliable and resilient electricity supply for its customers.

Temperature

From 1993 to 2023, Hydro Ottawa tracked the annual number of days with temperatures exceeding 30°C and the annual number of days with temperatures falling below -10°C. The data that Hydro Ottawa has tracked is detailed in Figure 23. The near-horizontal slope of the linear trend line indicates a lack of short-term trend in the number of days above 30°C. However, a slight decline is observed in the annual number of days that fall below -10°C.

Figure 23 - Number of Days Below -10° and Below and Number of Days Above 30° and Above



Hydro Ottawa will continue monitoring the frequency of days exceeding 30°C due to the operational challenges that increasing trend presents for electricity distribution systems. Elevated demand from air conditioning usage can strain system capacity, requiring peak load management strategies. Furthermore, equipment is at a higher risk of overloading and reduced efficiency, potentially necessitating increased maintenance and upgrades to transformers, conductors, and substations.

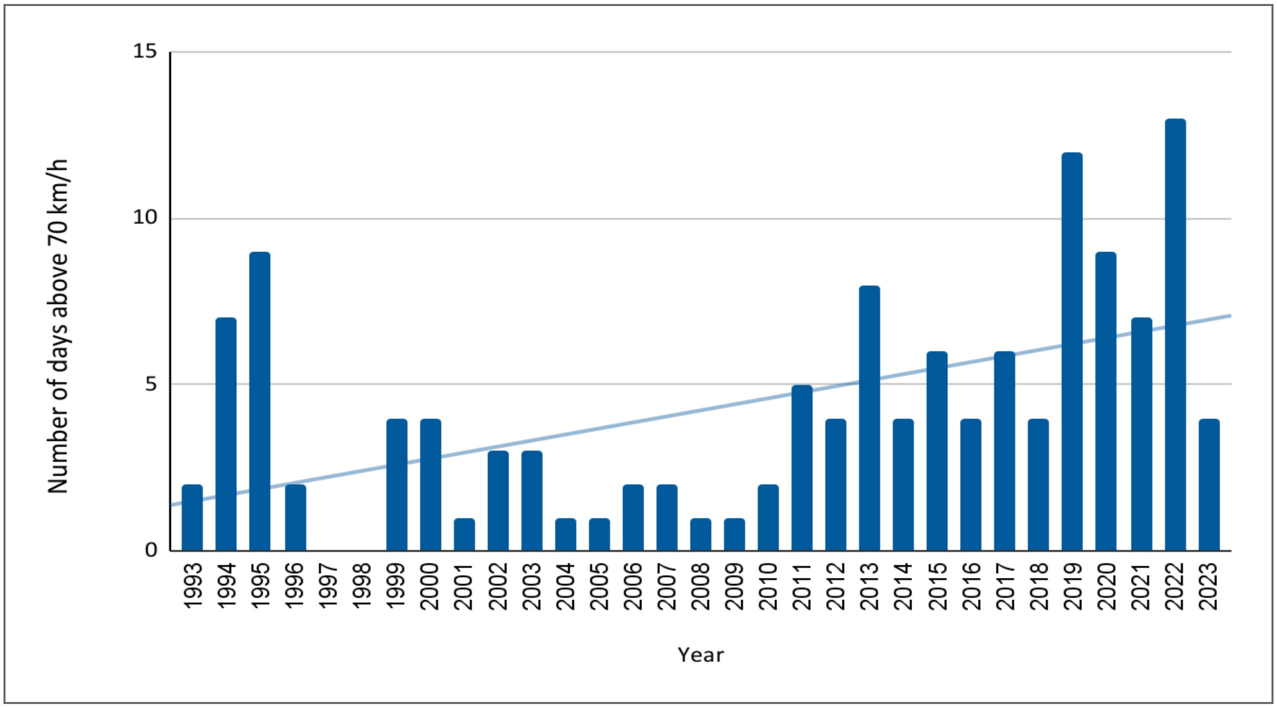
The number of days with temperatures below -10°C is an important metric for Hydro Ottawa, particularly given the increasing adoption of electrified space heating. For example, while heat pumps are efficient, they increase electricity demand significantly during periods of extreme cold, potentially posing operational challenges. Therefore, monitoring days with temperatures below -10°C is essential for accurate demand forecasting and effective system planning. Although no increasing trend in such cold days is currently observed, continued monitoring of this metric remains crucial for adapting to future climate and energy transitions further elaborated in Section 6.4.2 - Future Climate and Section 6.5 - System Demand and Growth Planning Considerations.

Wind Speed

From 1993 to 2023, Hydro Ottawa monitored the number of days when wind gusts exceeded 70 km/h, as illustrated in Figure 24. The graph demonstrates an overall upward trend in the number of days with gusts exceeding 70 km/h since 1993, with 2019 and 2022 in particular showing peaks with more than 10 days.

Figure 24 reveals a notable increase in the frequency of high-wind events, particularly since 2011. This observed trend highlights the need for Hydro Ottawa to maintain a system designed for resilience against such meteorological challenges. The data underscores the importance of ongoing vulnerability assessments and proactive asset hardening in high-risk areas. Given the observed impact of high-wind events on reliability, the data reinforces the need for proactive customer communication regarding outage risks and safety precautions.

Figure 24 - Number of Days Above 70 km/h Winds per Year



Extreme Weather Events

Hydro Ottawa has experienced firsthand the impact of weather events, with a series of severe storms in recent years causing significant damage and disruption to the electricity grid. Between 2017 and 2023, Hydro Ottawa faced multiple major weather events, impacting tens of thousands of customers:

- **2017**: Freezing rain, heavy snow, flooding, and a severe thunderstorm which impacted thousands of customers.
- **2018**: Freezing rain, high winds, and tornadoes caused widespread outages, impacting over 200,000 customers.
- **2019**: A flash storm, flooding, lightning strikes, and high winds which caused repeated disruptions throughout the year.
- **2021**: Lightning strikes caused further outages.

- **2022**: The devastating Derecho, with record-breaking wind speeds, which impacted over 180,000 customers and became the 6th costliest natural disaster in Canada's history. This was followed by a bomb cyclone in December, causing further outages.
- **2023**: An ice storm, freezing rain, and multiple lightning strikes continued the trend of severe weather impacts.

These weather events, excluding the 2019 flood, were categorized as Major Event Days (MEDs). For further information, refer to Section 4.4 of Schedule 2-5-3 - Performance Measurement for Continuous Improvement. Reliability impacts from weather events classified as MEDs are reported separately from standard reliability metrics. These events highlight the vulnerability of the power distribution network to high wind speeds and emphasize the need for strong adaptation and mitigation strategies to improve resilience.

6.4.2. Future Climate

In 2023, Hydro Ottawa commissioned Stantec to update the 2019 Distribution System Climate Risk and Vulnerability Assessment and the associated 2019 Climate Change Adaptation Plan. The primary objective of this undertaking was to evaluate the continued efficacy of the adaptation and mitigation measures outlined in the 2019 assessment, considering both updated climate projection data and current risk levels.

The 2019 assessment used Coupled Model Intercomparison Project Phase 5 (CMIP5) climate projections, an international project modeling future climate change under different emission scenarios, including temperature, precipitation, sea level, and extreme weather. For the 2023 Climate Reaffirmation report provided in Attachment 2-5-4(B) - Addendum Report to Distribution System Climate Vulnerability Risk Assessment and Climate Change Adaptation Plan, Stantec incorporated the latest available climate projection data Coupled Model Intercomparison Project Phase 6 (CMIP6) to update the Hydro Ottawa assessment. This update aimed to estimate climate parameter probabilities and determine whether the changes in the projection data significantly impact the risk scores assigned to Hydro Ottawa's infrastructure assets.

The Climate Reaffirmation report included updating the list of climate parameters to consider recent extreme weather events, updating climate parameter probabilities and impact severity based on input from Hydro Ottawa staff, and completing a forensic analysis of the May 2022 Derecho event.

Changes to the climate parameters can be seen in the Climate Reaffirmation report. Specifically, two additional high wind thresholds were established based on updated Environment and Climate Change Canada (ECCC) criteria for severe thunderstorm winds and the damages observed by the Northern Tornadoes Project in surveys following the May 2022 Derecho. The thresholds established included:

- **Wind speeds > 130 km/h**: Based on new ECCC severe thunderstorm winds and a 17% higher loading factor than the 120 km/h gust threshold used in the 2019 study.
- **Wind speeds > 180 km/h** (Derecho event equivalent): based on consistent EF-2 style observed damage in the Ottawa region and Doppler Radar near-surface wind speed recordings.

Climate parameters frequency and probability were updated using downscaled projections for the National Capital Region and CMIP6, where available. Changes were observed in annual and/or 30-year probabilities for several climate parameters in the 2050s. Frequency and probabilities were also established for new high wind thresholds. Increased consequence ratings for higher threshold wind speeds in both current and future climates resulted in increased risk scores. However, most risks did not experience a change in risk level. Table 19 summarizes the changes (highlighted in orange) and additions to consequences and risk scores.

The historical weather trends observed in 6.4.1 Historical Climate provide insight into the past climate patterns and influence future projections by providing baseline climate conditions. The method used in the Climate Reaffirmation report adjusts future climate projections based on similar historical trends presented in Section 6.4.1 - Historical Climate, allowing for shifts in temperature and wind patterns to be incorporated into long-term forecasting. Short-term weather events remain dependent on real-time atmospheric conditions, the approach used in the Climate Reaffirmation ensures that forecasts in temperature extremes and high-wind days reflect both historical variability and projected climate shifts, making the historical trends a factor in shaping the probabilistic forecast over longer timescales.

1 **Table 19 - Summary of Changes and Additions to Consequence and Risk Scores**

Climate Parameter: Threshold	Infrastructure Performance Category	Consequence Update	2019 Study		2023 Update	
			Consequence Score	2050s Cumulative Risk Score	Consequence Score	2050s Cumulative Risk Score
High wind: 120 km/hr	Asset Value - Financial score for Power Distribution - Overhead (N-S and E-W orientations) Lines and Poles	Increased consequence scores from 9 to 16 due to recent extreme wind experienced by Hydro Ottawa that led to more operational and capital expenses	9	81	16	102
High wind: 130 km/hr	All categories	Consequence scores mirror those of the 120 km/hr threshold	N/A	N/A	16	102
High wind: 180 km/hr	System accessibility, service quality, and resource efficiency for Power Distribution - Overhead (N-S and E-W orientations) Lines and Poles	Consequence scores assigned a 16 based on UWO's analysis of damage for the 2022 Derecho event	N/A	N/A	16	114
	Financial for Power Distribution - Overhead (N-S and E-W orientations) Lines and Poles	Consequence scores assigned a 25 due to damage experienced by Hydro Ottawa in the 2022 Derecho event	N/A	N/A	25	
Freezing rain: Ice accumulation of 25 mm	Financial for Power Distribution - Overhead (N-S and E-W orientations) Lines	Increased consequence scores for 4 to 9 due to recent freezing rain events experienced by Hydro Ottawa that led to more operational and capital expenses	4	16	9	26

2

The adaptation and risk mitigation plan was subsequently updated, incorporating input from workshops and addressing any risk scores that had changed to medium-very high under current or future climate scenarios. To ensure consistency, Stantec employed the same methodologies used in the 2019 report for this reassessment. The updated report also reviewed the adaptation measures proposed in the 2019 report. While most of these measures remained relevant, additional recommendations were made for strengthening pole line systems and improving real-time weather monitoring. Hydro Ottawa has made progress in implementing these measures but must continue addressing new and accelerating climate risks. In Attachment 2-5-4(B) - Addendum Report to Distribution System Climate Vulnerability Risk Assessment and Climate Change Adaptation Plan, Appendix B, "2023 Adaptation Status, Next Steps, and Barriers" details Hydro Ottawa's progress in implementing the 2019 adaptation measures.

Hydro Ottawa made significant strides in implementing the 2019 adaptation plan. Examples of the progress made since 2019 include:

- Strengthening North-South pole lines by installing a composite pole every fifth pole, along with additional guying and anchoring.
- Utilizing satellite imaging to monitor tree trimming growth and maintenance.
- Complete a cost/benefit analysis to convert overhead lines to underground infrastructure.
- Implementing wind restrictions for aerial work platforms during high winds.

Due to the substantial impact of the 2022 Derecho on overhead distribution infrastructure, design standards have been revised. Hydro Ottawa's Overhead Design Guideline now includes recommendations for anti-cascading strategies and infrastructure hardening, including installing composite poles with storm guying every five poles in vulnerable areas.

The updated climate study confirmed that continuous adaptation and mitigation strategies are necessary. This assessment supports planning to improve grid resilience and prioritize system reliability due to increasingly frequent severe weather events and growing reliance on stable power.

Hydro Ottawa's climate assessment aligns with the OEB's VASH - Draft Report[10] by developing climate forecast data derived from climate forecast models developed by Stantec. This data allows for a quantitative analysis comparing asset threshold criteria to the probability of extreme weather events during project evaluation, ensuring investments improve climate resilience within the distribution system.

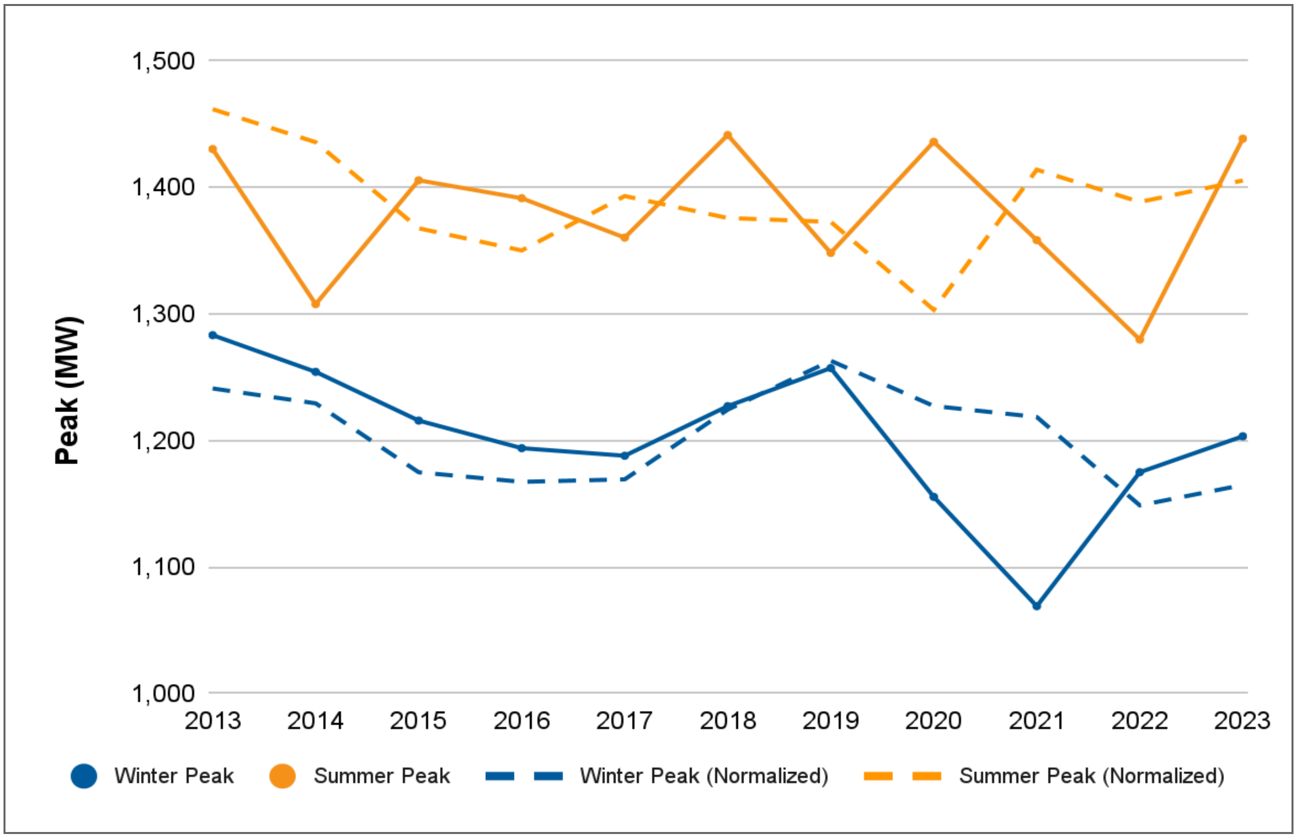
6.5. SYSTEM DEMAND AND GROWTH PLANNING CONSIDERATIONS

6.5.1. System Demand

In 2023, Hydro Ottawa purchased a total of 7,471 gigawatt hours of electricity from the provincial grid to supply customers. Figure 25 illustrates both the summer and winter peak demands from 2013 to 2023. The Hydro Ottawa system has continued to see a higher peak during summer, which has remained relatively stable over the past decade, ranging from a high of 1,441 MW in 2018 to a low of 1,280 MW in 2022.

[10] Ontario Energy Board, *Vulnerability Assessment - Draft Report*, EB-2024-0199 (December 17, 2024).

Figure 25 - Net System Summer & Winter Peak (2013-2023)[11]



To ensure the continued delivery of reliable and resilient electricity services to its expanding customer base, Hydro Ottawa must strategically expand its grid capacity to accommodate unprecedented demand growth. This increased demand is driven by several converging factors, detailed in Table 20, including residential growth, transportation electrification, and the increasing adoption of electrified space heating.

Residential growth, based on the City of Ottawa's population projections, is a primary contributor to increased energy consumption. The ongoing expansion of the City necessitates increased capacity to serve new residential customers. Further detailed in Section 6.5.2 - Residential Growth below.

[11] The values including embedded generation.

The increasing adoption of electric vehicles will also significantly impact electricity demand. Federal legislation mandates a complete transition to electric vehicle sales by 2035. This national shift is mirrored locally by the City of Ottawa's ambitious plan to fully electrify its bus fleet by 2036. Further detailed in Section 6.5.3 - Transportation Electrification below.

Finally, the growing prevalence of electrified space heating, particularly through the use of heat pumps, will further drive electricity consumption. This trend, aligned with broader electrification efforts, represents a substantial increase in demand for electricity. Further detailed in Section 6.5.4 - Electrified Space Heating below.

Table 20 - Ottawa Growth Factors

Factor	Description	Supporting Statistic
Residential Growth	Forecasted increases in housing and population will drive increased energy demand.	Ottawa population Compound Annual Growth Rate (CAGR) of 1.3% and dwelling CAGR of 1.5% between 2026 and 2031 as per the City of Ottawa Official Plan.[12]
Transportation Electrification	Increased adoption of electric vehicles.	Federal Government legislation requires 60%[13] of all light duty vehicles sold in Canada to be electric vehicles by 2030 and 100% by 2035, compared to 9% of vehicles sold in 2021. The City of Ottawa planned to procure 354 electric buses by 2027 and a full transition to electric buses by 2036.[14]
Electrified Space Heating	Increased adoption of electric space heating.	Increase of electric space heating in residential and commercial segments through combination of heat pumps and electric furnaces in Canada's net-zero scenarios, with heat pumps providing more than 50% of residential space heating needs by 2050, up from 6% in 2021.[15]

[12] City of Ottawa, "Growth projections for Ottawa: 2018-2046," https://ottawa.ca/en/living-ottawa/statistics-and-demographics/growth-projections-ottawa-2018-2046#section-26e79cf6-0a3c-4ab0-92fe-6a0c44150b93.
[13] Statistics Canada, "Watt's up? Electric Vehicles and future electricity generation needs," https://www.statcan.gc.ca/o1/en/plus/5497-watts-electric-vehicles-and-future-electricity-generation-needs
[14] Ottawa-Carleton Transportation, "Zero-Emission Bus," https://www.octranspo.com/en/our-services/vehicles/zero-emission-bus/
[15] Canada Energy Regulator, "Canada's Energy Future 2023: Energy Supply and Demand Projections to 2050," https://www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2023/

6.5.2. Residential Growth

For residential growth planning, Hydro Ottawa utilizes the City of Ottawa's *Growth Projections for Ottawa: 2018-2046* report.[16] This report projects a compound annual growth rate (CAGR) of 1.2% for population and 1.4% for dwellings between 2026 and 2036. Based on these projections, Hydro Ottawa anticipates a 13% population increase within its service area, equivalent to an additional 149,900 residents, between 2026 and 2036. This population growth will fuel a corresponding expansion in housing, with forecasts indicating a 15% increase in the number of dwellings over the same period. This growth is expected to be driven by both intensification and redevelopment initiatives, suggesting a focus on denser housing options within existing urban areas. This combination of population growth and increased housing units will contribute to a rising demand for energy within the residential sector.

As the city grows, formerly rural areas served by long distribution feeders are transitioning into urban centers. These long feeders, originally designed for lower population densities, often experience greater voltage fluctuations and are more susceptible to outages due to their extended length and exposure to environmental factors. This presents a challenge for Hydro Ottawa, as maintaining consistent and reliable service in these newly urbanized areas requires upgrades and potentially redesigning sections of the distribution network to meet the higher service quality expectations of urban customers. These upgrades can be complex and costly, requiring careful planning and execution to minimize disruption to existing customers.

City of Ottawa Growth Projections

The population, household, and employment growth forecasts presented in Table 21 have been obtained from the City of Ottawa Growth Projections for 2021-2036. The City of Ottawa published its New Official Plan as of November 2022, which includes updated growth projects.

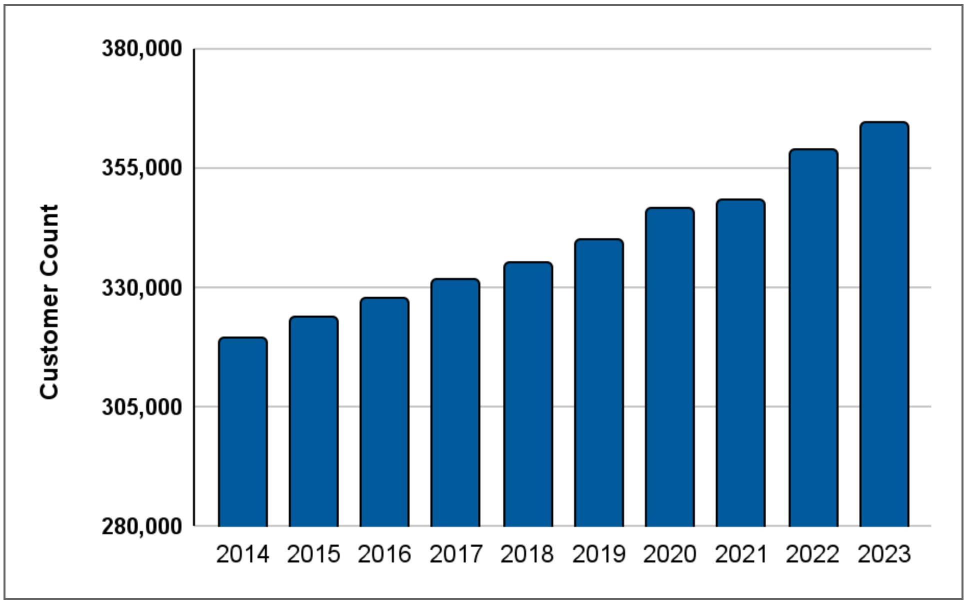
[16] City of Ottawa, "Growth Projections for Ottawa: 2018-2046," https://ottawa.ca/en/living-ottawa/statistics-and-demographics/growth-projections-ottawa-2018-2046#section-26e79cf6-0a3c-4ab0-92fe-6a0c44150b93

Table 21 - Projected Growth in Population, Households & Employment, City of Ottawa, 2021-2036

Population				
Year	**2021**	**2026**	**2031**	**2036**
Total	1,064,100	1,141,800	1,219,200	1,291,700
CAGR		1.4%	1.3%	1.2%
Households				
Year	**2021**	**2026**	**2031**	**2036**
Total	429,800	470,700	509,100	542,900
CAGR		1.8%	1.6%	1.3%
Employment				
Year	**2021**	**2026**	**2031**	**2036**
Total	662,400	698,400	731,500	764,400
CAGR		1.1%	0.9%	0.9%

Hydro Ottawa's customer base has grown at a consistent CAGR of 1.5% between 2014 and 2023, as shown in Figure 26. A comparison of overlapping data from 2018 to 2023 reveals a 1.7% CAGR for both the City of Ottawa's population growth and Hydro Ottawa's customer growth, demonstrating a strong correlation. This alignment with population growth projections supports Hydro Ottawa's expectation of a continuing upward trend in connection requests for residential subdivisions, associated mixed-use centers, and employment centers.

Figure 26 - Historical Customer Count



City of Ottawa Community Design Plans

Hydro Ottawa actively monitors the City of Ottawa's published Community Design Plans (CDPs) to understand projected residential and mixed-use center developments. CDPs are intended to guide change in designated growth areas, as identified in the City of Ottawa's Official Plan. The purpose of CDPs is to translate the City of Ottawa Official Plan's principles and policies to the community level. The City of Ottawa's Official Plan, which came into effect on November 4, 2022, directs the city's growth over time and establishes policies to guide development. Currently, 36 CDPs, encompassing a variety of development types, are available on the City of Ottawa's website[17]. A summary of these CDPs, linked to Hydro Ottawa Planning Regions, is provided in Table 22. Hydro Ottawa will continue to utilize these CDPs to identify areas anticipated to experience significant load growth due to increased density.

[17] City of Ottawa. "Community Design Plans." City of Ottawa, [Feb 2025], [URL: https://ottawa.ca/en/planning-development-and-construction/community-design/community-plans-and-studies/community-design-plans].

1 **Table 22 - City of Ottawa Community Design Plans Summary**

Study	Hydro Ottawa Planning Area	No. Res. Units	Land Use Type
Barrhaven South CDP	Barrhaven 8kV/South 28kV	6,862	Mixed-Use
Barrhaven South Expansion CDP	Barrhaven 8kV/South 28kV	1,752	Mixed-Use
Bank Street CDP	East 4kV & 13kV	990	Mixed-Use
Bayview Station District CDP	West 13kV & Central 4kV	3,594	Mixed-Use
Beechwood CDP	East 4kV & 13kV	819	Mixed-Use
Cardinal Creek Village Concept Plan	N/A (Hydro One Territory)	3,500	Mixed-Use
Carp Road Corridor CDP	N/A (Hydro One Territory)	-	Commercial
Village of Carp CDP	N/A (Hydro One Territory)	543	Mixed-Use
Village of Constance Bay Community Plan	N/A (Hydro One Territory)	204	Mixed-Use
East Urban Community (Phase 1 Area) CDP	East 8kV & 28kV	3,498	Mixed-Use
East Urban Community (Phase 2 Area) CDP	East 8kV & 28kV	1,726	Mixed-Use
East Urban Community (Phase 3 Area) CDP	East 8kV & 28kV	4,050	Mixed-Use
Fernbank CDP	West 28kV	11,000	Mixed-Use
Former CFB Rockcliffe CDP	East 4kV & 13kV	5,350	Residential
Greely CDP	N/A (Hydro One Territory)	729	Mixed-Use
Leitrim CDP	South-East 28kV	5,300	Mixed-Use
Mer Bleue CDP	N/A (Hydro One Territory)	3,000	Mixed-Use
Kanata North CDP	West 28kV (North)	2,900	Residential
Kanata West Concept Plan	West 28kV	5,000	Mixed-Use
North Gower CDP	N/A (Hydro One Territory)	520	Mixed-Use
Old Ottawa East CDP	Core 13kV & Central 4kV	2,250	Mixed-Use
Orleans Industrial Park Study	East 8kV & 28kV	-	Commercial
Richmond Road/Westboro CDP	West 13kV & Central 4kV	2860	Mixed-Use
Riverside South CDP	South-East 28kV	18,300	Mixed-Use
Scott Street CDP	West 13kV & Central 4kV	1,500	Mixed-Use

Study	Hydro Ottawa Planning Area	No. Res. Units	Land Use Type
South Nepean Town Centre CDP	Barrhaven 8kV & South 28kV	11,000	Mixed-Use
Uptown Rideau CDP	Core 13kV & Central 4kV	2,500	Mixed-Use
Transit-Oriented Development (TOD) Plans	East 4kV & 13kV	16,500	Mixed-Use
Village of Richmond CDP	West 28kV	2,700	Mixed-Use
Wellington Street West CDP	West 13kV & Central 4kV	950	Mixed-Use

City of Ottawa Transportation Master Plan

Hydro Ottawa incorporates the City of Ottawa's Transportation Master Plan (TMP)[18] in its planning process, particularly regarding plant relocation, asset renewal, and line upgrades necessitated by transportation projects. The TMP, a two-decade roadmap for the City of Ottawa’s transportation networks, emphasizes affordability and has resulted in the "Affordable Road Network," a prioritized subset of planned road projects focused on fiscal responsibility. Table 23 outlines the City of Ottawa Affordable Road Network projects between 2026 and 2031 that will influence Hydro Ottawa's infrastructure development, ensuring alignment with the City of Ottawa’s transportation priorities.

[18] City of Ottawa, “Transportation Master Plan, Exhibit 7.2: 2031 Affordable Road Network- Project By Phase- https://documents.ottawa.ca/sites/default/files/documents/tmp_en.pdf

Table 23 - City of Ottawa Affordable Road Network Projects 2026-2031

Sector	Project	Description
Southeast	Airport Parkway (2)	Widen from two to four lanes between Hunt Club Road and MacDonald-Cartier International Airport
Rural	Bank Street (2)	Widen from two to four lanes between Earl Armstrong Road extension and Rideau Road
Outer Urban	Blair Road	Widen from two to four lanes between Meadowbrook Road and Innes Road
Outer Urban	Coventry Road	Widen from two to four lanes between Belfast Road and St. Laurent Center
Outer Urban	Cyrville Road	Urbanize existing two-lane rural cross-section between Belfast Road and St. Laurent Center
Southwest	Earl Armstrong Road	Widen from two to four lanes between Limebank Road and Bowesville Road
West	Hope Side Road	Widen from two to four lanes between Eagleson Road and Richmond Road
West	Huntmar Drive	Widen from two to four lanes between Campeau drive extension and Cyclone Taylor Boulevard; widen from two to four lanes between Palladium Drive and Maple Grove Road
Southeast	Stitsville Main Street Extension	New two-lane road between Palladium Drive and Maple Grove Road
Inner Urban	Preston Street	Extend existing two-lane urban roadway Albert Street to Vimy Place (at Kichi Zībī Mīkan)
Southwest	Prince of Wales Drive	Widen from two to four lanes between Hunt Club Road and Merivale Road
Outer Urban	Tremblay Road	Widen from two to four lanes between Pickering Place and St. Laurent Boulevard

6.5.3. Transportation Electrification

The electrification of transportation in Canada, driven by federal and municipal climate targets, is poised to significantly reshape the nation's electricity infrastructure. Federal legislation, including the Canadian Net-Zero Emissions Accountability Act and the 2030 Emission Reduction Plan, mandates a rapid transition to electric vehicles, with targets of 20% of new light-duty vehicle sales being zero-emission by 2026, 60%[19] by 2030, and 100% by 2035. Similar targets exist for medium- and heavy-duty vehicles. This surge in EV adoption, fueled by substantial government incentives like the iZEV program and investments in charging infrastructure, will dramatically increase electricity demand.

In Ottawa, these national trends are amplified by the City's own aggressive climate goals, as outlined in its Climate Change Master Plan.[20] The City aims for 100% community emissions reduction by 2050 and 100% corporate emissions reduction by 2040, with transportation electrification playing a key role. Ottawa's plan includes procuring 354 electric buses by 2027, targeting a full transition to electric buses by 2036,[21] and encouraging residential EV adoption. This increased demand for electricity from both private vehicles and public transit will necessitate significant upgrades and expansion of the electrical distribution grid.

6.5.4. Electrified Space Heating

The increasing adoption of electric space heating, driven by Canada's net-zero targets, will necessitate significant growth in electricity infrastructure. This growth will be fueled by the shift from traditional heating methods to heat pumps and electric furnaces in both residential and commercial sectors. Specifically, heat pumps are projected to provide over 50% of residential space heating needs by 2050, a substantial increase from 6% in 2021.[22]

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[19] Statistics Canada, "Watt's up? Electric Vehicles and future electricity generation needs," https://www.statcan.gc.ca/o1/en/plus/5497-watts-electric-vehicles-and-future-electricity-generation-needs

[20] City of Ottawa, "Climate Change Master Plan" https://ottawa.ca/en/planning-development-and-construction/official-plan-and-master-plans/climate-change-master-plan#section-08062b40-74a0-4521-b619-93451ff489fe

[21] Ottawa-Carleton Transportation, "Zero-Emission Bus," https://www.octranspo.com/en/our-services/vehicles/zero-emission-bus/

[22] Canada Energy Regulator, "Canada's Energy Future 2023: Energy Supply and Demand Projections to 2050," https://www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2023/

Projections for this increased demand are based on data from Natural Resources Canada (NRCan),[23] the Canada Energy Regulator (CER),[24] Enbridge,[25] and the City of Ottawa.[26] These analyses consider factors such as expected technology adoption rates (heat pumps vs. electric resistance), weather data (particularly in climates like Ottawa), and the diminished efficiency of air-source heat pumps at temperatures below -10°C.

Electrifying space heating, primarily through heat pump adoption, is crucial for Canada's net-zero goals but will dramatically increase electricity demand, especially in colder climates like Ottawa due to reduced heat pump efficiency. This necessitates significant investment in electricity distribution infrastructure to ensure a capable and reliable energy transition.

[23] NRCan, “Residential Sector Energy Use, Ontario,” Residential Sector – Ontario | Natural Resources Canada
[24] Canada Energy Regulator, “Canada’s Energy Future 2023: Energy Supply and Demand Projections to 2050,” https://www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2023/
[25] Enbridge, “Pathways to Net-Zero Emissions in Ontario,” Pathways to Net-Zero Emissions In Ontario | Enbridge Gas
[26] City of Ottawa, “Climate Change Master Plan” https://ottawa.ca/en/planning-development-and-construction/official-plan-and-master-plans/climate-change-master-plan#section-08062b40-74a0-4521-b619-93451ff489fe

7. OVERVIEW OF ASSETS MANAGED

This section provides a comprehensive overview of the assets managed by Hydro Ottawa, diving into the asset demographics and conditions, asset failures and performance, asset risk profiles, and system utilization.

The detailed demographics and condition profile of each asset class are presented in the following sections: Station Assets (transformers, switchgear, batteries, and P&C equipment), Overhead Assets (distribution poles, overhead transformers, and switches), and Underground Assets (distribution cables, underground transformers, switchgear, vault transformers, and civil structures).

Asset failures and performance are reviewed further through performance measurement for continuous improvement, observing equipment failure trends to implement risk mitigation strategies.

Asset risk profiles, considering reliability, safety, environmental, financial, and compliance risks, were analyzed through PA modules. Reliability risk was the most significant factor due to its broad applicability and data availability.

Finally, system utilization is monitored through KPIs like the SLI and FLI, demonstrating capacity limitations, and in turn employs strategies such as Load Forecasting, Renewable Energy Integration, and Grid Modernization.

7.1. ASSET DEMOGRAPHICS AND CONDITION

This Section summarizes the demographics and condition profile for the major assets classes within Hydro Ottawa's distribution system. ACA is based upon health index calculations that are unique to each asset class. Hydro Ottawa categorizes and manages assets under four main systems: Stations, Overhead, Underground, and Metering. Each system has distinct types of assets that are specific to the system and are subject to different types of risks.

System Renewal Program investments, as outlined in Schedule 2-5-7 - System Renewal Investments, are focused on managing and mitigating the risk of asset failure within Hydro Ottawa's distribution network by renewing deteriorating asset infrastructure. The underlying asset demographics (in terms of TUL and condition) are a key consideration for system renewal investment planning in addition to the risk at each individual asset level. TUL refers to the expected duration an asset can reliably operate before it requires replacement or refurbishment. As a part of its asset renewal planning, Hydro Ottawa has grouped the asset age demographics into three categories:

1. **More than 10 Years of TUL Remaining:** Assets with a remaining TUL of over 10 years are considered to be in a stable condition and do not require immediate intervention. These assets are typically monitored through routine maintenance and inspections.
2. **Less than 10 Years of TUL Remaining:** Assets with a remaining TUL of less than 10 years are flagged for future intervention. These assets are not yet at the end of their TUL but will require attention and potential replacement or refurbishment within the 10-year timeframe.
3. **Reached or Exceeded TUL:** Assets that have reached or exceeded their TUL require immediate or short-term intervention. These assets are at the highest risk of failure and are prioritized for replacement or refurbishment in the short-term.

In addition to the TUL categorization, Hydro Ottawa also considers the Health Index value ranging from 0-100% to further assess the condition of each asset and the urgency of any required intervention. The Health Index provides a nuanced evaluation of asset health, allowing for more targeted and efficient maintenance and replacement strategies. The Health Index categories are as follows:

- **0-30% (Very Poor):** Assets falling within this range are considered to be in critical condition and pose an immediate risk of failure. These assets require immediate risk assessment and are prioritized for replacement or refurbishment to prevent service disruptions and safety hazards.

- **30-50% (Poor):** Assets within this range are in poor condition and require short-term attention. While not as critical as those in the 0-30% range, these assets are still at risk of failure and are scheduled for replacement or refurbishment based on the specific risk they pose and the potential consequences of failure.
- **50-70% (Fair):** Assets in this range are showing signs of degradation but are not yet at a critical stage. These assets require increased diagnostic testing and monitoring to assess their condition and rate of deterioration. Depending on the criticality of the asset and the nature of the degradation, remedial work or replacement may be necessary.
- **70-85% (Good):** Assets within this range are in good condition and do not require intervention beyond normal maintenance and inspections.
- **85-100% (Very Good):** Assets in this range are in a very good condition and require no intervention beyond normal maintenance and inspections.

Age and condition are among the parameters that drive Hydro Ottawa's overall risk-based asset management framework outlined in Section 5.1.4 - Asset Risk Assessment. The overall extent of investment required under each distribution asset renewal program is primarily driven by the extent of risk mitigated in the short term/long term and the ability for Hydro Ottawa to maintain system reliability through 2026-2030. This is discussed in the corresponding Alternatives Evaluation sections for each distribution asset renewal program in Schedule 2-5-7 - System Renewal Investments.

Hydro Ottawa's condition assessment process has evolved over the years (since 2014). Some key improvements implemented currently (in 2024) as compared to previous years include:

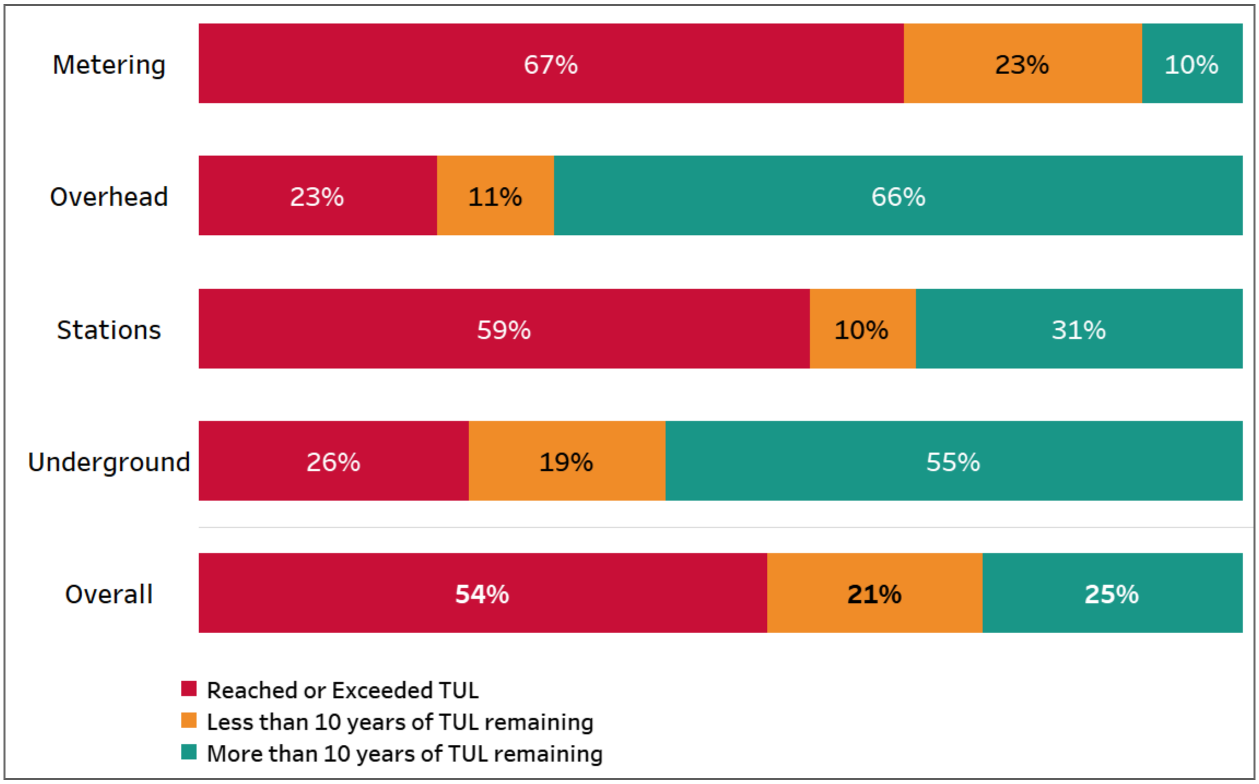
- Updating the health indexing framework to incorporate additional condition parameters gathered through inspection and maintenance programs.
- Reducing the heavy reliance on age as a major contributor to health index. Hydro Ottawa has accomplished this through two ways:
    - Decreasing the weighting assigned to age as a part of the health indexing process.

    - Translating age to condition based on the linear piecewise/linear relationship established between age and condition through the failure curve development exercise outlined in Section 4.4.4 - Failure Curves and Typical Useful Life Update. This approach was used to determine the equivalent condition value for assets that had a known age, but lacked a valid health index.
- Implementing validity to the health index process to ensure that at least 70% of the condition information is available to define a health index value.

These continuous improvement measures have made it difficult to compare Hydro Ottawa's current asset condition state to previous rate periods, as the asset condition profiles have changed since then. A key measure utilized in system renewal planning for 2026-2030 was the ability to forecast asset degradation patterns and risk projections into 2030 through Copperleaf PA, for Hydro Ottawa to intervene on the most impactful and deteriorated assets. The 2030 projections (in terms of age, condition and risk) have been instrumental in deciding on the preferred investment alternative/strategy as outlined in the corresponding Alternatives Evaluation sections for each distribution asset renewal program in Schedule 2-5-7 - System Renewal Investments.

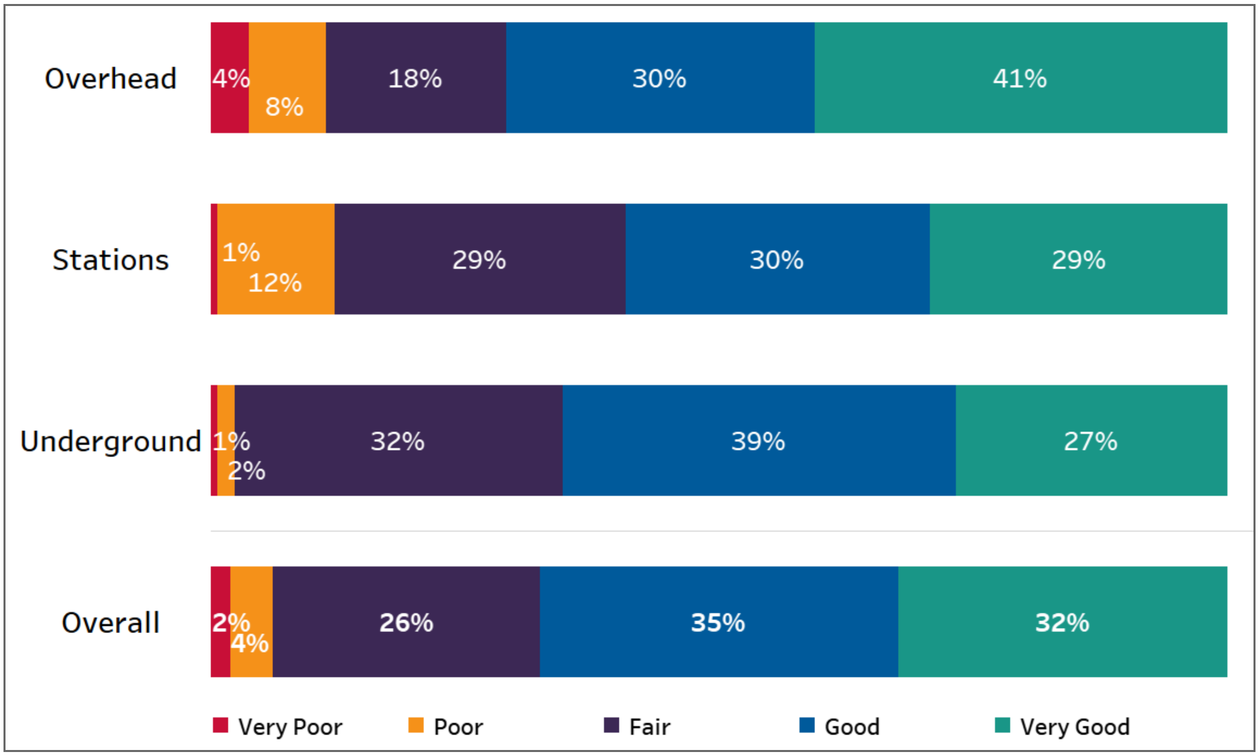
Hydro Ottawa's overall asset demographics, as seen in Figure 27, shows that a large portion (approximately 54%) of the asset population has reached its TUL, posing a higher risk of failure. An additional 21% of assets are within 10 years of reaching their TUL.

Figure 27 - Overall Asset Age Demographics



Hydro Ottawa's overall asset condition ratings are summarized in Figure 28 below. Based on the overall condition profile, approximately 6% of assets are in Poor or Very Poor condition. This presents an immediate and growing risk of asset failure and subsequent reliability impact to the system.

Figure 28 - Overall Asset Condition



The detailed demographics and condition profile of each asset class are presented in the following sections.

7.1.1. Station Assets

Hydro Ottawa station assets are an important part of delivering power to its customers. These assets are located within the fence of an electrical station. Out of the 92 stations that service Hydro Ottawa's customers, Hydro Ottawa fully owns 74. Hydro Ottawa and Hydro One jointly own 12 stations. These stations consist of various assets, some owned by Hydro One, and others owned by Hydro Ottawa. Hydro One wholly owns six stations that supply Hydro Ottawa customers. A list of these stations and their ownership is provided in Attachment 2-5-4(G) - Hydro Ottawa Station Table.

Figure 29 and Figure 30 show the age and condition demographic projections into 2040, without any intervention, as obtained through Copperleaf PA. It can be seen that approximately 65% of the station assets will reach the TUL by 2030, with the proportion increasing to 75% by 2040. On the condition front, approximately one-fourth of the asset population will reach a Very Poor/Poor condition by 2035 and increase to about 35% by 2040. Station renewal projects are complex and require extensive planning, procurement of long-lead equipment and execution over several years (for major station asset renewals).

Figure 29 - Station Asset Age Demographic Projections

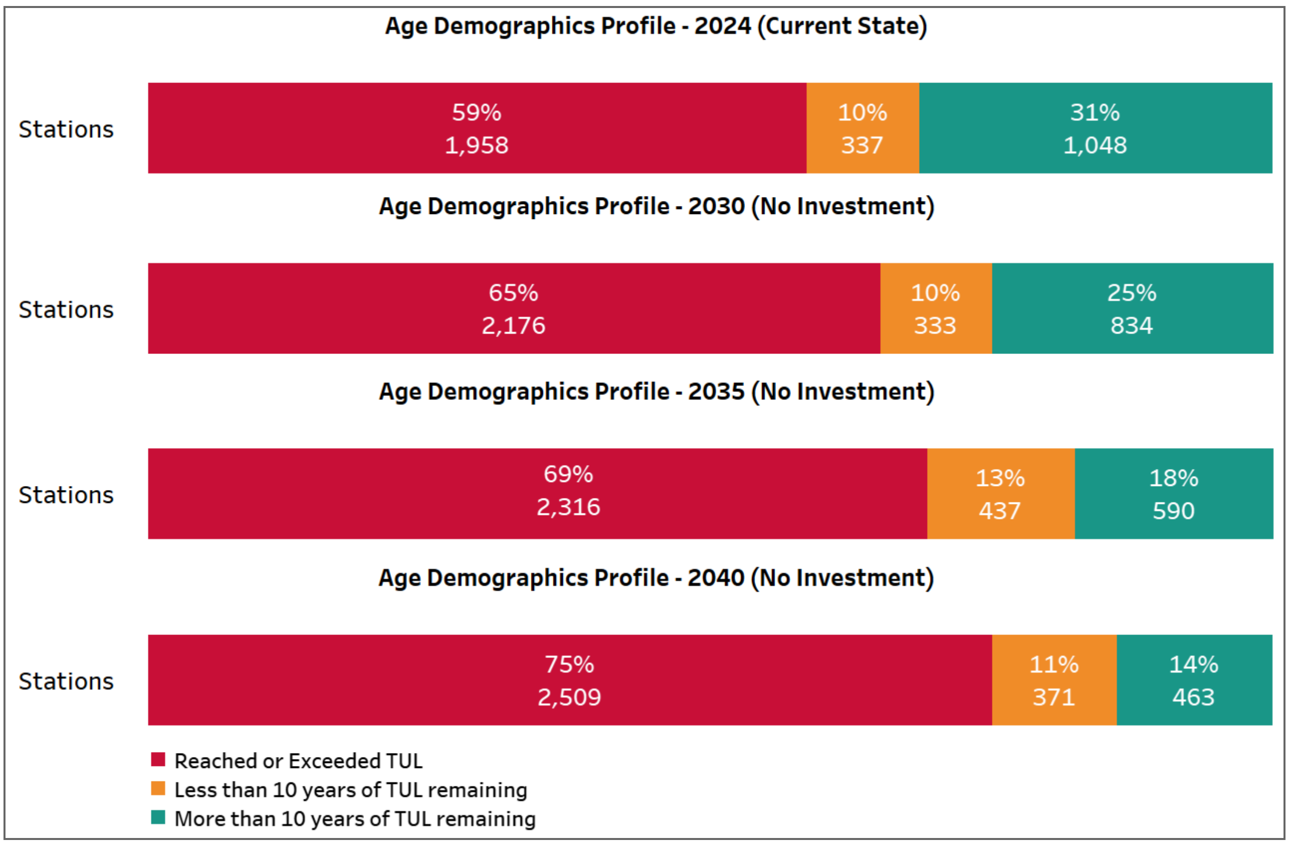
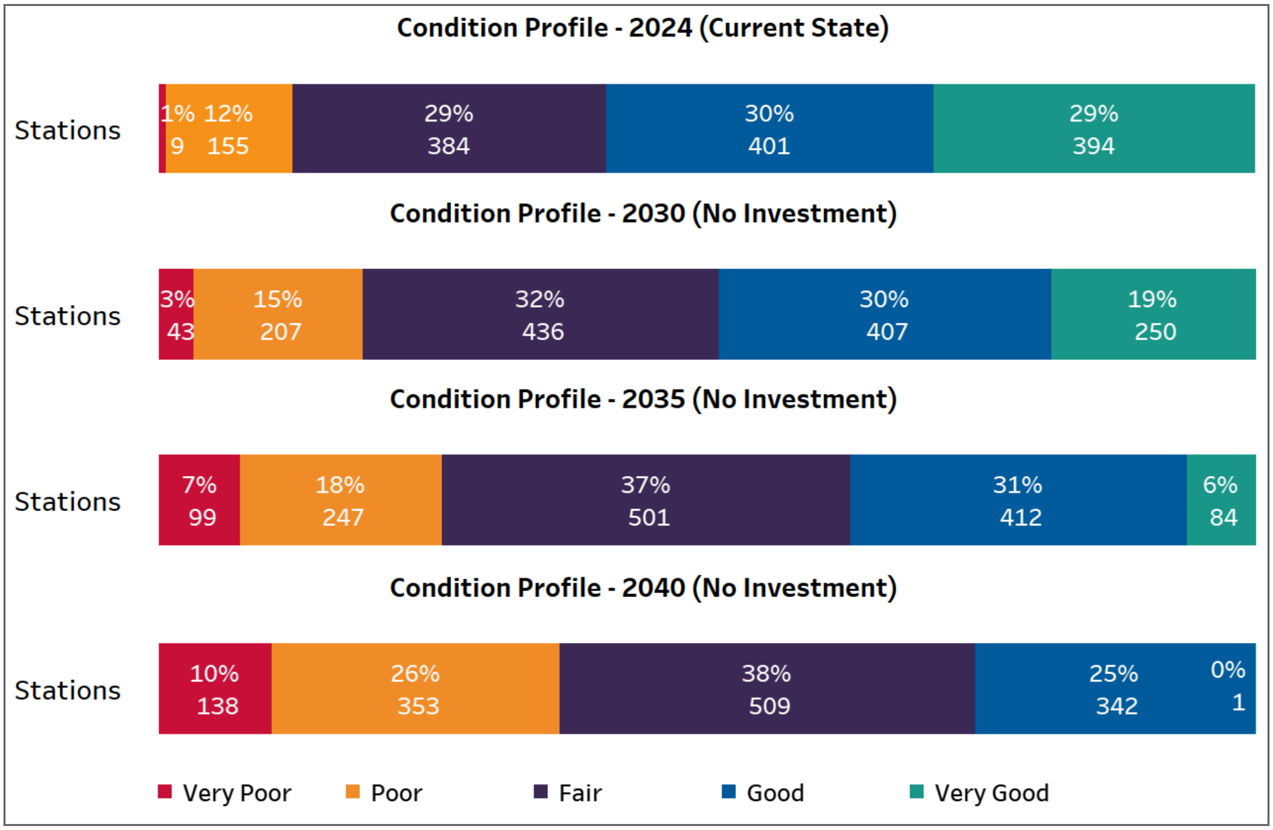


Figure 30 - Station Asset Condition Demographic Projections

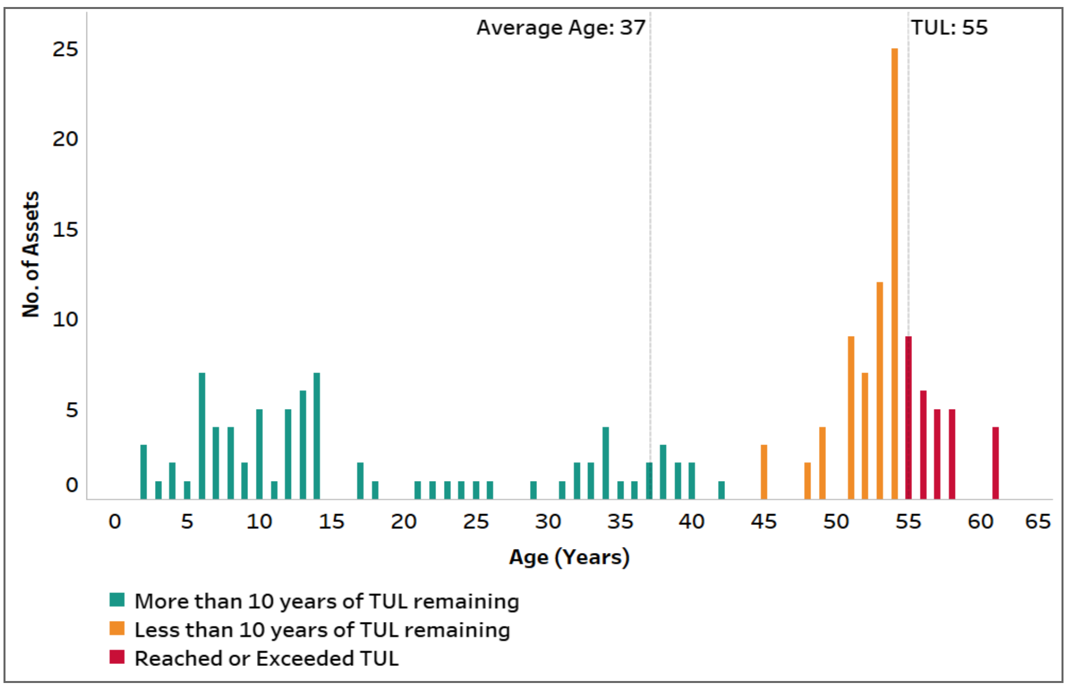


Hydro Ottawa utilized Copperleaf PA to gain a deeper understanding of potential future degradation patterns. This information was used to develop an appropriate, balanced asset renewal investment plan for 2026-2030. Based on these findings, Hydro Ottawa has proposed an increase in station asset renewal spending from the 2021-2025 period. This increase aims to manage long-term asset performance while maintaining affordability for customers. More details regarding Hydro Ottawa's system renewal plan for station assets are outlined in Section 2 of Schedule 2-5-7 - System Renewal Investments.

7.1.1.1. Station Transformers

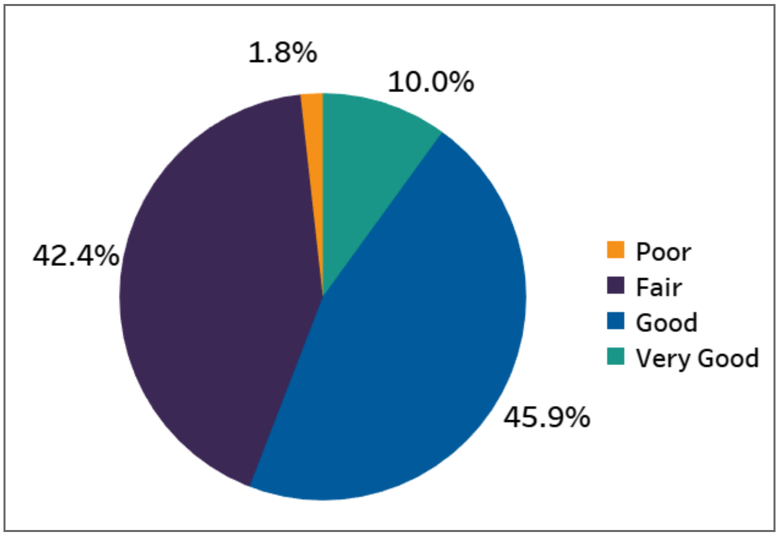
Station transformers are one of Hydro Ottawa's most critical asset classes due to the ability to affect thousands of customers. Hydro Ottawa owns 170 station transformers that operate at various voltages, connected to either Ontario's electric transmission grid or connected to the local sub-transmission system. Hydro Ottawa also supplies distribution stations and customers through 35 station transformers owned and maintained by Hydro One. Hydro Ottawa does not manage Hydro One-owned station transformers. The average age of Hydro Ottawa's station transformers is 37 years, with a TUL of 55 years; Figure 31 illustrates the population demographics.

Figure 31 - Station Transformer Age Demographics



The health index of a transformer is determined through various criteria such as visual inspections, power factor tests, load history, infrared scanning, oil analysis (dissolved gas analysis and degree of polymerization), as well as additional criteria for on-load tap changers, if applicable. The resultant health index is a condition rating from Very Good to Very Poor. This rating is an accurate representation of the current condition of the transformer and is used to drive maintenance and renewal programs. Hydro Ottawa has an active maintenance and monitoring program for its station transformers given their criticality in the system. A summary of Hydro Ottawa's station transformer condition is shown in Figure 32.

Figure 32 - Station Transformer Condition Demographics



7.1.1.2. Station Switchgear

The station switchgear asset class consists of breakers, switches, bus insulation, support structures, protection and control systems, arrestors, control wiring, ventilation, and fuses. Hydro Ottawa owns and maintains approximately 1,057 station breakers, which form the major part of the station switchgear asset class.

Due to the different TUL of each breaker type, it is more appropriate to break out station breakers per type, rather than as one asset group under station switchgear. Figures 33 to 36 illustrate the population demographics of each type. The TUL of air breakers is 42 years, and the average age is 54 years. The TUL of oil breakers is 55 years, and the average age is 60 years. The TUL of gas

(SF_6) breakers is 51 years, and the average age is 28 years. The TUL of vacuum breakers is 46 years, and the average age is 10 years.

Figure 33 - Station Air Breaker Age Demographics

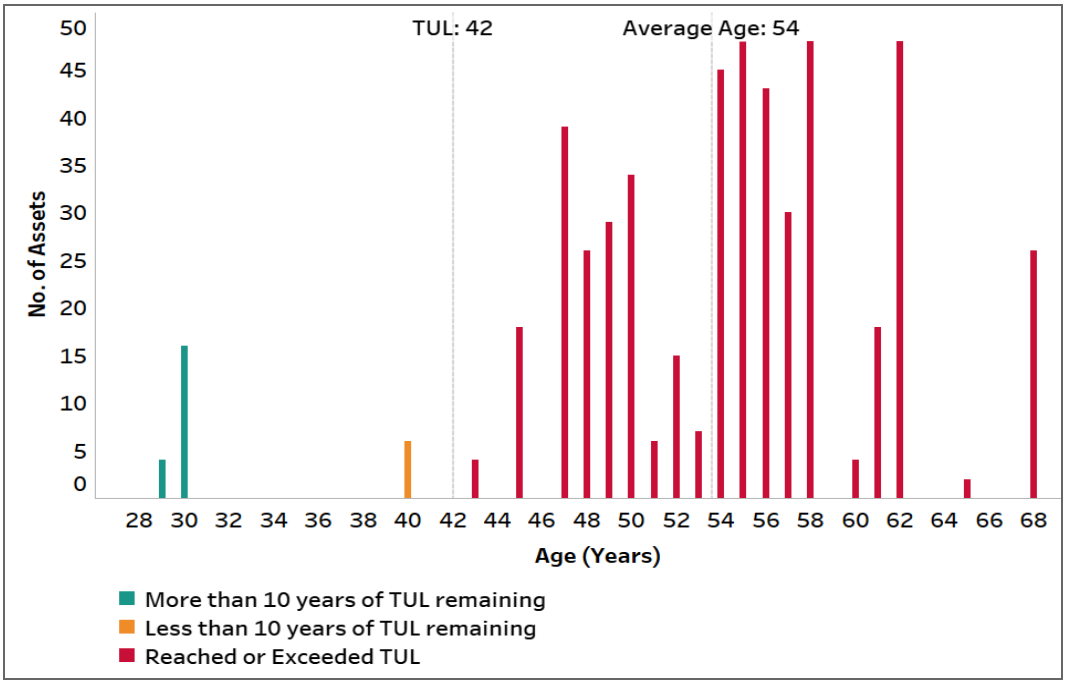


Figure 34 - Station Oil Breaker Age Demographics

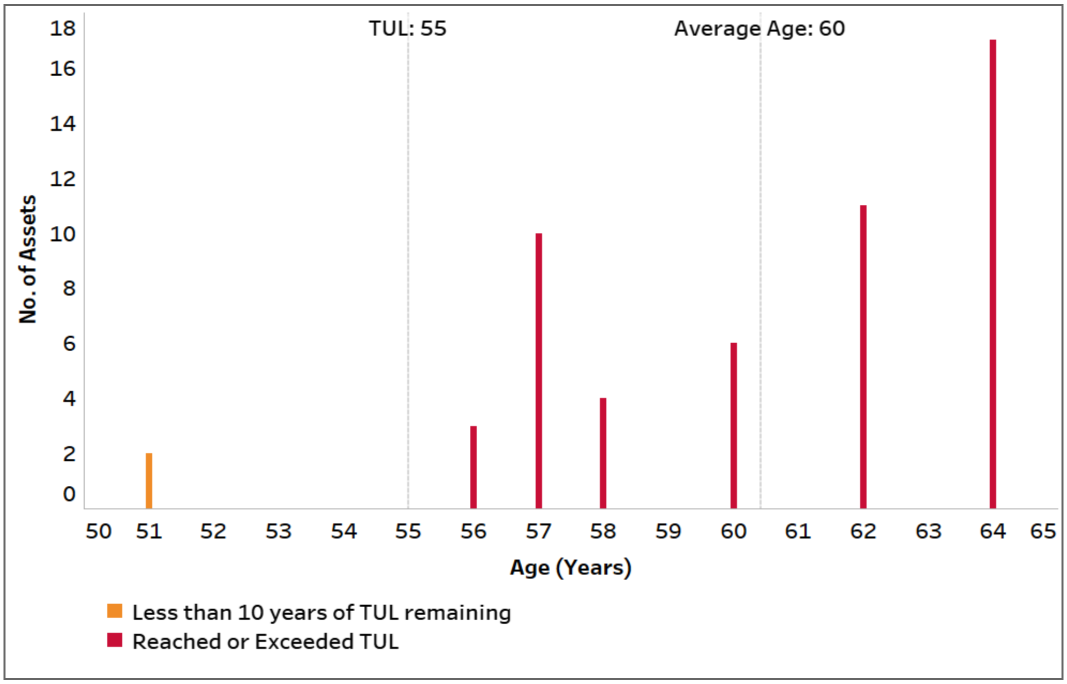


Figure 35 - Station SF6 (Metalclad and HV) Breaker Age Demographics

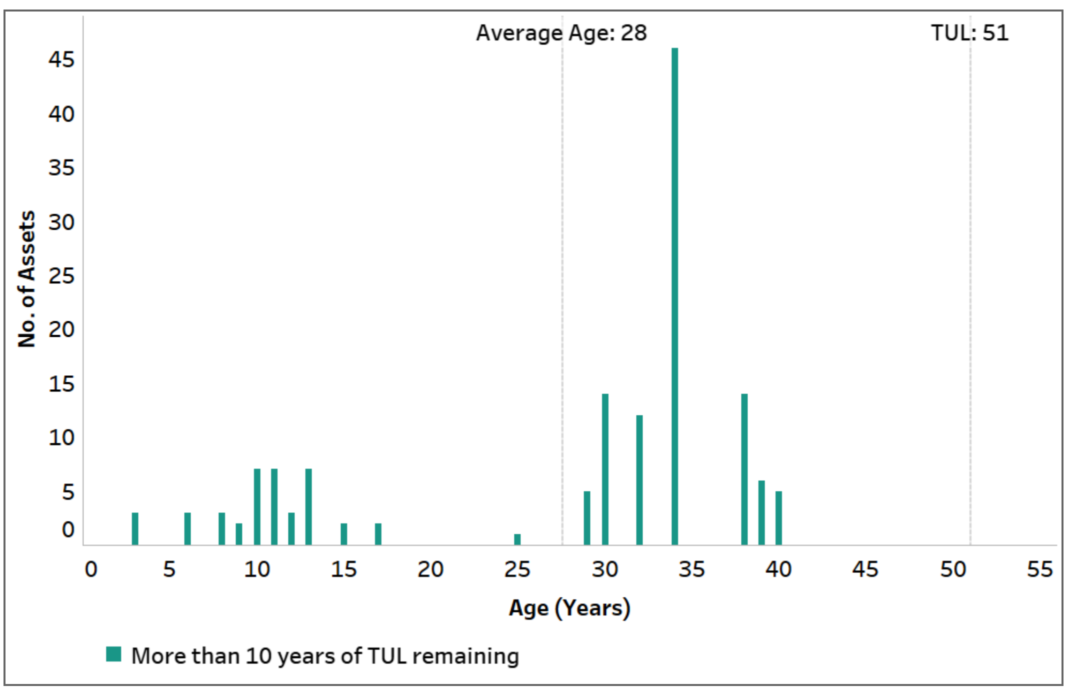
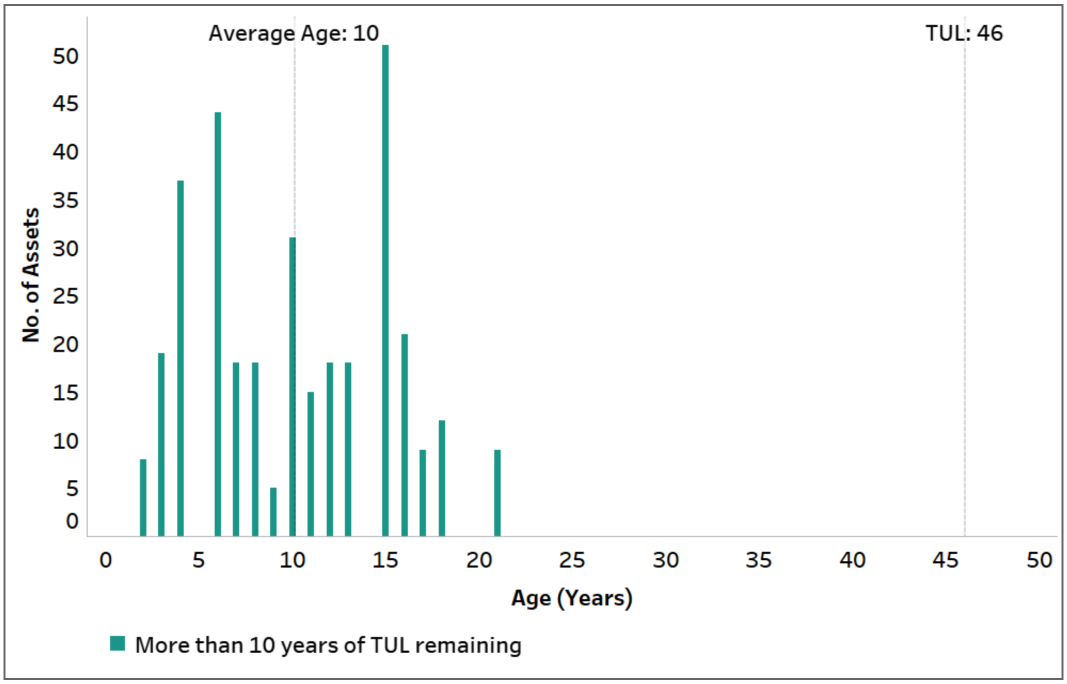
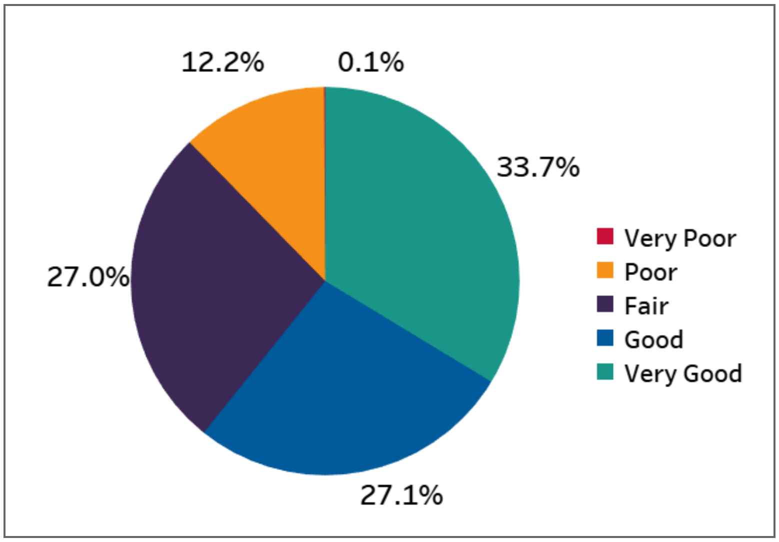


Figure 36 - Station Vacuum Breaker Age Demographics



The health index for station switchgear takes into account the many functional and supporting parts of the equipment. A qualitative assessment of the equipment condition, based on subject matter experience, is done on the switches, breakers, bus, insulation, and supporting structures. The equipment is then reviewed for functional obsolescence and the availability of spare parts. The health index is calculated using this information and the age of the equipment. A summary of Hydro Ottawa's station switchgear condition is shown in Figure 37.

Figure 37 - Station Switchgear Condition Demographics



7.1.1.3. Station Batteries

Hydro Ottawa's station batteries and chargers asset class provide power for operating station breakers and closing coils, DC lights, and relays when the station service power is lost. Hydro Ottawa owns 63 station battery banks and chargers within its stations. Due to the different expected operating life of each battery type, it is more appropriate to break out batteries per type, rather than one asset group. Figure 38 and Figure 39 illustrate the population demographics for each battery type. Vented lead-acid (VLA) batteries have a TUL of 17 years, with an average age of 12 years. Valve-regulated lead-acid (VRLA) batteries have a TUL of 15 years, with an average age of 8 years.

Figure 38 - Station VLA Battery Bank Age Demographics

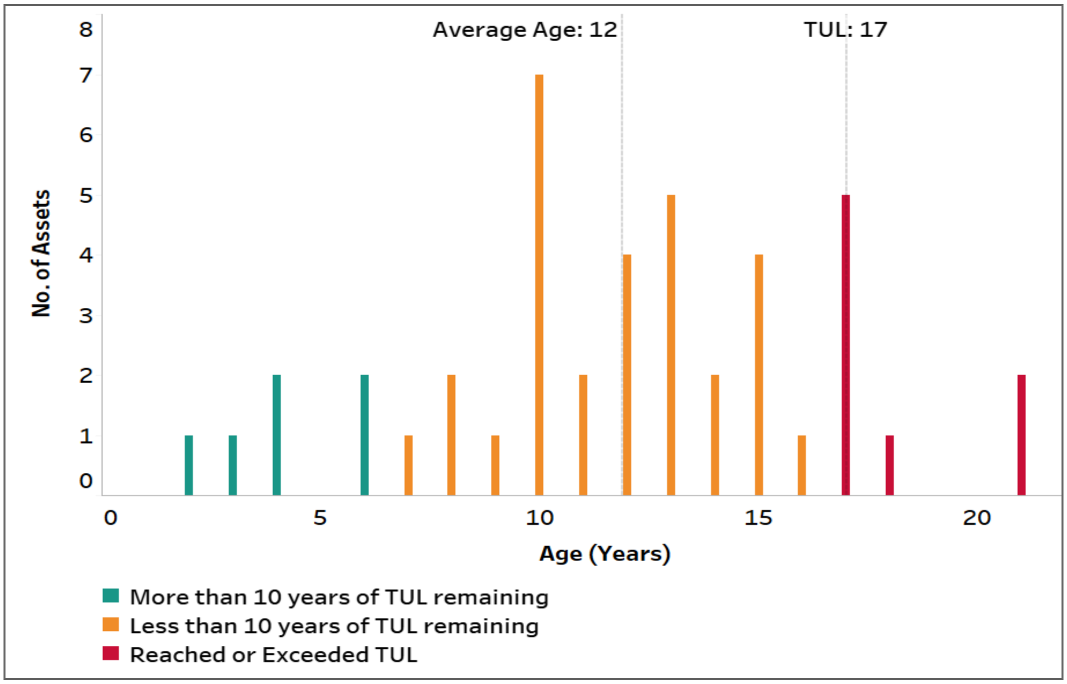
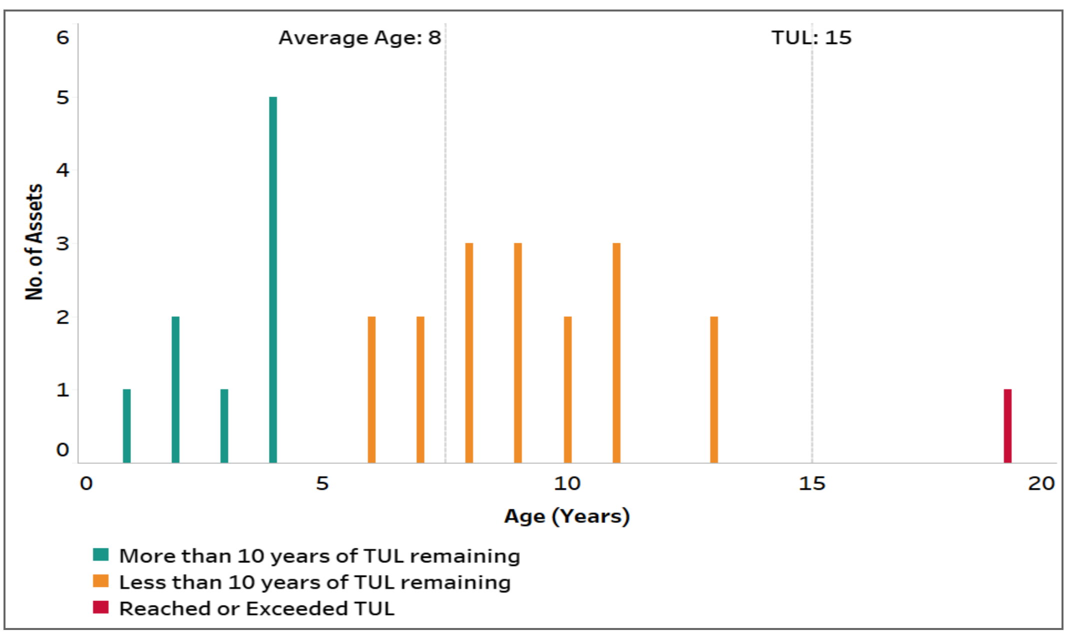


Figure 39 - Station VRLA Battery Bank Age Demographics



7.1.1.4. Station Protection & Control (P&C)

Hydro Ottawa P&C equipment facilitates the control and monitoring of the distribution system. Of the components contained within the P&C asset class, protective relays have a proactive testing and maintenance program. Figures 40 through 42 illustrate the population demographics of protective relay sets and show their average age. The TUL of protective relays is dependent on the relay type, and as such is 40 years for electromechanical, 30 years for electronic, and 25 years for microprocessor based relays.

Figure 40 - Station Electromechanical Relay Age Demographics

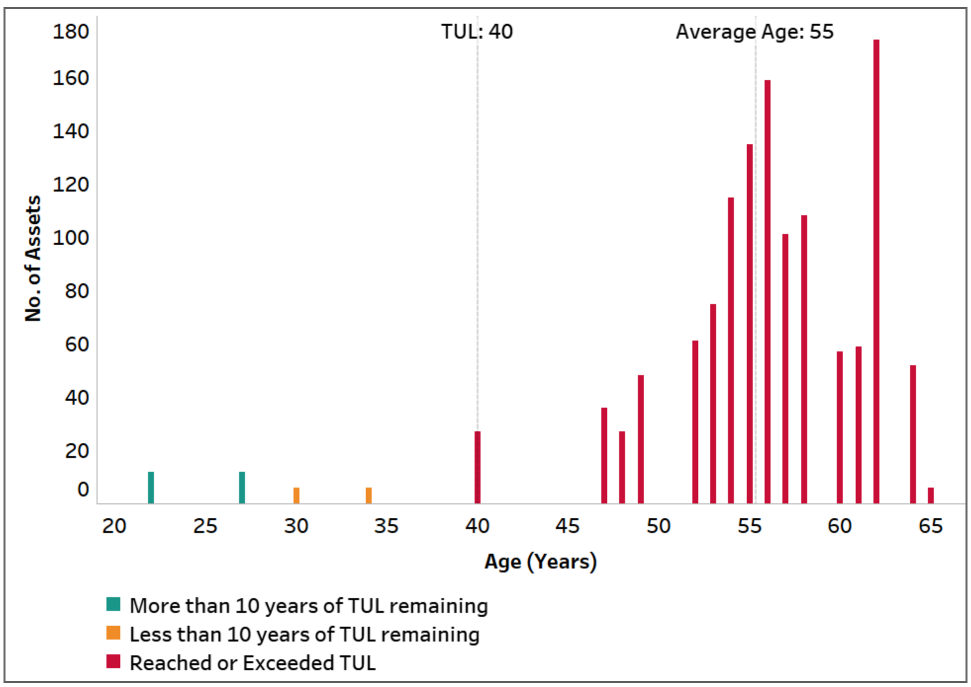


Figure 41 - Station Electronic Relay Age Demographics

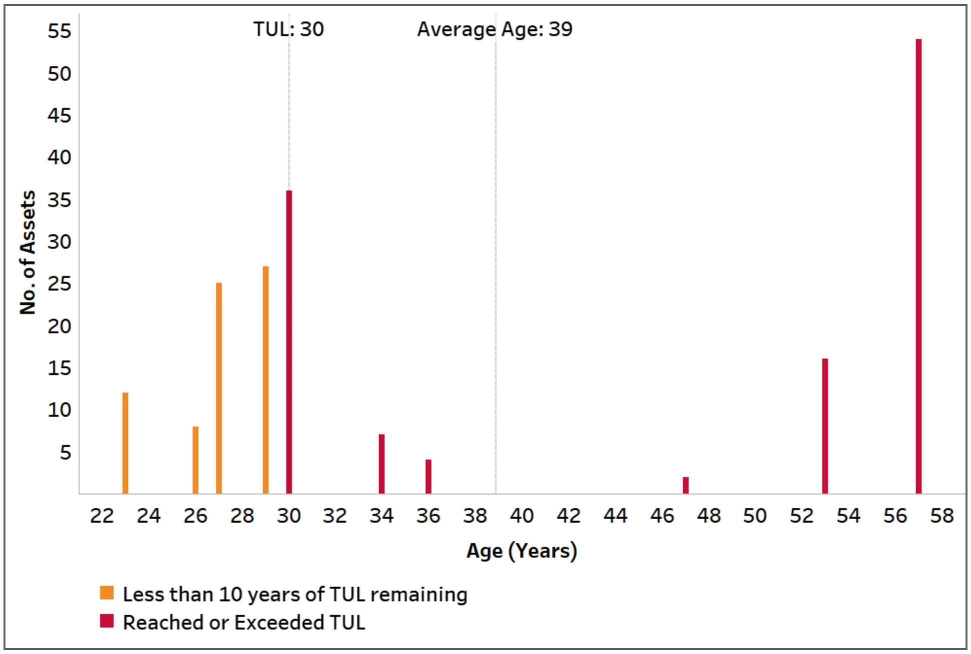
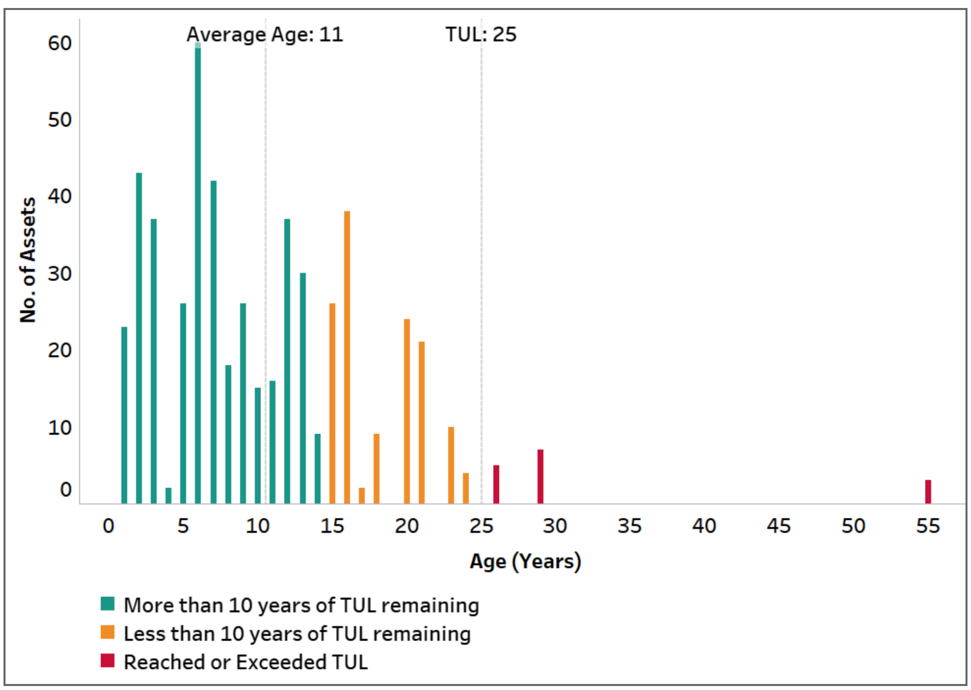


Figure 42 - Station Microprocessor Relay Age Demographics



7.1.2. Overhead Assets

Hydro Ottawa overhead assets are integral for the distribution of electricity. The overhead system, Hydro Ottawa's standard design for delivering power, is built in a range of locations. Overhead assets are broken into the following main asset classes:

- Distribution poles and fixtures
- Overhead distribution transformers
- Overhead distribution switches

Figure 43 and Figure 44 show the age and condition demographic projections of overhead distribution assets into 2040, without any intervention, as obtained through Copperleaf PA. It can be seen that approximately 30% of the overhead assets will reach the TUL by 2030, with the proportion increasing to 46% by 2040. On the condition front, approximately 19% of the asset population will reach a Very Poor/Poor condition by 2035 and increase to about 23% by 2040. Overhead distribution assets are also exposed to and impacted by extreme weather events, thereby impacting reliability and resulting in customer interruptions.

Figure 43 - Overhead Asset Age Demographic Projections

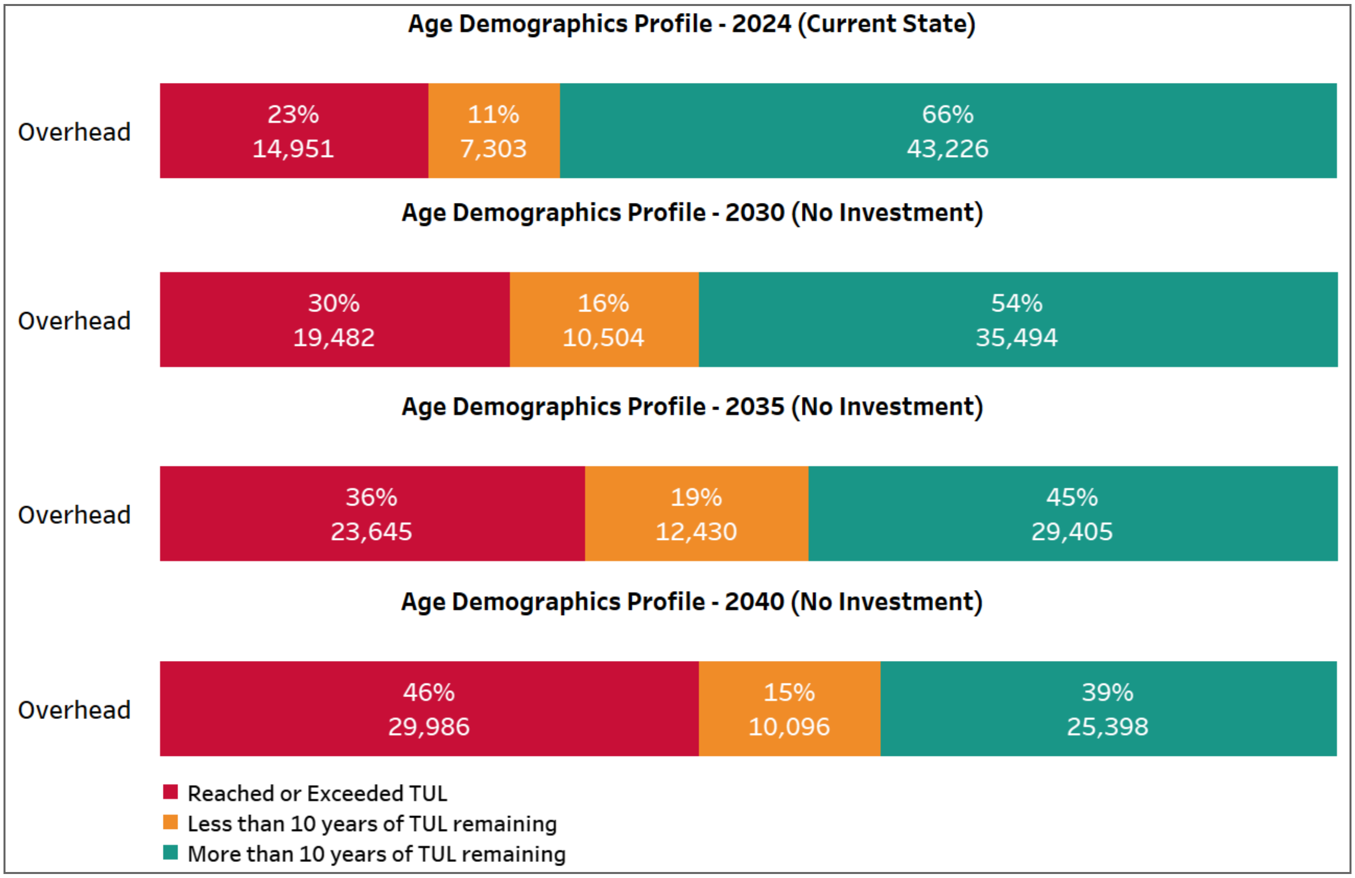
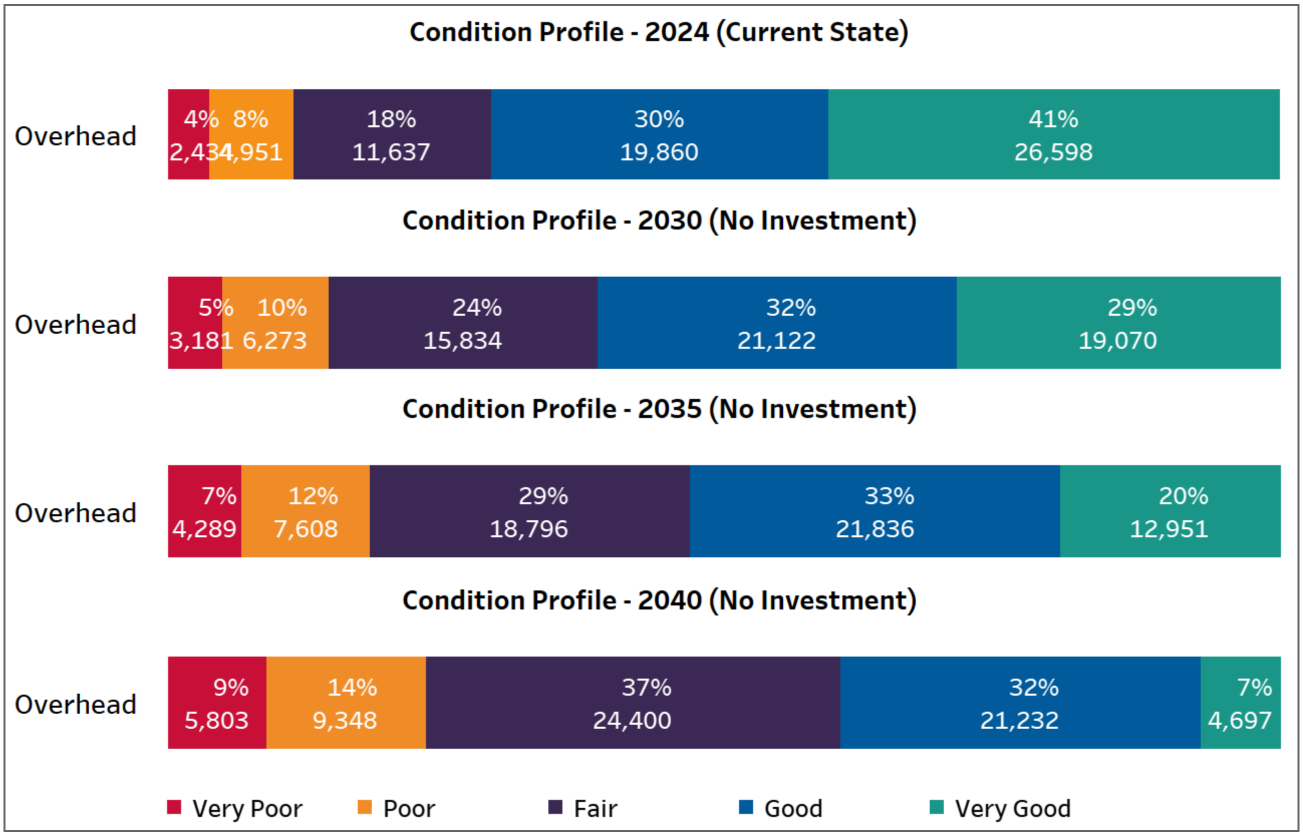


Figure 44 - Overhead Asset Condition Demographic Projections



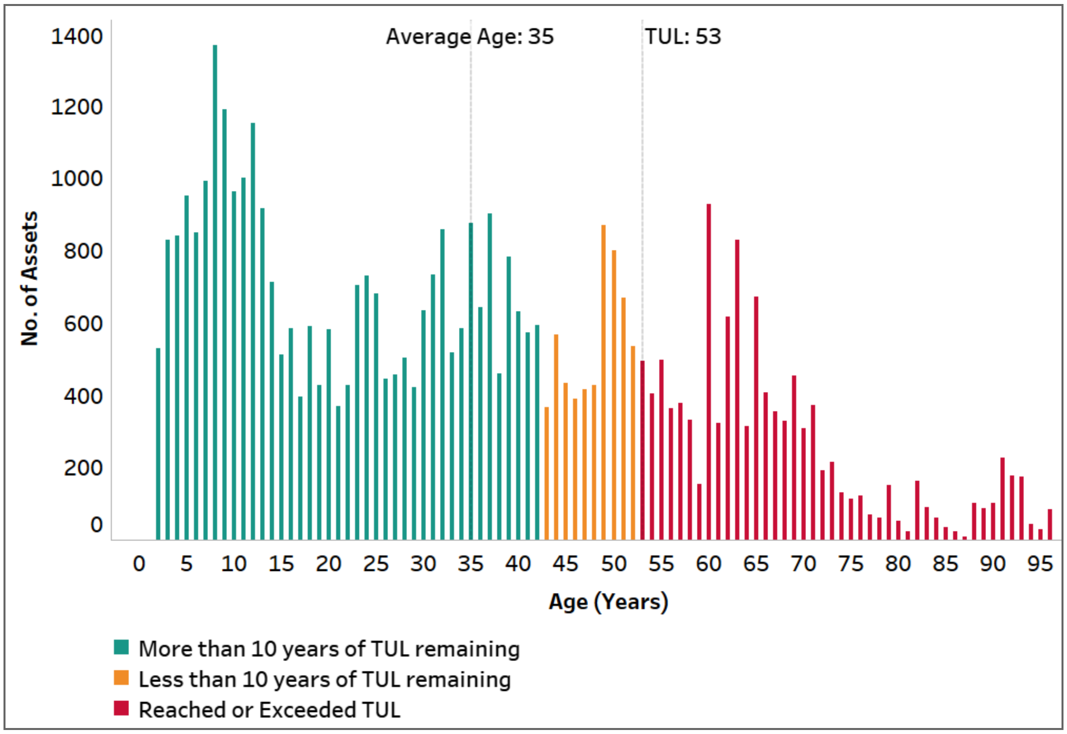
Hydro Ottawa utilized Copperleaf PA to gain a deeper understanding of potential future degradation patterns. This information was used to develop an appropriate, balanced asset renewal investment plan for 2026-2030. Based on these findings and the need for grid resilience (related to the increase in extreme weather events), Hydro Ottawa has proposed an increase in overhead asset renewal spending from the 2021-2025 period. This increase aims to manage asset performance while maintaining affordability for customers. More details regarding Hydro Ottawa's system renewal plan for overhead distribution assets are outlined in Section 3 of Schedule 2-5-7 - System Renewal Investments.

1 ### *7.1.2.1. Distribution Poles*

2 Hydro Ottawa owns approximately 46,636 wood poles in its service territory. The average age of
3 this asset class is 35 years and the TUL is 53 years, with the age demographics shown in Figure
4 45.

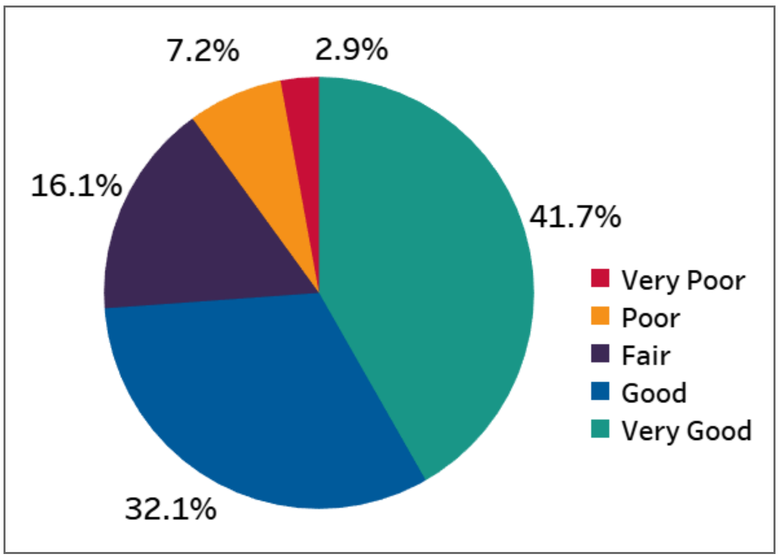
5

6 **Figure 45 - Distribution Wood Pole Age Demographics**

7 

The health index for wood poles is largely based on the estimated remaining mechanical strength in the pole's butt determined using resistograph measurements. Assessment of the pole's condition, and the condition of the ancillary equipment attached to it, are included as part of the process to identify candidate assets for corrective actions. A summary of known Hydro Ottawa's distribution pole conditions is shown in Figure 46.

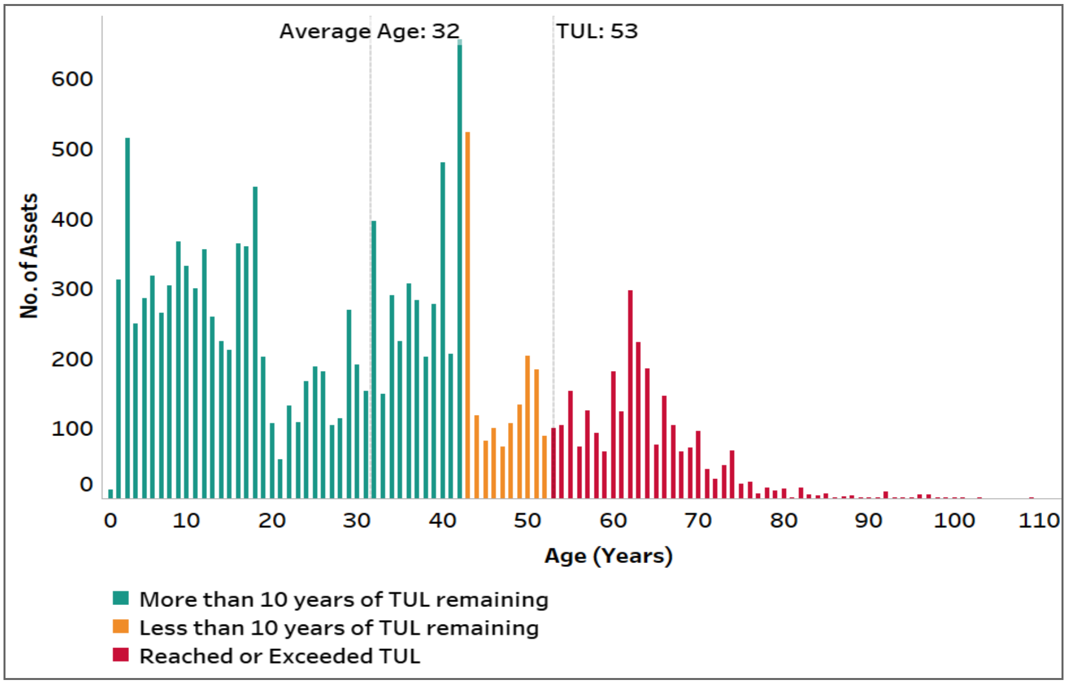
Figure 46 - Distribution Wood Pole Condition Demographics



7.1.2.2. Overhead Transformers

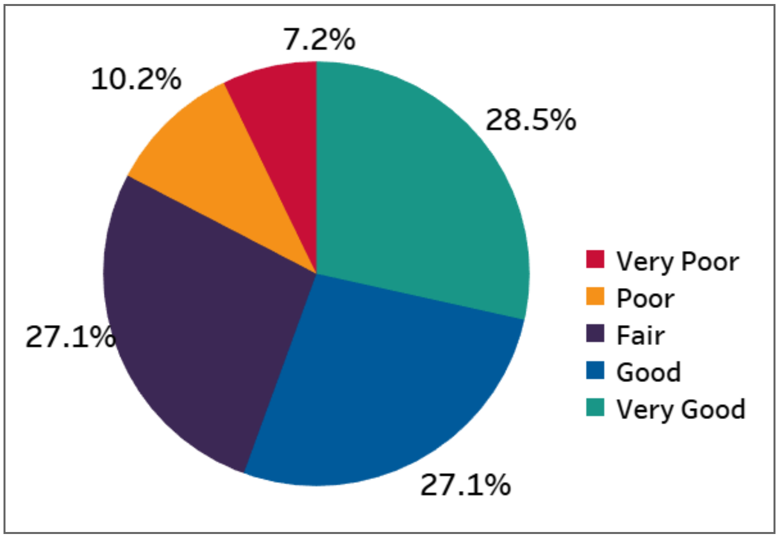
Hydro Ottawa owns and operates 15,218 overhead transformers. These are installed in both the front and rear lot to service Hydro Ottawa customers. The average age of this asset class is 32 years. Figure 47 illustrates the population age demographics. The TUL of overhead transformers is 53 years.

Figure 47 - Overhead Transformers Age Demographics



The health index for overhead transformers is based on age and asset condition data collected from planned programs of inspection that use both visual and IR inspection techniques. A summary of known Hydro Ottawa's overhead transformer conditions is shown in Figure 48.

Figure 48 - Overhead Transformer Condition Demographics



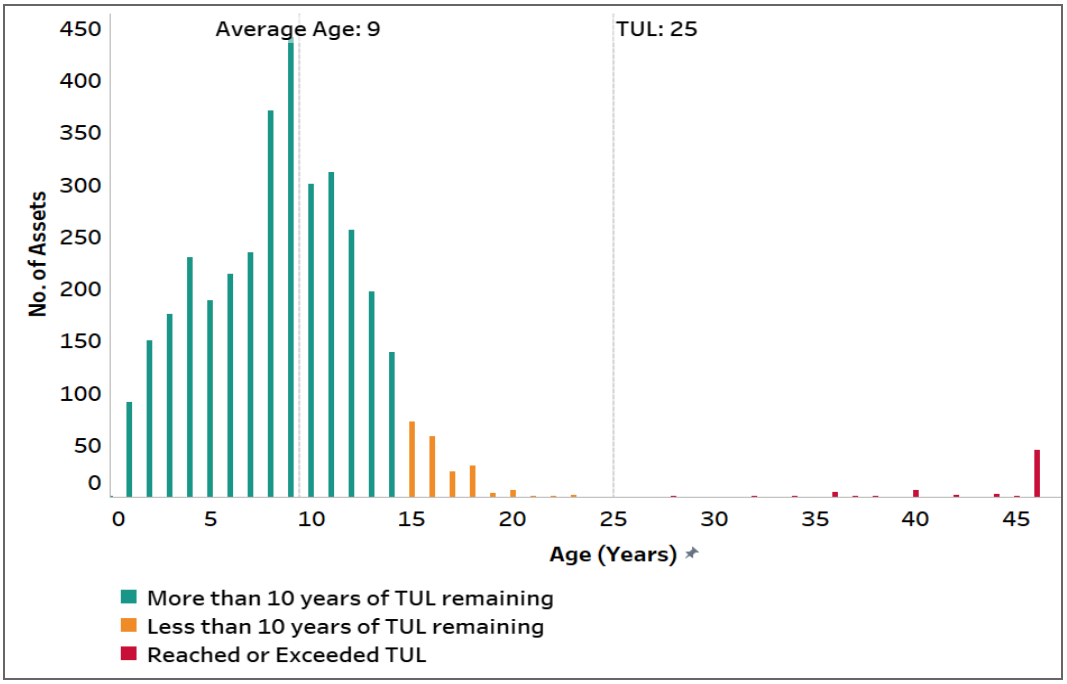
7.1.2.3. Overhead Distribution Switches and Reclosers

Hydro Ottawa's distribution overhead switch and recloser asset class consists of all overhead load break switches, reclosers, fuse cut-outs and inline switches, with a primary voltage rating up to and including 44kV. In general, the purpose of this asset class is to isolate faulted sections of Hydro Ottawa's distribution system, minimize the impact to customers, isolate sections of Hydro Ottawa's distribution system to enable work to proceed while affecting the smallest part of the distribution system possible, isolate customers through requests, and provides backup supply from other feeder(s).

Hydro Ottawa has numerous types of overhead switches with different functionality dependent on the required application. Hydro Ottawa owns 3,583 distribution overhead switches throughout the service territory.

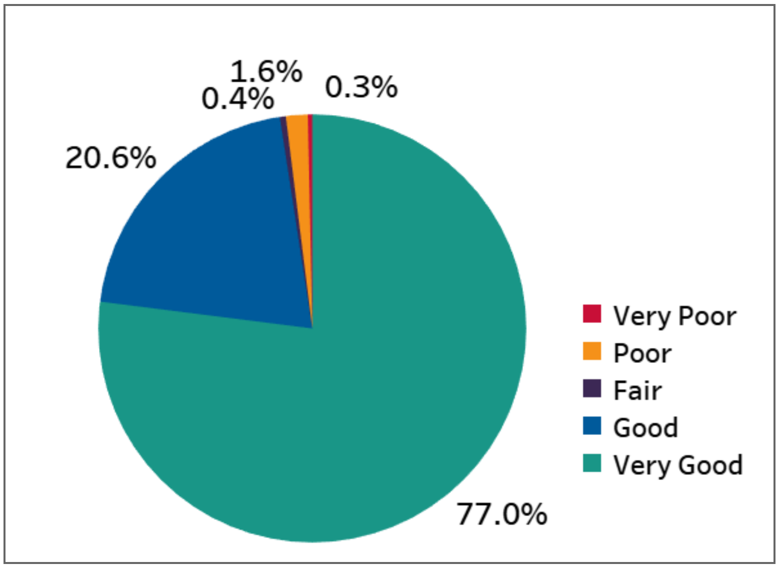
The average age of Hydro Ottawa's overhead load break/gang operated switches with a known age is 9 years; Figure 49 illustrates the population demographics for this asset class. The TUL of overhead load break/gang operated switches is 25 years.

Figure 49 - Overhead Switch Age Demographics



The health index for overhead complex switches is largely based on age and the results from thermographic scans. A complex switch is typically a 3-phase gang-operated device that is capable of interrupting load. Other criteria include the condition of insulators, solid blades, and operating mechanism. A summary of known Hydro Ottawa's overhead switch conditions is shown in Figure 50.

Figure 50 - Overhead Switch Condition Demographics



7.1.3. Underground Assets

Hydro Ottawa underground assets are integral for the distribution of electricity. The underground system consists of distribution assets and their respective supporting civil structures that enable delivery of energy to areas where the feasibility of the overhead system is reduced or where it is preferential to have improved aesthetics. Underground assets are broken into the following categories:

- Distribution cables (PILC, polymer)
- Underground transformers
- Underground switchgear
- Vault transformers
- Underground civil structures

Figure 51 and Figure 52 show the age and condition demographic projections of underground distribution assets into 2040, without any intervention, as obtained through Copperleaf PA. It can be seen that approximately 37% of the underground assets will reach the TUL by 2030, with the proportion increasing to slightly more than half (52%) by 2040. On the condition front, approximately 14% of the asset population will reach a Very Poor/Poor condition by 2035 and increase to slightly more than one-fourth (27%) by 2040.

Figure 51 - Underground Asset Age Demographic Projections

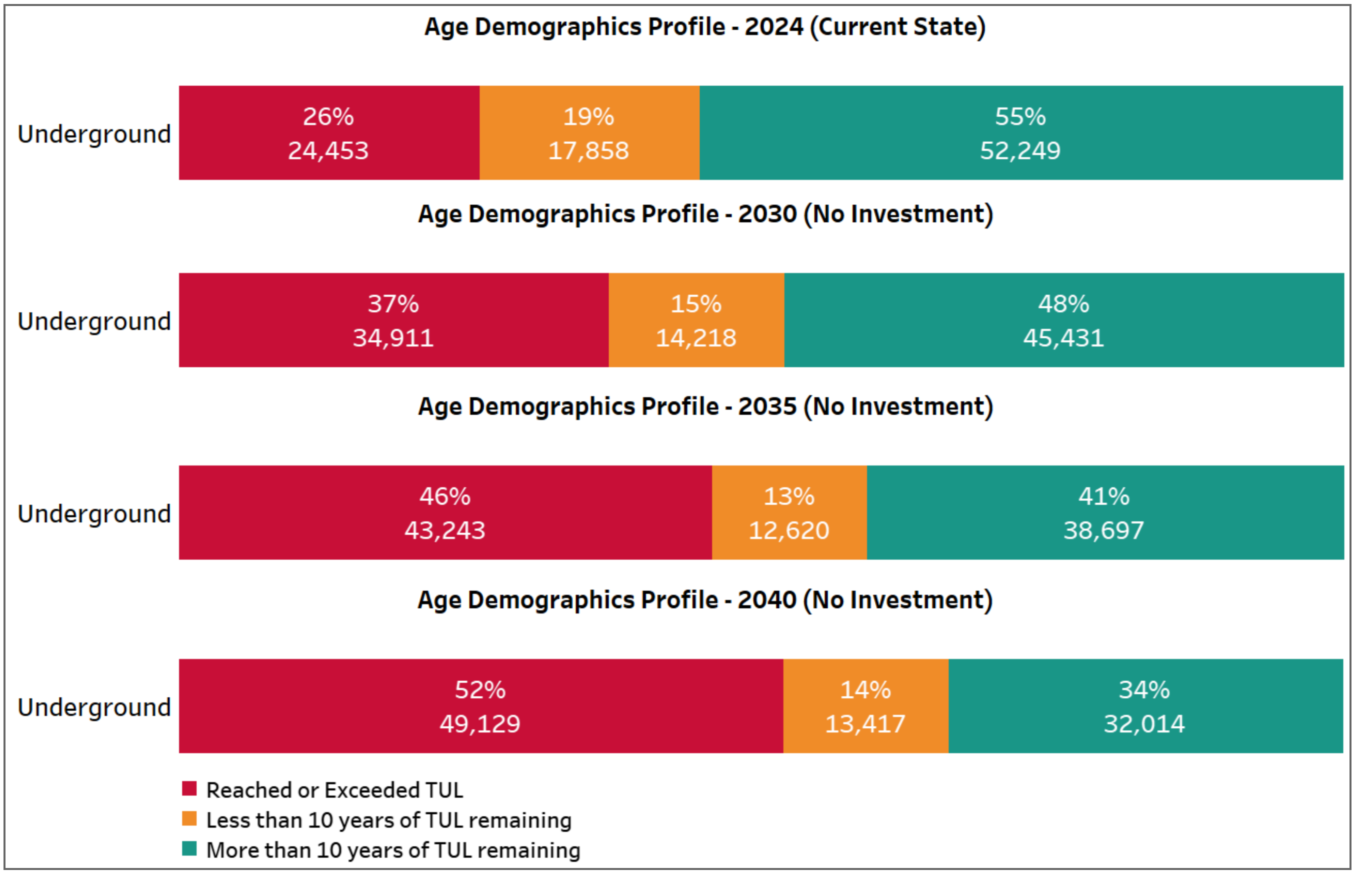
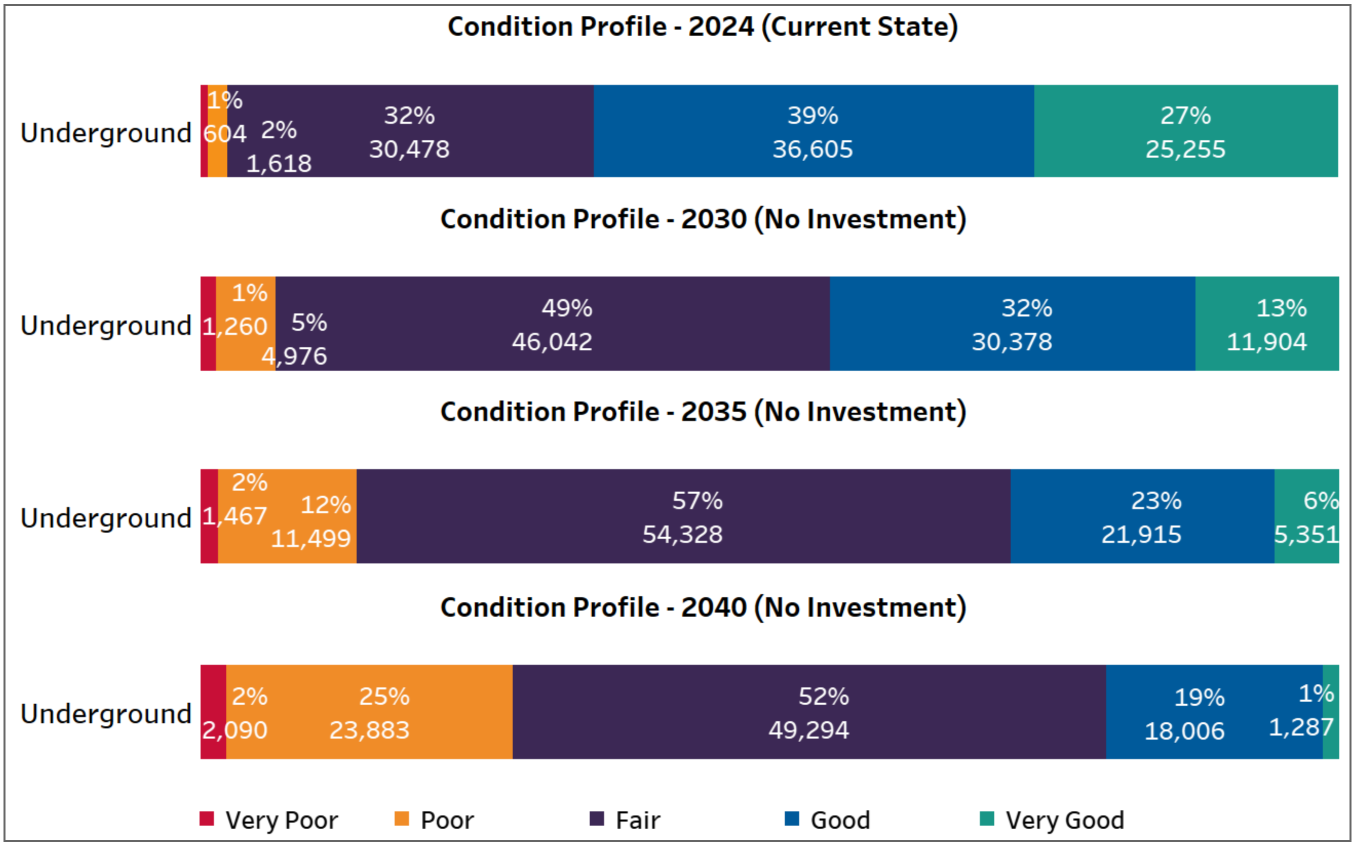


Figure 52 - Underground Asset Condition Demographic Projections



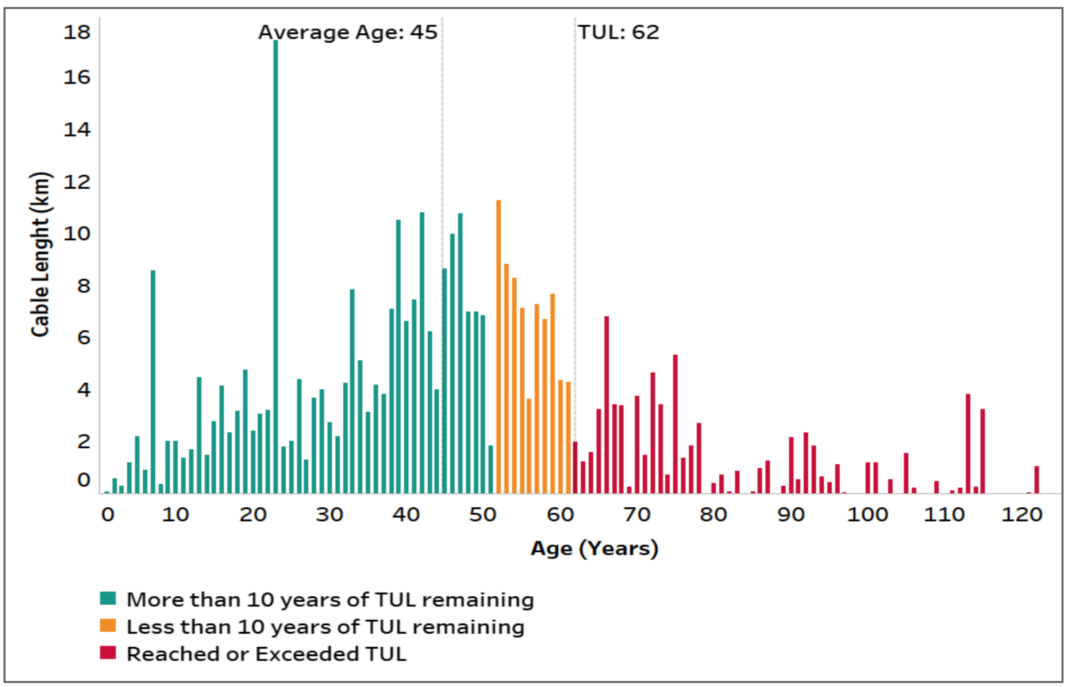
Hydro Ottawa utilized Copperleaf PA to gain a deeper understanding of potential future degradation patterns. This information was used to develop an appropriate, balanced asset renewal investment plan for 2026-2030. Based on these findings, Hydro Ottawa has proposed an increase in underground asset renewal spending from the 2021-2025 period. This increase aims to manage asset performance while maintaining affordability for customers. More details regarding Hydro Ottawa's system renewal plan for underground distribution assets are outlined in Section 4 of Schedule 2-5-7 - System Renewal Investments.

7.1.3.1. Distribution Cables (PILC)

Hydro Ottawa owns and operates 7,419 segments of triple conductor Paper Insulated Lead Cable (PILC). It was primarily installed in the Core of Ottawa on the 13kV system and is some of the oldest cables in the service territory. Due to higher material costs, increasing procurement lead times, and the need for specialized trades, Hydro Ottawa is moving to phase out this type of cable with polymer insulated cable.

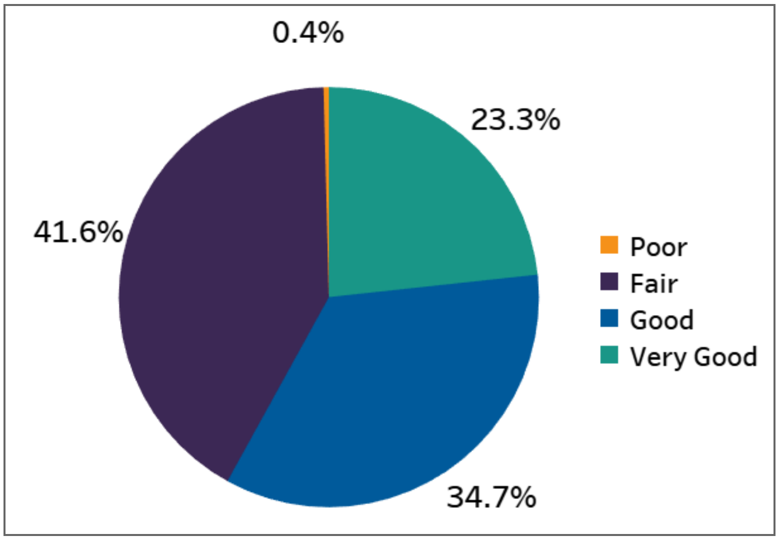
The average age of Hydro Ottawa's PILC cable is 45 years; Figure 53 illustrates the population demographics. The TUL of PILC cables is 62 years.

Figure 53 - PILC Cable Age Demographics



The health index for PILC cables is based on a combination of age, loading history and failure rate. A summary of Hydro Ottawa's distribution PILC cable conditions is shown in Figure 54.

Figure 54 - Distribution Cable (PILC) Condition Demographics



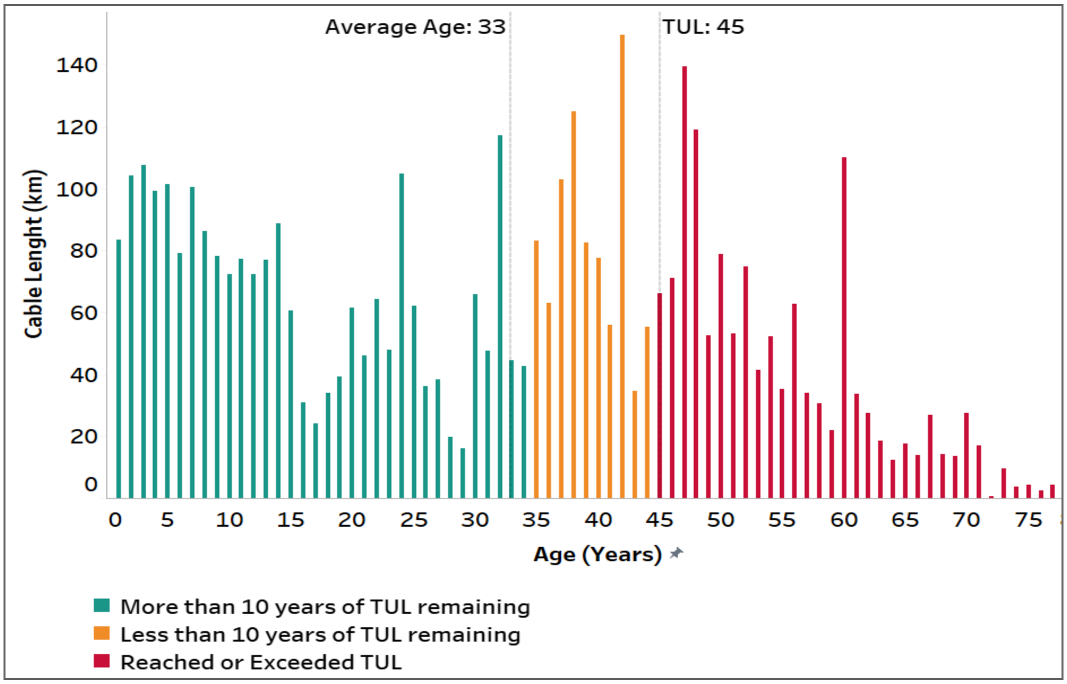
7.1.3.2. Distribution Cables (Polymer)

Hydro Ottawa owns and operates 59,101 segments of single conductor polymer cable (Cross-Linked Polyethylene (XLPE), Ethylene Propylene Rubber (EPR) and Butyl Rubber). The installation of this cable uses a mix of concrete-encased duct, direct-buried duct, and direct-buried cable that can add to the cost and labour requirements when replacing under planned and unplanned events.

The vast majority of the underground polymer cable is XLPE. EPR makes up a small portion of underground cables and has only recently been introduced as a replacement for PILC as it is phased out. For this reason, the condition assessment of underground polymer cable is focused on testing of XLPE cable.

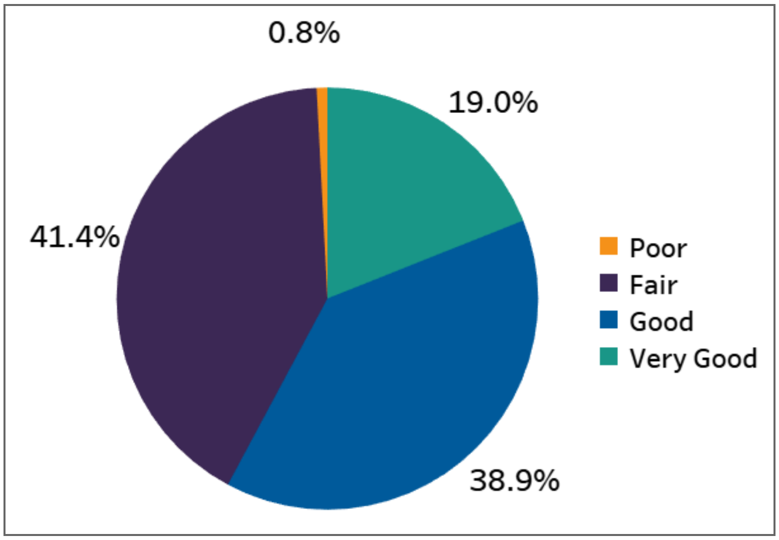
The average age of this asset class is 33 years; Figure 55 illustrates the population demographics. The TUL of XLPE cables is 45 years.

Figure 55 - Distribution Cable (XLPE) Age Demographics



The health index for XLPE cables is based on a combination of age, loading history and failure rate. A summary of Hydro Ottawa's distribution XLPE cable condition is shown in Figure 56.

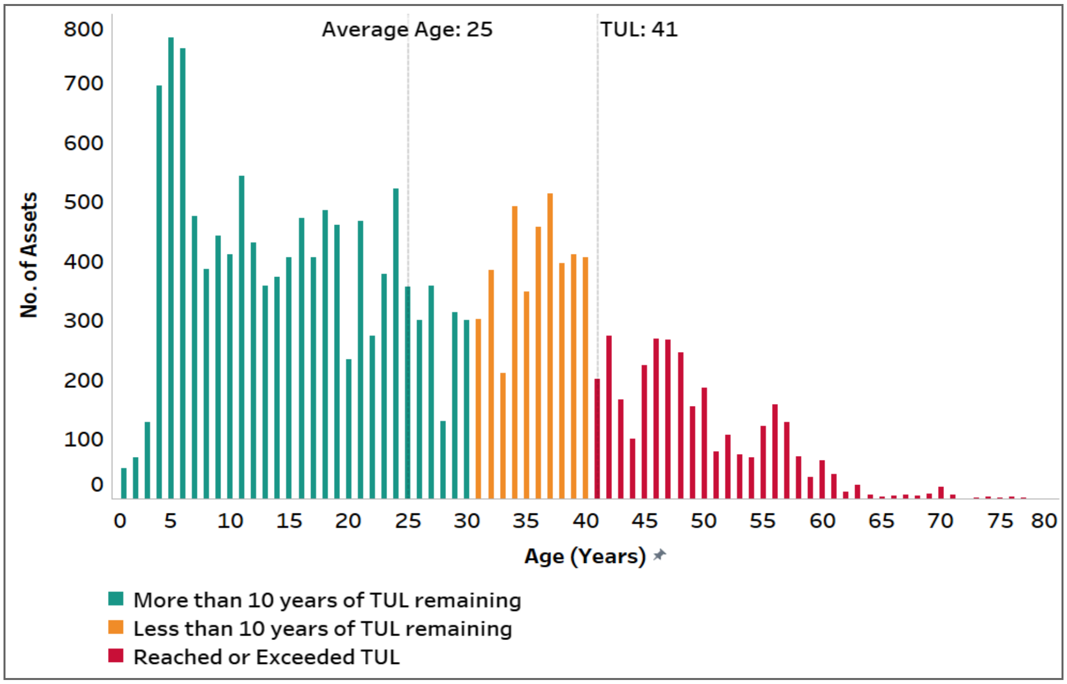
Figure 56 - Distribution XLPE Cable Condition Demographics



7.1.3.3. Underground Transformers

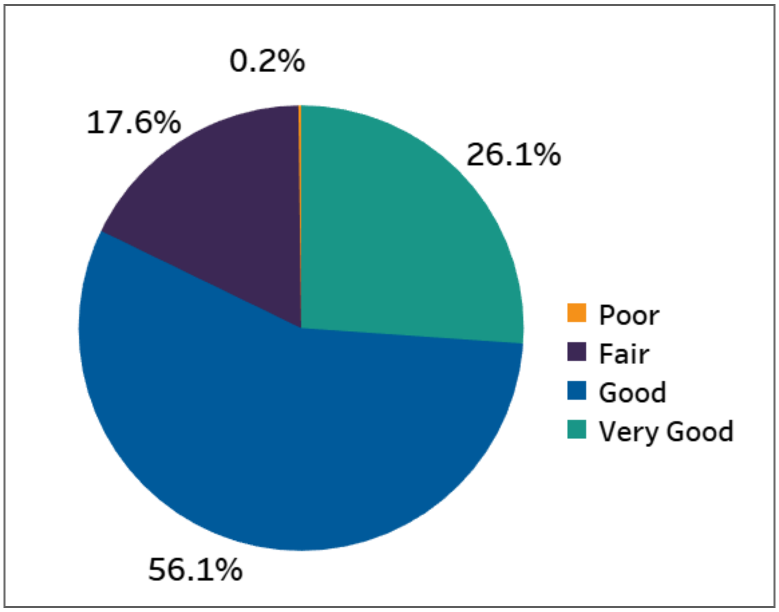
Hydro Ottawa owns and operates 18,875 underground transformers. These are installed in both the front and rear lot to service Hydro Ottawa customers. The average age of this asset class is 25 years. Figure 57 illustrates the population demographics. The TUL of underground transformers is 41 years.

Figure 57 - Distribution Underground Transformers Age Demographics



The health index for underground transformers is largely based on the visual and thermographic inspections. Other factors that influence the health index are the age, loading, and condition of the civil structure. A summary of known Hydro Ottawa's underground transformer conditions is shown in Figure 58.

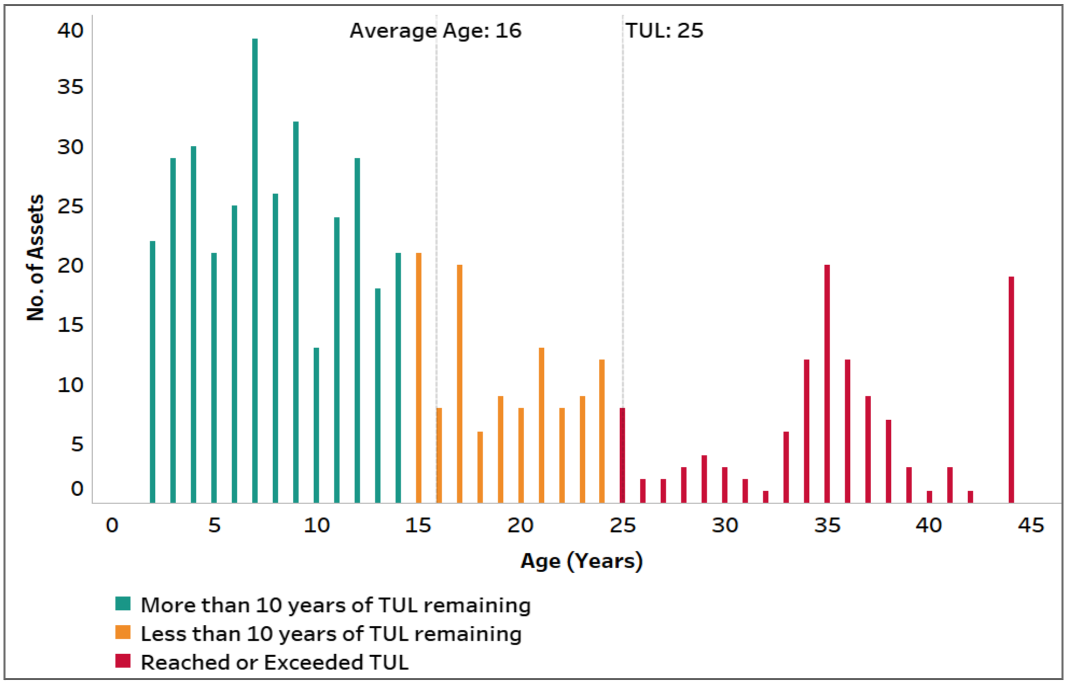
Figure 58 - Underground Transformer Condition Demographics



7.1.3.4. Underground Switchgear

Hydro Ottawa owns and operates 561 underground switchgear units. There are many different configurations and types of switchgear in service due to the amalgamation of the former utilities and their varying policies for servicing customers. The average age of this asset class is 16 years. Figure 59 illustrates the population demographics. The TUL of underground switchgear is 25 years.

1 **Figure 59 - Underground Switchgear Age Demographics**



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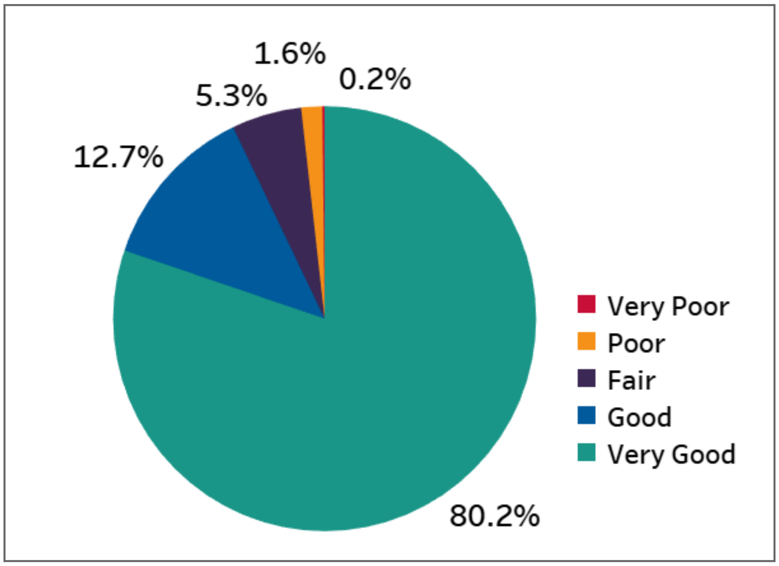
3

4 The health index for underground switchgear is largely based on age and the results from visual
5 and thermographic inspections. A summary of known Hydro Ottawa's underground switchgear
6 conditions is shown in Figure 60.

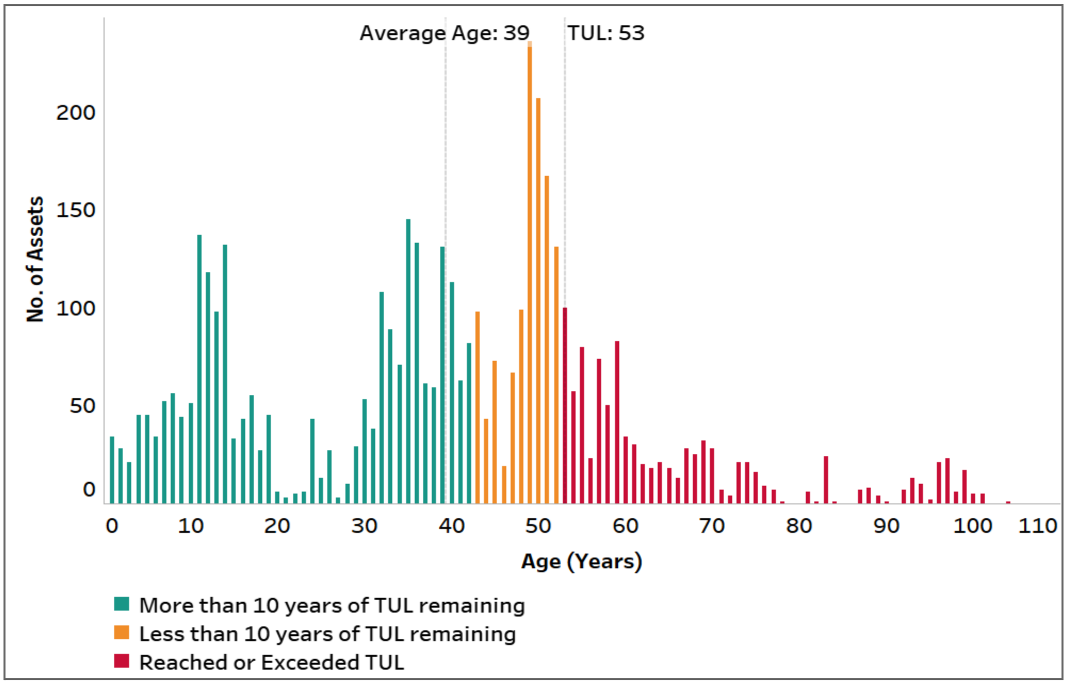
Figure 60 - Underground Switchgear Condition Demographics



7.1.3.5. Vault Transformers

Hydro Ottawa's vault transformers are located in building vaults and typically service a single large customer. Currently Hydro Ottawa owns 4,511 vault transformers. The average age of this asset class is 39 years. Figure 61 illustrates the population demographics. The TUL of vault transformers is 53 years.

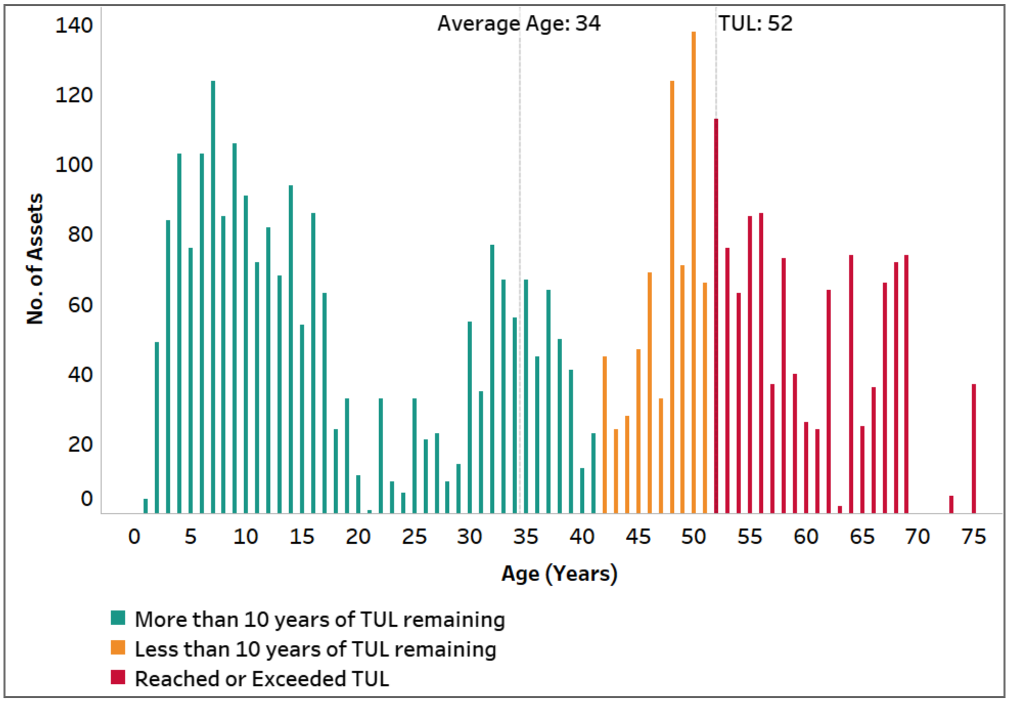
Figure 61 - Vault Transformer Age Demographics



7.1.3.6. Underground Civil Structures

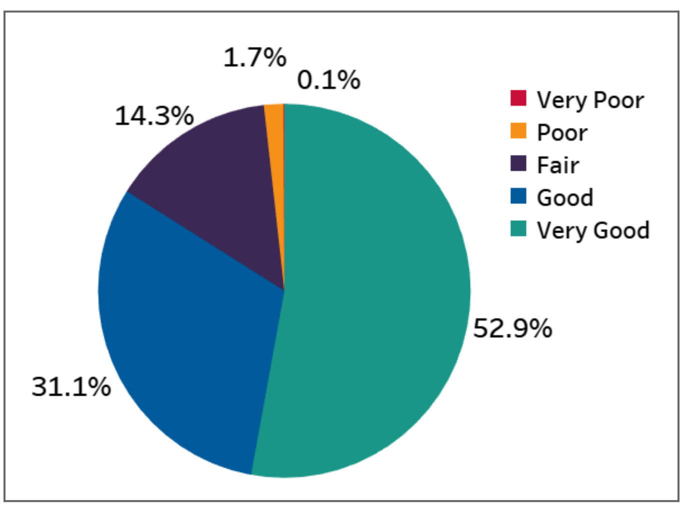
Hydro Ottawa's Underground Civil Structure asset class consists of duct banks, hand holes, and cable chambers forming a network through which cables may be installed. Distribution underground civil structures are used in areas where underground wiring is required, which allows for ease of access and protection of electrical equipment. Currently, Hydro Ottawa owns 3,904 cable chambers. The average age of this asset class is 34 years. Figure 62 illustrates the population demographics. The TUL of cable chambers is 52 years.

Figure 62 - Cable Chamber Age Demographics



The health index for cable chambers is primarily based on visual inspections. A summary of known Hydro Ottawa's cable chamber conditions is shown in Figure 63.

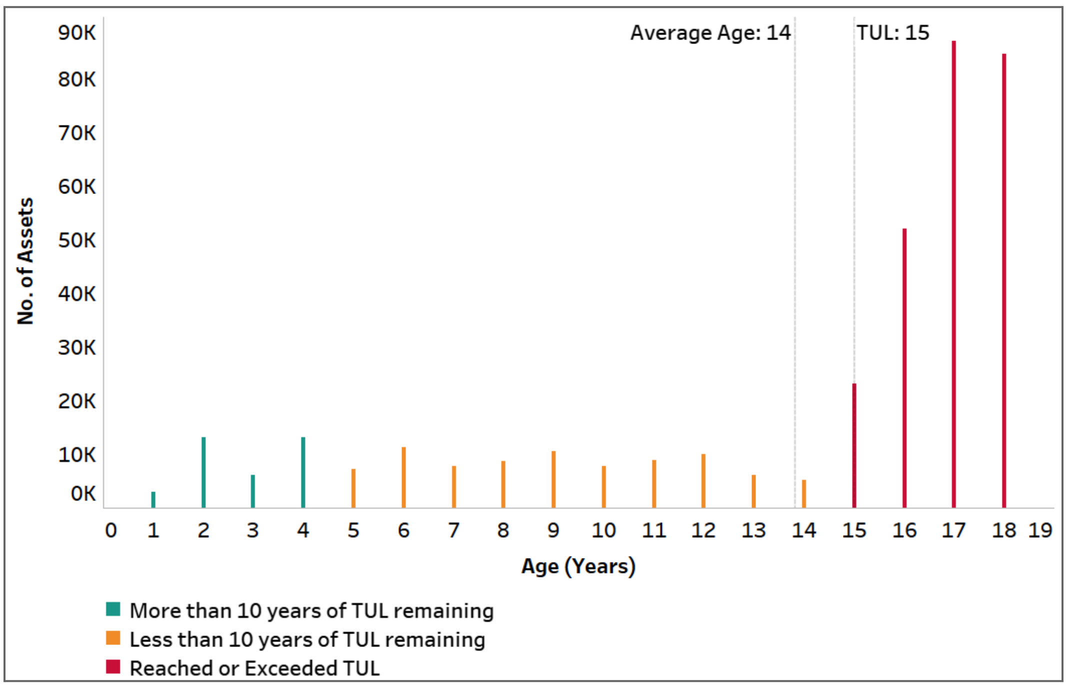
Figure 63 - Cable Chamber Condition Demographics



7.1.4. Metering Assets

Hydro Ottawa's metering asset class consists of residential meters, small commercial meters, and interval meters, all of which are essential for accurate customer billing, settlement with the IESO, and effective grid operations. Currently, Hydro Ottawa owns 366,212 meters. The average age of this asset class is 14 years; Figure 64 illustrates the population demographics. The TUL of a meter is 15 years.

Figure 64 - Current Age Demographics Profile of Residential and Small Commercial Meters



7.2. ASSET FAILURES AND PERFORMANCE

Asset performance metrics can be found in Section 3.3 of Schedule 2-5-3 - Performance Measurement for Continuous Improvement. Schedule 2-5-3 also contains a summary of asset failures that caused customer interruptions as outlined in Section 4.5.6 of Schedule 2-5-3 - Performance Measurement for Continuous Improvement.

7.3. ASSET RISK PROFILES

Hydro Ottawa utilized the PA module as the primary means for establishing risk at an individual asset level, rolled up to the asset class/system level. Key risk measures tied to reliability impact, safety implications, environmental considerations, financial aspect, and compliance have been considered in determining individual asset risk profiles. While all risk measures have been weighted equally in the PA model, reliability risk was found to be the major contributor, given its wide applicability across all asset types and data availability around asset failure modes and the related customer impact. More information regarding Hydro Ottawa's risk assessment process is outlined in Section 5.1.4 - Asset Risk Assessment.

Figure 65 shows the overall baseline reliability risk profile carried by Hydro Ottawa's asset systems in 2024, with the breakdown of the reliability risks associated with individual assets considered in the PA model shown in Figure 66.

Figure 65 - 2024 Baseline Reliability Risk Profile by Asset System

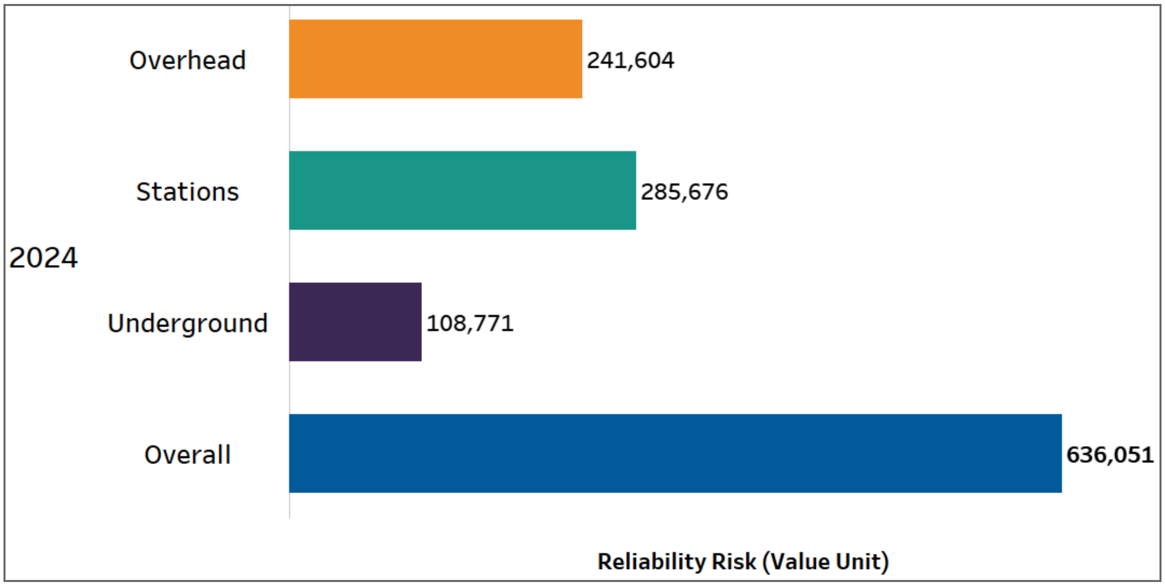
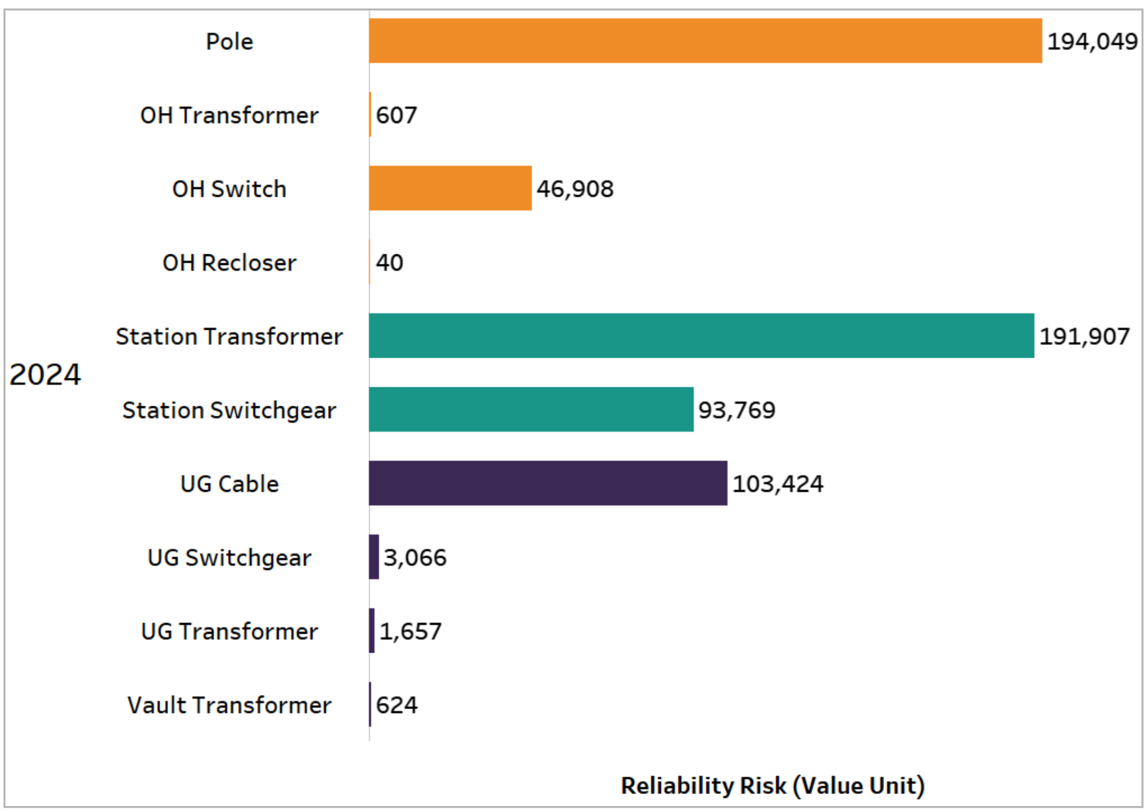


Figure 66 - 2024 Baseline Reliability Risk Profile by Individual Assets



7.4. SYSTEM UTILIZATION

Hydro Ottawa is facing a challenge in maintaining reliable power distribution while accommodating future load growth in some supply regions in its service territory. The current infrastructure is under strain, with eight stations already operating beyond their planned capacity limits (100%+ category in Figure 67) and an additional three stations approaching those thresholds (95%-100% category), as illustrated in Figure 67 and listed by planning region in Table 24. This situation highlights critical capacity constraints within the power distribution system.

Figure 67 - Stations by Planning Rating Thresholds

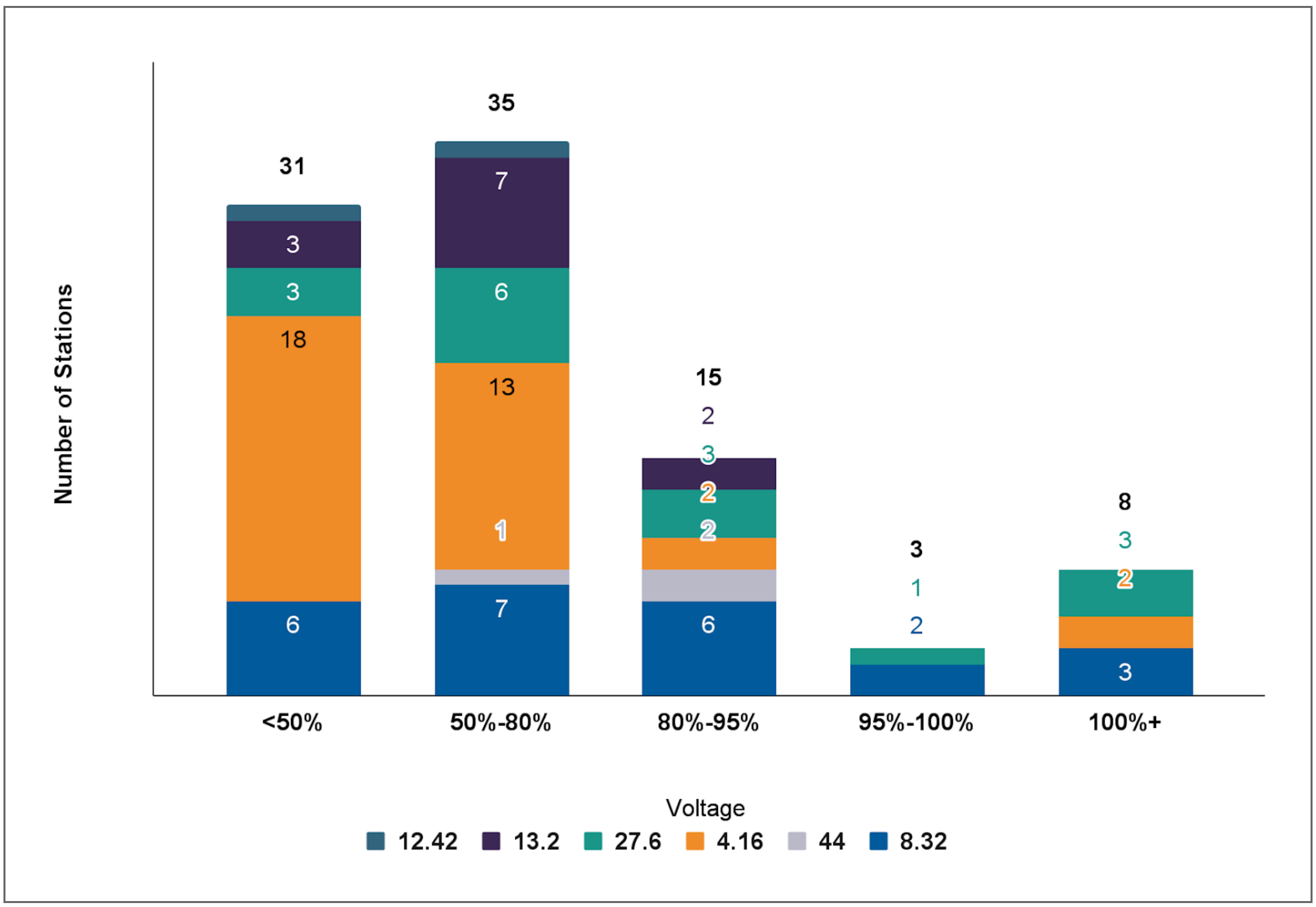


Table 24 - Stations Approaching or Above Planning Thresholds

Planning Threshold	Station	Planning Region
95%-100%	Stafford Road DS	Bells Corners/Bayshore 8 kV
95%-100%	Jockvale DS	Barrhaven 8 kV
95%-100%	Kanata MTS	West 28 kV (North)
100%+	Centrepointe MTS	Nepean 8 kV
100%+	Manordale MTS	Nepean 8 kV
100%+	Leitrim DS	South East 28 kV
100%+	Church DS	East 4 kV
100%+	Richmond North DS	West 8 kV
100%+	Vaughan DS	East 4 kV
100%+	Fallowfield MTS	South 28 kV
100%+	Marchwood MTS	West 28 kV (North)

Operating stations above their planning rating capacity has several detrimental effects on the overall system. Primarily, it significantly reduces the system's flexibility to effectively manage both planned maintenance and operational activities, as well as respond to unforeseen disruptions or abnormal system states, such as equipment failures, power surges, or extreme weather events.

This lack of flexibility can lead to cascading failures, where a problem at one station can quickly propagate to others due to the limited capacity to reroute power or isolate affected areas. This can result in widespread power outages, service disruptions, and potential damage to equipment.

Furthermore, operating stations beyond their intended capacity can accelerate equipment wear and tear, leading to more frequent maintenance requirements and a shorter overall lifespan. This can increase operational costs and further strain the system's ability to meet future load demands.

Hydro Ottawa must take proactive measures to address these capacity issues and ensure the long-term reliability and resilience of the power distribution system. This may involve a combination of strategies, such as upgrading existing stations, building new infrastructure, implementing demand-side management programs, and exploring innovative technologies to optimize system performance and accommodate future load growth.

Hydro Ottawa monitors utilization of assets through KPIs such as SLI and FLI detailed in Section 8.4 - Asset Utilization Policies and Practices.

Hydro Ottawa aims to ensure the stability, efficiency, and sustainability of Hydro Ottawa's distribution system by relying on several key strategies focused on system utilization, such as Load Forecasting and Capacity Planning, Renewable Energy Integration, NWSs, Demand Side Management and Energy Efficiency Programs, see more details in Section 9 - System Capacity Assessment and Grid Modernization Technologies as described in Section 3.4.2 - Grid Modernization Strategy.

8. ASSET LIFECYCLE OPTIMIZATION POLICIES AND PRACTICES

Hydro Ottawa is committed to providing a sustainable and dependable electricity service by optimizing asset lifecycles and ensuring reliability and cost-effectiveness through informed asset management practices. This is achieved by balancing maintenance, renewal, and replacement strategies and includes establishing TUL values; implementing asset replacement and refurbishment policies; conducting testing, inspection, and maintenance programs; and monitoring asset utilization.

The TUL of assets is determined through a robust process involving failure curve analyses and industry benchmarking. This ensures informed decisions about asset renewal and replacement, preventing premature retirement or extended use beyond safe operational lifespans. Corrective actions for assets include repair, refurbishment, or replacement, based on a case-by-case analysis considering factors like age, condition, maintenance history, new standards, and spare parts availability. Hydro Ottawa proactively replaces end-of-life assets and those posing immediate risks through the System Renewal program, while also evaluating opportunities for efficiencies during replacements.

Hydro Ottawa also employs various inspection techniques, including non-destructive testing and preventative maintenance, to assess asset performance and condition. The frequency and nature of these activities vary based on the asset type and are important to ensure the continued reliable operation of low-risk assets in a deteriorated condition (through relevant corrective maintenance). Corrective maintenance addresses minor issues and unforeseen failures to ensure grid reliability.

KPIs such as the SLI and FLI, are monitored to ensure efficient asset utilization and identify areas for improvement. This involves tracking station capacity and feeder capacity to prevent overloads, minimize downtime, and optimize resource allocation.

The following sub-sections highlight Hydro Ottawa's asset lifecycle optimization policies and practices in detail.

8.1. ASSET TYPICAL USEFUL LIFE

Hydro Ottawa partnered with Hatch to enhance asset failure curve knowledge and insights, aiming to refine the utility's risk- and value-based asset management framework. In addition to the primary goal of enhancing Hydro Ottawa's understanding of asset failure and degradation patterns (failure curve intelligence), this project also yielded crucial insights into the typical lifespans of various asset types. These recommended TUL values were not determined arbitrarily, but rather through a rigorous process that involved aligning the results from the failure curve simulation model with the maturity and reliability of the input data used, as well as drawing upon extensive industry experience and established benchmarks. Refer to Section 4.4.4 - Failure Curves and Update for details on this process.

The ability to establish these updated and empirically-grounded TUL values for the diverse range of asset types within Hydro Ottawa's infrastructure represents a significant achievement. These values provide a solid and defensible basis for making informed asset renewal and replacement decisions, ensuring that assets are not prematurely retired, leading to unnecessary capital expenditure, nor kept in service beyond their safe and reliable operational lifespan, which could increase the risk of failures and service disruptions.

Hydro Ottawa has categorized its assets into three groups based on their remaining TUL to facilitate asset renewal planning:

- **Assets with over 10 years of TUL remaining:** These assets are stable and don't need immediate action. They are routinely monitored through maintenance and inspections.
- **Assets with less than 10 years of TUL remaining:** These assets are not at the end of their lifespan but will need attention and possible replacement or refurbishment within 10 years.
- **Assets that have reached or exceeded their TUL:** These assets pose the highest risk of failure and are prioritized for immediate or short-term replacement or refurbishment.

A detailed report on the asset failure curve analysis and TUL determination is available in Attachment 2-5-4(D) - Failure Curves Review.

Table 25 shows a summary between the old and new TUL values for the various asset types considered as a part of the study. The suitability of the new TUL values were confirmed through a workshop between Hydro Ottawa and Hatch Subject Matter Experts. Factors such as the convergence of the failure curve simulation model, maturity of input data and industry experience were considered in finalizing the new TUL values, thereby making the new proposed changes more robust.

Table 25 - Summary of Typical Useful Life Values

Asset Type	Old Typical Useful Life (in years)	New Typical Useful Life (in years)
Station Transformers	55	55
Station Switchgear	42 (Air), 55 (Oil), 46 (Vacuum) and 51 (SF_6)	42 (Air), 55 (Oil), 46 (Vacuum) and 51 (SF6), 45 (HV SF_6)[27]
UG Switchgear	25 (Air) and 25 (SF_6)	25 (Air) and 25 (SF_6)
UG Transformers	53	41
OH Transformers	53	53
Vault Transformers	53	53
Vault Switchgear	25 (Air) and 25 (SF_6)	25 (Air) and 25 (SF_6)
OH Switches	25 (Manual) and 25 (SCADAmate)	25 (Manual) and 25 (SCADAmate)
Poles, Towers, Fixtures (Wood)	53	53
UG Polymer Cable	45 (XLPE and EPR)	45 (XLPE and EPR)
UG PILC Cable	62	62
Cable Chambers	52	54
Station Batteries	15 (VRLA batteries) and 25 (VLA batteries)	15 (VRLA batteries),17 (VLA batteries)
SCADA RTU, Relays and Communication Equipment	40 (Electromechanical relays), 15 (Electronic relays) and 25 (Microprocessor relays)	40 (Electromechanical relays), 30 (Electronic relays), 25 (Microprocessor relays)

8.2. ASSET REPLACEMENT & REFURBISHMENT POLICIES

Assets identified as needing corrective action (through periodic maintenance, field inspections, patrols, etc.) are evaluated to determine whether the asset should be repaired, refurbished, or replaced. Factors such as the age, condition, maintenance history, new standards, and availability of spare parts all influence the decision of whether or not to refurbish, repair, or replace the asset.

[27] Historically, HV SF6 was grouped within “SF6” with a TUL of 51.

Specific to asset replacements, Hydro Ottawa proactively replaces end-of-life assets in a deteriorated condition, as a part of the system renewal program outlined in Schedule 2-5-7 - System Renewal Investments. To determine the asset renewal needs, Hydro Ottawa uses PA to calculate the risk posed by individual assets. PA is also capable of predicting the degradation pattern, probability of failure, and progression of risk over time for each individual asset in Hydro Ottawa's service territory. This allows Hydro Ottawa to follow a risk-based asset replacement/intervention strategy. More details on Hydro Ottawa's asset risk assessment framework that drives system renewal investment planning can be found in Section 5.1.4 - Asset Risk Assessment.

Apart from this, assets which pose an immediate or imminent risk to the asset management objectives are repaired under maintenance or replaced under corrective renewal. These assets are identified immediately based on visual inspections or periodic maintenance and also based on recommendations by PA on low-risk assets in a deteriorated condition. Hydro Ottawa has a budget allocated for corrective renewal, outlined in Section 6 of Schedule 2-5-7 - System Renewal Investments. Repair and refurbishment activities are covered under the reactive maintenance budget and typically undertaken on asset sub-components, which if unaddressed may lead to a catastrophic failure.

Hydro Ottawa has also defined the criteria which determine corrective renewal for each individual asset class in order to determine the relevant budget program and timeline. An example for station transformers is provided in Table 26. Specifics on the emergency and critical renewal criteria for all asset classes are provided in Section 6 of Schedule 2-5-7 - System Renewal Investments.

Table 26 - Station Transformer Corrective Renewal Criteria

Emergency Renewal (Immediate Risk)	Critical Renewal (Imminent Risk)
Internal fault	Tap-changer failure
Bushing failure	Heavy gassing
Tank rupture (loss of oil)	Overheated bushing (found with IR scan)
Major issue found during maintenance	High furan level
Health index of 0%	Significant issues found in testing
	Insufficient health index (very poor / < 30%)

In addition to individual intervention assessments, each asset identified for replacement is evaluated for opportunities for efficiencies by assessing the condition of the other assets in proximity that may need to be replaced concurrently, evaluating future growth and demand, and determining if decommissioning is an option.

Repair actions are corrective interventions that involve the replacement of a minor component which can be obtained from stock materials or through manufacturer sourcing.

Refurbishment is expected to renew the asset and extend the TUL. These actions are also used to defer the need for replacement to a time where efficiencies can be found by replacing other assets at the same time. Typically, station assets, such as transformers and breakers, have been more economical to refurbish than overhead and underground assets. The refurbishment/repair actions are undertaken through targeted maintenance programs as detailed in Schedule 4-1-2 - Operations, Maintenance and Administration Program Costs.

To maintain overall system reliability and mitigate the related risks (safety, reliability, environmental, financial, and compliance), Hydro Ottawa uses a strategic, forward-looking approach that includes levelized spending and data-driven system renewal investment planning. The asset renewal strategy is designed to manage and mitigate asset risks by strategically replacing deteriorating infrastructure, not simply replacing all aged or deteriorated assets. Hydro Ottawa's proposed 2026-2030 System

Renewal investment plan does not aim to replace all degraded assets. Instead, it prioritizes replacement based on PA assessments, while balancing cost, resourcing and material availability, and short- and long-term risk. This comprehensive assessment emphasizes that Hydro Ottawa is making strategic choices about which assets to replace and at what rate, rather than simply replacing everything that is degraded. Specific details of each renewal program are outlined in Schedule 2-5-7 - System Renewal Investments.

8.3. TESTING, INSPECTION & MAINTENANCE PROGRAMS

To optimize the asset lifecycle and manage risk, Hydro Ottawa uses various programs and activities to evaluate the performance and condition of its assets. The practices used to assess risk include non-destructive testing and predictive and preventative maintenance, which help to drive corrective maintenance and capital investments.

Most of Hydro Ottawa's asset maintenance activities are performed on a predetermined periodic schedule. The cycle period is selected based on various factors such as asset age, equipment usage, equipment type, and typical operating life, to address manufacturers' recommendations, regulatory requirements in the DSC, and/or internal experience and standards. Table 27 outlines the inspection and maintenance cycles of each program.

Table 27 - Hydro Ottawa's Maintenance Programs

Asset	Activity Type	Cycle	Type
Stations	Station Inspections	Monthly	Predictive
	Thermographic Scans	Annually	Predictive
	Transformer Inspection	Annually	Predictive
	Transformer Oil Analysis	Annually	Predictive
	Transformer Maintenance	Every 3-5 Years	Preventative
	Transformer Tap Changer Maintenance	Every 1-8 Years	Preventative
	Switchgear and Breaker Inspection	Annually	Predictive
	Switchgear and Breaker Maintenance	Every 4-6 Years	Preventative
	Battery Testing	Annually	Predictive
	Relay Maintenance	Every 4-6 Years	Preventative
Underground	Underground Switchgear Thermographic and Visual	Every 3 Years	Predictive
	Underground Distribution Transformer Thermographic and Visual	Every 3 Years	Predictive
	Vault Inspections	Every 3 to 6 Years	Predictive
	Underground Switchgear CO2 Washing	Every 3 Years	Preventative
	XLPE/TRXLPE Cable Testing	200 Segments Annually	Predictive
	Cable Chamber Inspections	Every 10 Years	Predictive
Overhead	Overhead Visual and Thermographic Inspection	Every 3 Years	Predictive
	Vegetation Management	Every 2 to 3 Years	Preventative
	Pole Inspection	Every 10 Years	Predictive
	Critical Switch Inspection	Every 8 Years	Preventative
	Insulator Washing	Bi-Annual	Preventative

Aside from the preventative and predictive maintenance programs, Hydro Ottawa also tackles any repairs to the asset population through corrective maintenance. The repairs are performed to address minor issues that do not indicate that an asset has reached its TUL. This determination is made through a thorough inspection process, which includes both visual and detailed assessments/electrical testing, as shown in Table 27. The corrective maintenance activities might include tasks such as repairing, replacing, or refurbishing underlying asset components. Hydro Ottawa also carries out corrective maintenance to address unforeseen issues and failures in electrical assets, ensuring the continued reliability of the electrical grid.

Hydro Ottawa's electrical assets (especially in stations) require significant capital investments through 2026-2030 in renewals to maintain reliability (from a condition and risk perspective), based on the risk assessment process outlined in Section 5.1.4 - Asset Risk Assessment using Copperleaf PA. A significant level of investment is necessary to intervene on all deteriorated station and distribution assets, as outlined in Section 2.3.2 of Schedule 2-5-1 - Distribution System Plan Overview, Table 3. Hydro Ottawa selected the proposed alternatives to ensure that resourcing, material availability, customer affordability, and risk mitigation were properly considered and balanced in the decision, however in some cases, Hydro Ottawa is only able to balance short-term risk as a result of the selected alternative.

In response, Hydro Ottawa has planned increases in the frequency of testing, inspection, and maintenance activities for some asset classes where the planned replacement rate is not high enough to keep up with the pace that assets reach their TUL. Hydro Ottawa has also expanded the data collected through the inspection and maintenance programs to collect more comprehensive condition information. This approach allows Hydro Ottawa to gather additional condition information on deteriorating asset infrastructure and manage it accordingly. To this end, Hydro Ottawa proposes to increase investments in maintenance programs through 2026-2030 to mitigate failure risk of assets not immediately slated for replacement. Further details are outlined in Schedule 4-1-2 - Operation, Maintenance and Administration Program Costs. This strategic investment in maintenance programs supports a balanced approach to long-term asset performance.

Updates to the station maintenance program will include support for voltage conversion of 4kV station assets, and improved transformer maintenance (through targeted insulator washing, advanced diagnostic testing and ensuring the operational performance of online dissolved gas analysis (DGA) monitors). In addition, Hydro Ottawa will introduce advanced inspection technologies, such as drones, to gather more precise data on OH distribution assets. This will enable targeted maintenance and improve asset health assessments. Finally, Hydro Ottawa will focus on spending in its UG distribution asset maintenance programs. This includes leveraging advanced techniques to identify vulnerabilities and optimize capital investments.

By increasing the investment in maintenance activities, Hydro Ottawa can sustain asset performance while minimizing customer interruptions. These updates are intended to ensure that Hydro Ottawa's asset population remains functional and safe through 2026-2030. More information regarding the proposed O&M costs can be found in Schedule 4-1-2 - Operations, Maintenance and Administration Program Costs.

The following sections detail the testing, inspection, and maintenance practices for each asset type.

8.3.1. Station Assets

8.3.1.1. Station Transformers

Hydro Ottawa performs monthly station inspections where a visual inspection checks for any deficiencies and initiates corrective actions. Annually, Hydro Ottawa performs predictive maintenance on every station transformer, which includes a detailed visual inspection, oil analysis, and infrared scans. The oil analysis includes a dissolved gas and oil quality analysis. Every five years, a furan analysis is performed to assess the degradation of the transformer's paper insulation.

Several major station transformers are also continuously monitored through the SCADA system to provide operational and asset condition-related information. Various monitoring technologies have been added to station transformers due to the consequences associated with a failure. These include online DGA monitors, winding and oil temperature monitors and monitors to track tap changer status, cooling fan status, and loading information. Warnings and alarms from these monitoring units allow Hydro Ottawa to identify the need for corrective actions with real-time data. It also ensures that the transformers are not overloaded or overheating, which causes the insulation to degrade and reduces transformer lifespans. Figure 68 shows an example of the visual inspection of a station transformer.

Figure 68 - Visual Inspection of a Station Transformer

Every three to five years, station transformers are isolated for preventative maintenance, which includes electrical testing and mechanical maintenance. Transformer tap changer maintenance intervals vary with the type: oil-filled tap changers with no oil filter are maintained every one to two years, oil-filled tap changers with an oil filter are maintained every two to four years, and vacuum tap changers are maintained every six to eight years.

8.3.1.2. Station Switchgear

Hydro Ottawa performs monthly station inspections where a visual inspection is performed to check for any deficiencies and initiate corrective actions. Predictive maintenance is undertaken annually on station switchgear, which includes a detailed visual inspection and infrared scan. Every five years, preventative maintenance is performed on individual breakers. The breaker maintenance includes electrical, mechanical, and type-specific maintenance tasks to ensure the proper functioning of the breaker.

Every 10 years, detailed preventative maintenance is performed on the entire switchgear assembly. Switchgear maintenance includes detailed internal visual inspections; insulation resistance tests; and ensuring that there are no structural deficiencies, such as cracks, leaks or warped metal, in the switchgear.

8.3.1.3. Station Batteries

Batteries are visually inspected as part of the monthly station inspections to check for any deficiencies and initiate corrective actions. Annually, detailed predictive maintenance is performed on station battery banks; this includes a detailed visual inspection, infrared scan, and electrical and mechanical tests. Battery charger predictive maintenance consists of an annual visual inspection, electrical tests, and functional and alarm tests.

8.3.2. Overhead Assets

8.3.2.1. Distribution Poles

Hydro Ottawa inspects all of its distribution poles as part of multiple planned programs of inspection for overhead assets. This planned program of inspection subjects all of its distribution poles and associated attachments to both a visual and thermographic inspection on a rotating three-year cycle, identifying candidate assets for corrective actions.

Hydro Ottawa also conducts a predictive maintenance program of detailed inspection of all poles on a 10-year cycle. The data collected from this program is used to assess the pole's condition and estimate remaining strength using the results of non-destructive resistograph drill tests. Hydro Ottawa is also working on a drone inspection pilot program to gather more accurate condition information on pole mounted hardware.

8.3.2.2. Overhead Transformers

Hydro Ottawa inspects overhead transformers as part of multiple planned predictive maintenance programs. Transformers are inspected visually as part of the 10-year pole line inspection program and every three years as part of the infrared inspection program. Hydro Ottawa is also working on a drone inspection pilot program to gather more accurate condition information on overhead transformers.

8.3.2.3. Overhead Switches

Hydro Ottawa inspects all of its overhead switches as part of multiple planned programs of inspection for overhead assets. This planned program of inspection subjects all of its overhead switches to both a visual and thermographic inspection on a rotating three-year cycle identifying candidate assets for corrective actions. Hydro Ottawa is also working on a drone inspection pilot program to gather more accurate condition information on overhead switches.

Hydro Ottawa also conducts a separate planned program of detailed inspection and maintenance, based on a rotating eight-year cycle, on overhead load break gang-operated switches. The detailed inspection is to address switches that have a higher reliability consequence. Inspections are performed in the air, in closer proximity to the switch’s components, allowing for a more detailed inspection that could not be performed from the ground. Simultaneously, preventative maintenance is performed on the switch to ensure that it continues to operate as intended.

8.3.3. Underground Assets

8.3.3.1. Distribution Cables

Hydro Ottawa annually tests a portion of its polymer cables using non-destructive test methods to determine the cable’s probability of failure resulting from water tree migration, neutral corrosion, and partial discharge. Hydro Ottawa also combines this information with feedback from utility staff (such as the condition of related UG transformers/UG switchgear, physical condition, operational experience/failure trend based on similar installations, etc.), outage information, and the cable segment's age to determine if the cable would be a candidate for replacement.

PILC are not subjected to a dedicated planned program of inspection or maintenance and are instead included as part of the inspection of underground civil structures. A visual inspection is performed on a 10-year cycle, by qualified outdoor field staff, which includes reviewing the cable condition, racking within the cable chamber, and duct allocation.

8.3.3.2. Underground Transformers

Hydro Ottawa inspects its underground distribution transformers annually on a three-year cycle. The inspection process uses a visual inspection to identify transformers with broken components or leaking oil. A thermographic inspection is also performed to identify defective transformer components including elbows, bushings, and fuses. This process identifies candidate transformers for corrective actions including mechanical repair and component replacement. When repair isn't economical, the transformer is scheduled for replacement.

8.3.3.3. Underground Switchgear

Hydro Ottawa inspects and maintains all of its underground distribution switchgear on a planned basis. This planned program subjects all of its underground distribution switchgear to a visual and thermographic inspection based on a rotating three-year cycle. The maintenance of air-insulated switchgear also includes cleaning of its internal mechanism. The visual inspection records demographic information and the current condition, including the enclosure and civil base.

8.3.3.4. Vault Transformers

Hydro Ottawa inspects all of its vault transformers on a planned three-year cycle. This planned program subjects its vault transformers to a visual and thermographic inspection in addition to minor cleaning. The visual inspection records demographic information and the current condition.

Hydro Ottawa does not own the electrical supply room within customer-owned buildings. Deficiencies found that would affect the ongoing operations or identified safety risks are identified to the building owner to take corrective actions.

8.3.3.5. Underground Civil

Hydro Ottawa performs an inspection of its cable chambers on a 10-year cycle. The cable chamber inspection process involves a visual inspection and sounding test to assess the cable chamber's condition. The inspection includes reviewing the condition of the collar and lid, the roof, and the walls. Cable chamber components that pose an immediate risk to the public, workers, or reliability of the distribution system are identified for immediate corrective actions; if they pose a reduced risk, they are identified for planned corrective actions at a later date.

Through the use of experienced underground field workers, the electrical components installed within the cable chambers can be inspected and minor corrective actions addressed immediately. The visual inspection includes capturing information about the cable demographics, location of splices, and identification of duct allocation.

Other civil assets, including hand holes, ducts, and duct banks, are not subject to a planned program of inspection. Unforeseen failure of these assets poses a reduced risk to the public and workers.

8.4. ASSET UTILIZATION POLICIES AND PRACTICES

Hydro Ottawa monitors the operational performance of the distribution system by tracking annual levels of station capacity, feeder capacity, and system losses. Monitoring and managing the capacity and performance of these distribution systems are critical to prevent overloads, minimize downtime, and optimize resource allocation.

Two key metrics used in this context are the SLI and FLI.
The SLI and FLI are discussed in greater detail in Sections 8.3.1 - Station Assets and 8.3.2 - Overhead Assets. The importance and application of these measures are:

- **Capacity Planning:** Hydro Ottawa monitors these indices to identify which substations or feeders are under stress and require upgrades. This proactive approach ensures that adequate capacity is available during normal system conditions, avoiding unexpected outages and delivering reliable power supply to Hydro Ottawa's customers.
- **Load Management:** Hydro Ottawa uses these indices to identify areas of overloading and take measures such as system reconfiguration to redistribute loads or enhancing infrastructure to manage the load effectively.
- **Investment Decisions:** Hydro Ottawa can utilize SLI and FLI insights to prioritize investments in substations or feeders that are nearing/exceeding capacity limits, ensuring optimal use of resources and budget, and implement the appropriate actions required to maximize the value of the distribution assets throughout its lifecycle.
- **Reliability and Service Quality:** By keeping SLI and FLI within safe limits, Hydro Ottawa can maintain high reliability and service quality. This is crucial for customer satisfaction and compliance with regulatory standards.

8.4.1. Station Capacity

To improve System Accessibility, Station Capacity measures are tracked to provide insight for larger medium- and long-term capacity needs, as well as smaller capacity deficits that may be solved through load transfers.

System Service projects are initiated to address capacity constraints. Projects, in order of increasing complexity and cost, include extending distribution ties to other stations with available capacity, upgrading an existing station's planning capacity, and construction of a new station. The following measure quantifies capacity risks through demand comparisons to a station's planning and equipment ratings and by determining if stranded load is possible during the loss of a station transformer, Section 5.2.2 - Distribution System Assessment.

Station Load Index (SLI)

The SLI is a measure used to assess the load on a substation. It is a critical parameter for determining the current utilization of the substation's capacity and for planning future upgrades or expansions. SLI is typically calculated as the ratio of the peak load to the substation’s capacity rating (i.e. planning and/or design rating). The formula can be expressed as:

$$\textbf{SLI} = (\textbf{Peak Load}/\textbf{Capacity Rating})\times 100$$

The station load indices monitored by Hydro Ottawa are defined in Table 28:

Table 28 - Station Load Index

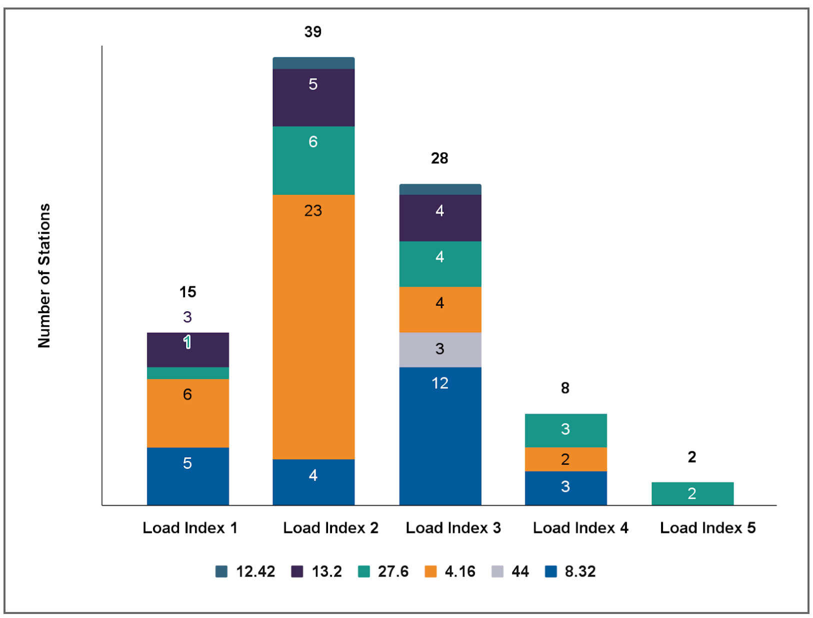
Load Index	Criteria	Explanation
5	x > 70% of Design Rating	Approaching thermal limit
4	x ≥ 100% of Planning Rating	Very heavily loaded, exceeding N-1 contingency
3	70% of Planning Rating ≤ x < 100% of Planning Rating	Heavily loaded, but within contingency
2	40% of Planning Rating ≤ x < 70% of Planning Rating	Moderately loaded
1	x < 40% of Planning Rating	Lightly loaded

- **Planning Rating:** The planning rating is the sum of either the transformers’ 10-day LTR or the allowable top load rating if no LTR is published, following the loss of the largest element in the station (N-1 contingency). For stations with a single supply and transformer, feeder ties from adjacent stations provide contingency backup and the planning capacity is based on the single unit’s rated capacity (10-day LTR or top load rating if LTR is not available).
- **Design Rating:** A transformer’s design rating specifies the maximum electrical power (in kVa or MVA) it can handle under optimal cooling conditions including fan-assisted heat dissipation. This rating ensures the transformer operates reliably within its thermal limits.

Hydro Ottawa monitors the percentage of stations with load indices of 4 and 5 to plan capacity upgrades and has completed significant station expansion projects, improving station performance within planning and design ratings.

In 2023, eight Hydro Ottawa stations had a SLI of 4 and two stations had a SLI of 5, as shown in Figure 69. Stations above 100% of their planning capacity (Load Index 4) limit the flexibility of the system to manage abnormal system states including planned activities. Stations operating at >70% of their design rating (Load Index 5) are approaching their design rating and need intervention to reduce their loading for contingency scenarios.

Figure 69 - Stations by Load Index



The list of stations with a SLI of 4 and 5 have been listed in Table 29.

Table 29 - Stations of Load Index 4 and 5

Region	Station	Voltage	2023 System Peak Day Load (MVA)	Planning Factor (%)	Design Factor (%)	Load Index
West 28kV	Janet King DS 28kV	27.6	26.5	88%	88%	5
West 28kV	Beckwith DS	27.6	3.9	105%	105%	5
West 28kV (North)	Marchwood MTS	27.6	45.7	138%	69%	4
South 28kV	Fallowfield MTS	27.6	32.0	114%	60%	4
East 4kV	Vaughan DS	4.16	7.3	109%	51%	4
West 8kV	Richmond North DS	8.32	6.8	136%	52%	4
East 4kV	Church DS	4.16	5.7	114%	46%	4
South East 28kV	Leitrim DS	27.6	26.6	106%	46%	4
Nepean 8kV	Manordale MTS	8.32	10.9	109%	45%	4
Nepean 8kV	Centrepointe MTS	8.32	14.9	106%	38%	4

Hydro Ottawa is utilizing multiple approaches to address the stations at a Load Index of 4 and 5. For information about Hydro Ottawa's plans to address system capacity, see Section 9.1 - Capacity Needs Assessment.

8.4.2. Feeder Capacity

Hydro Ottawa plans feeder capacity based on coincident peak loading and N-1 contingency. The majority of distribution feeders are paired so that if one feeder fails, its load can be transferred to an adjacent feeder. This arrangement minimizes the number of switching operations and the time required to restore full load. Hydro Ottawa also has feeders with dedicated backups; i.e., an alternative backup feeder that normally carries no load. Feeders with a dedicated backup can carry more load without overheating or sustaining damage. Please refer to Table 30 below.

The following factors are taken into consideration when determining the planning rating for a distribution feeder:

- **Egress Cable:** The conductor size, insulation material, and installation type.
- **Egress Design Rating:** Based on the cable specifications and ampacity calculations, a design rating is identified for the respective cable type.
- **Egress 8-hour Rating:** Based on the cable specification and ampacity calculations, a contingency 8-hour rating is identified for the respective cable type.
- **Overhead Conductor:** The conductor size is identified.
- **Overhead Conductor Rating:** A rating is identified for the respective conductor size based on manufacturer specifications.
- **Other Limitations:** Assets on the distribution system that could cause an ampacity limitation, such as jumpers or switches, are identified for the respective feeders.

Table 30 - Typical Egress & Conductor Ratings

Voltage	Typical Egress Cable	Egress Design Rating (A)	Egress 8hr Rating (A)	Typical Overhead Conductor	Overhead Conductor Rating (A)
4 kV	5 kV 350 Cu PILC	340	405	15 kV, 4/0 Cu	510
8 kV	15 kV, 500 MCM Cu XLPE	455	605	15 kV, 336 Al	500
12 kV	15 kV, 2/0 Al XLPE	210	280	15 kV, 336 Al	500
13 kV	15 kV, 500 MCM Cu PILC	425	510	15 kV, 477 Al	600
28 kV	29 kV, 750 MCM Al XLPE	455	620	29 kV, 556 Al	700
28 kV	29 kV, 1000 MCM Al XLPE	505	685	29 kV, 556 Al	700
44 kV	46 kV, 750 MCM Cu XLPE	545	720	46 kV, 556 Al	700

The planning rating for feeders **without** a dedicated backup is calculated as 50% of the egress 8-hour rating or 50% of the overhead conductor rating, whichever is lesser. This approach ensures that feeders always have capacity to backup adjacent circuits during N-1 contingency conditions.

The planning rating for feeders **with** a dedicated backup is calculated as the egress design rating or the overhead conductor rating, whichever is lesser. These feeders have a higher planning rating as they can rely on the dedicated backup for capacity in N-1 contingency scenarios.

The planning rating is calculated on an individual feeder basis to account for feeder specific limitations. This approach ensures that assets on the feeder never exceed their respective thermal limits while also identifying constrained areas on the network, such as undersized conductors, that could be upgraded to increase capacity on the entire feeder. The FLI is used to assess capacity risks through demand comparisons to a feeder's planning ratings and by determining if stranded load is possible during an N-1 contingency.

Feeder Load Index (FLI)

The FLI measures the load on individual feeders that distribute electricity from substations to consumers. It helps in assessing the performance and capacity utilization of these feeders, which helps in planning for feeder extensions to make station capacity available or create feeder ties between stations to improve reliability.

FLI is calculated as the ratio of the actual load on the feeder to its rated capacity (planning/design rating). The formula is:

$$\textbf{FLI} = (\textbf{Peak Load}/\textbf{Capacity Rating}) \times 100$$

The feeder load indices monitored by Hydro Ottawa are defined in Table 31.

Table 31 - Feeder Load Index

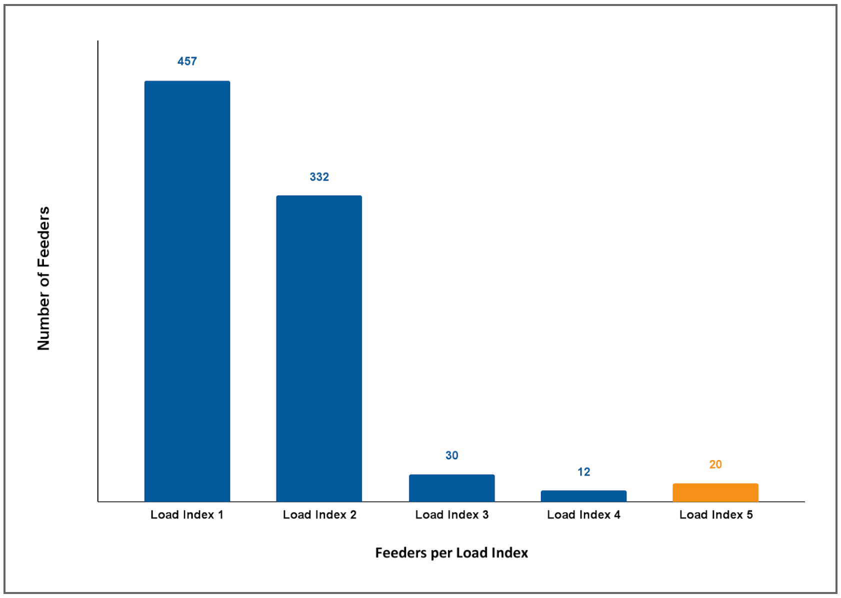
Load Index	Criteria	Explanation
5	x > 70% of Design Rating	Approaching thermal limit
4	x ≥ 100% of Planning Rating	Very heavily loaded, exceeding N-1 contingency
3	85% of Planning Rating ≤ x < 100% of Planning Rating	Heavily loaded, but within contingency
2	40% of Planning Rating ≤ x < 85% of Planning Rating	Moderately loaded
1	x < 40% of Planning Rating	Lightly loaded

Hydro Ottawa monitors the percentage of feeders with a load index of 4 and 5 to plan for feeder capacity upgrades and reliability improvement investments.

In 2023, 12 Hydro Ottawa feeders had a FLI of 4 and 19 feeders at a FLI of 5, as shown in Figure 70. Feeders must be maintained within the planning capacity to allow for efficient load transfer during N-1 contingency situations while respecting equipment ratings.

Feeders equal to or above 100% of their planning capacity (Load Index 4) limit the flexibility of the system to manage abnormal system states, including planned activities. Feeders operating at >70% of their design rating (Load Index 5) signal at approaching rated capacity and need some intervention to reduce the loading to be able to manage contingency scenarios.

1 **Figure 70 - 2023 Feeder Load Index**



2

3

4 The list of feeders with a FLI of 4 and 5 have been listed in Table 32 below.

1 **Table 32 - Feeders with Load Index 4 or 5**

Station	Voltage	Feeder	Planning Factor (%)	Design Factor (%)	Load Index
South March TS	44	A9M3	159%	79%	5
Jockvale DS	8.32	145F1	147%	73%	5
Parkwood Hills DS	8.32	190F5	146%	83%	5
Russell TS	13.2	5304	122%	73%	5
Nepean TS	44	22M27	117%	75%	5
Fallowfield MTS	27.6	FAL01	110%	75%	5
Cambrian MTS	27.6	CBNF5	108%	73%	5
Gladstone DS	4.16	UX03	80%	80%	5
Carling TS	13.2	TC4TM	79%	79%	5
Russell TS	13.2	TB2JP	79%	79%	5
Henderson DS	4.16	UN04	77%	77%	5
Carling TS	13.2	TC2TM	76%	76%	5
Florence DS	4.16	UF07	75%	75%	5
Carling TS	13.2	TC1TM	75%	75%	5
Carling TS	13.2	TC3TM	74%	74%	5
Bayswater DS	4.16	UJ07	72%	72%	5
Nepean DS	4.16	AB03	71%	71%	5
Bronson DS	4.16	SB02	71%	71%	5
Carling DS	4.16	SM12	70%	70%	5
Beckwith DS	27.6	BECKF2	105%	35%	5
Casselman DS	8.32	CAS-F2	168%	55%	4
Barrhaven DS	8.32	140F3	122%	67%	4
Startop DS	8.32	6F10	111%	61%	4
Parkwood Hills DS	8.32	190F2	109%	54%	4
Rideau Heights DS	8.32	180F4	109%	70%	4
Beaconhill DS	8.32	BCHF5	109%	60%	4
Casselman DS	8.32	CAS-F1	108%	36%	4
Richmond North DS	8.32	RHNF3	104%	31%	4
Centrepointe MTS	8.32	87F3	104%	51%	4
Hawthorne TS	44	48M2	103%	66%	4
Bridlewood MTS 8kV	8.32	BRDF6	102%	56%	4
Richmond North DS	8.32	RHNF2	102%	30%	4

9. SYSTEM CAPACITY ASSESSMENT

Hydro Ottawa's capacity planning process ensures that the distribution system is sufficiently sized to deliver reliable electricity to its expanding customer base. With growing energy demand and existing system constraints, Hydro Ottawa is focusing on powering the growing community by addressing the immediate and short-term needs over the 2026-2030 rate period. This requires immediate infrastructure investments aligned with long-term potential outcomes, promoting efficiency in capital deployment.

Hydro Ottawa's planning process takes into account existing and short-term system constraints, new developments, a rise in DERs, and a shift towards electrification informed by known large load requests. Other important drivers considered in the planning process are the need to build a more resilient grid to tackle climate change and its impacts to the distribution system, as detailed in Section 6.4.2 - Future Climate, and customer preferences evident through the engagement survey that supports making investments to further growth and electrification, for further details on the Customer Engagement Survey, see Schedule 1-4-1 - Customer Engagement Ongoing.

Transmission and distribution line availability is another key factor impacting system capacity. Transmission lines carry electricity from generating stations to substations, while distribution lines deliver power from substations to individual customers. If these lines are not adequate in number or capacity, they can limit the amount of electricity that can be delivered to customers. As described in Section 4 of Schedule 2-5-2 - Coordinated Planning with Third Parties, transmission assessment is led by the IESO through the IRRP Process. The current investment plan submitted through this application is in consultation with the IRRP working group and based on the needs assessment completed through the regional planning process. Plans will be revised, if necessary, based on the final IRRP report that is yet to be published.

Hydro Ottawa's System Capacity Assessment is a complex and technical process that analyzes large quantities of data from various sources to enable well-informed decisions about system upgrades and expansions, leveraging the planning forecast as its foundation. By investing in its electrical infrastructure, Hydro Ottawa can ensure that it has the capacity to meet the current needs of its customers by making prudent decisions to support the long term trajectory of the community.

This section describes Hydro Ottawa's capacity planning approach and is organized as follows:

- **Section 9.1:** Capacity Needs Assessment
- **Section 9.2:** Non-Wires Solutions to Address System Needs
- **Section 9.3:** System Capability Assessment for Renewable Energy Generation (REG) & DERs
- **Section 9.4:** Planning Load Forecasting

9.1. CAPACITY NEEDS ASSESSMENT

Hydro Ottawa utilizes the Planning Forecast, as detailed in Section 9.4 - Planning Load Forecasting, to assess and anticipate the immediate needs of the system. This forecast is then compared against established system limits and constraints to pinpoint areas requiring intervention. Identified issues are consolidated to develop a comprehensive and cohesive set of solutions. This section outlines the overall requirements to meet system capacity forecasts and the needs identification process, starting with determination of the immediate needs (by utilizing the Planning Forecast) and an evaluation of the medium to long-term requirements for efficient capital deployment (by utilizing the IRRP Forecast-as detailed in Section 9.4 - Planning Load Forecasting) followed by detailed assessment by planning region.

9.1.1. Overview

Table 33 summarizes the Wires and Non-Wires investment needs by planning region determined through the immediate and medium to long-term needs assessments.

1 **Table 33 - Investment Needs per Planning Region**

Planning Regions	Wire Solutions	Non-Wires Solutions (NWSs)	Capacity Addition (LTR-MVA)
44 kV	• A new 44 kV station (Hydro Road MTS) to cater to a specific need for the OC Transpo's Zero Emission Buses • Hydro One has plans to upgrade South March TS transformers due to end of life. Installing higher capacity transformers would aid in adding capacity to the region		171
South 28 kV	• Construction of a new 28 kV station (Greenbank MTS) to accommodate overloads in the 8 kV system and large load requests including the Regulatory and Science Main Project • Feeder integration plans for new station		120
South-East 28 kV	• Construction of a new station in the region along the 230 kV transmission corridor (Piperville MTS) to accommodate overloads and support future growth • Feeder integration plans for new station		120
East 28 kV	• With plans to decommission Bilberry TS and an Orleans feeder, a new 28 kV station is underway (Mer Bleue MTS) to manage existing load from Orleans TS and Bilberry TS • Cyrville MTS is proposed to be upgraded to support overload in the East 13 kV and East 8 kV regions and support large load requests including TerraCanada National Capital Area project • Feeder integration plans for new station		190
West 28 kV	• Additional transformer upgrade at Richmond South MTS to meet load requirements of the Department of National Defence Dwyer Hill Training Center • Upgrade and maintain transformer-level redundancy	Utility Owned Battery Storage	3
West 28 kV (North)	• Construction of a new 28 kV station to accommodate overloads and support future growth. • Feeder integration plans for new station	Non-Wires Customer Solutions Program	120 (plus NWCS: 10-15 MW)
West 13 kV	• Cable upgrades and remove equipment limitations at Hydro One stations - Carling TS • Slater TS upgrade completed • Conversion of Bronson[28] from 4 kV to 13 kV will help with capacity constraints and support Carling, Lisgar and Riverdale		150

[28] Conversion of Bronson is initiated in this 2026-2030 Rate Period but will only be energized in 2031.

Planning Regions	Wire Solutions	Non-Wires Solutions (NWSs)	Capacity Addition (LTR-MVA)
Core 13 kV	• Riverdale switchgear upgrade underway • Cable upgrades and remove equipment limitations at Hydro One stations - King Edward TS, Lisgar TS • Slater TS upgrade completed • Conversion of Bronson DS from 4 kV to 13 kV will help with capacity constraints and support Lisgar TS and Riverdale TS	Utility Owned Battery Storage Non-Wires Customer Solutions Program	63 (plus NWCS: 10-15 MW)
East 13 kV	• Hydro One has plans to upgrade Russell TS and Albion TS station transformers due to end of life • Installing higher capacity transformers would aid adding capacity to the region		68[29]
West 12 kV	• Strategic and phased voltage conversion		
Nepean 8 kV	• Voltage conversion of 8 kV to 28 kV in the long term supported by the new Greenbank station in the South 28 kV region		
Bells Corner/ Bayshore 8 kV	• None required	Utility Owned Battery Storage	8
Barrhaven 8 kV	• Voltage conversion of 8 kV to 28 kV in the long term supported by Cambrian MTS and the new Greenbank station in the South 28 kV region		
West 8 kV	• Voltage conversion of 8 kV to 28 kV in the long term		
Casselman 8 kV	• None required	Utility Owned Battery Storage	6
East 8 kV	• Voltage conversion of 8 kV to 28 kV in the long term supported by the station upgrades in the East 28 kV stations		
Central 4 kV	• Strategic and phased voltage conversion. Fisher DS is underway and Henderson DS will be initiated. • Strategic 4 kV-to-13 kV voltage conversion of Bronson DS		
East 4 kV	• Strategic and phased voltage conversion. Dagmar DS is underway. Church DS and Vaughan DS will be initiated		

In summary, to balance the need for increased capacity with affordability, Hydro Ottawa has identified areas for upgrades, including enhancing distribution infrastructure, building new stations, upgrading existing stations, utilizing NWSs, and implementing grid modernization initiatives. For new station

[29] Capacity added to the distribution system is driven by Hydro One investments.

capacity projects, please see further details in Section 2.3.2 of Schedule 2-5-8 - System Service Investments, Hydro Ottawa prioritized investments in areas with immediate, confirmed, and committed load requirements. Hydro Ottawa will continuously monitor the impact of electrification to minimize disruptions and ensure the ability to connect new customers.

9.1.2. Immediate Needs Assessment

This section details the assessment of currently overloaded stations and utilizes the Planning Forecast to outline planned investments critical for maintaining system reliability and accessibility required for initiation or completion within the 2026-2030 rate period.

As detailed in Section 8.4.1 - Station Capacity, the 2023 system peak demand assessment reveals ten[30] stations currently operating above planning capacity. To alleviate these constraints and accommodate existing committed loads, Hydro Ottawa is implementing the actions outlined in Table 34. Without these interventions, Hydro Ottawa would be unable to connect new customers and maintain station loading at or below planning levels.

These immediate needs are addressed through the MIPs, specifically Section 2 of Schedule 2-5-8 - System Service Investments and for the new stations, and feeder integration plans for those stations. Some distribution transfer projects may also be undertaken as part of Distribution Enhancements.

[30] Nine stations are operating above planning capacity and one is approaching design capacity.

Table 34 - Immediate System Needs

Planning Region	Need Criteria	Station	Planned Actions
44 kV	Existing Committed Load	Hydro Road MTS	• A new 44 kV station (Hydro Road MTS) to cater to a specific need for OC Transpo's Zero Emission Buses • Provides increased reliability to Hawthorne TS through feeder ties
East 28kV	Existing Committed Load	Cyrville MTS	• With plans to decommission Bilberry TS, a new 28 kV station is underway (Mer Bleue MTS) to manage existing load from Orleans TS and Bilberry TS • Cyrville MTS is proposed to be upgraded to support growth and large loads requests including the TerraCanada National Capital Area project • Distribution transfers to build redundancy and support growth in the East 8 kV system
West 28 kV	Existing Capacity Constraint + Committed Load	Janet King DS	• Utility Owned Battery Storage in the West 28 kV to support minor overloads • To support committed large load request from the Department of National Defence Dwyer Hill Training Center Upgrade, an additional transformer upgrade at the existing station to meet customer need and maintain transformer-level redundancy
		Beckwith DS	
West 28 kV (North)	Existing Capacity Constraint	Marchwood DS	• Construction of a new 28 kV station (Kanata North Station) to accommodate overloads and Kanata North Business developments
West 8 kV	Existing Capacity Constraint	Richmond North DS	• Managed through distribution transfers to build redundancy in the near term • Voltage conversion of 8 kV to 28 kV in the long term
South 28 kV	Existing Capacity Constraint + Committed Load	Fallowfield DS	• Construction of a new 28 kV station (Greenbank MTS) to accommodate overloads in the 8 kV system and large load requests such as the Regulatory and Security Science Main Project • Voltage conversion of 8 kV to 28 kV in the long term
Nepean 8 kV	Existing Capacity Constraint	Manordale DS	
		Centrepointe DS	
South-East 28 kV	Existing Capacity Constraint	Leitrim DS	• Construction of a new station (Piperville MTS) in the region along the 230 kV transmission corridor to accommodate overloads, residential growth and improved area reliability
East 4 kV	Existing Capacity Constraint	Church DS	• Strategic and phased voltage conversion removing limitations for connecting larger loads in the area. Dagmar DS is underway. Church DS and Vaughan DS will be initiated • Distribution transfers to build redundancy improving reliability
	Existing Capacity Constraint	Vaughan DS	

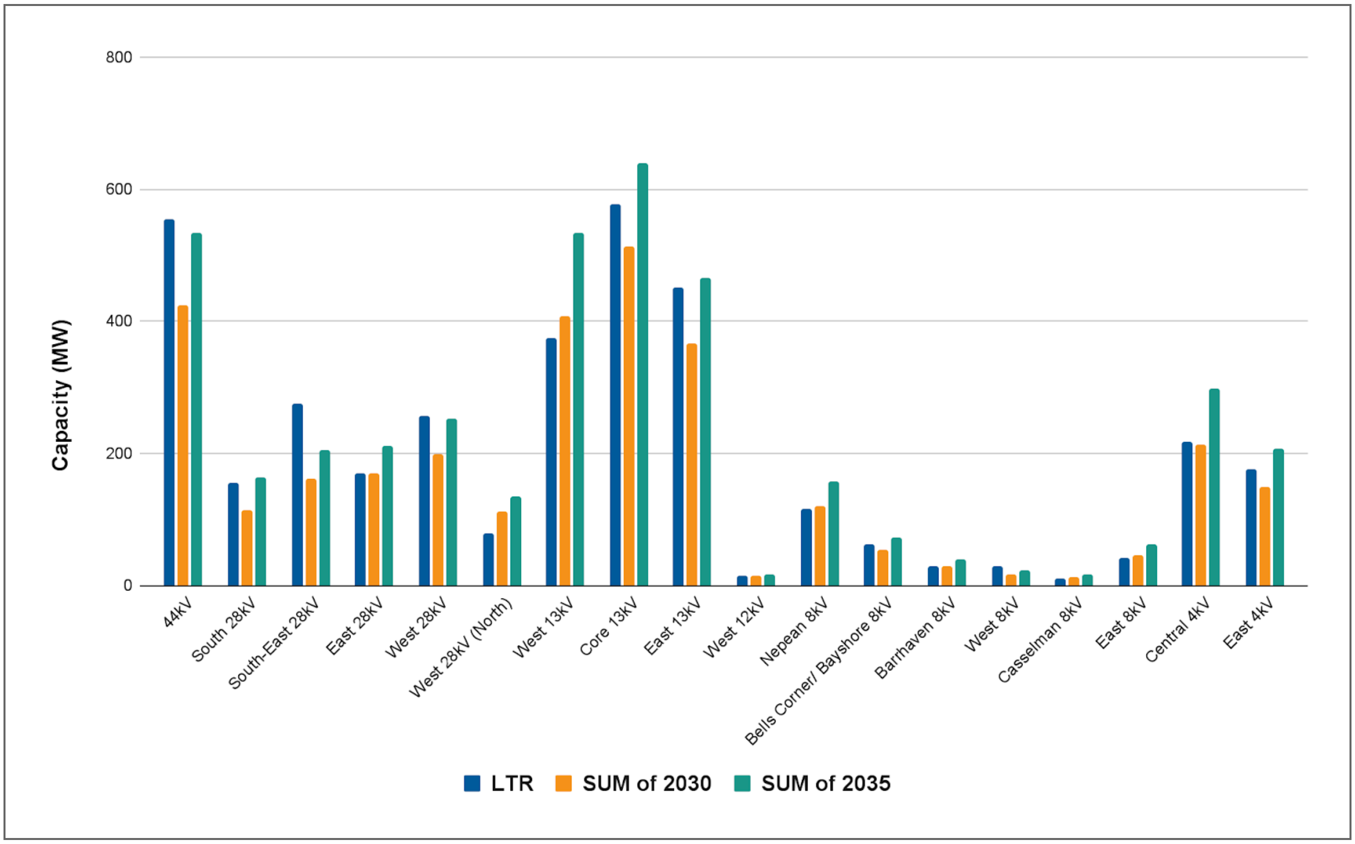
9.1.3. Medium and Long Term Needs Assessment

To proactively identify stations at risk of overload by 2030 and 2035 Hydro Ottawa analyzed the IRRP forecast in all regions, refer to Section 9.1.4 - Investments by Planning Region for the detailed region specific analysis. Given the four- to six-year lead time required for station upgrades and even longer lead times for transmission upgrades, focus on the medium to long-term outlook (beyond 2030) allows Hydro Ottawa to validate that capacity investments for immediate needs (informed through Hydro Ottawa’s planning forecast) strategically align with indications of long-term needs, ensuring efficient capital deployment and optimizing asset utilization.

To meet projected capacity needs by 2030, Hydro Ottawa will implement several measures, including distribution infrastructure enhancements, new station construction, existing station upgrades, NWSs, and grid modernization. New station projects are prioritized based on immediate, confirmed, and committed load requirements.

Hydro Ottawa's IRRP forecast shows that, even with the immediate planned actions undertaken, the system will not have enough capacity to meet the growing demand by 2035 in all planning regions. Figure 71 compares the megawatt (MW) forecast for 2030 and 2035 with current available capacity (including Piperville and Hydro Road Station) for the 18 planning regions considering both transmission and the downstream distribution-connected stations.

Figure 71 - 2030 & 2035 Forecast vs. Capacity



Out of the 18 planning regions, 7 will exceed the available capacity and 4 will be over 90% of available capacity by 2030. By 2035, 14 planning regions will exceed available capacity and 2 operating over 90% of available capacity when considering the IRRP forecast. Table 35 details the needs assessment for capacity increases required by 2030 and 2035, beyond the immediate needs outlined in Table 34.

1 **Table 35 - Needs Assessment 2030 and 2035**

Planning Region	Overload Capacity %:		Capacity Upgrade Needs
	2030	2035	
Barrhaven 8 kV	101%	137%	● Voltage conversion from 8 to 28kV to supply from the new Greenbank MTS
Bells Corner / Bayshore 8 kV	89%	118%	● Utility owned battery storage solutions for peak load management
Casselman 8 kV	113%	146%	● Utility owned battery storage solutions for peak load management
Central 4 kV	98%	137%	● Strategic and phased voltage conversion. Fisher AK is underway and Henderson UN will be initiated ● Distribution transfers to build redundancy ● Bronson SB is proposed to be upgraded to 13 kV to support growth in the West 13 kV region including projects like the Ottawa Hospital's New Campus
Core 13 kV	89%	111%	● Riverdale switchgear upgrade underway ● Cable upgrades and remove equipment limitations at Hydro One stations- King Edward TS, Lisgar TS to support growth related to the transit oriented developments and electrification growth ● Slater TS upgrade completed ● Conversion of Bronson DS from 4 kV to 13 kV will help with capacity constraints and support Carling TS, Lisgar TS and Riverdale TS. Although energization is beyond 2030, construction needs to start in this Rate App to meet forecasted demand ● Utility Owned Battery Storage for peak load management
East 8 kV	114%	152%	● Voltage conversion from 8 to 28kV to supply from the new upgraded Cyrville MTS or new Mer Bleue MTS
East 13 kV	81%	103%	● Hydro One has plans to upgrade Russell TS and Albion TS station transformers due to end of life which will add additional capacity to the region ● Distribution transfers to build redundancy
West 12 kV	95%	120%	● Strategic and phased voltage conversion
West 13 kV	109%	142%	● Cable upgrades and remove equipment limitations at Hydro One stations- Carling TS to support the Ottawa Hospital New Campus ● Slater TS upgrade completed ● Conversion of Bronson DS from 4 kV to 13 kV will help with capacity constraints and support Carling TS, Lisgar TS and Riverdale TS including projects like the Ottawa Hospital's New Campus

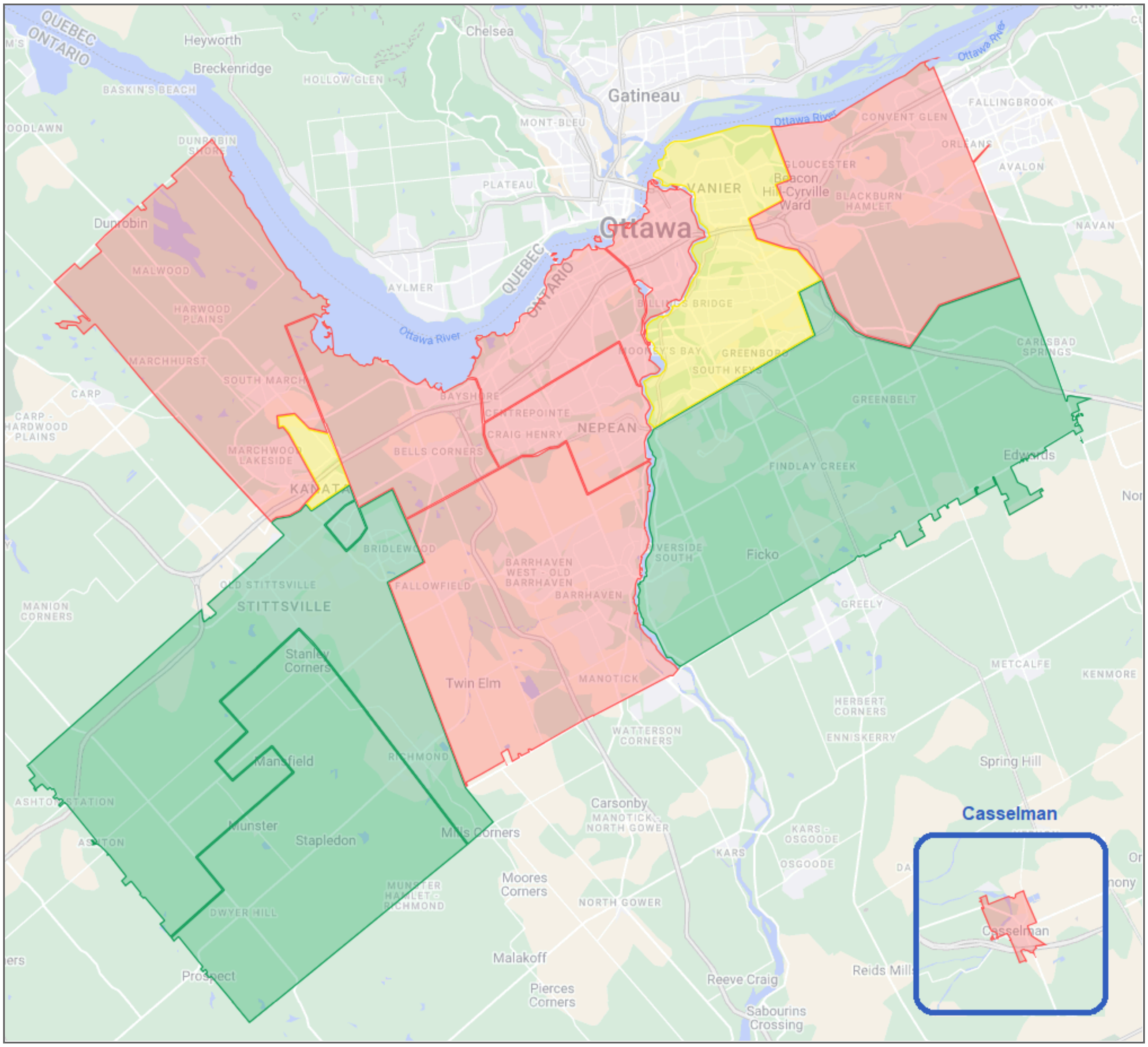
In conclusion, capacity investments identified through the immediate needs assessment as in Section 9.1.2 - Immediate Needs Assessment are efficiently sized to meet projected needs through 2035, maximizing long-term efficiency, as each new station is expected to remain in service for at least 50 years. The incremental cost of appropriately sizing infrastructure for the long term ensures efficient capital deployment and avoids premature rebuilding.

9.1.4. Investments by Planning Region

Hydro Ottawa's distribution system comprises several subsystems, or planning regions, segmented by operating voltage and geographic boundaries, typically aligned with pre-amalgamation utility demarcations as described in Section 6.2.3 - Planning Regions. Detailed summaries of each planning region follow.

Figure 72 visually represents capacity constraints in each of the planning regions based on the IRRP forecast. Red-highlighted regions indicate the highest concern, with projected loads exceeding planning limits within five years (by 2030). Yellow-highlighted regions represent moderate concern, with limits expected to be exceeded within five to ten years (2035). Green-highlighted regions are of least concern, not projected to exceed limits within ten years.

Figure 72 - Heatmap of Capacity Needs



In each of the planning region sub-sections below, there is first a figure of the region and then a second figure to assess the regional needs, which charts the historical weather normalized actuals (trend highlighted in green), Hydro Ottawa planning forecast (trend highlighted in blue), and the

IRRP forecast (trend highlighted in orange) and load inquiries received to date (trend highlighted in purple) over the Rate Application period.

9.1.4.1. 44 kV System

The 44kV system covers Hydro Ottawa's entire service area (excluding Casselman), fed by three stations: Hawthorne TS, Nepean TS, and South March TS.

This system serves numerous large commercial and industrial customers, as well as downstream 8kV, 12kV and 28kV distribution stations. Figure 73 shows the locations and supply areas of the 44kV stations. South March TS supplies the west, Nepean TS supplies the south, and Hawthorne TS supplies the east. There are distribution ties between South March TS and Nepean TS feeders, as well as between Nepean TS and Hawthorne TS feeders.

Figure 73 - 44kV Supply Region

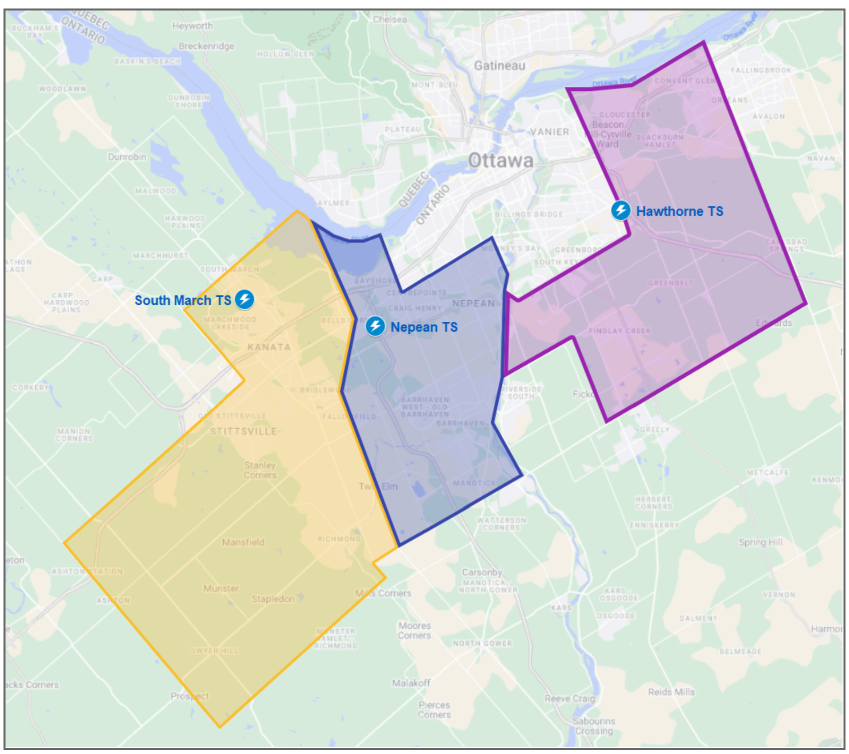
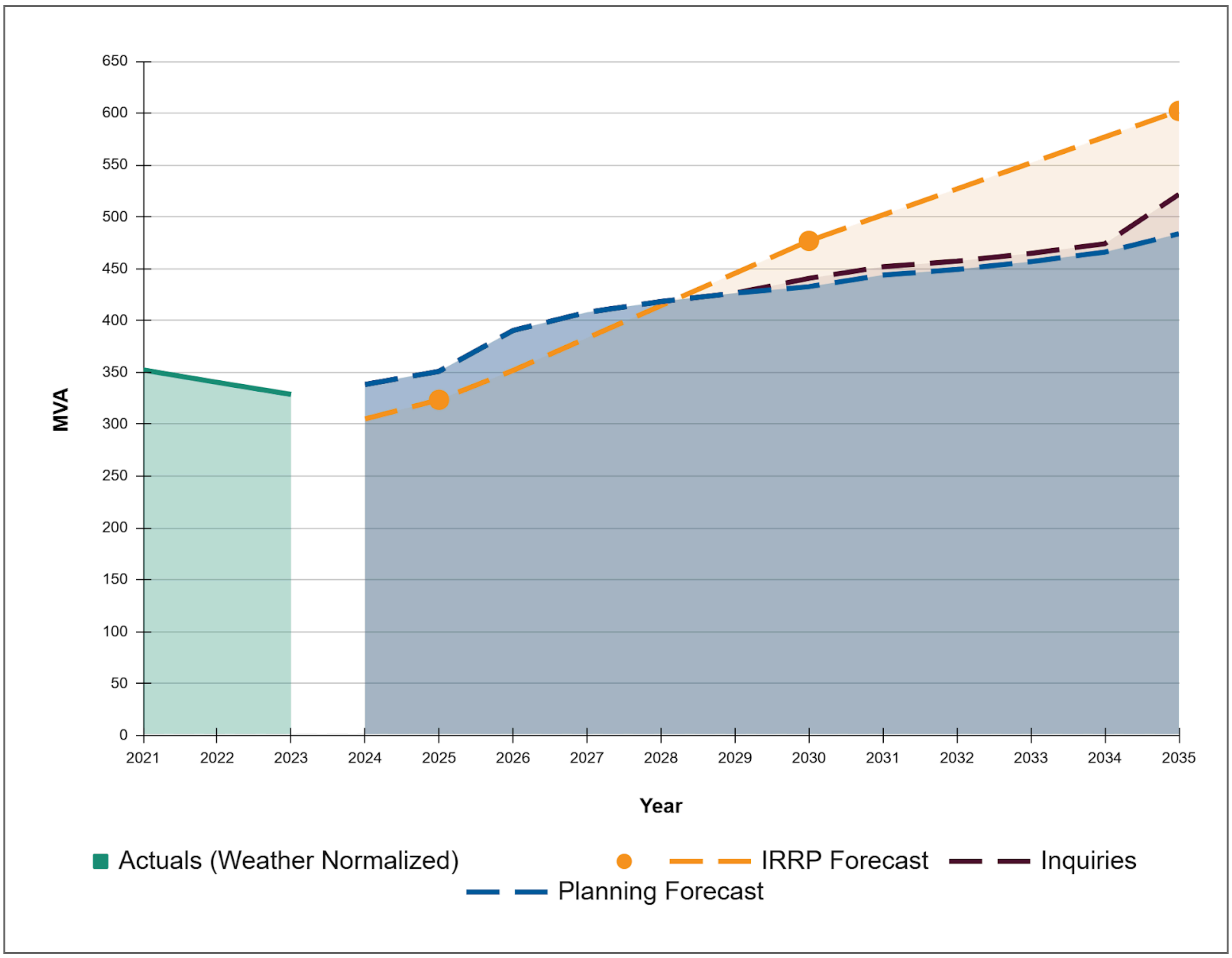


Figure 74 shows the weather normalized actuals, planning forecast, the IRRP forecast and customer inquiries in planning stages for the 44kV region out to 2035. There are some factors that will reduce this region's load in the coming years mainly due to voltage conversions from the 8kV and 12kV system to the 28kV system and with the planned energization of Piperville TS in 2026, some load will be transferred from Leitrim TS, reducing Hawthorne's total load. However, with natural load growth on the remaining connected 8kV stations and forecasted growth and electrification in the region, the overall region load is expected to increase.

Figure 74 - 44kV Planning Forecast and IRRP Forecast



Investments that will increase the capacity of the 44kV region are listed below:

- **South March TS Upgrade (Hydro One Investment)**
  The South March TS's two 230kV/44kV transformers, commissioned in 1971, need to be replaced due to their asset condition. Given the forecasted developments on the connected stations and overall system electrification that is expected, increasing the transformer capacity is required to meet the long-term demand forecast.
- **New Hydro Road Station (System Access - System Expansion)**
  To support a large load request (OC Transpo's Zero Emission Buses[31]), Hydro Ottawa is constructing a 100 MVA, 230kV to 44kV substation with six feeders, scheduled to be energized in 2027. For more details on the need and justification of this investment please refer to Section 4 of Schedule 2-5-6 - System Access Investments.

These investments align with the Needs Assessments conducted by the IRRP working group as part of the regional planning process, please refer to Section 4 of Schedule 2-5-2 - Coordinated Planning with Third Parties.

[31] Ottawa-Carleton Transportation, "Zero-Emission Bus," https://www.octranspo.com/en/our-services/vehicles/zero-emission-bus/

9.1.4.2. 28 kV System

Hydro Ottawa's 28kV supply system is comprised of five main areas:

1. South 28kV System
2. South-East 28kV System
3. East 28kV System
4. West 28kV System
5. West 28kV (North) System

9.1.4.2.1. South 28kV

The South 28kV supply region, as shown in Figure 75, covers the areas of Nepean south of the Greenbelt. It is supplied by Fallowfield MTS, Longfields DS, Limebank MTS, and Cambrian MTS. Despite the physical barrier of the river between Nepean and Gloucester, Limebank station plays an essential role in supplying both sides of the river, making it one integrated supply region.

Figure 75 - South 28kV Supply Region

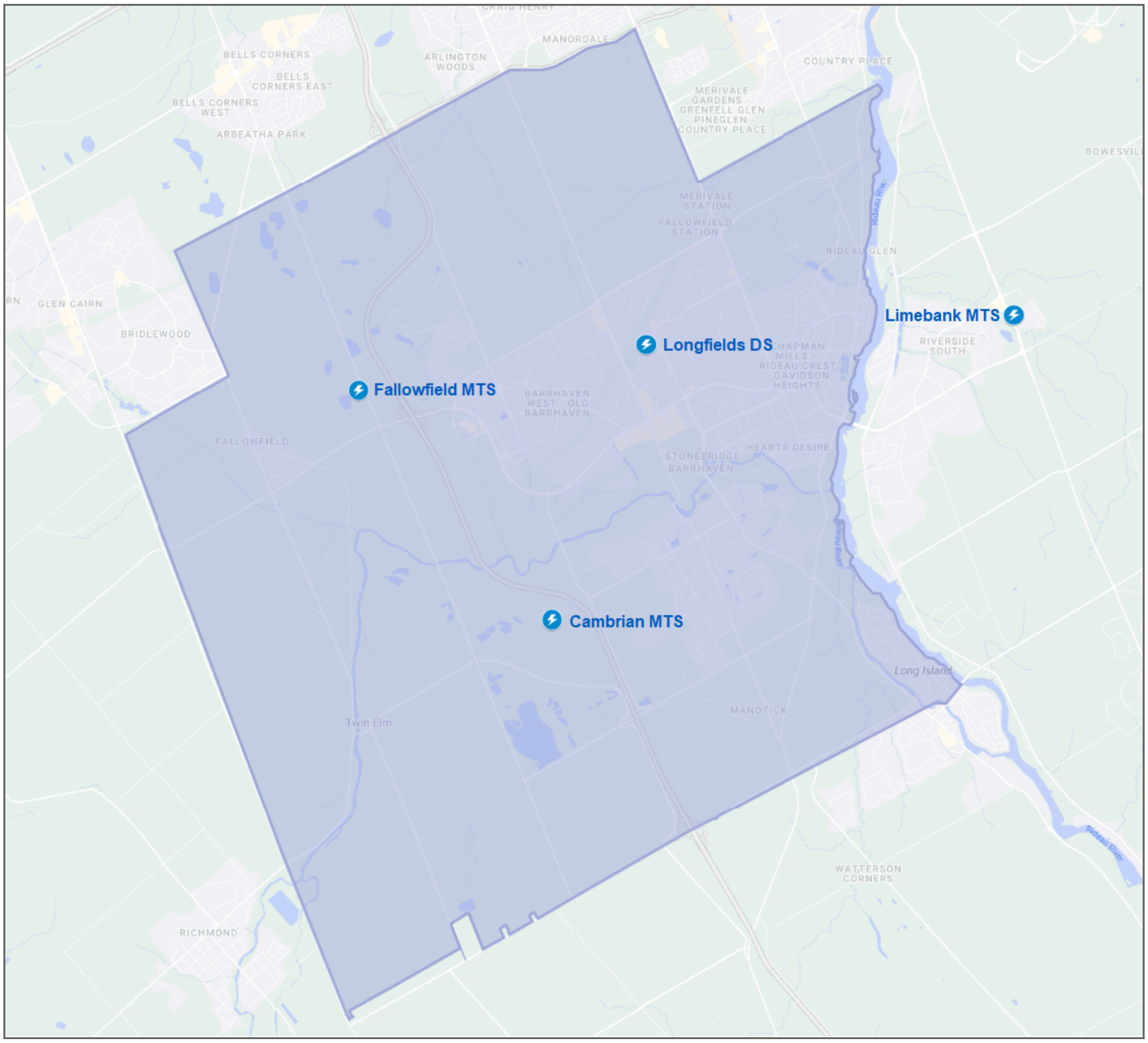
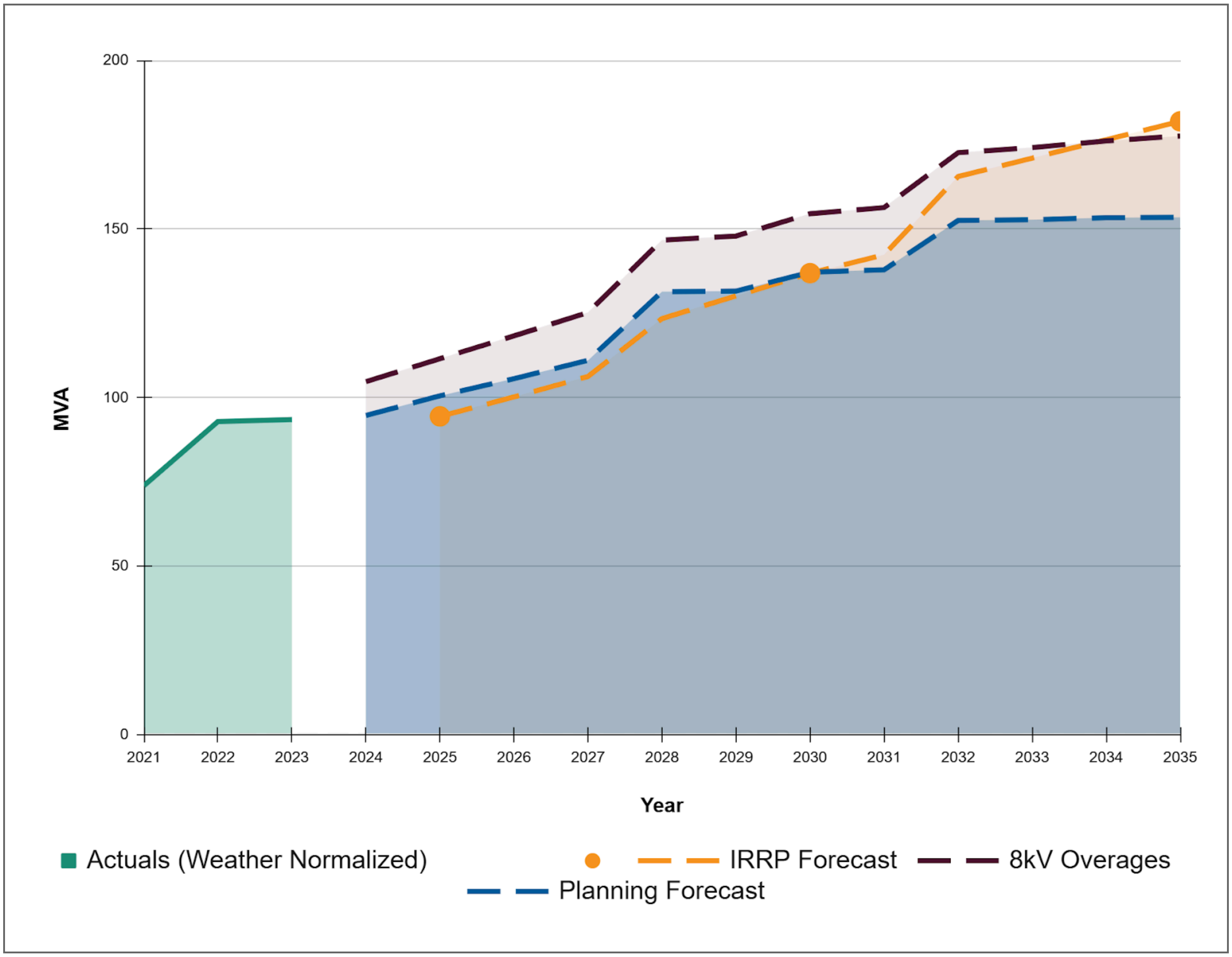


Figure 76 shows the weather normalized actuals, the planning forecast, the IRRP forecast and the new loads to be transferred from 8 kV overloaded stations, which represent the 28 kV Planning Forecast plus the additional capacity needed to address the overloaded 8 kV system for the region out to 2035.

Figure 76 - South 28kV Planning Forecast and IRRP Forecast



Energizing Cambrian MTS in 2022 has relieved the immediate capacity constraints just in time for Fallowfield MTS to reach its rated capacity in 2021. The increase in the South 28kV region's load between 2021 and 2023 can be explained by the transfer of load from Limebank MTS. Limebank MTS forms part of the South-East 28kV region and supported the South 28kV region while Cambrian MTS was being built; as such, post-energization, this load was transferred back to Cambrian MTS. The region is anticipating a large load request,[32] a laboratory facility staging major energizations in 2028 and 2032.

New Greenbank MTS (System Service-Capacity Upgrade)

A new 230 kV-connected 28 kV station with 100 MVA capacity and eight new feeders is proposed in the South 28kV region. This station is scheduled to be energized in 2028. For more details on the need and justification of this investment please refer to Section 2.3.2.1 of Schedule 2-5-8 System Service Investments.

This capacity upgrade aligns with the Needs Assessments completed by the IRRP working group as part of the regional planning process, please refer to Section 4 of Schedule 2-5-2 - Coordinated Planning with Third Parties. A comprehensive transmission supply evaluation, conducted with Hydro One and the IESO through the regional planning process, will determine the most feasible and reliable power delivery option for the new substation.

[32] Government of Canada, "Government of Canada invests in laboratories to support science in Canada." https://www.canada.ca/en/public-services-procurement/news/2024/03/

9.1.4.2.2. South-East 28kV System

The South-East 28kV supply region, encompassing southern Gloucester, is supplied by Limebank MTS, Uplands MTS, and Leitrim DS, as shown in Figure 77. Although geographically separated from Nepean by the river, Limebank MTS is crucial for supplying both areas, creating interdependence between the South 28kV and the South-East 28kV systems.

Figure 77 - South East 28kV Supply Region

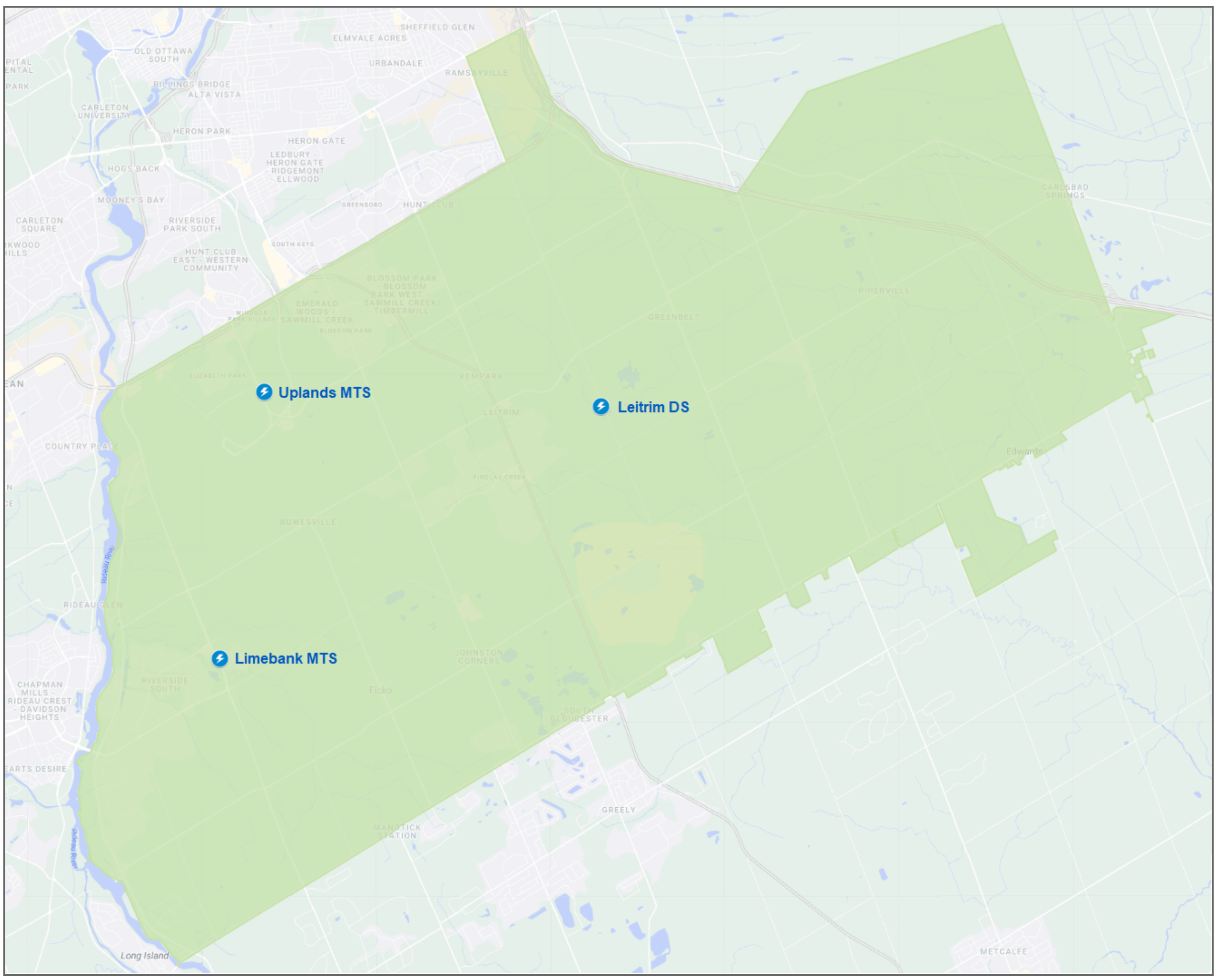
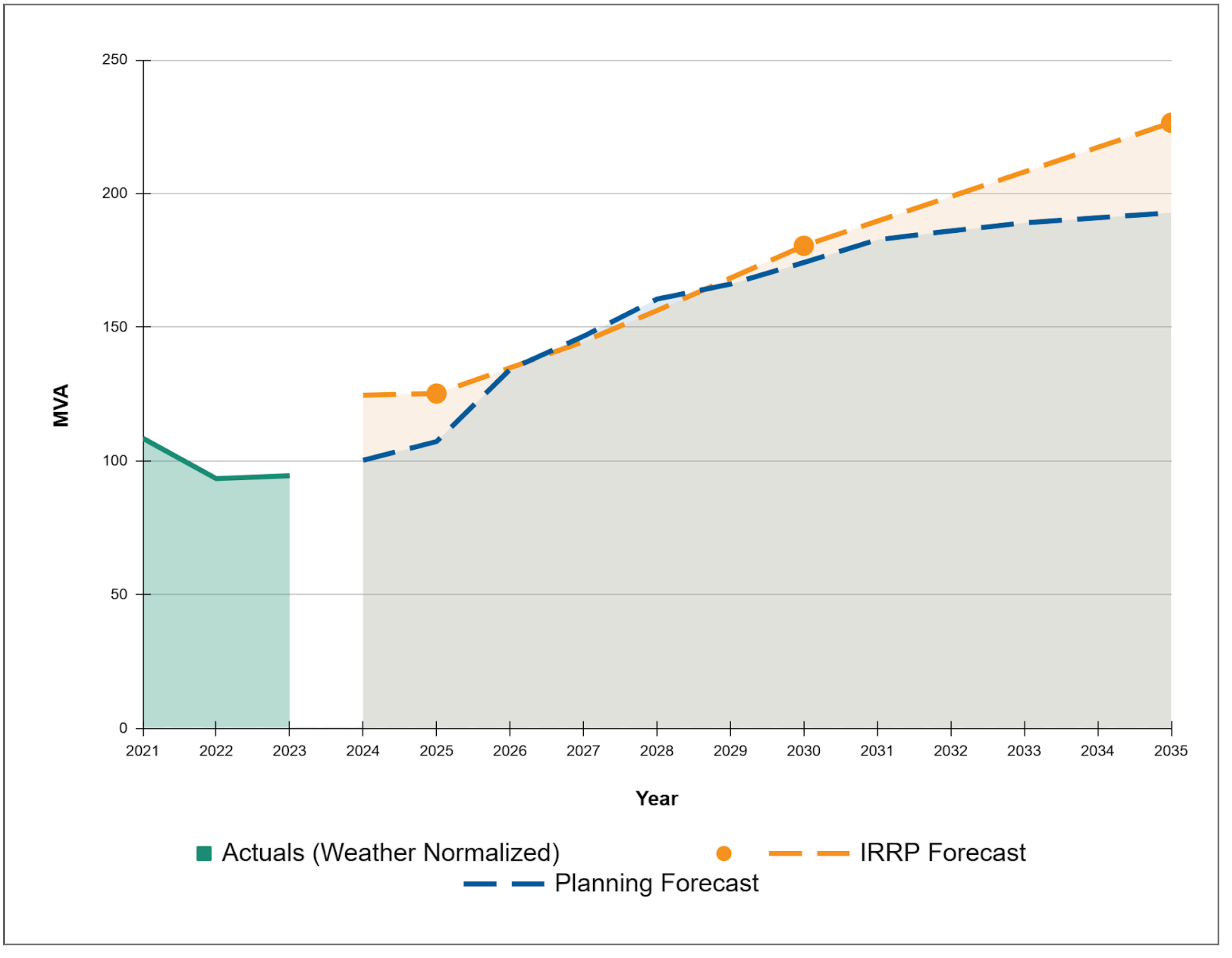


Figure 78 shows the weather normalized actuals, the planning forecast and the IRRP forecast for the region out to 2035.

Figure 78 - South East 28kV Planning Forecast and IRRP Forecast



New Piperville MTS (System Service-Capacity Upgrade)

To accommodate growing load forecast in the South-East region, shown in Figure 78, the new Piperville MTS is under construction, with planned energization in 2026. This project, approved as part of the 2021-2025 Rate Application, will be a 230kV-connected station with two 100 MVA transformers and capacity for eight new feeders. For more details on the need and justification of this investment please refer to Section 2.3.2.1 of Schedule 2-5-8 - System Service Investments.

This capacity upgrade investment is consistent with the Needs Assessments conducted by the IRRP working group as part of the regional planning process, please refer to Section 4 of Schedule 2-5-2 - Coordinated Planning with Third Parties. A comprehensive transmission supply evaluation, in collaboration with Hydro One and the IESO, was completed to determine the most feasible and reliable power delivery solution for Piperville MTS, ensuring its optimal operation.

9.1.4.2.3. East 28kV System

The East 28kV supply region is defined by the former Gloucester and Ottawa municipal boundary and Highway 417 to the south. The region is supplied by transmission-connected 28kV stations Cyrville MTS, Bilberry TS, Orleans TS, and Moulton MTS, as shown in Figure 79. Hydro Ottawa also owns a single 28kV circuit from Hydro One's Orleans TS station, which supports the region.

Figure 79 - East 28kV Supply Region

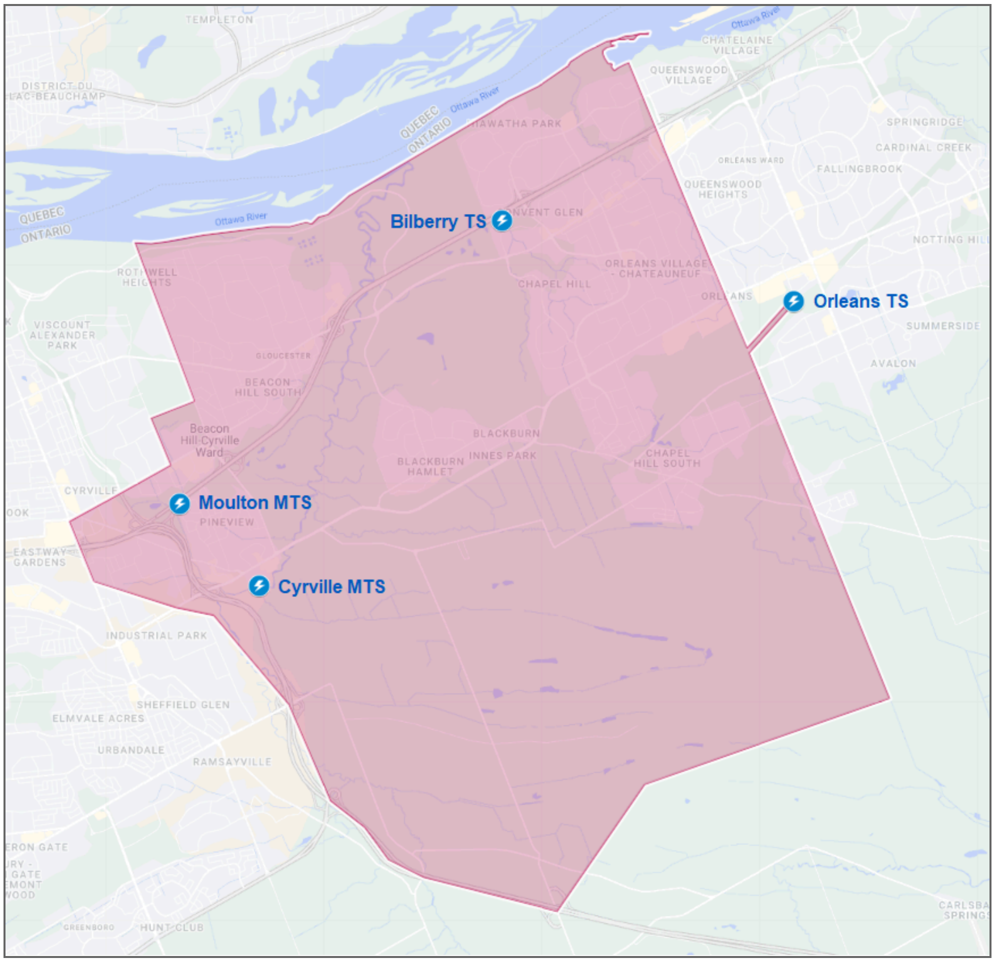
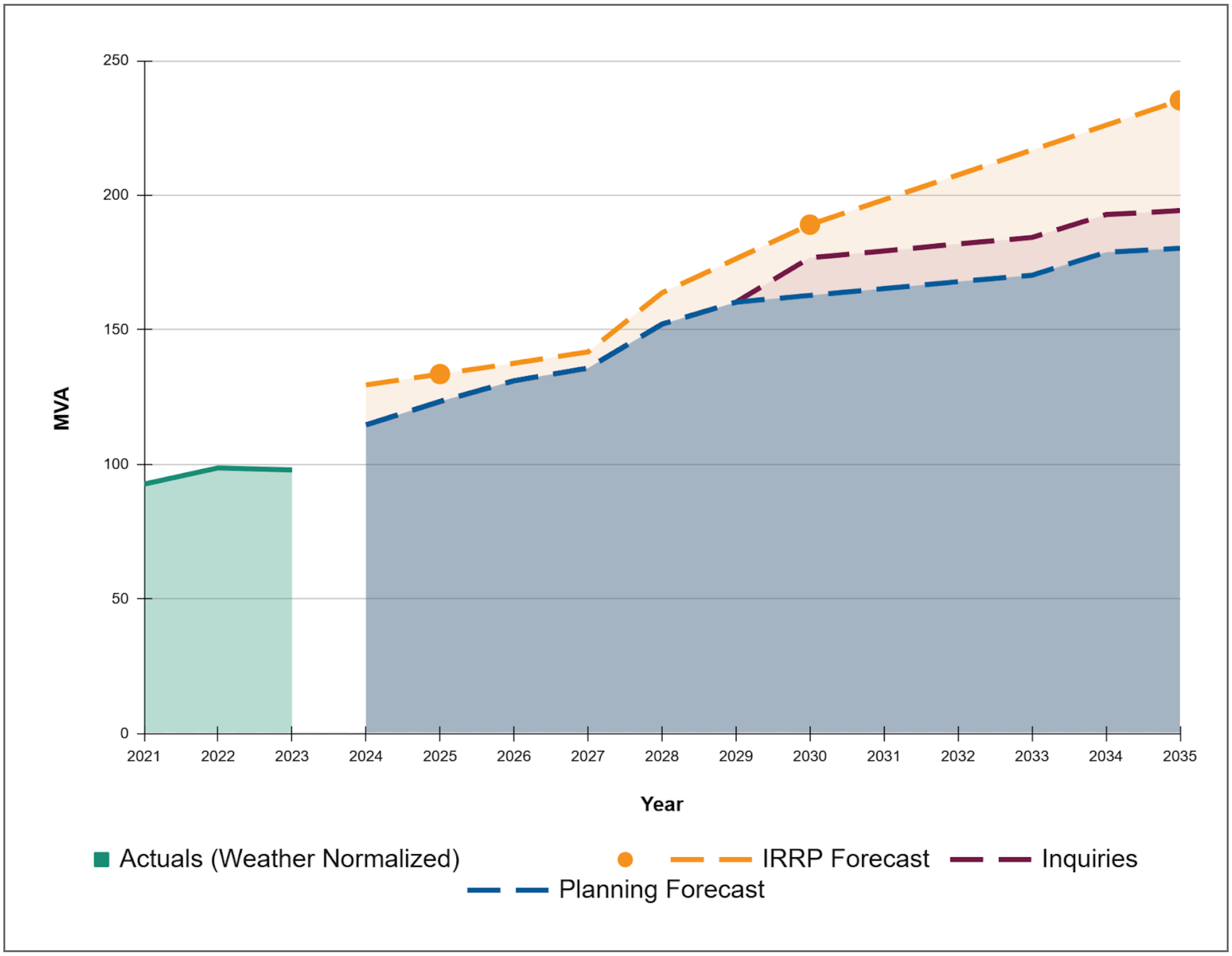


Figure 80 illustrates the weather normalized actuals, the planning forecast, the IRRP forecast and customer inquiries in planning stages for the region out to 2035.

Figure 80 - East 28kV Planning Forecast and IRRP Forecast



New Mer Bleue MTS (System Service-Capacity Upgrade)

Hydro Ottawa will energize a new station in 2028, Mer Bleue MTS. The station will include two 100 MVA transformers and eight feeders. For more details on the need and justification of this investment please refer to Section 2.3.2.1 of Schedule 2-5-8 - System Service Investments.

This capacity upgrade investment is consistent with the Needs Assessments by the IRRP working group as part of the regional planning process, please refer to Section 4 of Schedule 2-5-2 -

Coordinated Planning with Third Parties. A joint transmission supply evaluation with Hydro One and the IESO through the regional planning process is underway to determine the most feasible and reliable power delivery option for Mer Bleue MTS.

Cyrville MTS Upgrade (System Service-Capacity Upgrade)

The existing Cyrville MTS is proposed to be upgraded by replacing two existing 50 MVA transformers with 100 MVA by 2028 to cater to a large load request.[33] For more details on the need and justification of this investment please refer to Section 2.3.2.1 of Schedule 2-5-8 - System Service Investments.

This capacity upgrade aligns with the IRRP working group Needs Assessments as part of the regional planning process. A comprehensive transmission supply evaluation, conducted with Hydro One and the IESO, will determine the most feasible and reliable power delivery solution for the upgraded Cyrville MTS.

9.1.4.2.4. West 28kV System

The West 28kV supply region encompasses the majority of Kanata South, most of the township of Stittsville, and the western region of Goulbourn. These areas are supplied by Bridlewood MTS and Terry Fox MTS in Kanata South, Janet King DS in Stittsville, and the BECK-F2 feeder, supplied from Hydro One-owned Beckwith DS, in Goulbourn, as shown in Figure 81. Upon completion, the upgraded Richmond South MTS will provide 28kV supply to the Richmond area, which is currently supplied at 8kV.

[33] Government of Canada,"Government of Canada announces milestones for new science facilities in National Capital Area" https://www.canada.ca/en/public-services-procurement/news/2024/07/government-of-canada-announces-milestones-for-new-science-facilities-in-national-capital-area.html

Figure 81 - West 28kV Supply Region

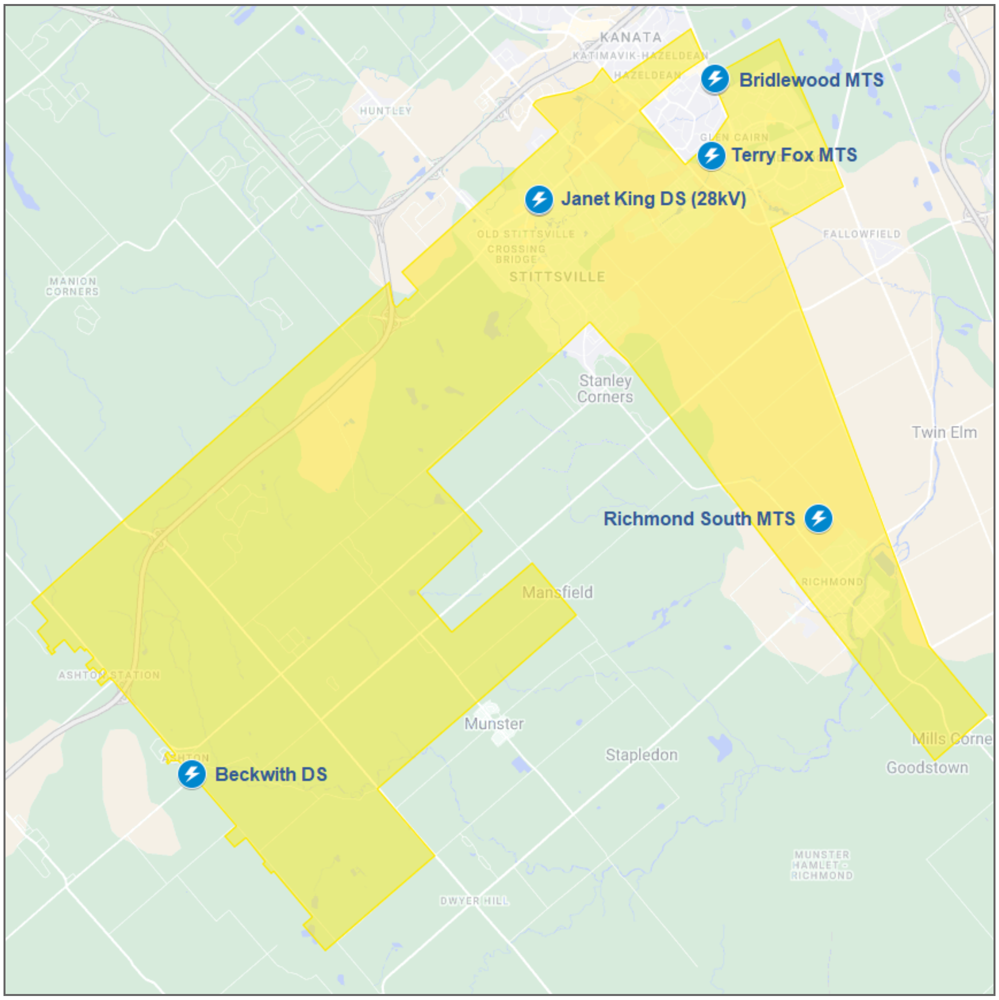
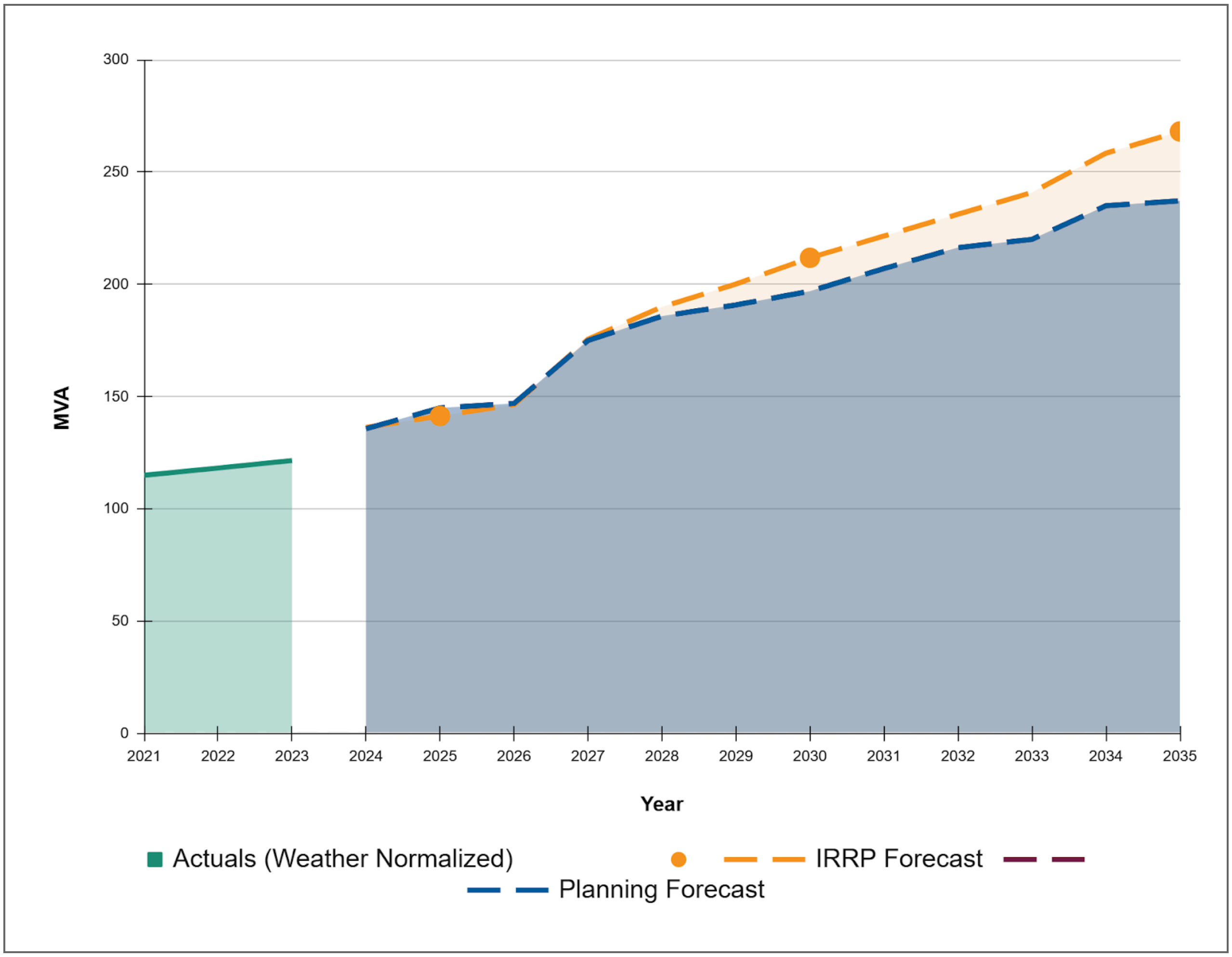


Figure 82 the weather normalized actuals, the planning forecast and the IRRP forecast for the region out to 2035. primarily due to the large load from the Department of National Defence in this area, coupled with ongoing electrification and development projects.

Figure 82 - West 28kV Planning Forecast and IRRP Forecast



Richmond South MTS Station Upgrade (System Access - System Expansion)

The Richmond South MTS station upgrade and feeders expansion addresses a large load request from the Department of National Defence.[34] For more details on the need and justification of this investment please refer to Section 4.3.2 of Schedule 2-5-6 - System Access Investments.

[34] Department of Nation Defence, "Minister Anand announces $1.4 billion investment to upgrade Dwyer Hill Training Centre infrastructure," https://www.canada.ca/en/department-national-defence/news/2023/03/

Non-Wires Solutions

A 2.5MW utility owned BESS is being proposed for this region. For more details on the need and justification of these solutions refer to Section 2.3.2.3 of Schedule 2-5-8 - System Service Investments.

9.1.4.2.5. West 28kV (North) System

The West 28kV (North) region encompasses the areas supplied by Kanata MTS and Marchwood MTS, both located at the Station Road site in Kanata North, as shown in Figure 83.

Figure 83 - West 28kV (North) Supply Region

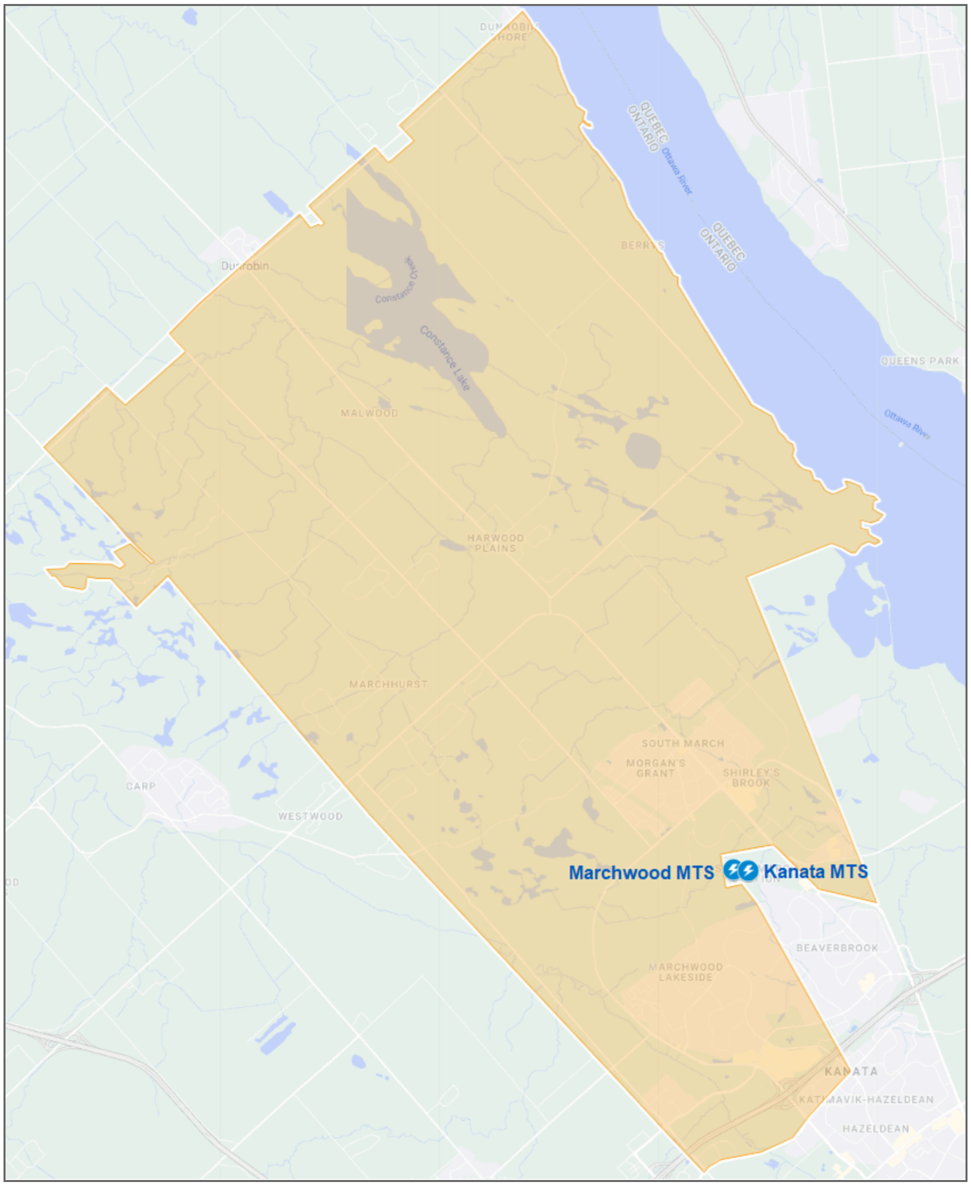
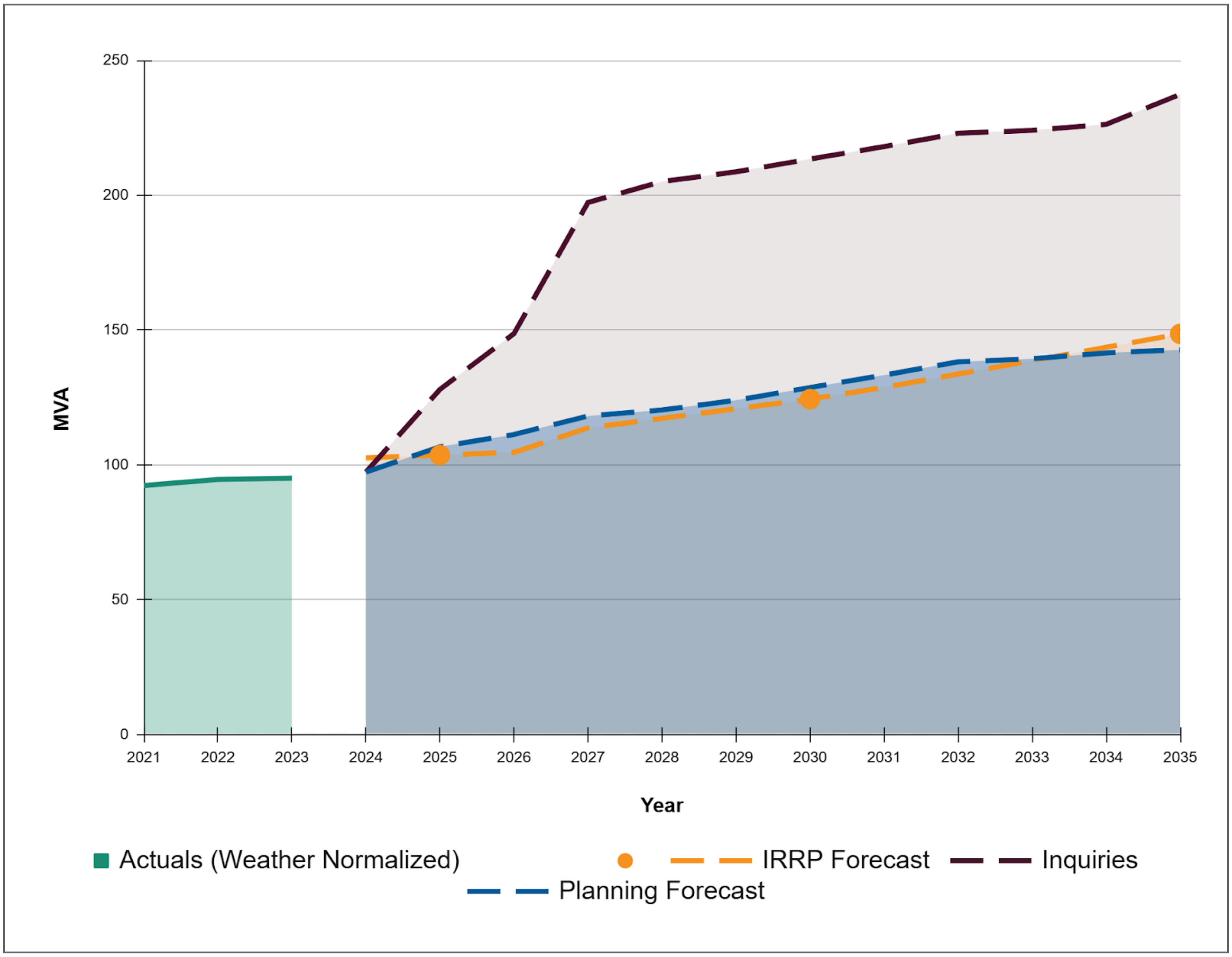


Figure 84 shows the weather normalized actuals, planning forecast, the IRRP forecast and customer inquiries in planning stages for the region out to 2035.

Figure 84 - West 28kV (North) Planning Forecast and IRRP Forecast



Since completing the planning forecast, Hydro Ottawa has seen increased data center connection requests in the region. While increased data center load is expected, market uncertainty exists regarding grid connectivity versus on-site generation and load growth within the service territory. Given these uncertainties, Hydro Ottawa will continue to monitor and assess the need as the market evolves.

New Kanata North MTS (System Service-Capacity Upgrade)

A new 230 kV-connected 28 kV station with 100 MVA capacity and eight new feeders is proposed in the West 28kV (North) region. This station is scheduled to be energized in 2028. For more details on the need and justification of this investment please refer to Section 2.3.2.1 of Schedule 2-5-8 - System Service Investments.

This investment aligns with the Needs Assessments completed by the IRRP working group as part of the regional planning process, please refer to Section 4 of Schedule 2-5-2 - Coordinated Planning with Third Parties. A joint transmission supply evaluation with Hydro One and the IESO through the regional planning process is underway to determine the optimal power delivery solution.

Non-Wires Solutions

Non-Wires Customer Solutions are being evaluated to provide peak demand support as an interim measure to manage capacity constraints. For more details on the need and justification of these solutions refer to Section 2.3.2.3 of Schedule 2-5-8 - System Service Investments.

9.1.4.3. 8 kV System

Hydro Ottawa 8kV supply system is comprised of five main regions:

1. Nepean 8kV
2. Bells Corners/Bayshore 8kV
3. Barrhaven 8kV
4. West 8kV
5. Casselman 8kV
6. East 8kV

Of the twenty-three 8kV stations, five are supplied by the 115kV transmission system, one is supplied by both 44kV and 115kV sources, and the remaining seventeen are supplied from 44kV.

9.1.4.3.1. Nepean 8kV System

The Nepean 8kV supply region includes the northern portions of Nepean. This region is supplied by the Manordale MTS, Centrepointe MTS, Woodroffe DS, Epworth MTS, Merivale MTS, Parkwood Hills DS, Borden Farms DS, and Rideau Heights DS. Figure 85 shows the supply region of the Nepean Core 8kV System.

Figure 85 - Nepean 8kV Supply Region

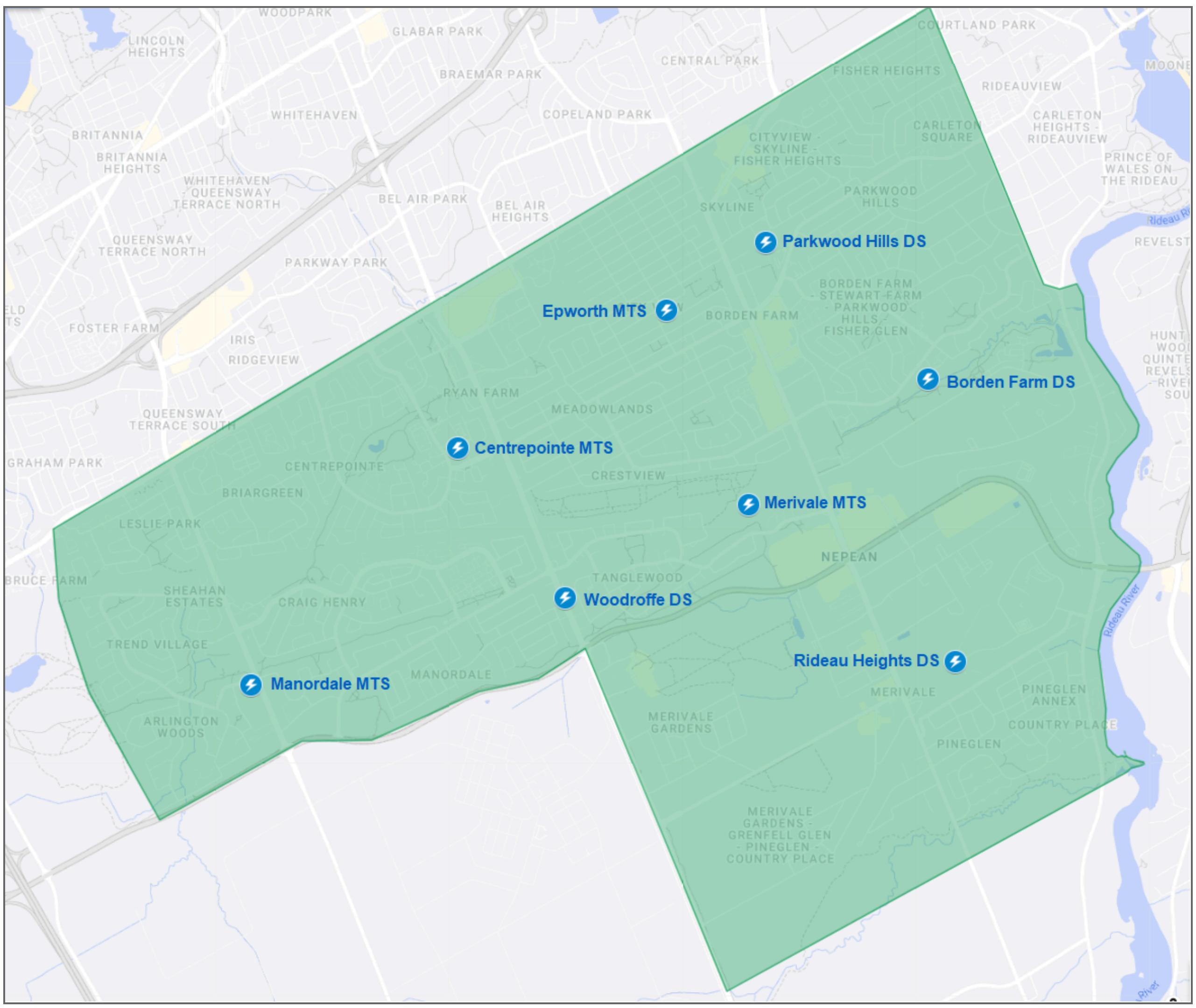
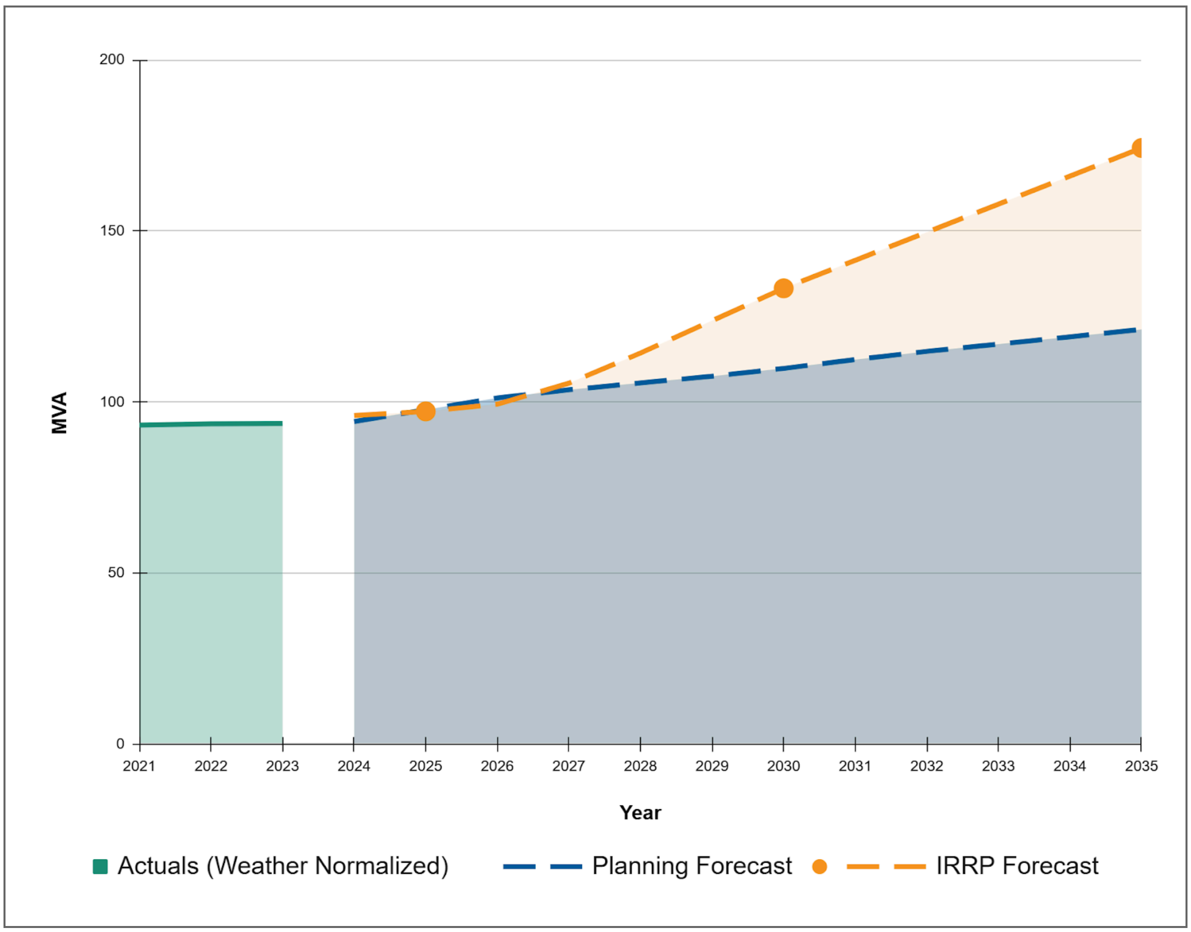


Figure 86 shows the weather normalized actuals, the planning forecast and the IRRP forecast for the region out to 2035. Centrepointe MTS and Manordale MTS in this region are exceeding their planning capacity ratings, as noted in Table 29 above. Growth is concentrated in the Nepean employment area, where trunk feeders are at or nearing their capacity limits and existing feeder interconnections are limited. Several feeders in this region have exceeded their planning capacity, as noted in Table 32 above.

Figure 86 - Nepean 8kV Planning Forecast and IRRP Forecast



Switching operations were performed on Parkwood Hills DS feeders in 2024 to reduce overloaded feeders below planning capacity. Similar switching operations are planned for the Borden Farm DS feeder. Rideau Heights DS has limited ties options, making load transfers difficult.

- The 8 kV system presents several challenges:
  - Compared to 28 kV, 8 kV is less efficient for long-distance power distribution, leading to greater losses and voltage drop issues beyond approximately 5km, while 28 kV remains effective up to 15km.
  - The maximum capacity of an 8 kV feeder is 3.6MVA, versus 16.4MVA for a 28 kV feeder, significantly limiting the ability to accommodate the large load requests.
  - Heavy loading on the 8 kV stations in the Nepean and Barrhaven regions is hindering new customer connections.

The new Greenbank MTS expected to energize in 2028 will support the growth in this region, please see further details in Section 2.3.2.1 of Schedule 2-5-8 - System Service Investments.

9.1.4.3.2. Bells Corners/Bayshore 8kV System

The Bells Corners/Bayshore 8kV supply region covers the northwest portion of Nepean. This region is supplied by Bayshore DS, Queensway-Carleton Hospital (Q.C.H) DS, Stafford Road DS, and Bells Corners DS, as shown in Figure 87.

Figure 87 - Bells Corners/Bayshore 8kV Supply Region

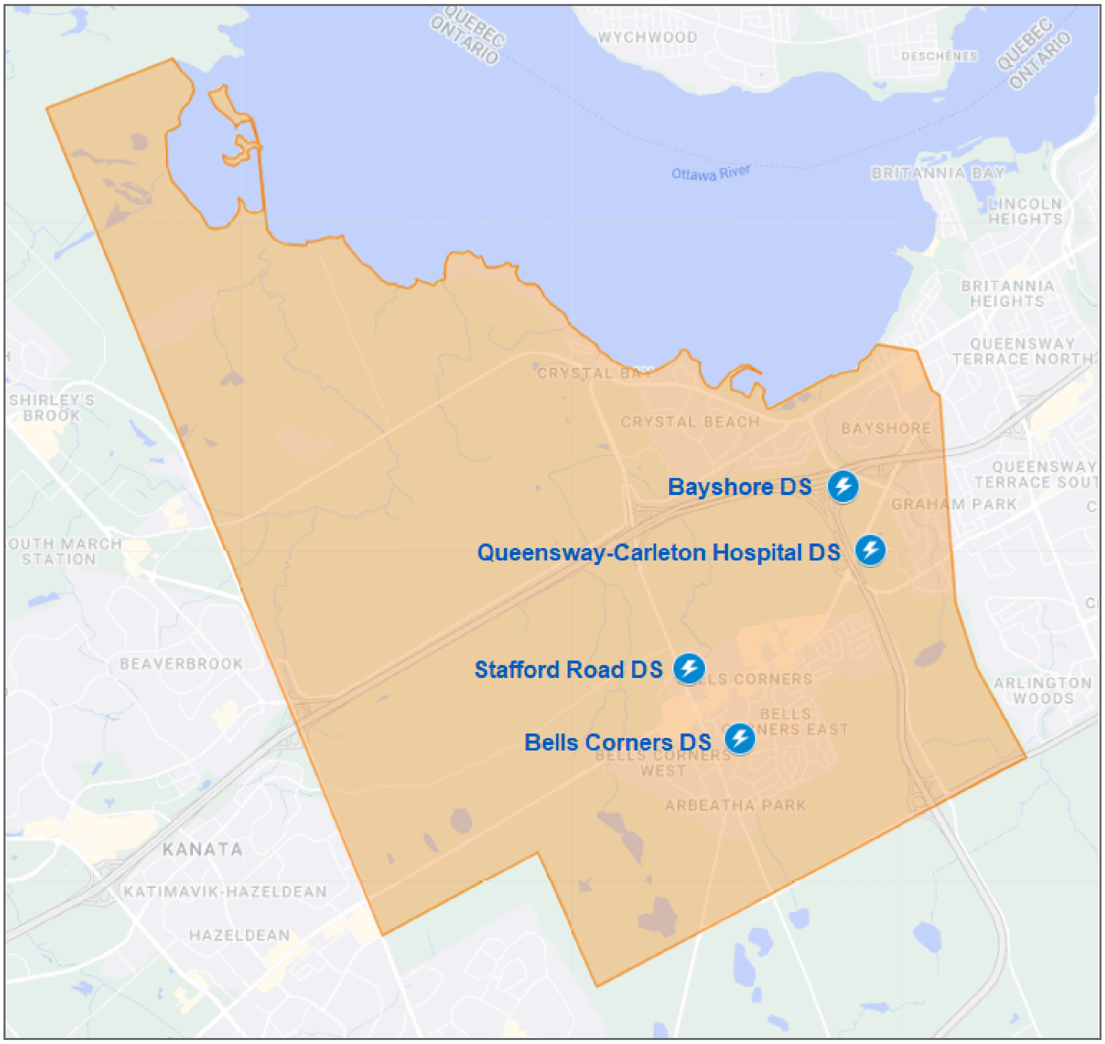
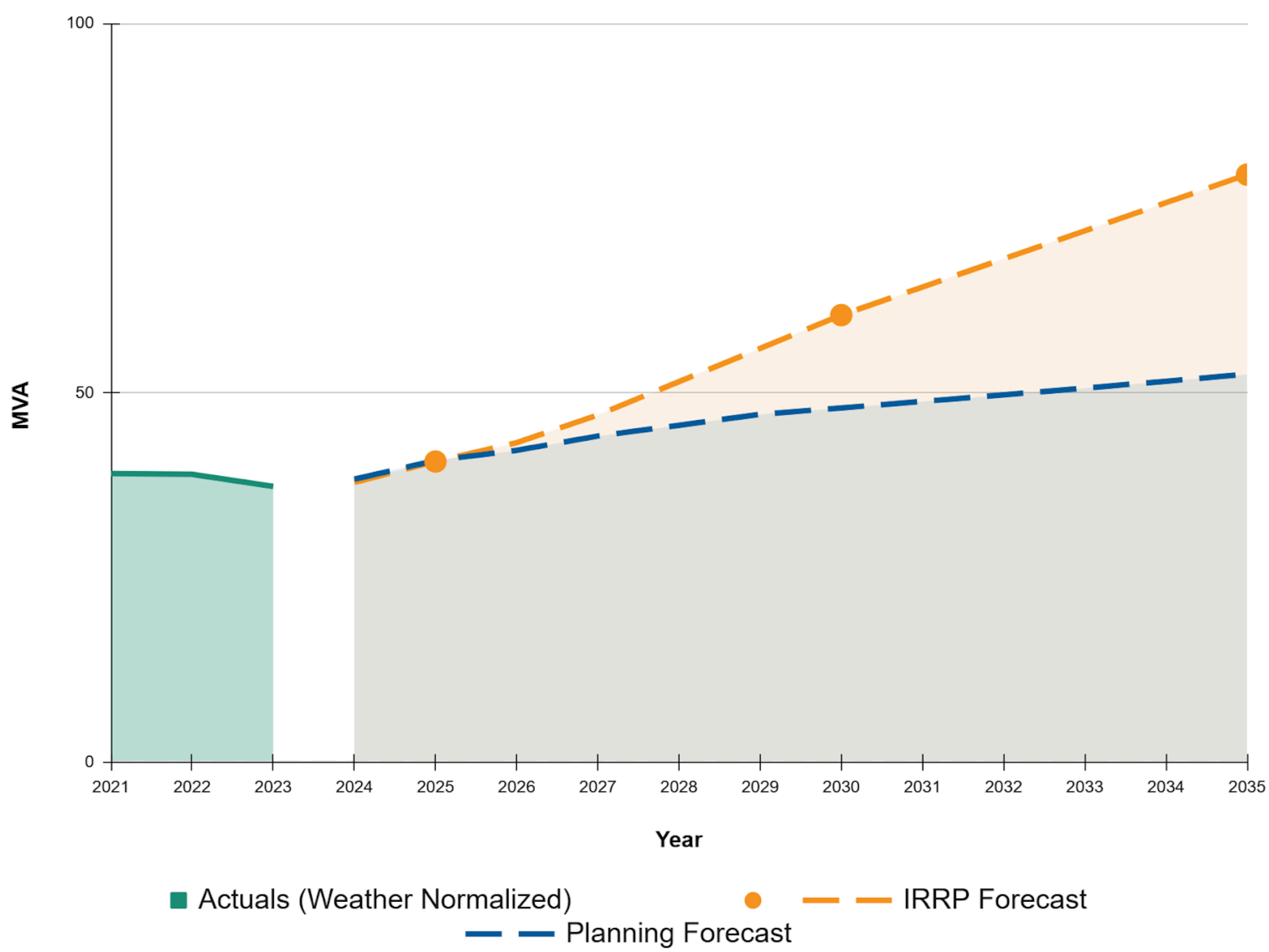


Figure 88 shows the weather normalized actuals, the planning forecast and the IRRP forecast for the region out to 2035. While no stations are exceeding their planning capacity, Bayshore DS and Stafford DS are approaching their limits.

Figure 88 - Bells Corners/Bayshore 8kV Planning Forecast and IRRP Forecast



Bells Corners DS underwent a full rebuild in 2023, replacing two transformers with three 12.5MVA units to facilitate the decommissioning of Stafford DS by 2026. Load from Stafford DS T2 has already been transferred to Bells Corners DS, and the T1 is scheduled for transfer in 2025 after feeder extensions from Bells Corners are completed.

Non-Wires Solutions

Hydro Ottawa proposes 7 MW of utility owned BESS to manage peak load in this region. For more details on the need and justification of this solution refer to Section 2.3.2.3 of Schedule 2-5-8 - System Service Investments.

9.1.4.3.3. Barrhaven 8kV System

Hydro Ottawa operates two 8kV substations in the Barrhaven 8kV region: Barrhaven DS and Jockvale DS, as shown in Figure 89.

Figure 89 - Barrhaven 8kV Supply Region

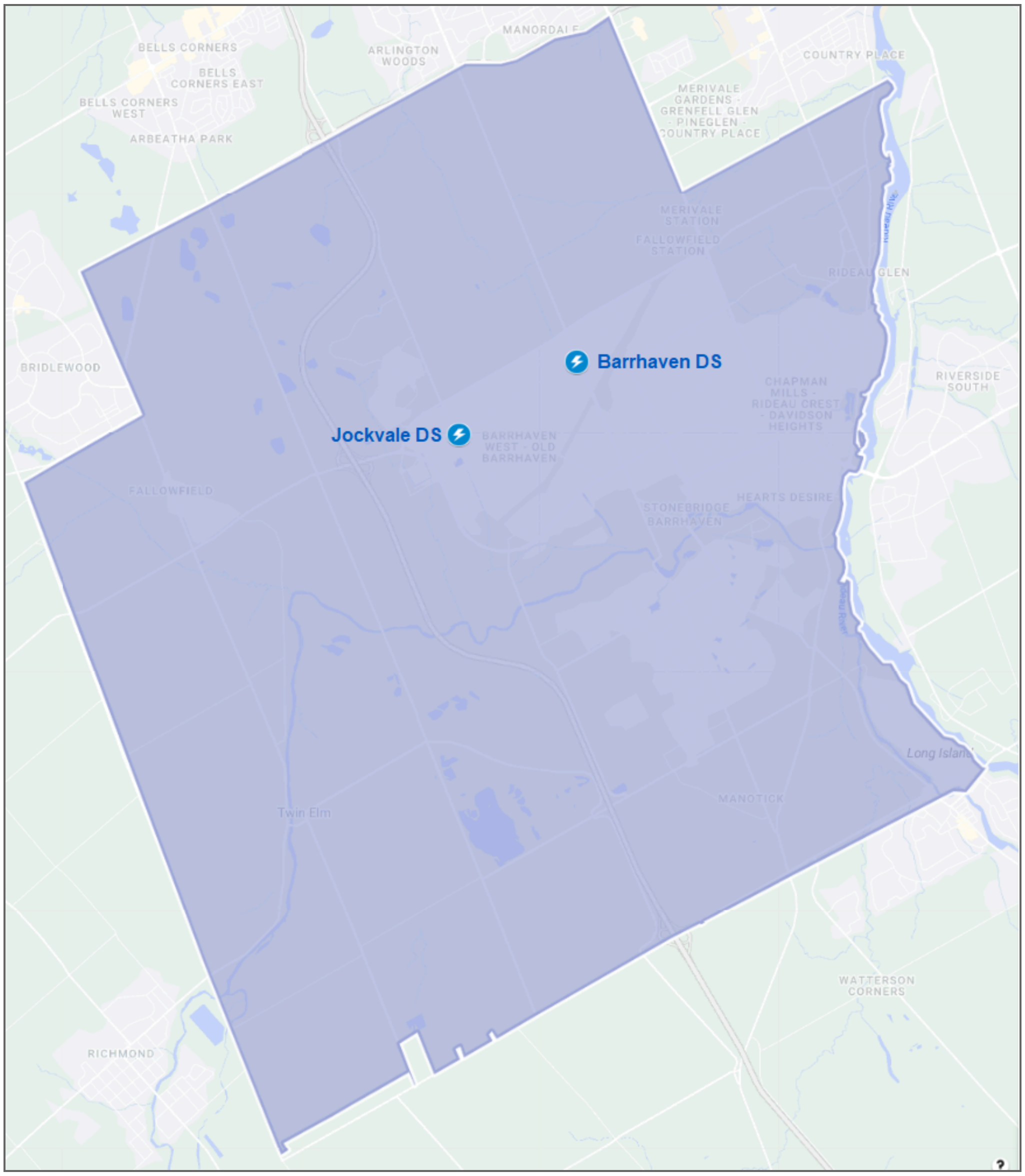
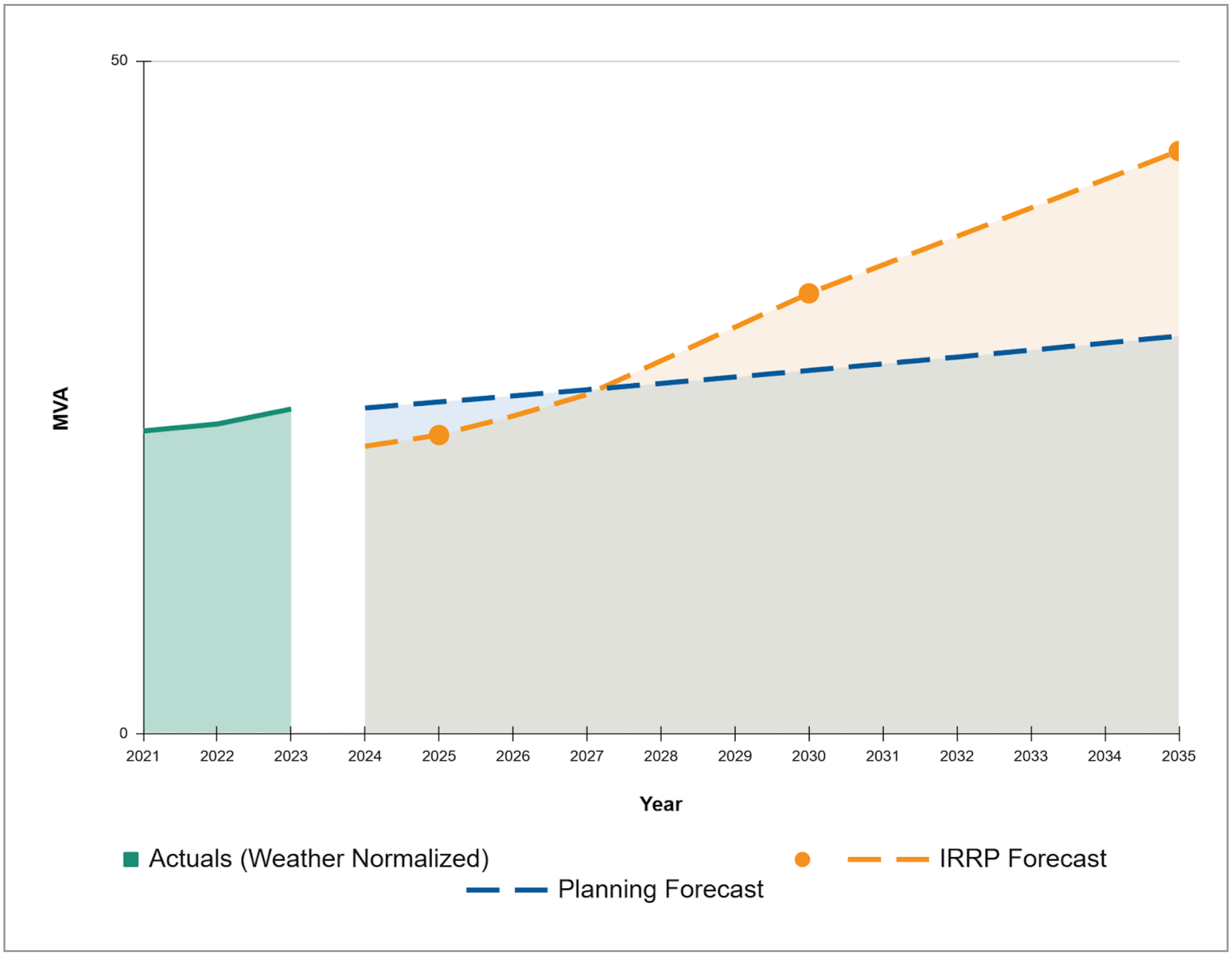


Figure 90 shows the weather normalized actuals, the planning forecast and the IRRP forecast for the region out to 2035. Since the Barrhaven 8kV region falls within the South 28kV supply region, most new developments will connect to the 28kV system. To address the overloaded feeders, switching operations are planned to balance the loading and customer count, ensuring all feeders operate within the established limits. Long-term plans include gradually decommissioning the Barrhaven 8kV system through voltage conversion to 28kV.

Figure 90 - Barrhaven 8kV Planning Forecast and IRRP Forecast



- The 8 kV system presents several challenges:
  - Compared to 28 kV, 8 kV is less efficient for long-distance power distribution, leading to greater losses and voltage drop issues beyond approximately 5km, while 28 kV remains effective up to 15km.

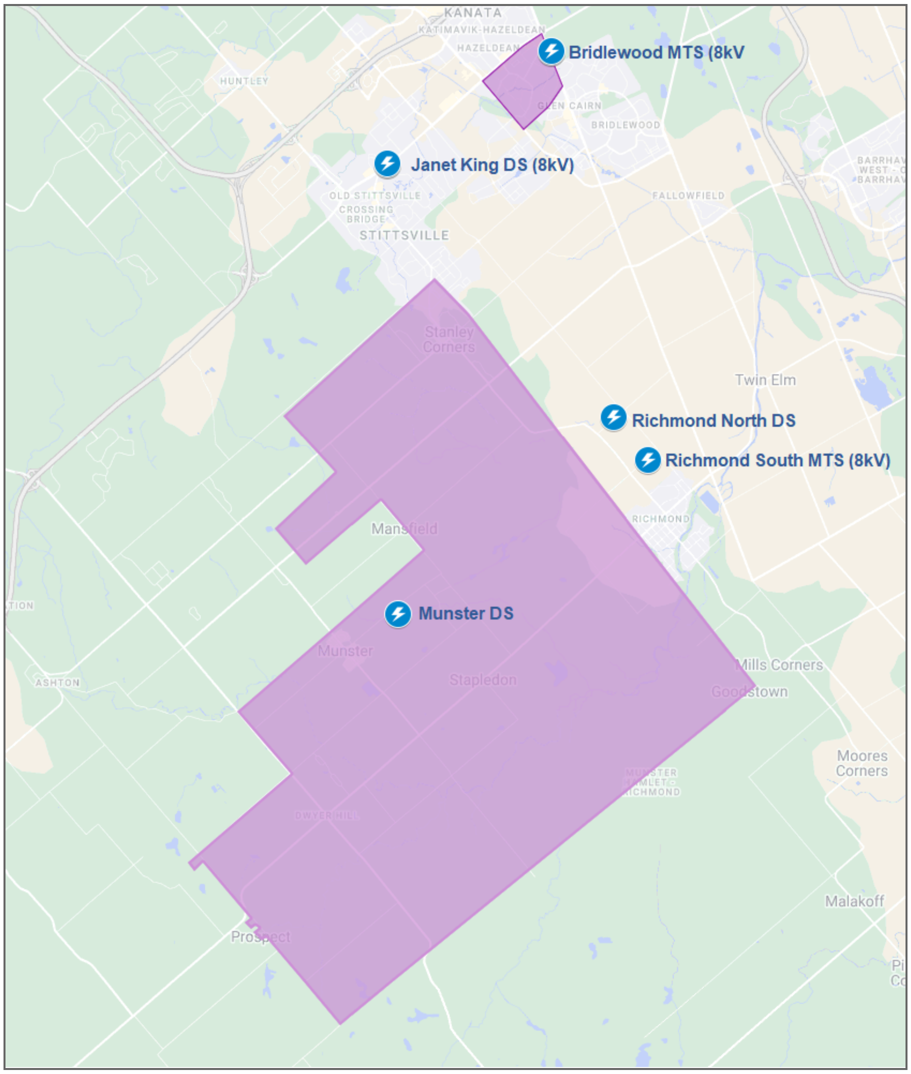
- ○ The maximum capacity of an 8 kV feeder is 3.6MVA, versus 16.4MVA for a 28 kV feeder, significantly limiting the ability to accommodate the large load requests.
- ○ Heavy loading on the 8 kV stations in the Nepean and Barrhaven regions is hindering new customer connections.

The new Greenbank MTS expected to energize in 2028 will support the growth in this region, please see further details in Section 2.3.2.1 of Schedule 2-5-8 - System Service Investments.

9.1.4.3.4. West 8kV System

The West 8kV supply region covers Glen Cairn, parts of Stittsville, Richmond Village, Munster and rural Goulbourn. These areas are supplied by Bridlewood MTS in Kanata, Janet King DS in Stittsville, Richmond North DS and Richmond South MTS in Richmond Village and Goulbourn, and Munster DS in Munster. Figure 91 shows the supply region of the West 8kV System.

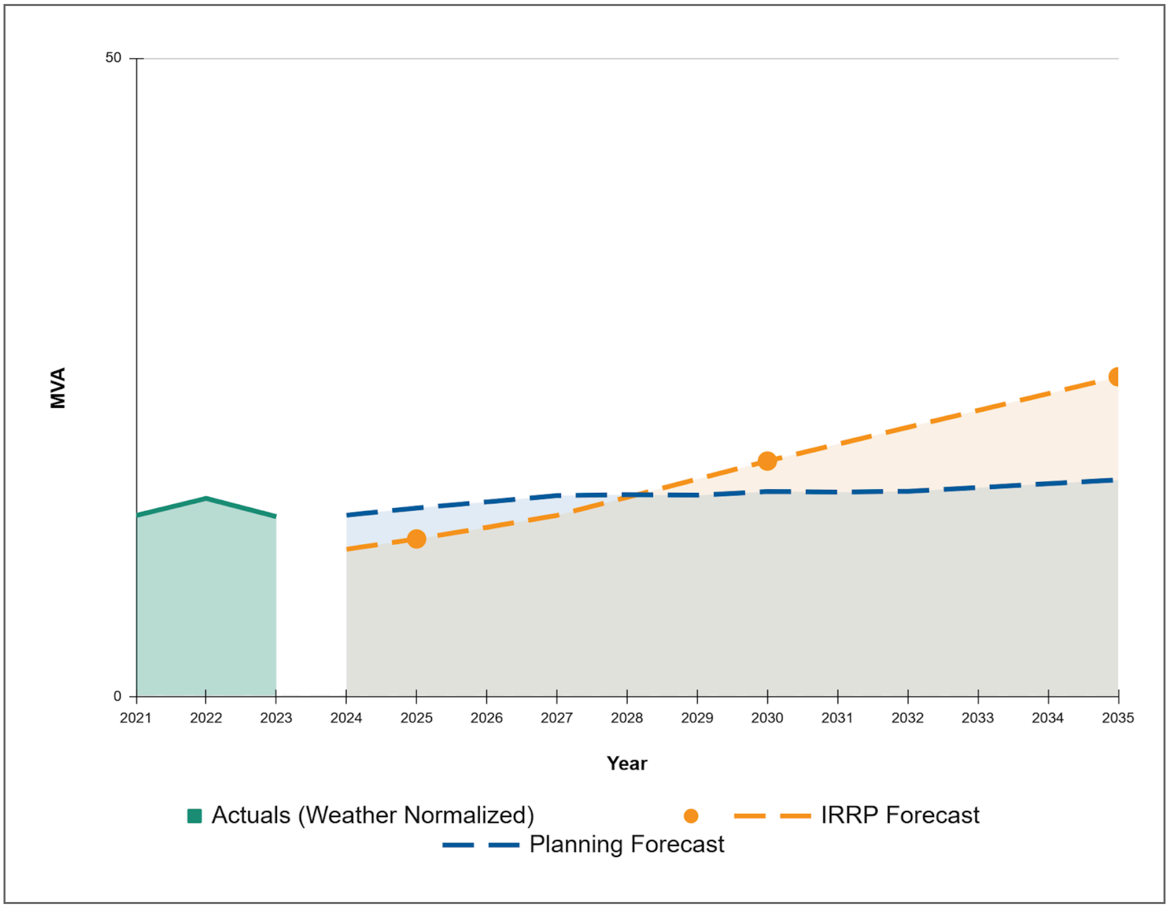
1 **Figure 91 - West 8kV Supply Region**



2

3 Figure 92 shows the weather normalized actuals, the planning forecast and the IRRP forecast for
4 the region out to 2035.

Figure 92 - West 8kV Planning Forecast and IRRP Forecast



The West 8kV area covers a large geographical region with limited backup feeder options between stations, except for Richmond North DS and the 8kV feeders from Richmond South MTS. Completed in 2019, upgrades to Richmond South MTS introduced the 28kV system in this region. The station has two 3MVA step-down transformers to supply the remaining 8kV load until the phased voltage conversion to 28kV is complete. Voltage conversion projects in this region will be done through System Renewal as assets reach end of useful life and are identified for replacement due to limitations on the 8kV system elaborated in Section 9.1.4.3.1 - Nepean 8kV system.

9.1.4.3.5. Casselman 8kV System

The Municipality of Casselman is supplied from a single Hydro Ottawa station, Casselman DS, via four 8kV feeders. One of these feeders serves as a dedicated backup for the others. The Casselman supply area is shown in Figure 93.

Figure 93 - Casselman 8kV Supply Region

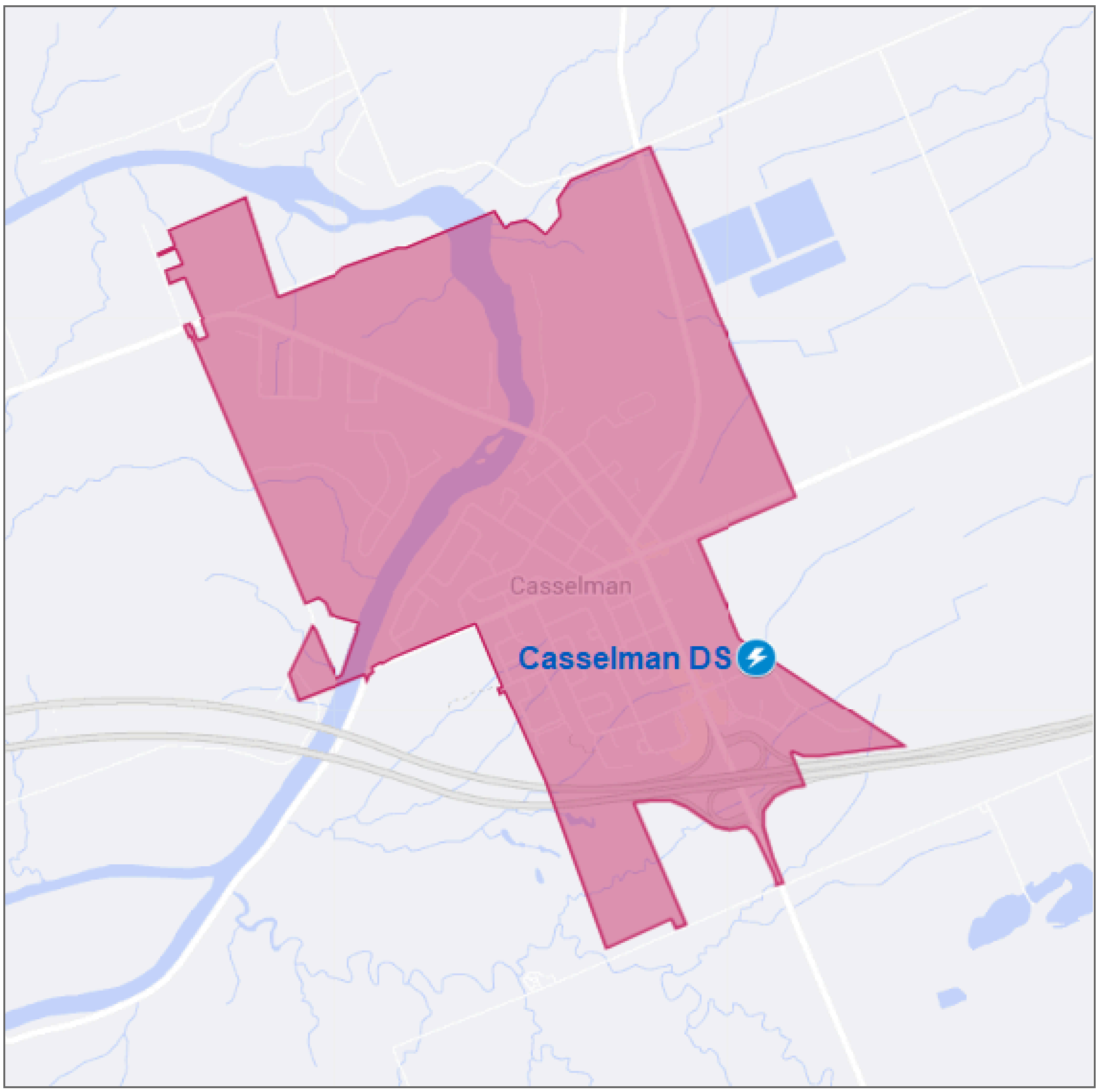
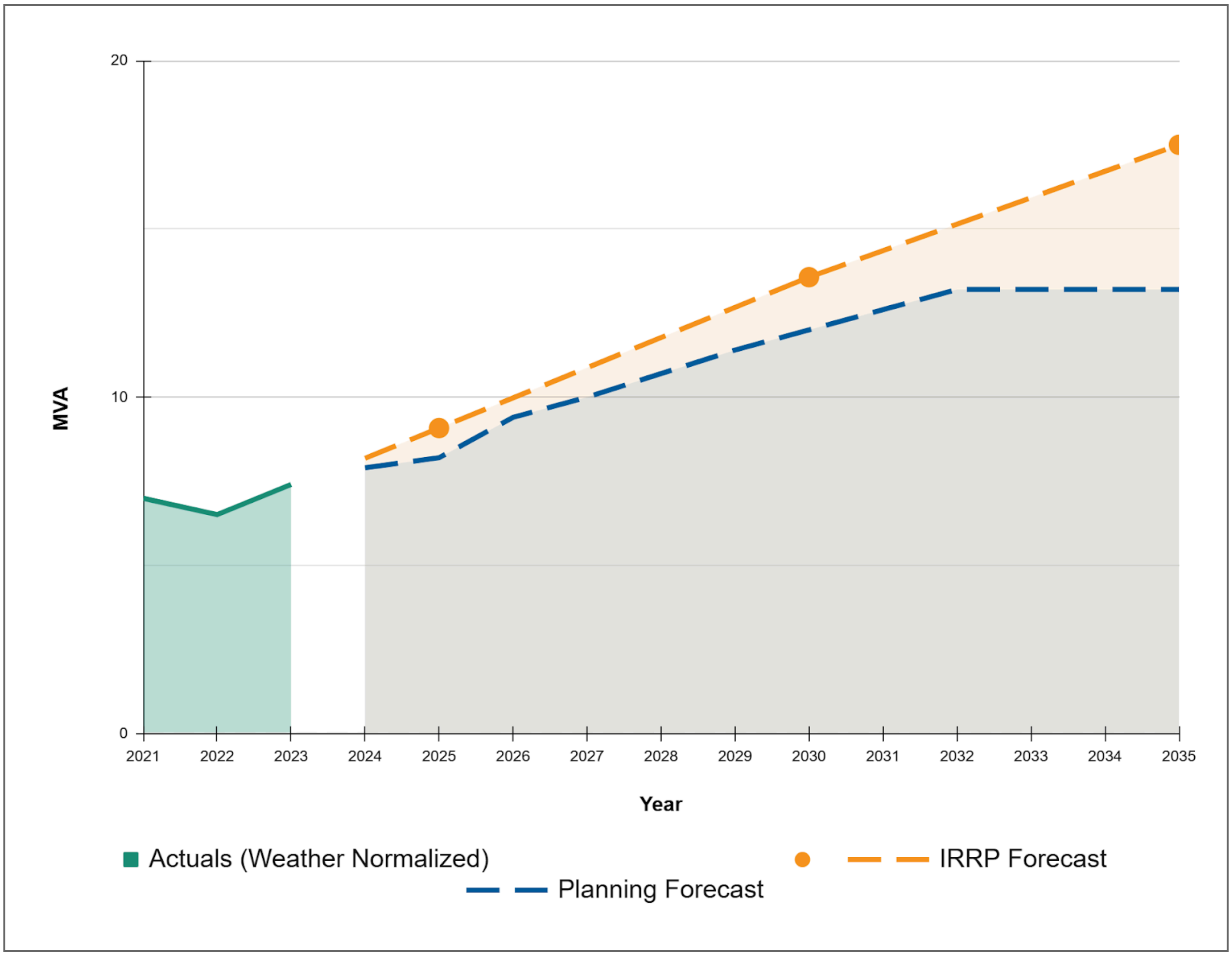


Figure 94 shows the weather normalized actuals, the planning forecast and the IRRP forecast for the region out to 2035. Two feeders, CAS-F2 and CAS-F1, are overloaded, see Table 32 above. To address these issues, switching operations and new switches will balance the load among the feeders, ensuring they operate within the established limits.

Figure 94 - Casselman 8kV Planning Forecast and IRRP Forecast



Non-Wires Solutions:

Hydro Ottawa proposes a 5 MW battery to manage peak load in this region. For more details on the need and justification of this solution refer to Section 2.3.2.3 of Schedule 2-5-8 - System Service Investments.

9.1.4.3.6. East 8kV System

The East 8kV supply region, bounded by the former Gloucester and Ottawa municipal boundary and Highway 417 to the south, as shown in Figure 95, is served by Startop DS, Blackburn DS, and Beacon Hill DS. These stations are supplied from Hawthorne TS.

Figure 95 - East 8kV Supply Region

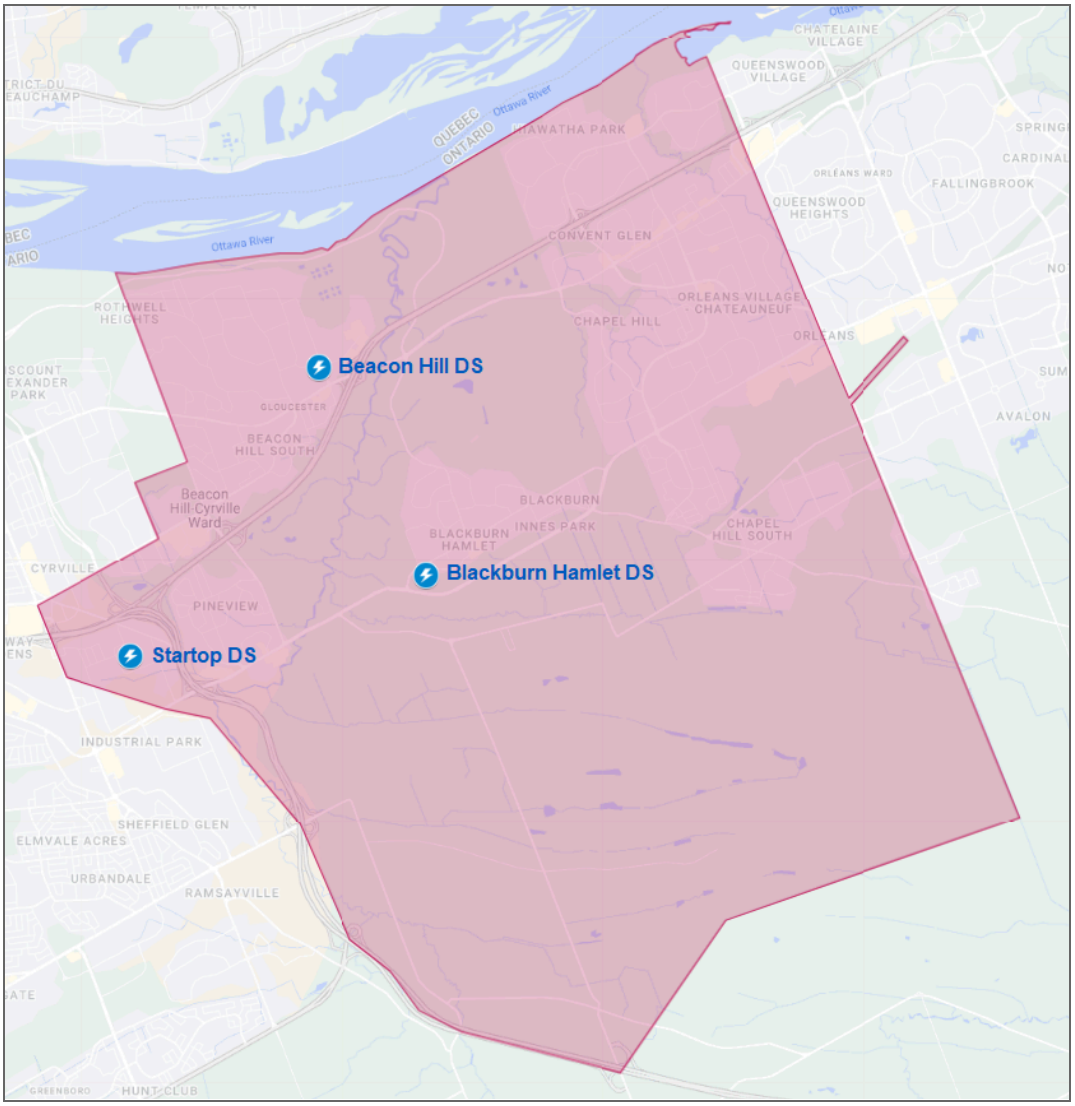
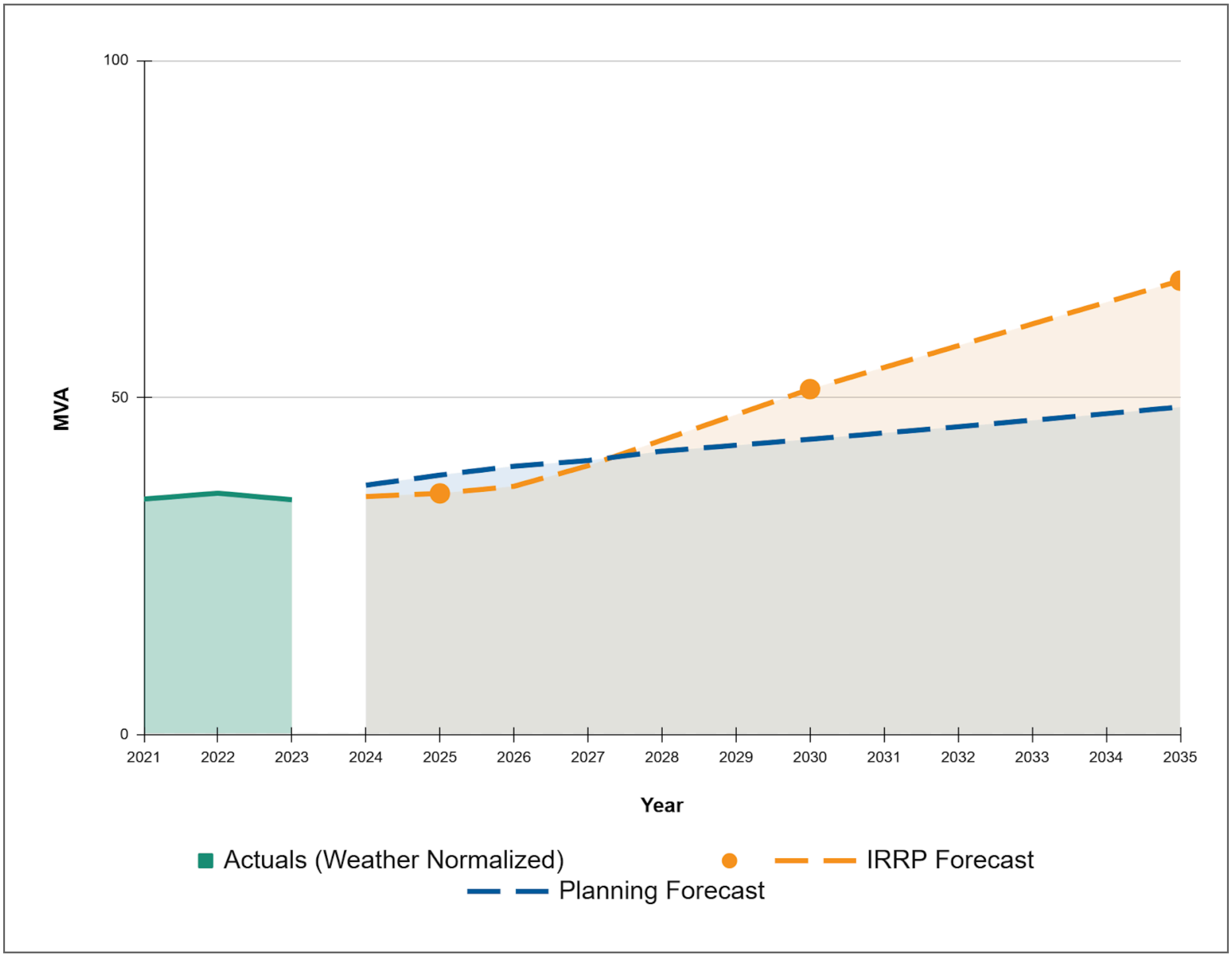


Figure 96 shows the weather normalized actuals, the planning forecast and the IRRP forecast for the region out to 2035.

Figure 96 - East 8kV Supply Area Planning Forecast and IRRP Forecast



One feeder from each of the three stations is currently overloaded, see Table 32 above. To address this, Hydro Ottawa has planned several mitigation strategies. Switching operations are planned to redistribute load from the overloaded feeder at Startop DS and to balance the load at Beacon Hill DS, which has available capacity on other feeders. Additionally, a voltage conversion has been planned at Blackburn DS to transfer several sections to the 28kV system. Since the East 28kV supply region is nearby, any large developments will connect to the 28kV system instead of the East

8kV due to limitations in the 8kV system. This multi-pronged approach aims to ensure the continued reliable operation of the East 8kV system while accommodating future growth and development in the region.

9.1.4.4. 12 kV System

The 12kV system supplies two areas of Kanata, located north and south of Highway 417 at Eagleson Road. These communities are supplied by Beaverbrook MS and South March DS, with the only 12kV distribution ties being connections between these two stations. Refer to Figure 97 for a visual representation of this region.

Figure 97 - 12kV Supply Area

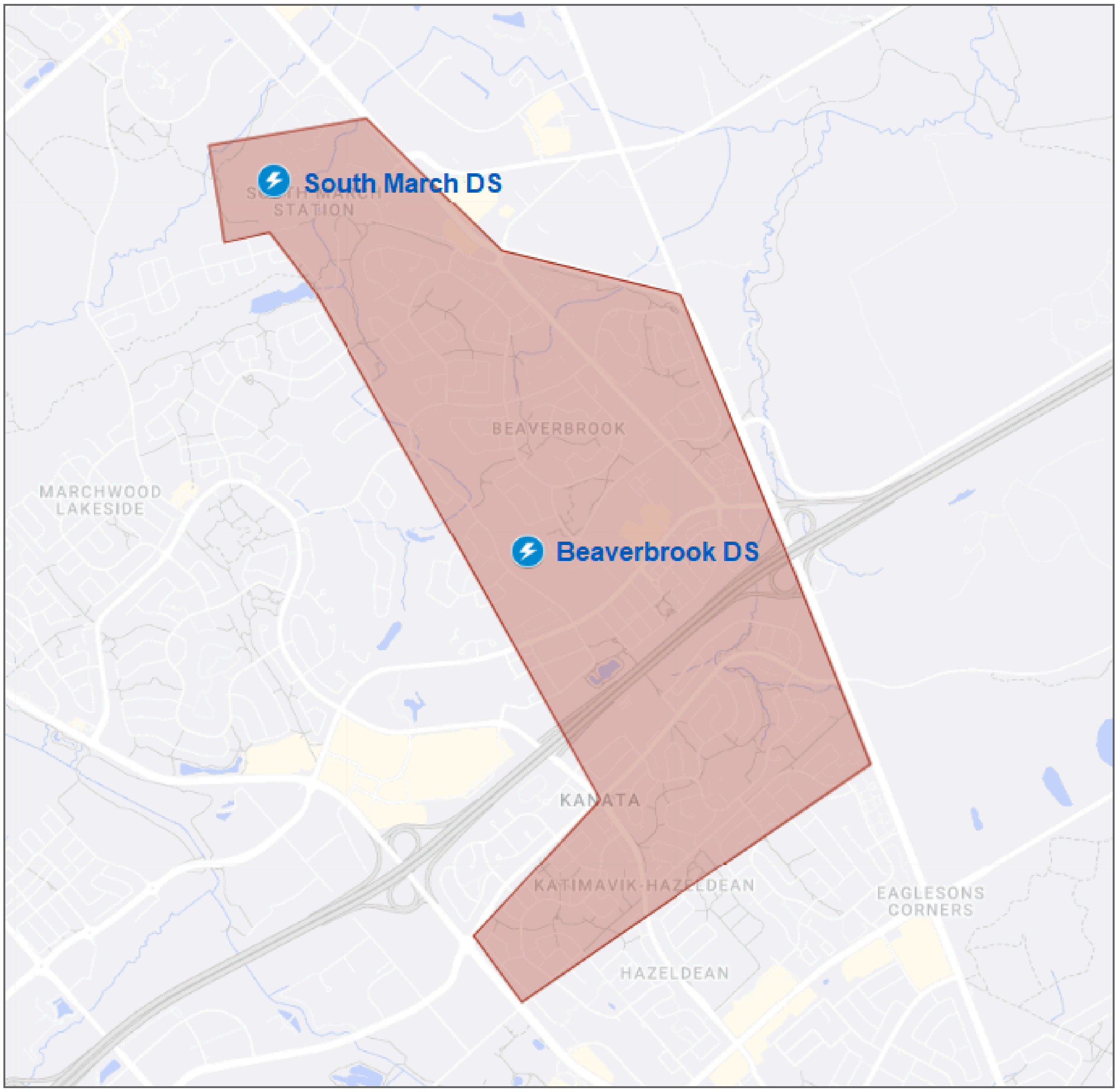
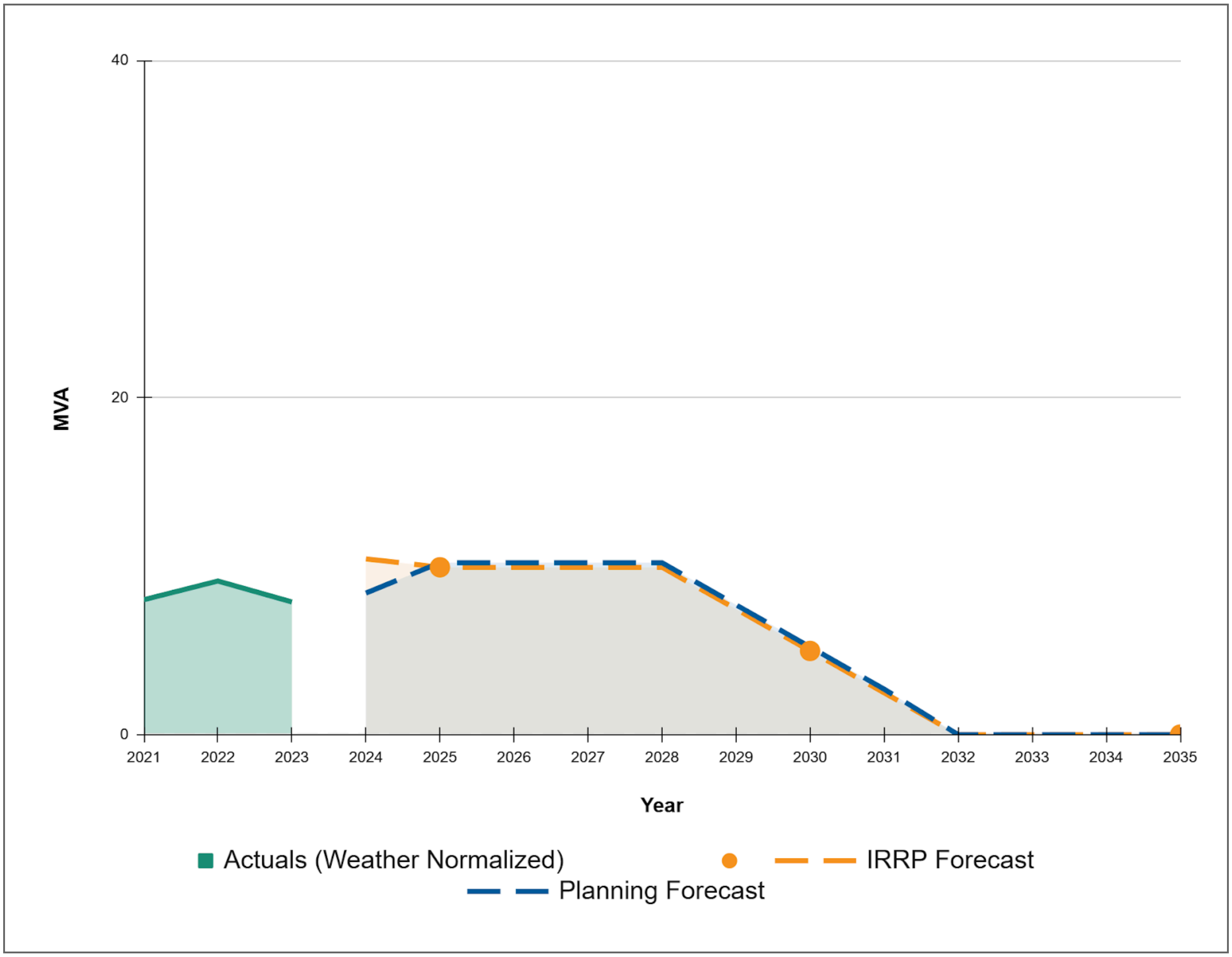


Figure 98 shows the weather normalized actuals, the planning forecast and the IRRP forecast for the region out to 2035.

Figure 98 - 12kV Planning Forecast and IRRP Forecast

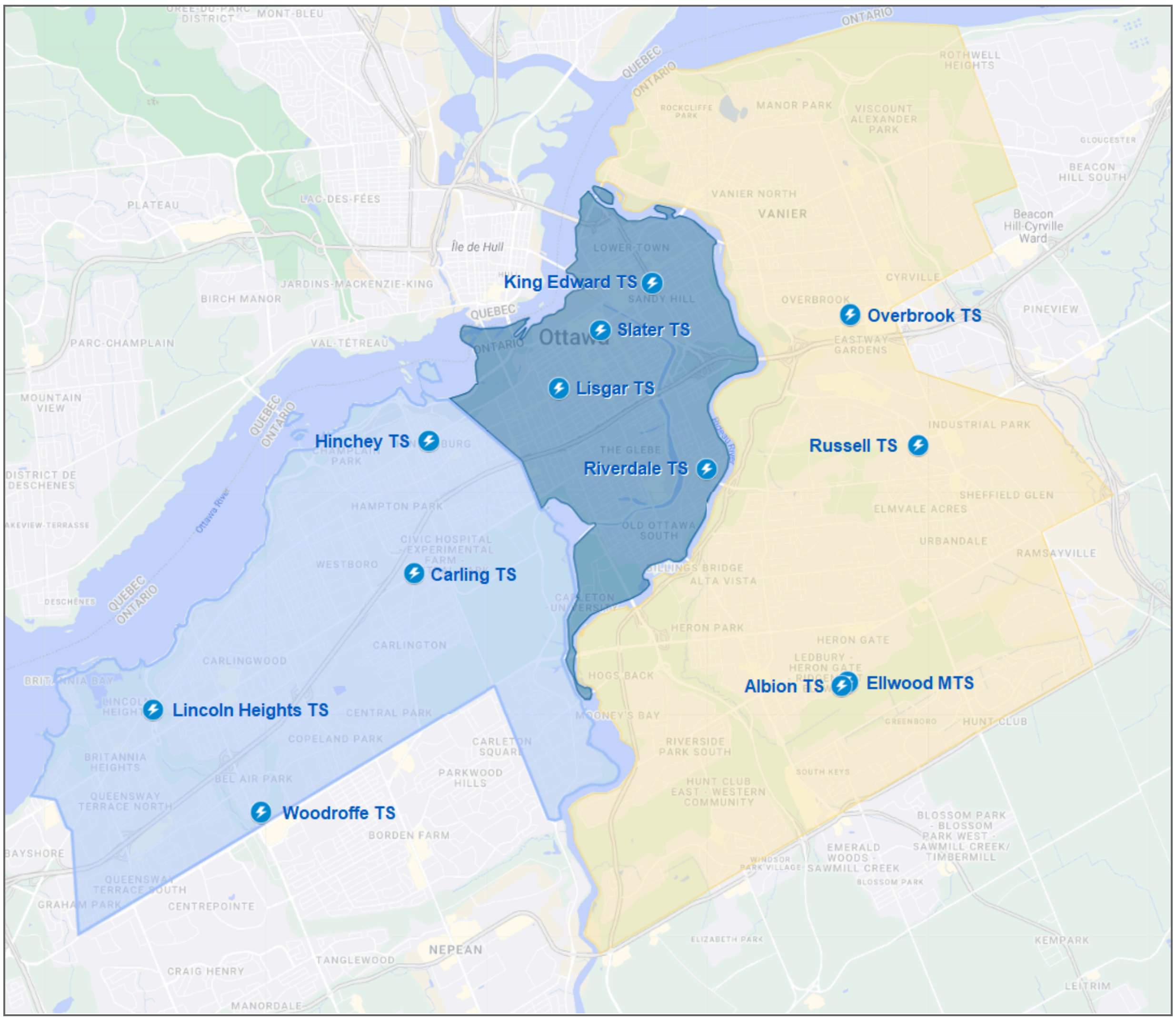


Work has begun to replace end-of-life distribution cables and transformers in preparation for a 28kV conversion. After the new 28kV station in Kanata North, see more details in Section 9.1.4.2.5 - West 28kV (North) System, is energized and the 12kV load is fully transitioned, Beaverbrook DS and South March DS will be decommissioned in phases, starting in 2028.

9.1.4.5. 13 kV System

The Hydro Ottawa 13kV supply region is divided into three areas: West 13kV, Core 13kV, and East 13kV, encompassing 12 stations. These areas align with the 4kV system described in Section 9.1.4.6 - 4kV System. Figure 99 shows the 13kV supply region and station locations.

Figure 99 - 13kV Supply Region

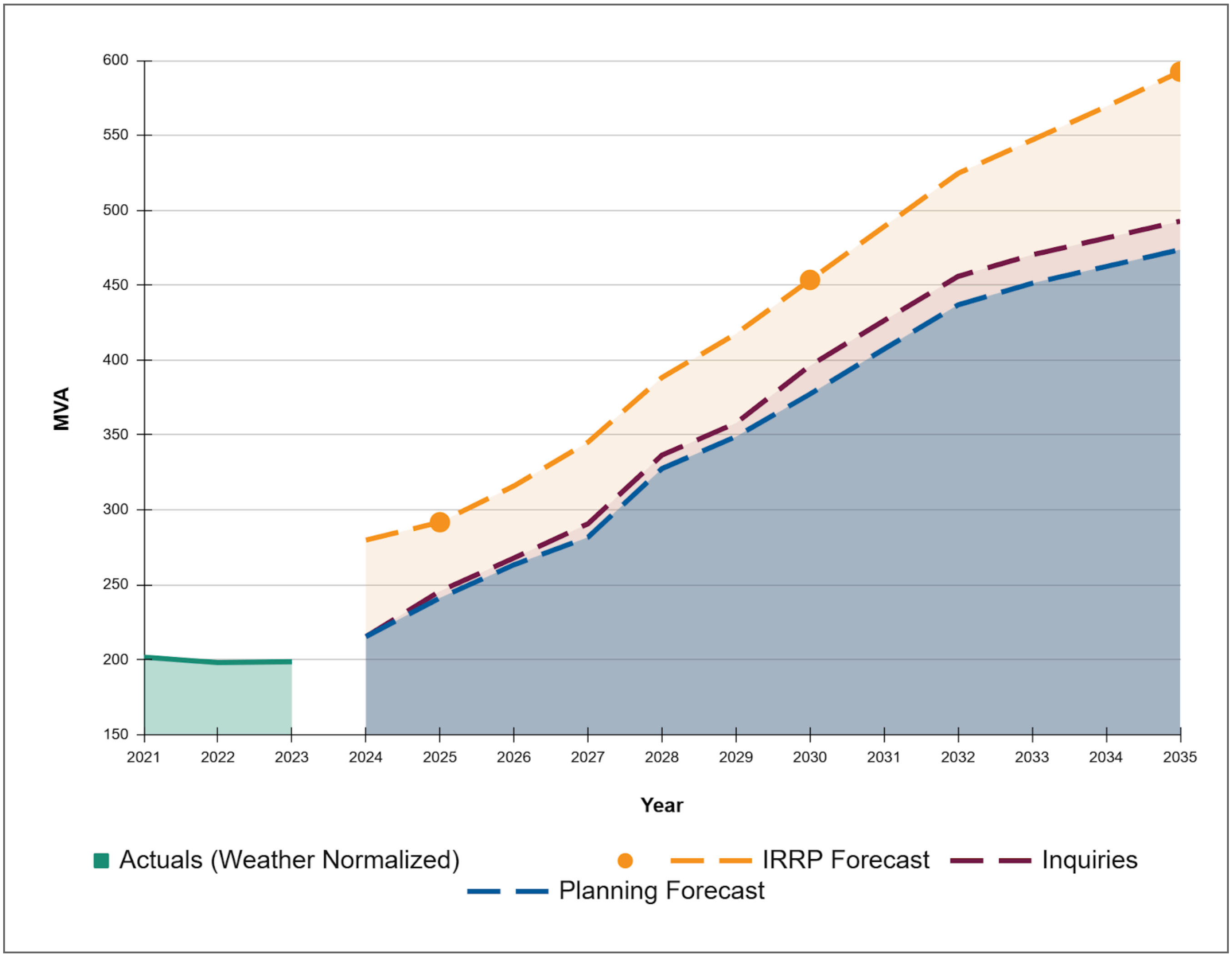


Through the Official Plan, the City of Ottawa is promoting new growth by means of intensification within central Ottawa. This impacts the 13kV system as it covers mostly established areas. Many new developments are trading in low-rise apartments for larger, high-density residential buildings.

West 13kV System

The West 13kV supply region extends from Bayview Yards and west of Preston Street to Bayshore Drive, north of Baseline Road. This region is supplied by Hinchey TH, Carling TS, Woodroffe TS, and Lincoln Heights TS. Hinchey TH also supports the Core 13kV supply region. Figure 100 shows the weather normalized actuals, planning forecast, the IRRP forecast and customer inquiries in planning stages for the region out to 2035.

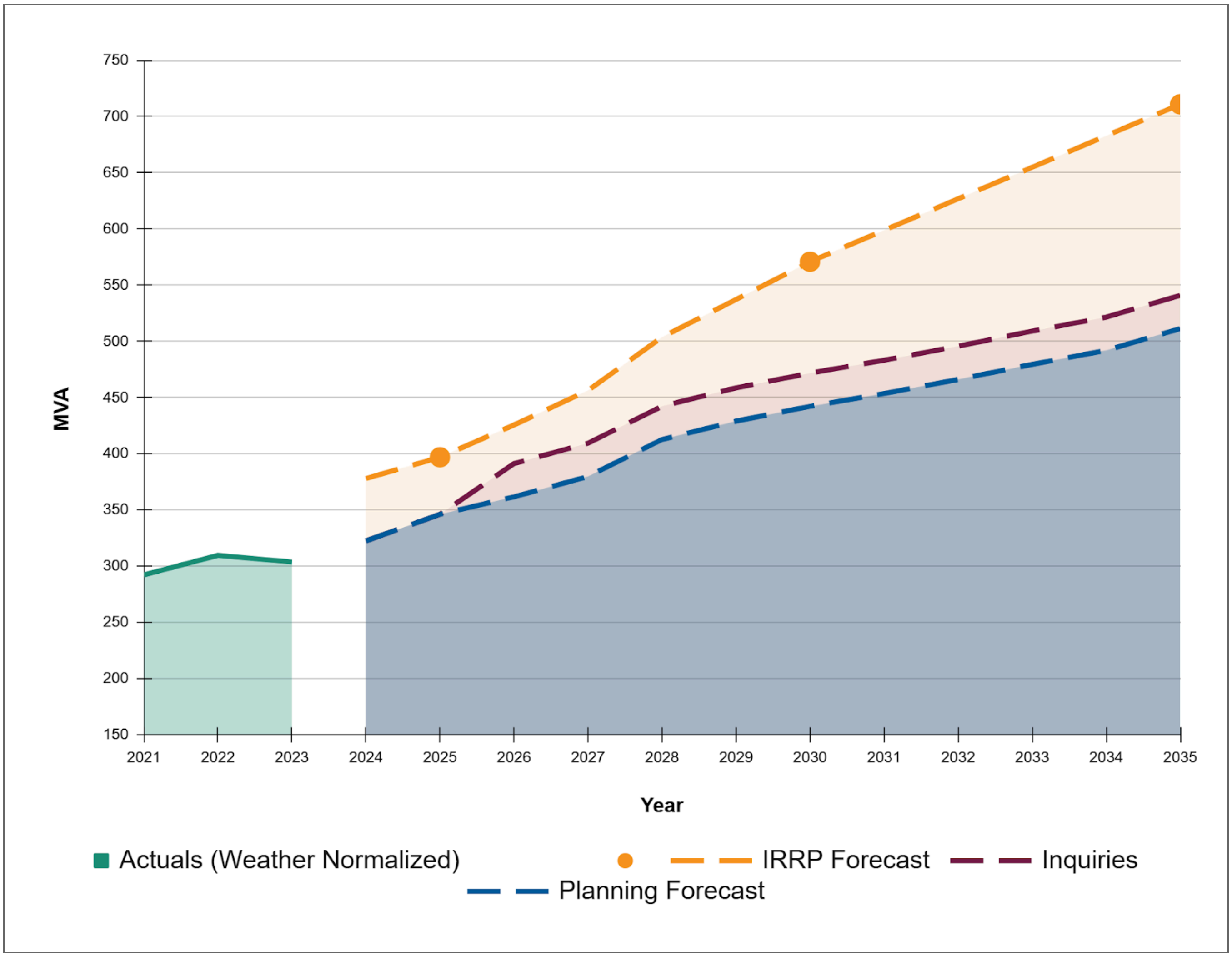
Figure 100 - West 13kV Planning Forecast and IRRP Forecast



Core 13kV System

The Core 13kV area follows the Rideau River to the east and covers LeBreton Flats to the west. This region is supplied by King Edward TS, Slater TS, Lisgar TS and Riverdale TS. Riverdale TS and King Edward TS also support the East 13kV supply region. Figure 101 shows the weather normalized actuals, planning forecast, the IRRP forecast and customer inquiries in planning stages for the region out to 2035.

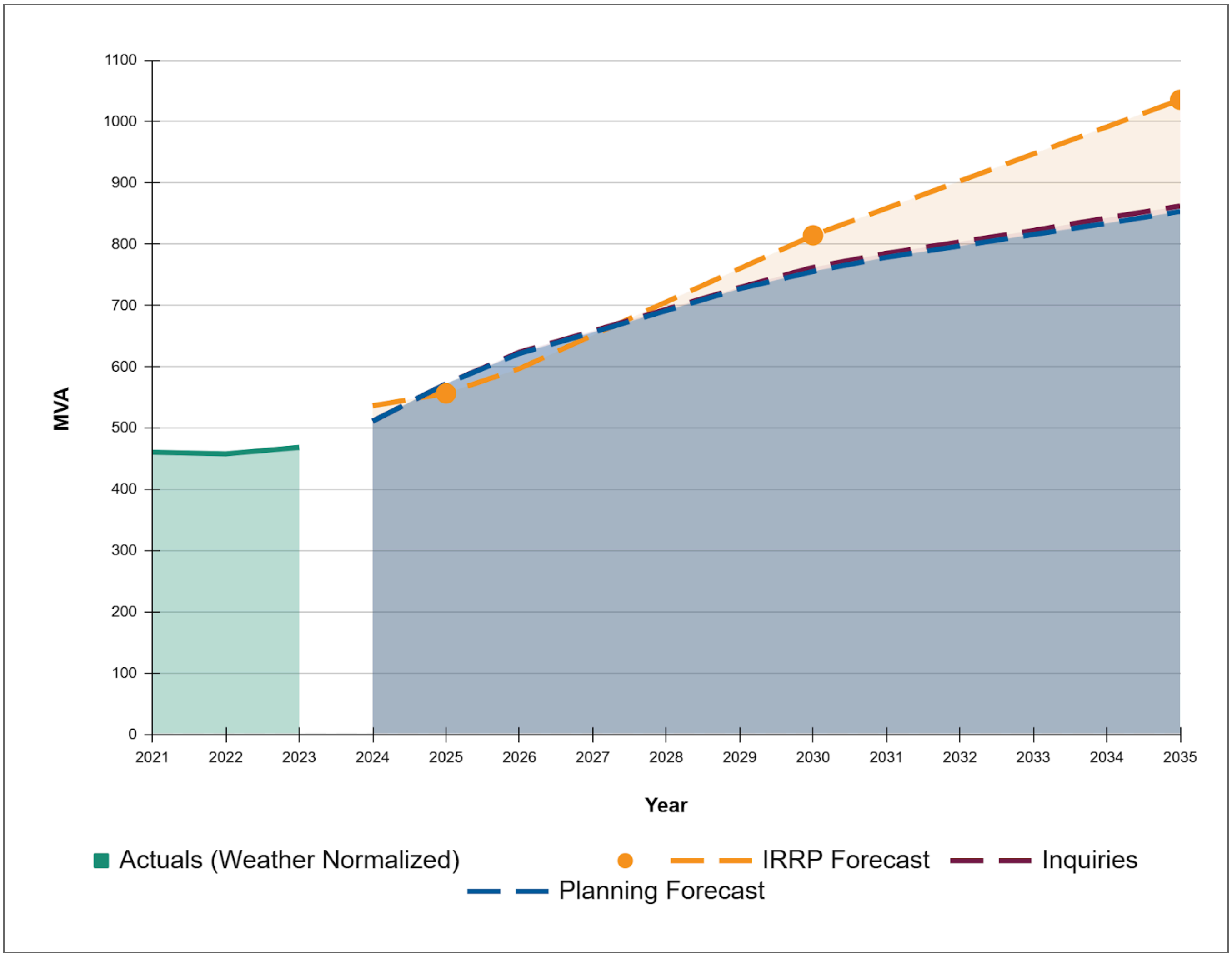
Figure 101 - Core 13kV Planning Forecast and IRRP Forecast



East 13kV System

The East 13kV supply region covers the eastern portion of the Old City of Ottawa. This region is supplied by the Russell TS, Albion TS, Ellwood MTS and Overbrook TS. Figure 102 shows the weather normalized actuals, planning forecast, the IRRP forecast and customer inquiries in planning stages for the region out to 2035.

1 **Figure 102 - East 13kV Planning Forecast and IRRP Forecast**



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4 **Overall Strategy**

5 Capacity upgrades and new station interconnections are needed to manage and transfer load within
6 the 13kV system. System expansions will also be necessary to meet growing demand. Feeders with
7 minor overloads and minimal growth forecasts will be monitored.

8

Several limitations currently prevent some Hydro One owned stations from operating at full capacity. These station-specific limitations include issues with secondary cables, transformers, switches, and protection and control equipment. Plans are in place to address and eliminate these constraints as explained below. In addition, conversion of Bronson DS from 4kV to 13kV and NWSs will further increase 13kV system capacity and support load growth in the adjacent stations like Riverdale TS, Carling TS and Lisgar TS, see further details in Section 9.1.4.6 - 4kV system.

These initiatives are vital for supporting regional growth and electrification plans. By enabling each station to operate at its full potential, Hydro Ottawa can provide more reliable service and meet the increasing electricity needs of its customers and large load requests such as the Ottawa Hospital[35] slated to be connected to the 13kV system, facilitating the transition to a more electrified and sustainable future. The investments detailed below are consistent with the Needs Assessments by the IRRP working group as part of the regional planning process, see Section 4 of Schedule 2-5-2 - Coordinated Planning with Third Parties.

Riverdale TS Switchgear Capacity Upgrade (System Service-Capacity Upgrade)

The overall station capacity is limited by a lack of available breakers in the secondary switchgear lineup. To address this, the switchgear will be replaced by 2027, adding eight feeder breakers. This project, approved as part of the 2021-2025 Rate Application, will allow the station to utilize the full capacity, connect new customers, and support future growth in Old Ottawa East and South regions. Additionally, the bus ampacity will be increased to accommodate potential future transformer upgrades. These enhancements will ensure Riverdale TS can meet the region's growing electricity needs.

Slater TS Transformer Upgrade (Hydro One Investment)

Slater TS's T1 transformer failed in early 2018 and was replaced by Hydro One with a larger 100 MVA unit to support future growth and provide contingency capacity for the Core 13kV region. The

[35] Ottawa Hospital, "The Ottawa Hospital's New Campus," https://newcampusdevelopment.ca/.

remaining transformers, T2 and T3, are nearing end-of-life and have been replaced with larger 100 MVA units in 2024. This upgrade also eliminated short circuit constraints, allowing for greater DER integration in the region.

Lisgar TS Transformer and Cable Upgrade (Hydro One Investment)

Lisgar TS currently has two transformers with a total capacity of 81 MVA. Thermal constraints due to existing generation sources are limiting the connection of new DERs. To address this and increase the station's capacity, Transformer T1 will be replaced by 2026.

In addition to the transformer replacement, the secondary cable at Lisgar TS is also limiting its operational capacity. Upgrading this cable will allow the station to operate at its full potential, supporting future developments and customer connections.

King Edward TS Cable Upgrade (Hydro One Investment)

The secondary cable at King Edward TS is currently preventing the transformers from operating at full capacity. The station, with two transformers and an available capacity of 97 MVA, is projected to exceed its N-1 rating in 2026 due to near-term load growth. Upgrading the secondary cable will increase the station's capacity, relieving capacity constraints in the Core 13kV system and supporting the load growth resulting from the Ottawa LRT project.

Carling TS Cable Upgrade (Hydro One Investment)

The cables at Carling TS are currently preventing the transformers from operating at full capacity. Replacing aging and limiting cables at the station will increase the available station capacity, relieving capacity constraints and supporting the load growth.

Russell TS Transformer Upgrade (Hydro One Investment)

Russell TS is projected to exceed its capacity by 2027. To address this, the two transformers will be replaced in 2027, increasing capacity. Additionally, new distribution ties will allow transfer from Russell TS to neighboring stations including Ellwood MTS, Albion TS, and Overbrook TS.

Albion TS Transformer Upgrade (Hydro One Investment)

Albion TS is projected to exceed its limits by 2034. Hydro One plans to replace the two transformers due to end-of-life equipment and the new transformers will be efficiently sized to meet the forecasted growth. Additionally, new distribution ties will enable load transfer from Albion TS to neighboring stations including Ellwood MTS, Russell TS, and Overbrook TS. Loads across the 13kV system will be continuously monitored and forecasted to ensure adequate supply.

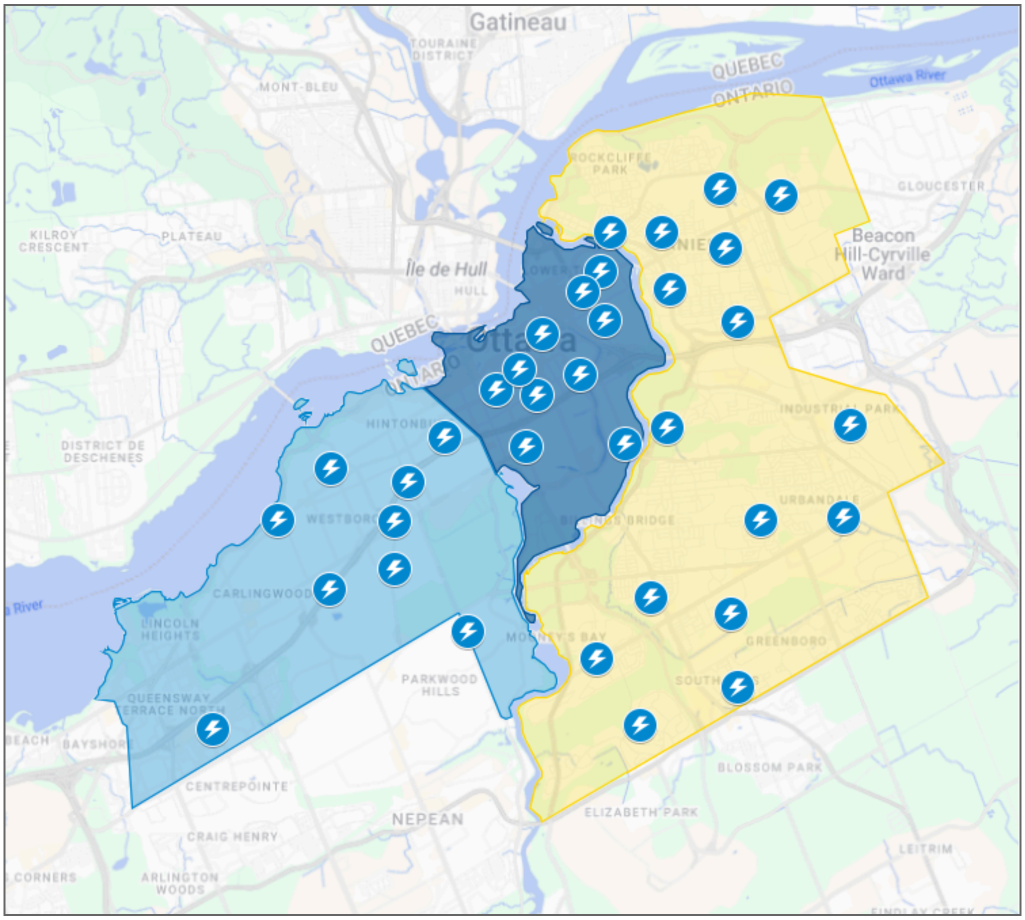
Non-Wires Solutions

Hydro Ottawa proposes 10 MW of utility owned BESS and non-wire customer solutions to manage short term and long term peak load in this region. For more details on the need and justification of this solution refer to Section 2.3.2.3 of Schedule 2-5-8 - System Service Investments.

9.1.4.6. 4kV System

Hydro Ottawa's 4kV system consists of two supply regions, Central 4kV (highlighted in blues), and East 4kV (highlighted in yellow). Figure 103 below illustrates this region as it spans across the more historical parts of Ottawa.

Figure 103 - Overall 4kV Supply Region[36]



Central 4kV

The Central 4kV supply region covers the area west of the Rideau River, east of Highway 416, along the north shore of the Ottawa River, and south to Baseline Road. This region includes 19 stations: Augusta DS, Bayswater DS, Bronson DS, Cambridge DS, Carling DS, Clifton DS, Clyde DS, Edwin DS, Fisher DS, Florence DS, Gladstone DS, Henderson DS, Hillcrest DS, Holland DS, King Edward DS, Nepean DS, Riverdale DS, Shillington DS, Slater DS. Figure 104 shows the Central 4kV supply region.

[36] The station names are deliberately left out as it would be too cluttered to have all of them on the same map; see Figure 106 (Central 4kV Supply Region) and Figure 108 (East 4kV Supply Region) for the station names.

Figure 104 - Central 4kV Supply Region

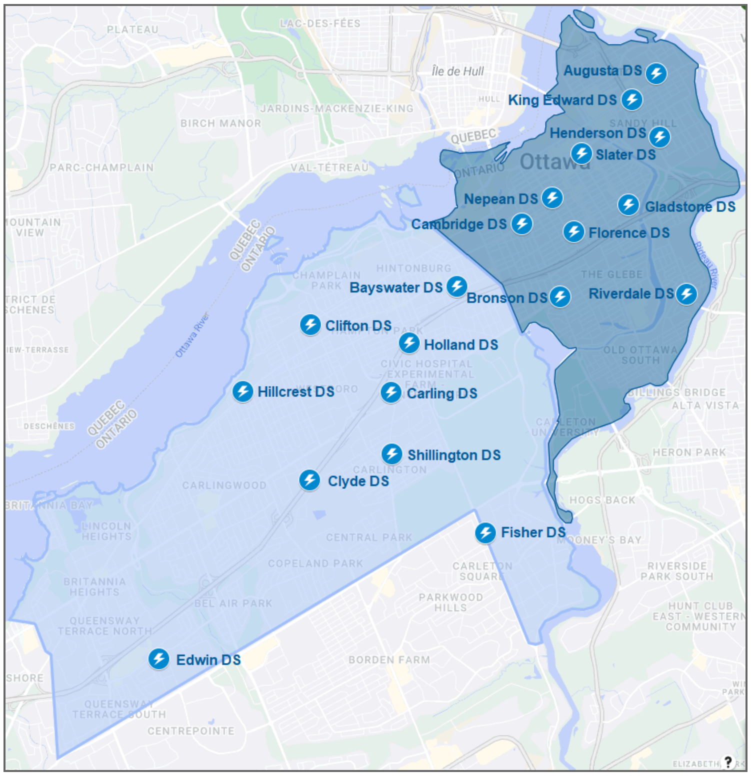
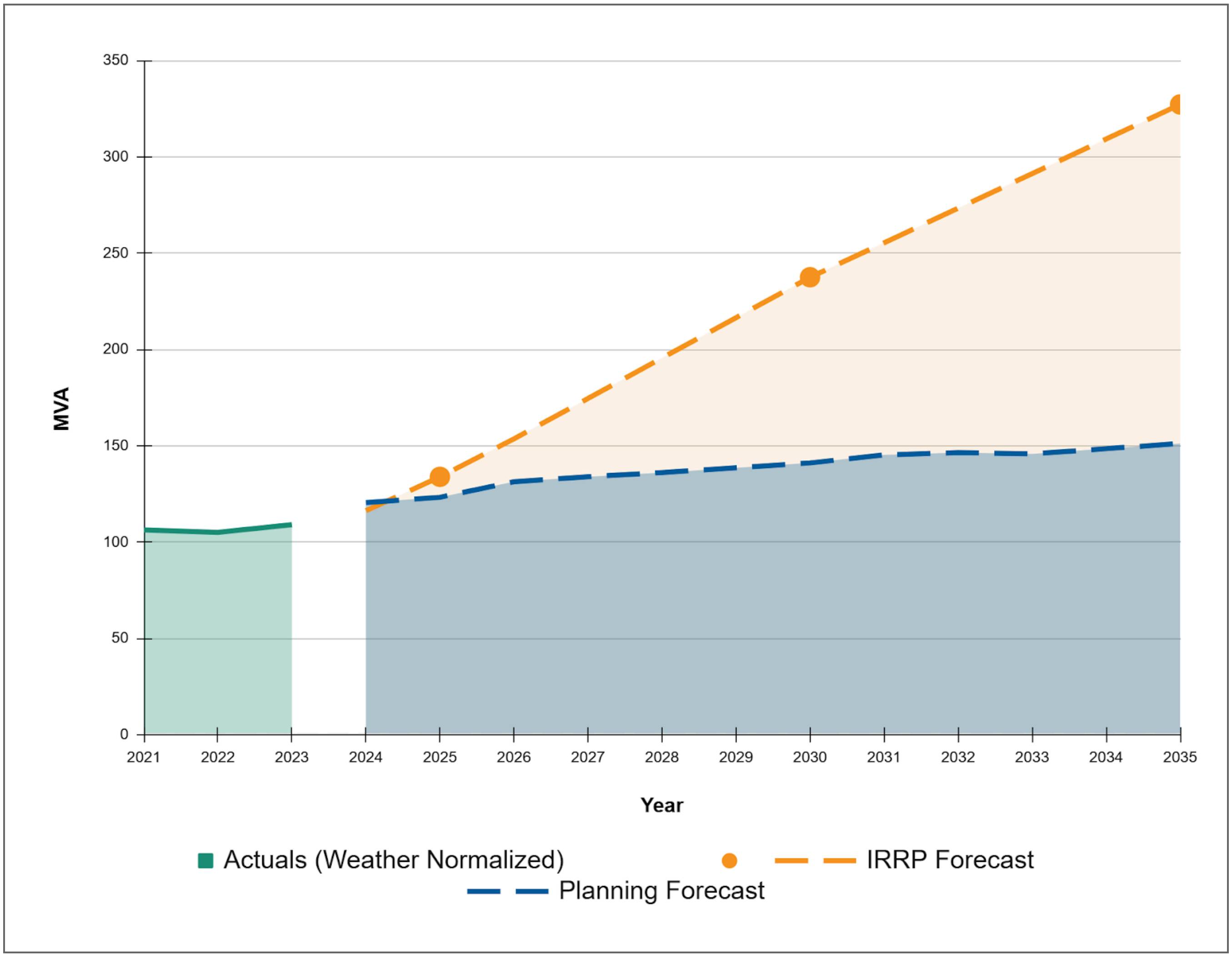


Figure 105 shows the weather normalized actuals, the planning forecast and the IRRP forecast for the region out to 2035.

Figure 105 - Central 4kV Planning Forecast and IRRP Forecast



East 4kV

The East 4kV supply region covers the area west of Blair Road, east of the Rideau River, and north of Hunt Club Road. This region is supplied by 16 substations: Albion DS, Bantree DS, Beechwood DS, Brookfield DS, Cahill DS, Church DS, Dagmar DS, Eastview DS, Langs Road DS, McCarthy DS, Overbrook DS, Playfair DS, Queens DS, Urbandale DS, Vaughan DS, and Walkley DS. Figure 106 shows the East 4kV supply region and substations.

Figure 106 - East 4kV Supply Region

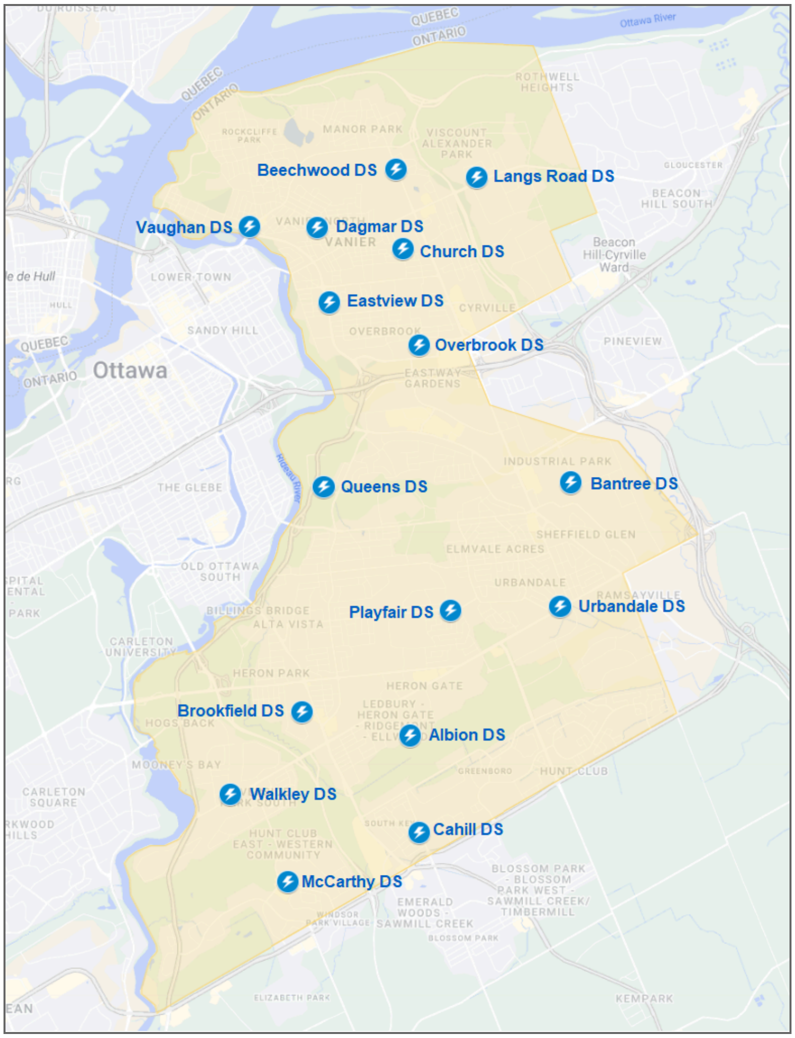
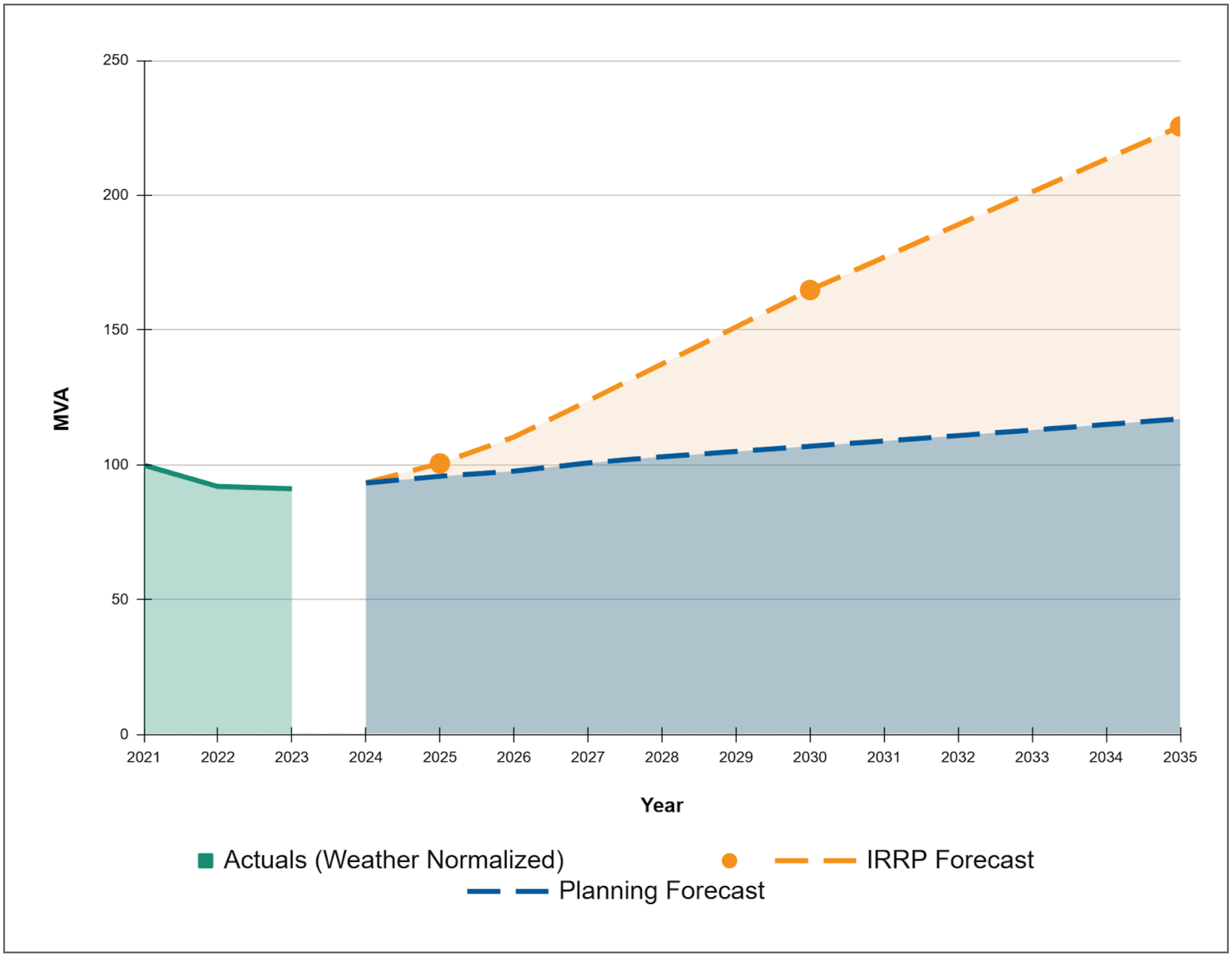


Figure 107 shows the weather normalized actuals, the planning forecast and the IRRP forecast for the region out to 2035.

Figure 107 - East 4kV Planning Forecast and IRRP Forecast



All thirty-five 4kV substations are supplied by twelve 13kV stations, providing electricity for the majority of the residential load in the regions. The City of Ottawa's Official Plan promotes intensification, with many new developments transitioning from low-rise apartments to larger, high-density condos and apartment buildings and transit oriented development. This growth, teamed up with electrification needs, speaks towards demand growth in the 4kV system. Areas like the Glebe, Rideauview, and Vanier are expected to experience significant growth in the near future.

Voltage Conversion Strategy

Hydro Ottawa is phasing out its 4kV system by strategically converting to 13kV during renewal. This shift is driven by the 4kV system's inability to handle increasing loads from electrification, which require higher service sizes and loop transformation only achievable at 13kV. Instead of rebuilding aging 4kV stations, Hydro Ottawa is prioritizing voltage conversions to enhance system reliability, accessibility, and capacity. The challenges faced by the 4 kV system is elaborated below:

- Compared to 13 kV, 4 kV is less efficient for long-distance power distribution, leading to greater losses and voltage drop issues beyond approximately 5km, while 13 kV remains effective up to 10km.
- The maximum capacity of a 4 kV feeder is 2.3MVA, versus 9.7MVA for 13 kV, significantly limiting the ability to accommodate the large load requests.

Beyond completion of the planned conversions of Dagmar DS and Fisher DS initiated in the 2021-2025 period, Vaughan DS, Henderson DS, and Church DS will also be converted to 13kV due to the condition and age of their 4kV assets, Section 2 of Schedule 2-5-7 - System Renewal Investments. Additionally, strategic voltage conversions are planned in the Bronson DS region to prepare for its upgrade to 13kV mainly driven by capacity constraints.

Dagmar DS voltage conversion

Dagmar DS, a 4kV substation in the East 4kV region serving part of Vanier, as well as its distribution network, have reached end-of-life. Due to capacity and site space constraints, voltage conversion to 13kV was chosen over asset renewal. Initially planned for completion within this application, the project is now expected to start in 2025 and be completed by 2027.

Fisher DS voltage conversion

Fisher DS, a 4kV substation in the Central 4kV region serving Rideauview as its distribution network, has reached end-of-life. Voltage conversion to 13kV was determined to be more beneficial than a station rebuild at 4kV, offering improved reliability and capacity to meet growing demand. This conversion requires replacing and upgrading all distribution assets to 13kV standards. Construction began in 2022 and is expected to be complete by 2027.

Henderson UN, Church AA and Vaughan UG voltage conversion

As part of the overall voltage conversion strategy, Henderson DS, parts of Church DS, and Vaughan DS, will be converted to 13kV. This is primarily driven by end-of-life 4kV station assets. Converting these customers to a 13kV supply and decommissioning the 4kV stations is advantageous to meet growing demand, support electrification, and progress towards phasing out the end-of-life 4kV system in the service territory.

Bronson DS upgrade and associated voltage conversion

Bronson DS, a 4kV substation serving the Glebe and part of Bank Street, will be upgraded to 13kV to increase capacity and reliability. For more details on the need and justification of this investment please refer to Section 2.3.2.1 of Schedule 2-5-8 - System Service Investments.

This capacity upgrade aligns with the Needs Assessments completed by the IRRP working group as part of the regional planning process, see Section 4 of Schedule 2-5-2 - Coordinated Planning with Third Parties.

9.2. NON-WIRES SOLUTIONS TO ADDRESS SYSTEM NEEDS

In March 2024, the OEB updated its "Non-Wires Solutions Guidelines for Electricity Distributors"[37] (previously known as the CDM Guidelines for Electricity Distributors) to reflect "the fact that Non-Wires Solutions to address system needs can encompass a broader range of solutions than traditional conservation and demand management, including, but not limited to, third-party distributed energy resources such as energy storage and distributed (embedded) generation".

It is the OEB's expectation that LDCs submitting rate filings in 2026 and beyond be fully consistent with the OEB's Benefit-Cost Analysis Framework (BCA Framework) and will be "required to incorporate consideration of NWSs into their distribution system planning process, by considering whether a distribution rate-funded NWSs may be a preferred approach to meeting a system need, thus avoiding or deferring spending on traditional infrastructure."[37] While Hydro Ottawa's Application is submitted in advance of requirements for rate applications to be fully consistent with the BCA Framework, Hydro Ottawa has been working to update its planning process to include evaluating NWSs potential for meeting local distribution system needs. Where feasible, and where there is overlap between local distribution system and bulk system needs, this process has and will continue to include collaborating with the IESO, and making use of their Local Initiatives Program (LIP) within the Electricity Demand Side Management (eDSM) Framework for mutual benefit. Also within the eDSM Framework, there is proposed new funding dedicated for LDCs to develop and implement local eDSM programs that address distribution system needs and also provide upstream benefits to the IESO-controlled bulk system.

Of note, regulatory and policy work regarding funding and implementing NWSs and local eDSM activities is evolving, with updated mechanisms and additional guidance anticipated in 2026 or 2027. When regulatory policy solidifies, and guidance and the process to share costs between the local and bulk systems are formalized, Hydro Ottawa will adjust its NWSs Assessment Process

[37] Non Wire Solutions Guidelines for Electricity Distributors- https://www.oeb.ca/sites/default/files/uploads/documents/regulatorycodes/2024-04/OEB_2024%20NWSs%20Guidelines_20240328.pdf

described below accordingly. Refer to Section 9.2.4.3 - “Stream 2” Local NWSs Program Opportunities for additional insight around future regulatory and policy changes.

9.2.1 Hydro Ottawa NWSs Assessment Criteria

Hydro Ottawa's System Capacity Assessment is a crucial process that analyzes planning forecasts to inform decisions about necessary system upgrades and expansions. This ensures that Hydro Ottawa can reliably and adequately meet both current and future customer energy needs. The NWSs assessment utilizes the IRRP forecast, which specifically focuses on the medium- to long-term outlook (beyond 2030) and takes into account the potential effects of decarbonization efforts. By considering these long-term impacts, Hydro Ottawa can better contextualize potential challenges and opportunities that may arise in the future. For more details regarding the IRRP Forecast refer to Section 9.4.2.

A key benefit of this forward-looking approach is that it allows Hydro Ottawa to validate that the capacity investments made to address immediate needs in the near term (until 2030)—as informed by Hydro Ottawa’s planning forecast—are also strategically aligned with the anticipated long-term energy requirements. This alignment ensures efficient capital deployment and optimizes asset utilization.

Based on a thorough analysis of the needs identified for each of the Hydro Ottawa planning regions described in Section 9.1.4 - Investments by Planning Region; it has been determined that the majority of these needs will require wire solutions, meaning upgrades and expansions to the physical grid infrastructure. While NWSs are not expected to cause substantial avoidance or deferral of the identified wire capacity investment needs, they will play a crucial role in moderating the pace of system demand growth and enhancing reliability in the 2026-2030 period, while continuing to support the grid in the long term. This moderation will provide Hydro Ottawa with the lead time to construct the necessary long-term grid infrastructure solutions that are aligned with the evolving system demand. There are three scenarios identified where NWSs would have the greatest potential in supporting capacity needs:

Scenario 1: Stations Requiring Capacity Risk Mitigation in the Near-Term

This scenario applies to stations that are currently facing capacity constraints and require immediate risk mitigation measures until a permanent wire solution can be implemented. This may be due to an inability to transfer loads to nearby stations or due to anticipated additional capacity needs in the near term. In these cases, NWSs can manage demand and ensure reliable service while the necessary grid infrastructure upgrades are being planned and constructed.

Scenario 2: Distribution Connected Stations with Minor Overloads

This scenario focuses on distribution connected stations where both the planning and IRRP forecasts project overloads of less than 7.5MVA (50% of maximum capacity for a new 8kV station/ 50% of maximum capacity of a 28kV feeder) by 2030. These stations must have limited connections to adjacent stations to support overloads. Additionally, wire alternatives would require a combination of distribution and station expansion along with potential transmission upgrades, resulting in significant capital investments which is not economically feasible. NWSs can play a supportive role by managing demand and reducing the need for near-term infrastructure investments, and they can provide additional reliability benefits by helping to balance loads.

Scenario 3: Planning Regions Overloaded by 2030

This scenario pertains to planning regions where overloads by 2030 are expected based on the IRRP forecast, even after the implementation of proposed wire solutions. It also includes planning regions that are already experiencing transmission system constraints, as identified through Regional Planning. In these cases, NWSs will be essential in managing demand to ensure that the system can operate reliably within limits.

9.2.2 NWSs Under Consideration

The rapid advancement and adoption of DER present an unprecedented opportunity to revolutionize grid planning, operations and management. By strategically leveraging DER technologies as NWSs, Hydro Ottawa can innovate its approach to planning and addressing distribution system needs and empower customers while paving the way for a more reliable, resilient and sustainable energy future.

9.2.2.1 Non-Wires Customer Solutions Program

There are four initial programs under further evaluation within the Non-Wires Customer Solutions portfolio for deployment, which are described below. Hydro Ottawa also expects to use outputs from the IESO's Local Achievable Potential Study (L-APS), scheduled to complete in Q2 2025, to validate the programs. Hydro Ottawa expects that its Non-Wires Customer Solutions Program could eventually include, where feasible and cost effective, other demand side management programs delivering both distribution grid benefit as well as greenhouse gas emission reductions.

These programs will build on province-wide incentive offers available within the eDSM Framework, where applicable. It is anticipated that cost-sharing will be determined based on the split of bulk and local system benefits determined by the BCA and informed by the L-APS. Funding requested will support customer participation with incentives, and will be used to raise awareness of these local programs through targeted marketing. As advancements and understanding of the broader use of DER technology continues to evolve, regulatory policy around DERs solidifies, and additional sources of funding emerge, additional opportunities for NWSs will be reviewed and considered for implementation.

1. **Save on Energy Retrofit Adder Program**

   Hydro Ottawa is working with the IESO to explore relaunching an updated version of a retrofit adder program, similar to the "Kanata North Retrofit+" (KNR+) program. From 2020-2022 and funded by Interim Framework (IF), Hydro Ottawa administered the KNR+ program cost effectively in the targeted area of Kanata North and achieved 2.47MW of gross demand savings by providing enhanced incentives and technical support to eligible customers, leveraging the existing platform used for the province-wide Retrofit Program. During recent conversations, IESO has signaled that opening access to the Retrofit Regional Adder[38] - required for this program concept - is a strong possibility.

As stated in the KNR+ program evaluation report,[39] enhanced technical support provided to customers by Hydro Ottawa was a key differentiator in the success of the KNR+ program. Under this new program, Hydro Ottawa will assign a CDM Energy Conservation engineer to assist customers in identifying and developing potential projects in the targeted area of need. Existing customer relationships and communication channels can be utilized to promote the program as Hydro Ottawa has CDM staff already in place who can leverage these relationships for initial engagement and technical support. Please refer to Schedule 1-4-1 - Customer Engagement Ongoing for greater detail on how the CDM team is engaging with and supporting customers. Funding within the Non-Wires Customer Solutions Program would be used for targeted marketing campaigns, and a possible local incentive adder further encouraging customers to participate.

2. Residential Demand Response (DR) Program

Residential DR has the potential to deliver significant benefits to both the local distribution grid and the bulk system. To achieve maximum benefits, Hydro Ottawa would need to establish reliable and predictable load reduction through the program by effectively monitoring enrollment and leveraging technology to schedule and operate curtailment events. Curtailment events would need to be targeted to specifically address distribution system needs while prioritizing a positive customer experience.

Hydro Ottawa has been exploring the potential of leveraging IESO's existing "Peak Perks"[40] residential DR platform for mutual benefit. Peak Perks offers incentives to customers with

[38] https://www.saveonenergy.ca/For-Business-and-Industry/Programs-and-incentives/Local-Initiatives#regionaladders
[39] Kanata North Retrofit+ program evaluation report, https://www.ieso.ca/-/media/Files/IESO/Document-Library/conservation/EMV/2022/PY2022-IF-Hydro Ottawa-Kanata-North-Evaluation-Report.pdf
[40] https://saveonenergy.ca/en/For-Your-Home/Peak-Perks

eligible smart thermostats in exchange for allowing minor temperature setbacks during peak demand periods. Further evaluation with IESO is needed in order to determine whether the Peak Perks program and platform can support Hydro Ottawa's system planning and deliver tangible distribution system benefits in its current form. Funding within the Non-Wires Customer Solutions Program would be used for targeted marketing campaigns, and allow for the possibility of an enhanced incentive to further encourage customers located in priority areas of need to enroll.

3. Commercial Demand Response Program

While the IESO's Capacity Auction already allows for commercial customer participation in DR, Hydro Ottawa recognizes the potential for further opportunity adjacent to the Capacity Auction.

Program operation is expected to involve third-party aggregators for customer qualification, event management, and measurement/verification. In addition to those activities, funding within the Non-Wires Customer Solution Program could be used for targeted marketing campaigns and incentive payments to enroll participants.

IESO's 2025-2027 eDSM plan[41] also states IESO plans to launch a new commercial HVAC DR program in 2026. Hydro Ottawa will explore the possibility of a commercial DR program that - following BCA evaluation - addresses distribution needs and delivers bulk system benefit.

4. Solar PV and Energy Storage Program

Hydro Ottawa has collaborated with the IESO and supported the delivery of the Ottawa DER Large Solar PV Funding Incentive that was operating within the IESO 2021-2024 CDM Framework. This measure, launched on January 8, 2024, was available to commercial customers within eligible postal codes in the Ottawa area. This regional program attracted strong interest from customers, and solar incentive programs have now been expanded to all

[41] 2025-2027 Electricity Demand Side Management Program Plan- https://ieso.ca/-/media/Files/IESO/Document-Library/eDSM/2025-2027-DSM-Plan-with-Beneficial-Electrification.pdf

customers across the province as part of the new eDSM Framework announced on January 9, 2025.[42]

To maximize the value of intermittent solar generation, Hydro Ottawa is evaluating the benefits of local incentive adders for behind the meter customer owned solar PV and energy storage. A combined offering would enhance benefits to both the local distribution grid and the bulk system by allowing for predictability in output during times of system need.

Funding within the Non-Wires Customer Solution Program would be used to incentivize customers and for targeted marketing campaigns to encourage participation.

For further details on the costs associated with the Non-Wires Customer Solutions Program, see Schedules 6-3-5 - Other Income & Deductions and 4-1-2 - Operations, Maintenance and Administrative Program Costs.

9.2.2.2 Battery Energy Storage System (BESS)

In the electric utility industry, BESS is emerging as a viable solution to address a variety of challenges, including peak load management, grid reliability, and the integration of renewable energy sources. BESS involves the use of advanced battery technologies to store excess energy generated during periods of low demand or high production and release it during periods of high demand or low production. This capability offers numerous benefits to the overall electricity grid.

9.2.2.2.1 Utility Owned Battery Energy Storage System

Utility-owned BESS installations are being strategically deployed in areas where minor grid overloads are predicted that do not necessitate the construction of an entirely new substation, and where options to offload are limited or nonexistent. Additionally, BESS solutions will play a crucial

[42] Save On Energy,"Retrofit Program," https://saveonenergy.ca/For-Business-and-Industry/Programs-and-incentives/Retrofit-Program

role in areas where wire solutions are being implemented, but smaller-scale overloads are still anticipated in the mid-term. These installations align with the assessment criteria outlined in Section 9.2.1 - Hydro Ottawa NWSs Assessment Criteria and aim to provide targeted support where traditional grid infrastructure may not be immediately necessary or where additional capacity is required in the near future.

Utility-owned BESS installations present several advantages, including direct control and localized grid support. By owning and operating these installations, Hydro Ottawa can efficiently integrate them into the existing grid infrastructure, allowing for streamlined maintenance, optimized performance, and reduced reliance on third-party providers. This is critical since the areas selected for utility owned BESS installations have limited to no alternative options to support excess demand in the near term.

9.2.2.2.2 Commercial Customer Owned Battery Energy Storage Systems

BESS solutions that are located behind the meter, and owned and operated by commercial customers in partnership with the LDC, have the potential to deliver tangible distribution system grid benefits when located in targeted areas and deployed in concert with system needs. Although interest in BESS facilities is growing, current penetration of these systems is low across Hydro Ottawa's service territory, with only 3 BESS assets larger than 100kW connected to the distribution system, none of which are located in areas of need.

Hydro Ottawa has been exploring partnering with a customer planning for a behind the meter BESS in an area of need. After extensive discussions over several years, significant challenges remain. Namely the complexities of the customer's decision-making process including needs assessment, Industrial Conservation Initiative participation, cost-benefit analysis for both parties and implementation timelines. Despite technical, economic, regulatory, and customer-related barriers, Hydro Ottawa is continuing to pursue the potential of partnering with customers interested in BESS to support grid needs as policy and regulatory frameworks adapt around the use of DERs.

9.2.3 Proposed NWSs by Planning Region

Following the assessment criteria outlined in 9.2.1, NWSs were considered as part of the capacity planning process by Hydro Ottawa's planning region. Table 36 summarizes the regions and solutions being proposed.

Table 36 - Non-Wires Solutions by Planning Region

NWSs Assessment Criteria	Planning Regions	Non-Wires Solutions
Scenario 1, 3	West 28kV (North)	• Non-Wires Customer Solutions Program
Scenario 2	West 28 kV	• 2.5 MW of Utility Owned BESS at Beckwith DS
Scenario 2	Bells Corners/ Bayshore 8 kV	• 7 MW of Utility Owned BESS in the Bells Corners/Bayshore 8kV region
Scenario 2	Casselman 8 kV	• 5 MW of Utility Owned BESS at Casselman DS
Scenario 1, 3	Core 13 kV, West 13kV	• 10 MW of Utility Owned BESS in the 13kV region • Non-Wires Customer Solutions Program

9.2.3.1 West 28kV (North)

Selection of this region for the deployment of NWSs was based on Scenario 1 and 3 of the NWSs Assessment criteria, Section 9.2.1 - Hydro Ottawa NWSs Assessment Criteria. There are existing capacity constraints in the Kanata North region due to rapid technology sector growth which has spurred a surge in large load requests. Immediate risk mitigation through Non-Wire Customer Solutions is being proposed until the new Kanata North station is energized. Non-Wires Customer Solutions will continue supporting this region in the long term considering the IRRP forecast. For more details on the need and justification for this solution please refer to Section 2.3.2.3 of Schedule 2-5-8 - System Service Investments

9.2.3.2 West 28kV

Selection of this region for the deployment of NWSs was based on Scenario 2 of the NWSs Assessment criteria, Section 9.2.1 - Hydro Ottawa NWSs Assessment Criteria. The Beckwith DS is currently capacity constrained and has limited transfer capability with adjacent stations. The demand forecast of this station until 2030 is minimal and wire upgrades will not be economically viable. For more details on the need and justification for this solution please refer to Section 2.3.2.3 of Schedule 2-5-8 - System Service Investments.

9.2.3.3 Bells Corners/Bayshore 8kV

Selection of this region for the deployment of NWSs was based on Scenario 2 of the NWSs Assessment criteria, Section 9.2.1 - Hydro Ottawa NWSs Assessment Criteria. Bayshore DS and Q.C.H DS are approaching their planned capacity and are forecasted to exceed their capacity by 2030. They have limited inter-station ties between each other and are otherwise isolated from the rest of the 8kV system. The demand forecast of this station until 2030 is minimal and wire upgrades will not be economically viable. For more details on the need and justification for this solution please refer to Section 2.3.2.3 of Schedule 2-5-8 - System Service Investments.

9.2.3.4 Casselman 8kV

Selection of this region for the deployment of NWSs was based on Scenario 2 of the NWSs Assessment criteria, Section 9.2.1 - Hydro Ottawa NWSs Assessment Criteria. The forecasted demand at Casselman DS is expected to exceed its planning capacity by 2030 and is isolated from Hydro Ottawa's distribution system not allowing for the capability to create inter-station ties. The demand forecast of this station until 2030 is minimal and wire upgrades will not be economically viable. For more details on the need and justification for this solution please refer to Section 2.3.2.3 of Schedule 2-5-8 - System Service Investments.

9.2.3.5 Core 13kV and West 13kV

Selection of this region for the deployment of NWSs was based on Scenario 1 and 3 of the NWSs Assessment criteria, Section 9.2.1 - Hydro Ottawa NWSs Assessment Criteria. The combined forecast of Carling TM, Lisgar TL and Riverdale TR is expected to exceed planned capacity by 2028 and the 115kV transmission supply for this region is constrained. Even with the proposed wire upgrade (Bronson DS upgrade in 2032), support will be required from NWSs considering the long term outlook. Immediate risk mitigation through Non-Wire Customer Solutions and Utility Owned

BESS solutions are being proposed until Bronson station is upgraded. Non-Wires Customer Solutions will continue supporting this region in the long term considering the IRRP forecast. For more details on the need and justification for this solution please refer to Section 2.3.2.3 of Schedule 2-5-8 - System Service Investments.

9.2.4 Evolution of the NWSs Assessment Process

Hydro Ottawa has evolved to incorporate the NWSs evaluation process within the capacity planning process. As with all processes, the expectation is to make continued improvements by integrating lessons learned from the deployment of NWSs by Hydro Ottawa, its customers, and peers in Ontario and across North America, as the technology, regulations and landscape evolves. For example, the Non-Wires Customer Solutions Program described in Section 9.2.2.1 - Non-Wires Customer Solutions Program has the potential to be deployed across other areas of the distribution system in the future to address the scenarios described in Section 9.2.1 - Hydro Ottawa NWSs Assessment Criteria as they occur. Additionally, Hydro Ottawa is making investments in systems and tools - including behind the meter disaggregation technology and energy analytics tools - that are able to provide powerful insights and further inform both the NWSs assessment process and the design and deployment of Non-Wires Customer Solutions. Refer to Section 6 of Schedule 2-5-9 - General Plant Investments for additional details. By adapting its process, Hydro Ottawa will ensure that NWSs become an integral part of meeting local system needs to drive customer value.

9.2.4.1 EV Everywhere Pilot

Hydro Ottawa has been working with project partner BluWave-ai on EV Everywhere[43] - an innovation project funded in part by the IESO's Grid Innovation Fund. The pilot project pairs PA with local DR programming for electric vehicles as well as battery storage with the aim to test how the technology can help address localized system needs as EV adoption increases. The intent is to further understand the potential impacts and operational needs of EVs for DR. With over 150 customers enrolled in the pilot, surpassing the pilot target of 50 customers, electric vehicle

[43] https://hydroottawa.com/en/save-energy/save-energy-homes/ev-everywhere

on-command charging dispatch is being tested with participating customers. The learnings for the EV dispatch portion of EV Everywhere include:

- Determining how to accurately forecast available NWSs capacity;
- Understanding the coordination required to communicate with EV users;
- Designing and testing the DR system, the actual response rates (i.e. registrants that are plugged in and are not opting out) amongst participants, and evaluating the benefits.

In parallel, to provide a proxy of the impact of a future state with wider adoption of EVs with bi-directional energy flow, two BESS solutions will be installed within the Hydro Ottawa system in early 2025 to prepare and familiarize the company with the operation and dispatch of energy storage in response to a predicted overload scenario. Lessons learned from the EV Everywhere BESS portion are intended to support standards creation, selection considerations for BESS units (such as siting, MW and MWh capacity, and battery and energy management system features), BESS Integration (use impact assessment, data value, information visibility to stakeholders), strategic application, and maintenance.

A key component to the EV Everywhere project is communication network, data management, and data security. In a prior residential EV charging pilot, as described in Section 2.1.1.4 of Schedule 1-4-1 - Customer Engagement Ongoing, pilot data was obtained that was used to help provide initial expectations of how EVSEs would be used. This data has also supported forecasting load expectations and assessing how to size electrical service entrances and distribution transformers to meet expected capacity needs and adjust distribution and power design standards accordingly. Overall, the EV Everywhere project will drive learnings and inform opportunities to further expand the use of NWSs to address local system needs.

9.2.4.2 Ottawa DER Accelerator Project (ODERA)

The ODERA project is envisioned to build on the learnings from EV Everywhere, to further develop PA and granular demand-response technology for application to a larger ecosystem of customer devices (e.g. thermostats, EV chargers, battery storage and electric water heaters), while advancing Hydro Ottawa's grid modernization roadmap. With further technology development, this project could become a scalable and viable NWSs option to address needs in other areas. This project - which has received the support of federal funding - is further described in Section 3 of Schedule 2-5-8 - System Service Investments.

9.2.4.3 "Stream 2" Local NWSs Program Opportunities

Regulatory and policy work around NWSs will continue to evolve. The OEB has released the phase 1 BCA Framework - the Distribution Service Test (DST) - while phase 2, which will outline the approach to calculate both local and bulk system benefits and costs, known as the Energy System Test (EST) is forthcoming. Secondly, an IESO-LDC working group was established to assist with operationalizing "Stream 2" eDSM activities and in which Hydro Ottawa participates, has not completed its work.

Stream 2 programs are local NWSs programs, designed and administered by local distribution companies, that benefit both the local and bulk systems. The IESO's initial eDSM plan allocates funding to LDCs for local eDSM programs addressing distribution system needs, beginning in 2027. Once the working group's work is finalized and the process and funding mechanisms are available, Hydro Ottawa will align its NWSs efforts accordingly.

9.2.4.4 Alternative Energy Models

Alternative Energy Models such as local flexibility markets, Distribution System Operator capabilities, and Total Grid Orchestration capabilities are relatively new approaches in the energy sector to help manage the complex grid of the future. As Ontario pushes for greater DER participation, Hydro Ottawa will continue to evolve its processes and capabilities to be ready to unlock the value DERs can provide at the local level. Hydro Ottawa is exploring the constructs of these models and is starting to put in place the controlling elements for DER enablement needed to support any of these alternative models. Hydro Ottawa will continue to explore options to achieve benefits and will adapt to new responsibilities in the future around planning, facilitation, and coordination of DERs as these energy business models continue to evolve.

9.3. SYSTEM CAPABILITY ASSESSMENT FOR RENEWABLE ENERGY GENERATION AND DISTRIBUTION ENERGY RESOURCES

9.3.1. Historical Connections DER Applications

Within Hydro Ottawa's service territory, there is a considerable amount of connected distributed generation, or DERs. These energy resources represent all manners of electric generation and storage, including grid-connected solar panels, hydro-electric generators, natural-gas turbines, and battery storage facilities. In the last five years, the Hydro Ottawa service region has seen strong growth in the connected capacity of renewable generation, entirely as grid-connected photovoltaic generators, as can be seen in Figure 108.

Non-photovoltaic DERs have not seen significant growth. The Ottawa region's natural hydroelectric potential has largely been captured already, and there is strong disincentivization to construct carbon-producing combustion generation facilities, while there are strong incentives to construct renewable energy facilities. Additionally, BESS facilities continue to grow, with four in its service territory with an aggregate capacity of ~2MW, the highest individual capacity being 1,000kW.

In 2017, the IESO discontinued the microFIT program, which was a popular means of connecting small-scale residential photovoltaic systems (less than 10kW) to the grid. Despite the end of this program, Hydro Ottawa remains committed to ensuring that proposed DERs may connect to the grid whenever possible. Hydro Ottawa's programs for net metering (bidirectional flow of power to a premise) or load displacement (on-site generation that offsets premise's load) are available to customers as an alternative to the microFIT program. From 2019 to 2023, almost 300 new renewable DERs were connected under the net metering and load displacement programs, as can be seen in Figure 109 below, representing a 26% increase over that period. Of these, 88% were 10kW or under DERs.

Figure 108 - Total System DER Capacity 2019-2023

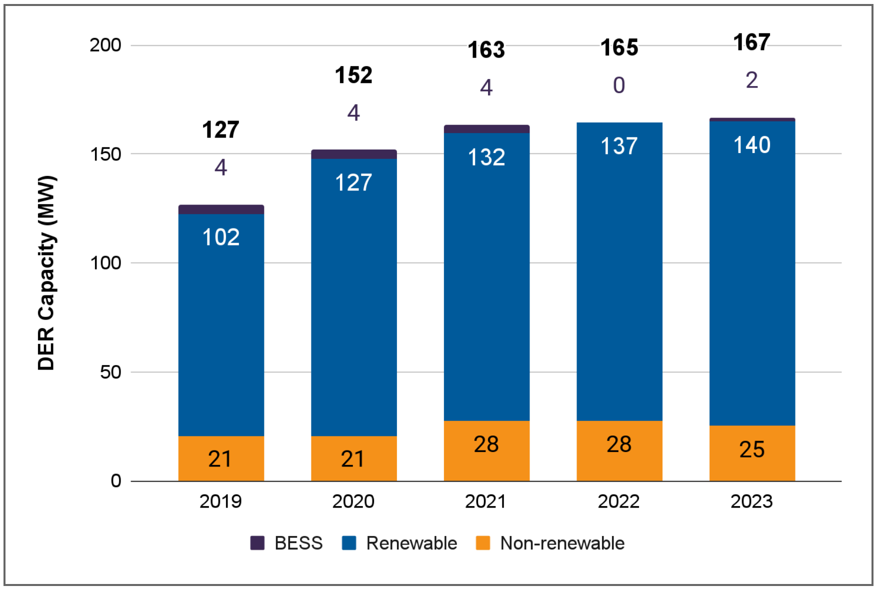
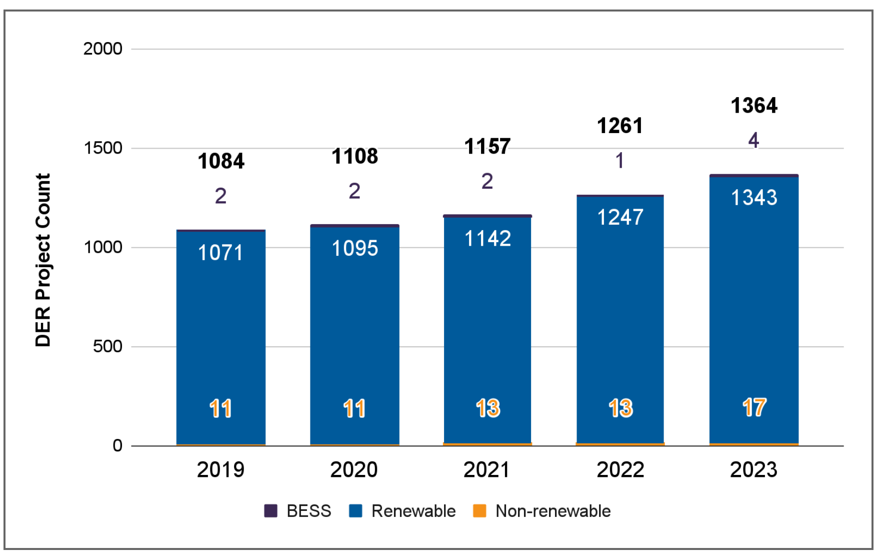
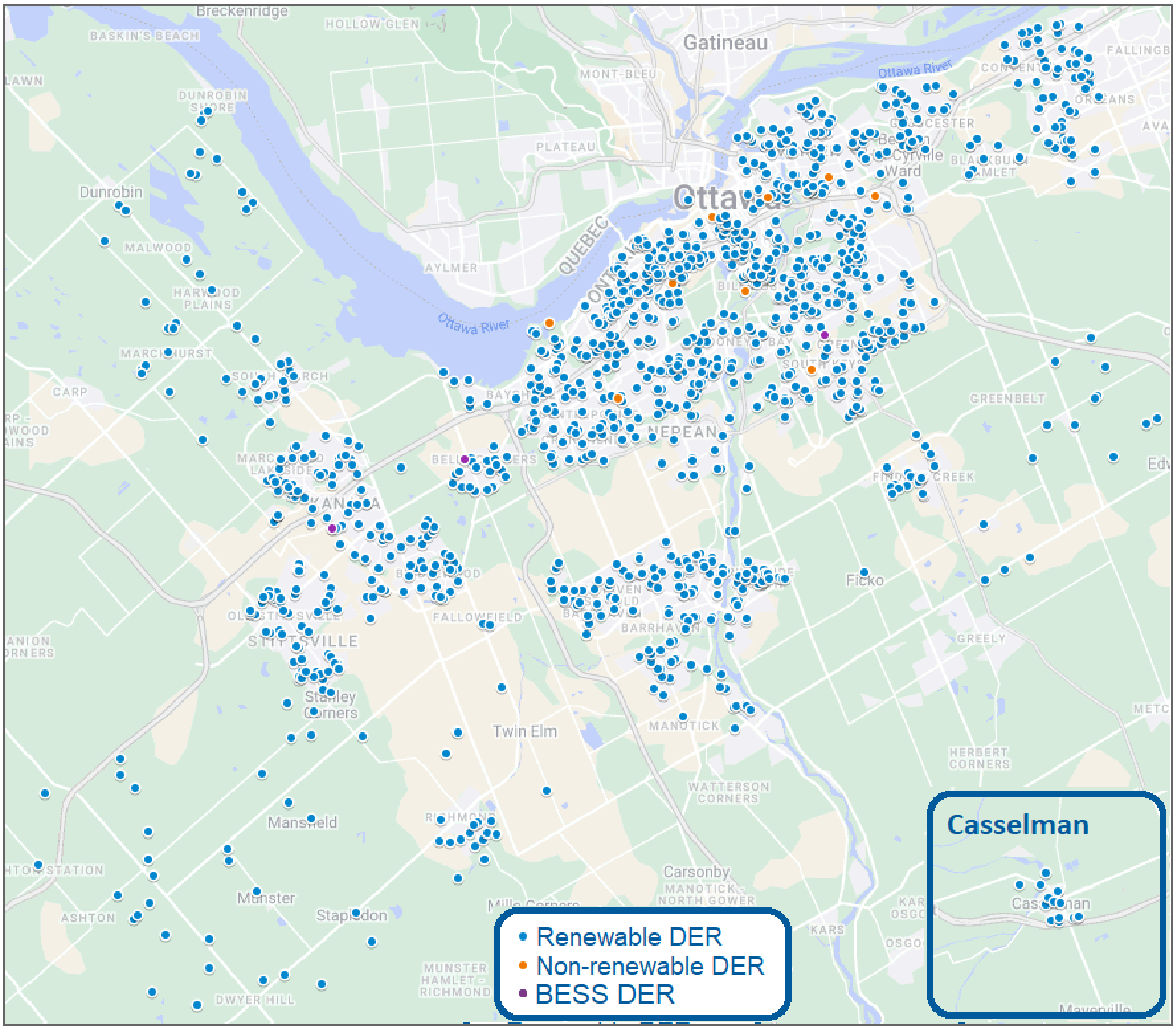


Figure 109 - Total System DER Count 2019-2023



The continuing success of DERs is visible in Figure 110, which maps the existing renewable and non-renewable DERs across the Hydro Ottawa service territory.

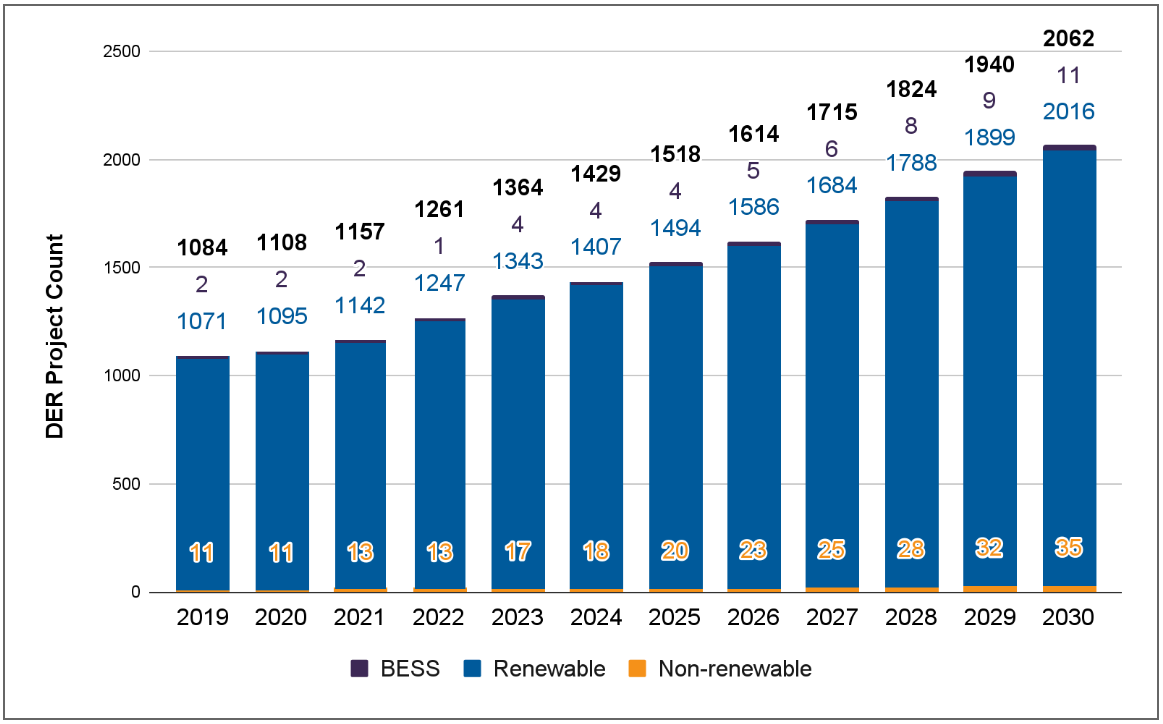
Figure 110 - Map of DER Projects in Hydro Ottawa Service Area



9.3.2 Generation Forecast

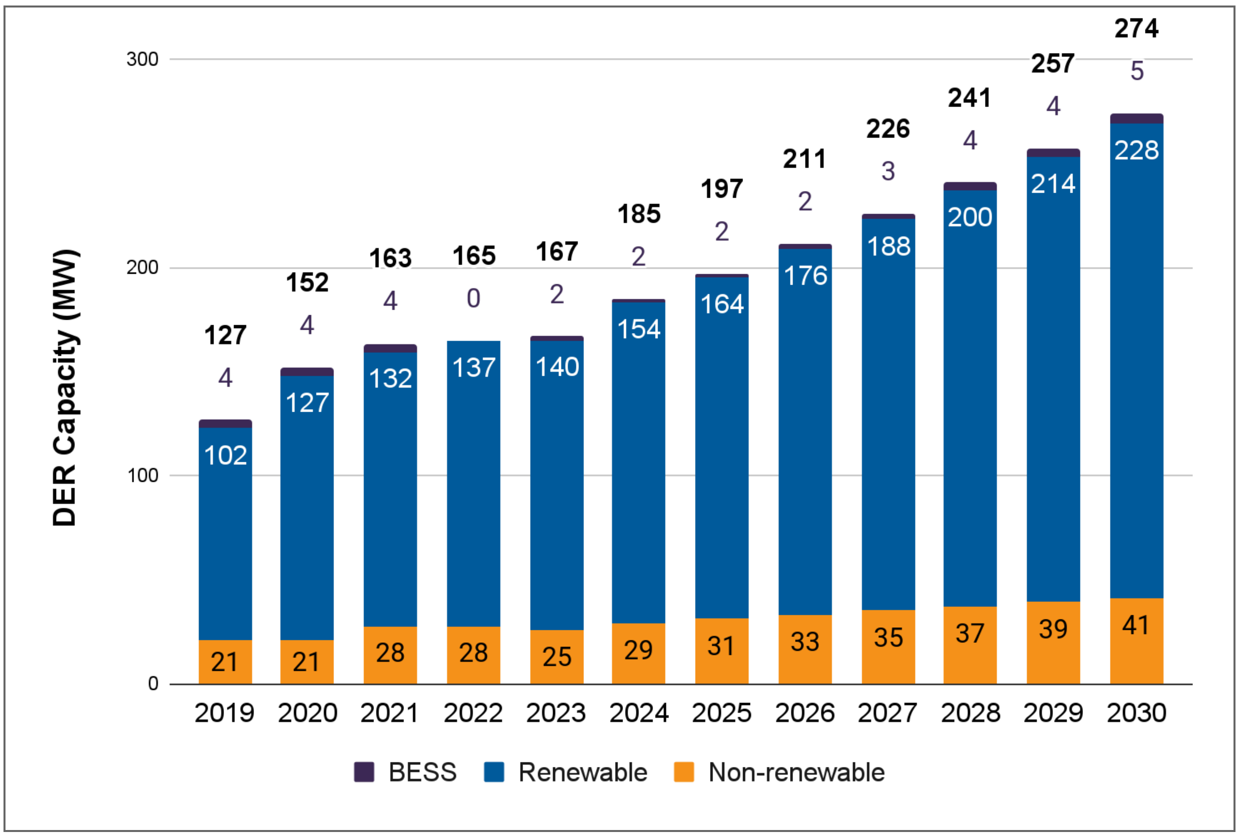
Hydro Ottawa's 2026-2030 DER forecast takes into account historical data, planned projects, current customer programs and the prevailing economic climate. Ultimately, customer choice fuels the demand for DERs and this demand is highly sensitive to policy influences, particularly the availability of funding and incentive programs. Predicting the precise timing, magnitude, and likelihood of customer adoption is challenging due to the numerous policy, economic, and technological variables at play - actual growth could deviate if new programs, incentives or technologies are introduced. The latest Hydro Ottawa forecast anticipates a total of 2,016 renewable projects by the end of 2030, in comparison to the 1,343 installed as of the end of December 2023. The forecast also anticipates 35 non-renewable and 11 BESS projects by the end of 2030, shown in Figure 111.

Figure 111 - Historical and Forecasted DER Projects



The forecast anticipates the cumulative installed renewable DER capacity to reach 228 MW by the end of 2030, as per Figure 112. The cumulative non-renewable DER capacity is projected to increase to 41 MW by the end of 2030, with BESS capacity increasing to 5 MW. With policy emphasis on decarbonization, it is expected that the number of renewable and energy storage DER projects will continue to increase beyond 2030.

Figure 112 - Historical and Forecasted DER Capacity



9.3.3. System Capability to Connect DER

Connecting new DERs to the distribution system requires careful evaluation of several key factors. Hydro Ottawa must ensure that the grid can safely and reliably accommodate the additional generation without compromising existing infrastructure or the quality of service to customers. This assessment includes analyzing the system's short-circuit capacity, thermal limits, and the potential impact of reverse power flow.

Furthermore, Hydro Ottawa must consider the effects of DERs on power quality. Maintaining stable voltage and frequency levels is crucial, and the connection of a DER should not introduce disturbances or create issues for other grid users. The potential for islanding, where a DER becomes isolated from the main grid but remains energized, also requires thorough investigation to prevent safety hazards. Each of these considerations is described in greater detail below as related to current system capacity and forecasted DER capacity from 2026-2030.

Short Circuit Capacity Constraints

Connection of DERs will increase the available current that flows through the distribution system during faults. The total available current during faults cannot exceed the equipment ratings. Currently Ellwood MTS is restricted due to short circuit capacity constraints. Consequently, substations fed from Ellwood MTS are also restricted - all Cahill AN feeders, Brookfield feeders AF02 through AF04, McCarthy AQ02 through AQ04, Albion feeders UA05 through UA07, and Walkley feeders UZ05 through UZ12. The Ellwood MTS short circuit constraint results in a total of 36 restricted feeders, as outlined in Table 37. More details on steps being taken by Hydro Ottawa to deal with the Ellwood MTS constraints is elaborated in Section 9.3.4 - Capacity Investments for DER Connections.

1 **Table 37 - Restricted Feeders and Number of Connected Customers**

Station Name	Feeder Designation	Restriction	# of Connected Customers
Ellwood	ELW01	Short Circuit Capacity	-
	ELW02	Short Circuit Capacity	64
	ELW03	Short Circuit Capacity	-
	ELW04	Short Circuit Capacity	1,038
	ELW05	Short Circuit Capacity	1,131
	ELW06	Short Circuit Capacity	5
	ELW07	Short Circuit Capacity	1,771
	ELW08	Short Circuit Capacity	1,149
	ELW09	Short Circuit Capacity	1,048
	ELW10	Short Circuit Capacity	973
	ELW11	Short Circuit Capacity	836
	ELW12	Short Circuit Capacity	673
	ELW13	Short Circuit Capacity	1,044
	ELW14	Short Circuit Capacity	808
Cahill	AN02	Short Circuit Capacity	-
	AN03	Short Circuit Capacity	-
	AN04	Short Circuit Capacity	365
	AN05	Short Circuit Capacity	399
	AN06	Short Circuit Capacity	251
	AN07	Short Circuit Capacity	-
	AN00	Short Circuit Capacity	-
Brookfield	AF02	Short Circuit Capacity	61
	AF03	Short Circuit Capacity	381
	AF04	Short Circuit Capacity	252
McCarthy	AQ02	Short Circuit Capacity	187
	AQ03	Short Circuit Capacity	453

Station Name	Feeder Designation	Restriction	# of Connected Customers
	AQ04	Short Circuit Capacity	330
Albion	UA05	Short Circuit Capacity	501
	UA06	Short Circuit Capacity	307
	UA07	Short Circuit Capacity	341
Walkley	UZ05	Short Circuit Capacity	382
	UZ06	Short Circuit Capacity	654
	UZ07	Short Circuit Capacity	241
	UZ10	Short Circuit Capacity	-
	UZ11	Short Circuit Capacity	665
	UZ12	Short Circuit Capacity	277
Lisgar	TL01	Thermal Capacity	6
	TL03	Thermal Capacity	-
	TL05	Thermal Capacity	755
	TL07	Thermal Capacity	-
	TL09	Thermal Capacity	215
	TL11	Thermal Capacity	-
	TL13	Thermal Capacity	2
	TL15	Thermal Capacity	-
	TL17	Thermal Capacity	-
	TL19	Thermal Capacity	674
	TL21	Thermal Capacity	364
	TL23	Thermal Capacity	31
	TL25	Thermal Capacity	424

Thermal Capacity Constraints

Exceeding the feeder ampacity rating results in overheating the conductors and connected equipment, thereby reducing the effective life of the asset or causing immediate equipment failure.

For DERs, the available thermal capacity is the full feeder ampacity rating, less the contingency loading. Lisgar TS currently has thermal constraints on T1, resulting in a total of 13 restricted feeders, as shown in Table 37. More details on steps being taken by Hydro Ottawa to deal with these constraints is elaborated in Section 9.3.4 - Capacity Investments for DER Connections.

Reverse Power Flow Considerations

When transformers are identified as having reverse flow capability as per manufacturer specification, the limiting factor is 60% of the top transformer rating plus minimum station load. For station transformers that have limited or no capability for reverse power flow, the limiting factor is the station minimum load. Only Lisgar TS is currently restricted by reverse power flow at the station.

Power Quality Considerations

There are various power quality concerns that are considered when connecting distributed generation on the system, including harmonics, phase imbalance, voltage instability, and flicker. Each of these factors is investigated as part of the connection impact assessment for proposed DERs.

Anti-islanding Considerations

DERs may introduce safety and power quality issues in the event of continued unsanctioned generation after the loss of distribution supply. The installation of transfer trip functionality and alternate anti-islanding methods such as reverse power flow protection may be used to mitigate the potential for the unsanctioned islanding of individual generators. Currently transfer-trip is required for generation connections equal to or larger than 500kW. Anti-islanding measures are investigated as part of the connection impact assessment for proposed DERs.

9.3.4. Capacity Investments for DER Connections

Hydro Ottawa currently has two stations in its distribution system with restrictions on generation connection. Ellwood MTS restrictions are due to short circuit limitations, while Lisgar TS is limited by minimum normal loading on the station bus, thus raising reverse power flow concerns should additional generation be installed.

Options are being assessed to remove short circuit limitations at Ellwood MTS. One of the alternatives being assessed is installing fast switching protective devices at the closed bus tie, thereby removing the short circuit constraint at the station and all downstream substations fed from Ellwood MTS. This solution is still at the planning stages and feasibility is left to be determined. In the interim, Hydro Ottawa is investigating the feasibility of operating Ellwood MTS with an open bus tie to temporarily remove the short circuit limitation until a permanent solution can be implemented.

Hydro One is addressing the constraint at Lisgar TS through the replacement of the T1 transformer to a unit that has reverse flow capability - the work will be completed by 2025. In addition, Hydro Ottawa is currently in discussions with Hydro One through the IRRP on timings to replace the T2 transformer at Lisgar TS with a larger unit to address future demand growth within the downtown area.

Hydro Ottawa is actively pursuing the solutions above to remove the short circuit restrictions on 36 feeders and the thermal restriction on 13 feeders, in order to accommodate new DERs. These initiatives demonstrate Hydro Ottawa's commitment to exploring and implementing feasible alternatives to enable DER connections even in areas with existing network constraints. This approach ensures that customers seeking to integrate DERs can be effectively accommodated wherever possible.

9.4. PLANNING LOAD FORECASTING

Hydro Ottawa's capacity planning process evaluates the distribution grid's ability to serve current and future customers safely and reliably, using the system load forecast as its foundation. The system load forecast was informed by two types of forecasts: Hydro Ottawa Planning Forecast and the IRRP Forecast. It is important to note that these forecasts are different from the revenue load forecast explained in detail in Section 9.4.3 - Planning Load Forecast vs. Revenue Load Forecast.

9.4.1. Hydro Ottawa Planning Forecast

Hydro Ottawa's Planning Forecast projects station-level load increases until 2030. It is guided by the City of Ottawa's Official Plan, City planning circulations, CDPs and consultations with developers and considers:

- Historical weather-normalized load from system coincident peak (currently summer) at the station level,
- Planned developments (residential, mixed-use, and employment)
- Known large load requests, see Section 9.4.1.1 - Large Load Request Trends and
- Customer requests in initial planning phases

While systemic impacts of space heating and transport electrification are not explicitly modeled, known large load requests, some of which are driven by electrification, are included. This detailed station-level approach is specifically used to inform near-term capacity needs across distribution subsystems, out to 2030.

9.4.1.1. Large Load Request Trends

Hydro Ottawa received large electrification load requests in the 2021-2025 period ranging from 5 MVA to 57 MVA. These requests encompass a variety of customers, from large institutions, like universities and hospitals, to technology companies and federal agencies. The main driver for the majority of large load requests was electrification of space heating, water heating, and transportation in order to align with municipal and federal decarbonization goals. The use of electric heat pumps, electric bus charging, and electric industrial water heating results in a significant increase in loading for large facilities, particularly when transitioning the entire facility to electric. The cumulative demand requests received through to January 1st 2025, with the respective energization timelines, are illustrated in Figure 113. Figure 113 highlights 110 MVA of large loads successfully integrated into the grid between 2010 and 2023 (blue), 113 MVA of confirmed customer commitments, secured through signed Offers to Connect and slated for completion by 2028 (orange), and a further 199 MVA of potential load requests, encompassing preliminary inquiries through to formal load summary submissions (grey and green). Should these potential requests materialize by 2030, Hydro Ottawa anticipates an unprecedented 312 MVA increase in its total load demand over the 6 year span of 2024-2030; a three-fold increase from the 110MVA connected in the previous 10 years.

Figure 113 - Cumulative MVA Large Load Requests

9.4.2. IRRP Forecast

The IRRP forecast submitted by Hydro Ottawa to the IESO for the regional planning process is built with a focus on the medium to long-term outlook (beyond 2030) that considers a sensitivity analysis due to effects of decarbonization goals. This is in alignment with the Regional Planning Process Advisory Group's (RPPAG) Load Forecasting Guideline.[44] Previously, mid to long-term forecasting relied on historical consumption patterns and projected growth rates based on observable past trends. However, with the introduction of decarbonization goals and the resulting electrification of

[44] RPPAG Load Forecasting Guideline-
https://www.oeb.ca/sites/default/files/Load-Forecast-Guidance-Document-RPPAG-20221013.pdf

buildings, water heating, and transportation, this methodology is no longer adequate to model the potential impacts these shifts have on electricity demand.

Hydro Ottawa leveraged the hourly system coincident peak forecasts from the Decarbonization Study's Reference Scenario, see details in Section 9.4.2.1 - Decarbonization Study to inform the IRRP forecast. This helps contextualize potential long-term impacts of decarbonization. Aligning with the Decarbonization Reference Scenario in the medium to long-term is required for the regional planning process as transmission level investments that add capacity to the provincial grid have longer lead times (> 5 years). This also allows Hydro Ottawa to validate that capacity investments for immediate needs (informed through Hydro Ottawa's planning forecast) strategically align with indications of long-term needs, ensuring efficient capital deployment and optimizing asset utilization.

9.4.2.1. Decarbonization Study

To support the transition to a more advanced forecasting methodology for medium to long-term system needs, Hydro Ottawa engaged Black & Veatch to conduct a Decarbonization Study to examine the impact of decarbonization initiatives on Hydro Ottawa's distribution system through 2050. Refer to Attachment 2-5-4(F) - Decarbonization Study for details on the study.

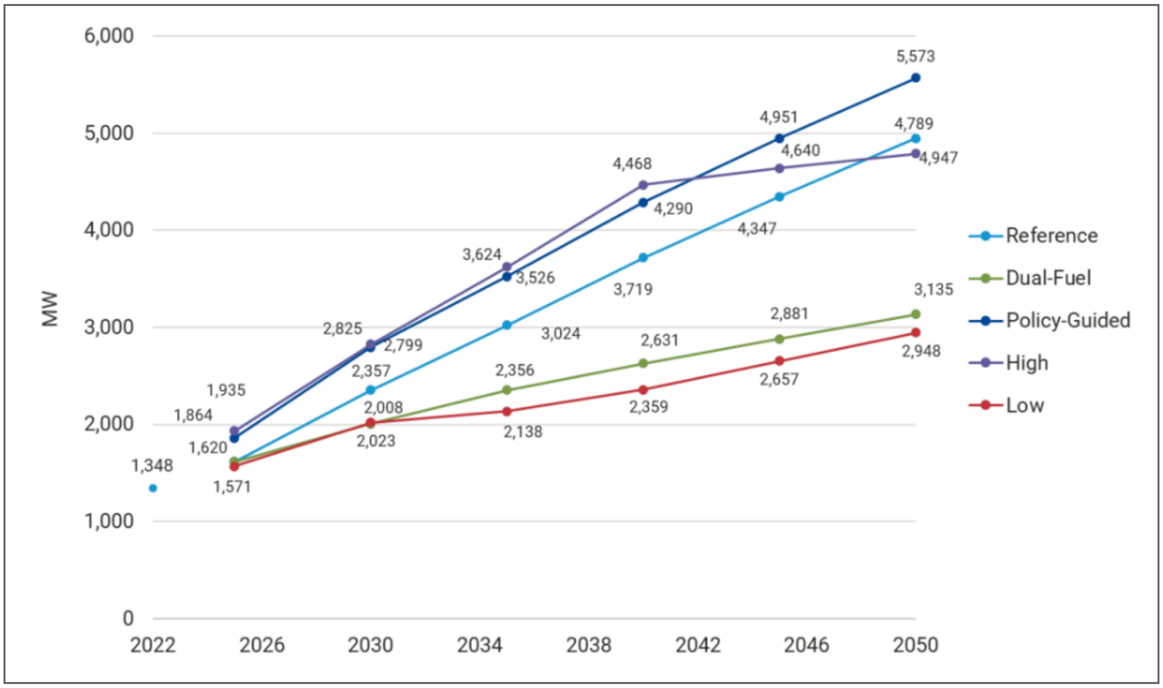
The Decarbonization Study outlines five scenarios that assess the impact of decarbonization initiatives on Hydro Ottawa's distribution system until 2050. Decarbonization levers such as population growth, energy efficiency, electric vehicle adoption, and building heating assumptions were adjusted within each scenario. Load modeling was divided into Baseline and New Electrification load categories. These scenarios illustrate potential impacts on Hydro Ottawa's load profiles. The five scenarios are outlined in Table 38 below.

Table 38 - Decarbonization Study Scenarios

Scenario	Description
Policy-Guided Scenario	• Models strict adherence to Canada's 2030 Emissions Reduction Plan and the Canadian Net-Zero Emissions Accountability Act. • Assumes full electrification of buildings and transportation, representing an aggressive decarbonization pathway. • Provides insights into the potential challenges and infrastructure requirements under ambitious climate goals.
Reference Scenario	• Represents the most likely outcome based on current trends in Hydro Ottawa's load forecast. • Assumes a moderate pace of decarbonization, with increasing electrification in the mid-to-long term. • Serves as the primary basis for evaluating the distribution system impact and potential solutions.
Dual-Fuel Scenario	• Sensitivity analysis applied to the Reference Scenario, focusing on space heating and water heating. • Assumes a significant portion of buildings will adopt dual-fuel heating systems, using both electricity and low-carbon gas. • Helps assess the impact of continued gas use on peak demand during extreme cold temperature and overall load growth.
High Case Sensitivity	• Explores a more aggressive decarbonization and electrification pathway than the Policy-Guided Scenario. • Assumes accelerated adoption of electric vehicles (EVs) and higher efficiency gains in heating technologies. • Helps evaluate the potential for rapid load growth and the need for proactive grid investments.
Low Case Sensitivity	• Considers a less aggressive decarbonization and electrification pathway than the Policy-Guided Scenario. • Assumes slower EV adoption and a higher proportion of buildings continuing to rely on decarbonized gaseous fuels. • Provides insights into the potential for slower load growth and the implications for infrastructure planning.

Hydro Ottawa leveraged Black & Veatch projections for the Reference Scenario to inform its medium to long-term forecast that was submitted to the IESO as part of the regional planning process - the IRRP Forecast. The five scenarios are depicted in Figure 114.

Figure 114 - Decarbonization Scenario Peak by Year[45]



The Reference scenario is based on historical data and existing trends, and assumes increasing policy-driven decarbonization leading to electrification in the medium to long-term. This scenario was selected because in the Reference Scenario, the new electrification load forecast is characterized by a tempered pace of decarbonization in the short-term which meets Canada's 2030 Emissions Reduction Plan and Canada's wider 2050 decarbonization goals. Further, this scenario assumes full electrification of most buildings, with a minority continuing to utilize gas distribution networks by 2050. The Reference scenario sees the system transition to winter peaking by 2030, largely driven by projections on space heating, where electrification rates in buildings lead to spikes in space heating when temperatures are low and impact heating efficiency.

9.4.3. Planning Load Forecast vs. Revenue Load Forecast

The planning forecast serves as the foundation for evaluating the distribution system's capacity to

[45] Figure 38 in Attachment 2-5-4(F) - Decarbonization Study

accommodate future electricity demand. This forecast plays a pivotal role in identifying both the locations and the timing of necessary system upgrades. By considering factors at various levels of granularity—including the station and planning region—the planning forecast allows for a nuanced and targeted approach to system expansion. Its emphasis on location specificity and its incorporation of coincident peak demand requirements—the periods when electricity demand is at its highest—ensure that the distribution system remains robust and capable of meeting the needs of consumers, even during peak load periods. More details on justification for station capacity needs are available in Section 2.3.2 in Schedule 2-5-8 - System Service Investments.

In contrast, the revenue load forecast, outlined in Schedule 3-1-1 - Revenue Load and Customer Forecast, is primarily employed for financial planning and the determination of distribution rates and allocating revenue requirements. This forecast centers on billing consumption and billing demand rather than the locational coincident peak demand, measured in MWs. While the planning forecast is granular and location-specific, the revenue load forecast takes a more aggregated approach. It considers a broader array of factors, such as economic trends, population growth, energy efficiency initiatives, and the impacts of CDM programs. The development of the revenue load forecast typically relies on historical billing data, sophisticated econometric models, and customer class segmentation, enabling a comprehensive understanding of revenue requirements and informing the establishment of distribution rates.

In essence, the planning forecast and the revenue load forecast serve distinct yet complementary purposes within the electricity distribution system. Both forecasts use the same foundational considerations built upon shared core principles, influencing elements, and underlying assumptions on how energy consumption will evolve. However, the planning forecast ensures the system's physical capacity to meet future peak demand (the worst case scenario), while the revenue load forecast supports financial planning and rate setting through annual consumption. By recognizing the differences in their focus and level of aggregation, Hydro Ottawa leverages these forecasts effectively to optimize both the operational and financial performance of the electricity distribution system.

ea technology

CERTIFICATE OF CONFORMANCE

Certificate of Conformance

This is to certify that the Asset Management System of

Hydro Ottawa Limited

2711 Hunt Club Road, Ottawa, K1G 4G2, Canada

is in conformance with the requirements specified within the following Asset Management Standard:

ISO55001: 2014

The scope of the Asset Management System is applicable to:

- The electricity distribution and electrical energy supply assets owned, managed and operated by Hydro Ottawa Ltd. including:
  - All electricity distribution system assets.
    - This includes metering assets and communication systems between all applicable sets of assets.
    - This excludes fleet and IT businesses.
  - All core processes that are applicable to the Asset Management System, including internal resources and control of external service providers contributing to asset management.

This certificate is applicable to the following Hydro Ottawa Ltd. locations:

- Main Office & East Operations (2711 Hunt Club Road, Ottawa, K1G 4G2, Canada)
- Training Centre (4565 Bank Street, Gloucester, K1T 3W6, ON, Canada)
- West Operations (100 Maple Grove Road, Kanata, K2V 1B8, ON, Canada)
- Warehouse & South Operations (201 Dibblee Road, Nepean, K2R 1J2, ON, Canada)
- Central Operations (1275 Carling Avenue, Ottawa, K1Z 1A2, ON, Canada)

CERTIFICATE OF CONFORMANCE

Signed For EA Technology

A McHarrie: Head of Asset Management
Issued by: EA Technology Limited
Capenhurst Technology Park
Capenhurst
Chester. CH1 6ES

Certificate Number: EA2309001

Certification issue date: 18th September 2023

Certificate expiry date: 17th September 2026

IAM endorsed ASSESSOR

Addendum Report to Distribution System Climate Vulnerability Risk Assessment and Climate Change Adaptation Plan

FINAL REPORT

December 4, 2023

Prepared for:
Hydro Ottawa Limited

Prepared by:
Stantec

Project Number:
160925222

Limitations and Sign-off

The conclusions in the Report titled Addendum Report to Distribution System Climate Vulnerability Risk Assessment and Climate Change Adaptation Plan are Stantec's professional opinion, as of the time of the Report, and concerning the scope described in the Report. This report should be read in conjunction with the original Distribution System Climate Risk and Vulnerability Assessment, 2019 and Hydro Ottawa Climate Change Adaptation Plan, 2019. The opinions in the document are based on conditions and information existing at the time the scope of work was conducted and do not take into account any subsequent changes. The Report relates solely to the specific project for which Stantec was retained and the stated purpose for which the Report was prepared. The Report is not to be used or relied on for any variation or extension of the project, or for any other project or purpose, and any unauthorized use or reliance is at the recipient's own risk.

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Prepared by: Rocard, Jennifer — Digitally signed by Rocard, Jennifer Date: 2023.12.04 17:06:51 -04'00'
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Approved by: ______________________
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Nicole Flanagan, P.Eng.
Climate Solutions Leader, Canada
Printed Name and Title

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Executive Summary

Stantec Consulting Ltd. (Stantec) was retained to by Hydro Ottawa Limited (HOL) to conduct an update to the Distribution System Climate Risk and Vulnerability Assessment and Climate Change Adaptation Plan, 2019. The main objective of the study was to identify if the climate adaptation and risk mitigation measures recommended in the 2019 adaptation plan are still appropriate for the existing risk levels and consequences. This study uses additional and updated climate projection data to estimate climate parameter probabilities and identifies whether these changes lead to materially different risk scores for Hydro Ottawa's infrastructure assets over the study period. The study involved updating the list of climate parameters to include additional high wind thresholds representative of recent extreme weather events, update climate parameter probabilities, impact severity (based on input from Hydro Ottawa personnel), and risk scores, completing a forensic analysis of the May 21, 2022 Derecho event; and a workshop with staff to evaluate adaptation plan progress and assess potential changes to consequence ratings from the 2019 risk assessment, updating where appropriate the adaptation and risk mitigation plan using input from the review workshop and where risk scores changed to medium-very high under current and future climate. For consistency, the same methods used in the 2019 report were also used in this reassessment.

Two additional high wind thresholds were established for this update based on updated Environment and Climate Change Canada (ECCC) criteria for severe thunderstorm winds and the damages observed by the Northern Tornadoes Project in surveys following the 2022 May Derecho event. The thresholds established included:

- Wind speeds > 130 km/h – Based on new ECCC severe thunderstorm winds and with 17% higher loading factor than the 120 km/h gust threshold used in the 2019 study.
- Wind speeds > 180 km/h (Derecho event equivalent) – based on consistent EF-2 style observed damage in Ottawa region and Doppler Radar near surface wind speed recordings.

The climate analysis completed for the 2019 study was based on Coupled Model Intercomparison Project Phase 5 (CMIP5) Global Climate Models (GCMs) climate projections. CMIP5 climate projections formed the basis of the *IPCC Fifth Assessment Report* (IPCC, 2013). The "Delta Approach" downscaling method was used to generate localised climate change projections from 37 CMIP5 GCMs. Projected frequencies of occurrence and likelihoods were assessed based on the multi-model ensemble projections under the RCP8.5 scenario.

Following the completion of the 2019 study, new climate projection data has become available. In 2020, the National Capital Commission and the City of Ottawa released climate projection data for the RCP4.5 and RCP8.5 scenarios for the National Capital Region (NCR). In 2021/2022, the Intergovernmental Panel on Climate Change (IPCC) released its *Sixth Assessment Report* (AR6) based on climate projections from the Coupled Model Intercomparison Project Phase 6 (CMIP6) and based on the new Shared Socio-economic Pathway (SSP) climate change scenarios. Where possible, the projected frequency of occurrence and probability of the selected climate parameters for the CRVA were updated based on these new climate projection data sources.

The climate parameter frequency of occurrence and probabilities were updated using, where possible, the downscaled National Capital Region projections and downscaled CMIP6 projections. Annual and/or 30-year probabilities for the 2050s (2041-2070) changed for the following climate parameters:

- Rain: 50 mm in 1 hr
- Invasive species: Emerald Ash Borer kill temperature (daily minimum temperature of -30°C or colder)
- Frost: Hard freeze-thaw cycles (daily Tmax/Tmin temperature fluctuation of ±4°C around 0°C)

While tornadoes have impacted the Ottawa region more frequently in the last decade, the probability rating for tornado occurrence has not changed. Probability ratings were established for two scenarios: 1) the likelihood of a single point within Hydro Ottawa's service area being struck by a tornado and 2) the likelihood of a tornado occurring anywhere within the service area. In the risk assessment, the higher likelihood was carried forward and used to estabilsh potential risk.

Frequency of occurrence and probabilities were also established for the new high wind thresholds of wind speeds > 130 km/hr and > 180 km/hr.

Risk scores increased due to higher consequence ratings for current and future climate for higher threshold wind speeds (120 km/hr) and for newly established thresholds (130 km/hr and 180 km/hr). However, for most risks, no risk level change was observed.

To handle additional risks from higher wind thresholds, the following risk adaptation measures should be considered:

- Consider a study on pole characteristics (i.e. age and guying locations) from the 2022 Derecho to determine potential vulnerability of pole tops.
- Consider the impact of climate change on recently (or future) hydro poles being grown (i.e. wood density and strength)
- Consider establishing additional supply capacity and storage for key components (e.g. poles) in the event that a major or catastrophic event impacts a large portion of the service area
- Consider real-time or automated monitoring system for severe weather events or creating a staff position for a meteorologist to handle coordination between utilities and monitoring potential upstream outages before they impact HOL service area
- Continue with planned adaptation planning actions already underway, including an undergrounding study, anti-cascading study and strategy, and asset hardening however, new risk should be utilized in decision making a cost/benefit studies underway.

Other risk mitigation measures developed in the 2019 study remain relevant based on the conversations conducted at the 2023 reaffirmation workshop.

Acronyms / Abbreviations

AEP	Annual Exceedance Probability
AR5	5th Assessment Report
AR6	6th Assessment Report
BCCAQv2	Bias Correction/Constructed Analogues with Quantile delta mapping reordering, version 2
CanDCS-U5	Canadian Downscaled Climate Scenarios – Univariate (CMIP5)
CanDCS-U6	Canadian Downscaled Climate Scenarios – Univariate (CMIP6)
CMIP5	Coupled Model Intercomparison Project 5
CMIP6	Coupled Model Intercomparison Project 6
ECCC	Environment and Climate Change Canada
EF	Enhanced Fujita Scale
GCM	Global Climate Model
IDF	Intensity-Duration-Frequency
IPCC	Intergovernmental Panel on Climate Change
NTP	Northern Tornadoes Project
PCIC	Pacific Climate Impacts Consortium
PIEVC	Public Infrastructure Engineering Vulnerability Committee
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
RSI	Risk Sciences International
SSP	Shared Socioeconomic Pathway

1 Introduction

Stantec Consulting Ltd. (Stantec) completed this scope of work to provide Hydro Ottawa Limited (HOL) with an Updated Distribution System Climate Vulnerability Risk Assessment and Climate Change Adaptation Plan, as appropriate, given some of the recent major weather events, specifically:

- September 21, 2018 – Tornadoes
- April 15, 2019 – Lightning storm and flooding
- July 5, 2019 – Windstorm
- June 14, 2021 – Summer/Lightning storm
- May 21, 2022 – Derecho storm
- December 23, 2022 – Winter storm

This update addresses only the revised risks and adaptation measures and should be read in conjunction with the original reports:

- Distribution System Climate Risk and Vulnerability Assessment, dated September 11, 2019 (Stantec, 2019a)
- Hydro Ottawa Climate Change Adaptation Plan, dated November 11, 2019 (Stantec, 2019b)

1.1 Background

A Climate Risk and Vulnerability Assessment (CRVA) and an Adaptation Plan was conducted was developed for HOL conducted by Stantec in 2019 (Stantec, 2019a-b) using:

- Available climate data for the region and their projection into the future using internationally accepted Intergovernmental Panel on Climate Change (IPCC) projection data, and
- Forensic analysis of three significant weather events that occurred in 2018 and resulted in widespread outages / costly recoveries, including a freezing rain event in April, a heavy wind event in May, and a series of tornados that touched down in September in the Ottawa region.

The climate data was used to conduct a climate risk assessment using Engineers Canada's Public Infrastructure Engineering Vulnerability Committee's (PIEVC) assessment protocol (Engineers Canada, 2011) and estimate the vulnerability and risk of Hydro Ottawa's electrical distribution system to climate change and extreme weather events.

The risk assessment included a workshop with Hydro Ottawa personnel, interviews with stakeholders, and an analysis of past climatic events to characterize the impacts and consequences of climate on Hydro Ottawa's assets. Risks were evaluated by combining the climate hazard likelihood with the consequence information. The results of the 2019 report were used to determine where infrastructure vulnerabilities to climate change were present and identify adaptation options to increase resilience.

1.2 Objective

The main objective of this update was to add new climate parameters for wind, utilize new climate data, revise risk based on more extreme weather events and establish new climate risk scores and risk mitigation measures as part of the update to the climate risk and adaptation plans. The outcome of the project is to identify revised climate risk scoring and whether there are any additional climate adaptation and risk mitigation measures required as a result of the revised assessment.

1.3 Scope

The following scope of work has been completed as part of this assessment.

1. **Climate Parameter Probability Update:** Assessment of past and recent weather events looking for new and more accurate climate data that has been available since the most recent assessment. Revision of likelihood scores for the Hydro Ottawa service area where necessary.
2. **Risk Assessment Update:** Evaluating the possible changes to the consequence ratings for any events, in particular focusing on the high and very high risks from the 2019 report.
3. Incorporation of an evaluation of the six weather related events into the impact rating and adding layers of wind speeds between 80 and 180 km/hr with the representative frequency data (for the same current and future scenarios developed in the 2019 report).
4. Provision of a forensic evaluation of the Derecho event that occurred on May 21, 2022. For this task, Stantec included the services of a subconsultant form the University of Western Ontario Northern Tornadoes Project (NTP), the foremost severe weather experts in Canada. This task included access to data from the NTP collected past event, leveraging extensive damage survey, impacts data, and mapping as well as engagement during the risk assessment workshops and executive board presentation. The primary resource from NTP were also part of the 2019 report, which allows for continuity with service delivery between Stantec, NTP, and Hydro Ottawa.
5. Identification of the impacts of various wind events across the additional laminations identified and rank the impacts / consequences (i.e., probability x impact) to provide overall risk levels in accordance with the Enterprise Risk Management rating system.
6. **Adaptation Plan Update:** Review of the status of climate adaptation and risk mitigation measures from the 2019 report using input from a review workshop to determine appropriateness based on updated risk levels and hazards.
7. **Addendum Report and Presentation of Results:** Provide an addendum report for both the 2019 Climate Risk and Vulnerability Assessment and Climate Change Adaptation plan based on the to reflect the new findings. Prepare and deliver an executive summary presentation to senior management, including an overview of the Derecho event and findings from the forensic study.

2 Climate Analysis Update

This section describes the data and methods used to update climate parameter frequencies of occurrence and probabilities, followed by a discussion on the climate parameters with adjusted probability scores based on the updated climate projection data reviewed. The climate parameters investigated, and methods used to estimate probabilities align with the 2019 report, except where otherwise noted.

2.1 Methodology

2.1.1 Climate Data

The climate analysis completed for the 2019 study was based on Coupled Model Intercomparison Project Phase 5 (CMIP5) Global Climate Models (GCMs) climate projections. CMIP5 climate projections formed the basis of the *IPCC Fifth Assessment Report* (IPCC, 2013). The “Delta Approach” downscaling method was used to generate localised climate change projections from 37 CMIP5 GCMs. Projected frequencies of occurrence and likelihoods were assessed based on the multi-model ensemble projections under the RCP8.5 scenario.

Since the completion of the 2019 study new climate projection data has become available. In 2020, the National Capital Commission and the City of Ottawa released climate projection data for the RCP4.5 and RCP8.5 scenarios for the National Capital Region (NCR). In 2021/2022, the Intergovernmental Panel on Climate Change (IPCC) released its *Sixth Assessment Report* (AR6) based on climate projections from the Coupled Model Intercomparison Project Phase 6 (CMIP6) and based on the new Shared Socio-economic Pathway (SSP) climate change scenarios. Where possible, the projected frequency of occurrence and probability of the selected climate parameters for the CRVA were updated based on these new climate projection data sources.

2.1.1.1 NCR Projections

The National Capital Commission (NCC) and the City of Ottawa have released a comprehensive climate change projection study for the National Capital Region (NCR). The NCR projections were developed using a collaborative and impacts driven approach and relying on ECCC and various GCMs and Regional Climate Model (RCM) datasets (City of Ottawa, 2020). The downscaled NCR climate projections have a high spatial resolution (10 km) and output numerous climate variables and indices for the RCP4.5 and RCP8.5 scenarios over the period of 2011-2100.

The primary source of climate projections for the NCR projections was high -resolution (~10 km) downscaled climate projections for Canada from 24 CMIP5 GCMs, referred to as the Canadian Downscaled Climate Scenarios – Univariate (CMIP5) (CanDCS-U5). The Pacific Climate Impacts Consortium (PCIC) has produced the CanDCS-U5 projections using the hybrid BCCAQv2 (Bias Correction/Constructed Analogues with Quantile delta mapping reordering, version 2) downscaling method (Cannon, 2015; Cannon et al., 2015). Additional climate projection data used for the NCR projections came from RCMs include CORDEX/UQAM, CanRCM4 (ECCC), INRS/Ouranos, and the University of PEI.

2.1.1.2 Shared Socio-economic Pathways

The IPCC's *Sixth Assessment Report* presents the latest global and regional assessments of climate change and its impacts using a set of five new illustrative emissions scenarios, referred to as Shared Socioeconomic Pathways (SSPs). The SSPs are based on five narratives describing alternative socioeconomic developments, including "sustainable development" (SSP1), "middle-of-the-road development" (SSP2), "regional rivalry" (SSP3), "inequality" (SSP4), and "fossil-fueled development" (SSP5) (see Table 2 in Riahi et al., 2017 for detailed descriptions). SSP5-8.5 represents a scenario with very high GHG emissions, with CO2 emissions that roughly double from current levels by 2050.

The climate analysis in the 2019 report used climate projections for the high emissions Representative Concentration Pathway – RCP8.5. The radiative forcing trajectories in RCP8.5 and SSP5 generally correspond (Riahi et al., 2017) and represent similar climate projection scenarios. Of the RCP and SSP scenarios, the RCP8.5 and SSP5 trajectories more closely match historical emissions, respectively, and therefore represent plausible emissions tracks into the future (Smith and Myers, 2018; Schwalm et al., 2020; Mohanty and Simonovic, 2021). Therefore, to provide a conservatively high estimate of projected climate change and its associated impacts, the CVRA focuses on the RCP8.5 and SSP5 emissions scenarios.

2.1.1.3 CanDCS-U6 Projections

Recently, global climate models (GCMs) driven by the SSPs have contributed to CMIP Phase 6 (Eyring et al., 2016), which forms the basis of the IPCC *Sixth Assessment Report* (IPCC, 2021). Downscaling methods are often used to produce finer spatial resolution projections from these GCMs. PCIC has produced high-resolution (~10 km) downscaled climate projections for Canada for 26 CMIP6 GCMs for three Shared Socioeconomic Pathway (SSP) projection scenarios, referred to as the Canadian Downscaled Climate Scenarios – Univariate (CMIP6) (CanDCS-U6). PCIC produced the downscaled projections for the simulated period of 1950-2100 using the hybrid BCCAQv2 downscaling method.

2.1.1.4 Levels of Confidence in Projections

Future climate conditions presented in this climate profile are retrieved from climate projections produced by downscaled GCMs, specialized literature, and professional judgement of Stantec's climate scientists. Some climate variables can be projected into the future with more confidence than others. The level of confidence in climate projections is dependent on the understanding of the processes involved in the climate phenomena, ability of climate models to simulate the phenomena, degree of agreement among the climate models (e.g., range of uncertainty), and the supporting evidence (e.g., theory, specialized literature, expert judgement, etc.). For example, projections based on GCMs and downscaling of such models are considered:

- Adequate (high confidence) for general temperature and precipitation projections,
- Less adequate (moderate confidence) for extreme parameters, and
- Inadequate for combined events (low confidence) such as freezing rain.

Combined or complex climate variables are normally inferred from other climate variables and result in lower confidence for projections. For example, freezing rain is a complex process and the projected prevalence of freezing rain events under future climate conditions is not as well understood as other variables such as temperatures.

All climate models have inherent shortcomings in fully and accurately representing the real climate system. Therefore, it is not recommended to rely only on one or two climate models to estimate future climate. Instead, an average of several climate models (a multi-model mean) tends to give a more reliable estimate of future climate (IPCC, 2013; 2021). The use of ensembles and multi-model means is common in climate science and is strongly encouraged as “best practice” (IPCC, 2013; 2021). Using ensembles and multi-model means provide insight into uncertainties in climate model projections. Therefore, the ensemble mean of the 26 CMIP6 GCMs is presented in this assessment.

2.1.2 Derecho Event May 21, 2022 Forensic Analysis

As part of the reaffirmation study, Stantec included the expertise of meteorologists from Western University’s Northern Tornadoes Project (NTP) and Northern Hail Project (NHP) to provide expert advice and analysis in the form of a forensic assessment of the May 21, 2022, severe windstorm. Termed a “derecho”, this storm severely impacted Hydro Ottawa’s infrastructure.

Doctor David Sills, Executive Director of the Northern Tornadoes Project (NTP), and Simon Eng, Research Meteorologist with the Northern Hail Project (NHP) and former consulting meteorologist on the original 2019 study, were asked to support the Hydro Ottawa reaffirmation study to address the following questions and concerns:

- *Significant concern regarding impacts associated with 120 km/h winds:* A peak wind gust reading of 120 km/h was recorded at Ottawa International Airport during the event. Wind speeds of this magnitude were included in the original climate risk assessment (Stantec 2019) but the May 21, 2022, storm generated impacts far greater than had been anticipated for winds of this magnitude.
- *The number and severity of weather-related outage events in recent years:* Several very high impact severe weather events have affected Hydro Ottawa’s system since the late-2010s. This has triggered concerns that these events are increasing in frequency to such an extent that their effects may not be manageable.
  - In particular, the southern-portion of the City has been severely affected by both the 2022 Derecho event and one of the September 2018 tornadoes: This raised concerns that this specific region within Hydro Ottawa’s service area was particularly vulnerable to severe thunderstorm-related wind events.
- *The May 21, 2022, storm indicated the need for identifying additional damage thresholds:* To help support future planning and continued efforts to increase resilience to current and future climate impacts, the risk assessment framework required the identification of additional, higher wind speed thresholds than had been previously identified in the original 2019 risk assessment (Stantec 2019).

Evidence using damage-based wind speed estimates, coupled with a review of Doppler radar wind velocity information, as well as evidence from other locations along the Derecho path, strongly indicates that the 120 km/hr wind gust measured at Ottawa International Airport was *not* representative of the wind speeds experienced during the event in the most severely impacted portions of Hydro Ottawa’s system.

These pieces of evidence generally indicate much stronger winds which likely reached 180-195 km/h. As a result, additional wind thresholds were established and are further described in Section 2.1.3. Further information from the forensic analysis of the Derecho event can be found in Appendix C.

2.1.3 Additional High Wind Thresholds

Initial wind thresholds for the 2019 study included high wind gusts of 120 km/h and easterly winds of 60 km/h and 80 km/h at seasonal and annual time periods. Two additional high wind thresholds were established for this update based on updated Environment and Climate Change Canada (ECCC) criteria for severe thunderstorm winds and the damages observed by the Northern Tornadoes Project in surveys following the 2022 May Derecho event. The thresholds established included:

- Wind speeds > 130 km/h – Based on new ECCC severe thunderstorm winds and with 17% higher loading factor than the 120 km/h gust threshold used in the 2019 study
- Wind speeds > 180 km/h (Derecho event equivalent) – based on consistent EF-2 style observed damage in Ottawa region and Doppler Radar near surface wind speed recordings

2.1.4 Climate Parameter Probabilities

Climate parameter frequency of occurrence and probability were based on either the NCR projections, CanDCS-U6 projections, or literature review (which included specialized studies, climate analogues, and professional judgement). The climate projections data sources used for each climate parameter, for the 2019 study and the 2023 update, are presented in Table 1. The baseline probabilities from the 2019 report are maintained in this study because their calculation relied on high-quality measurements obtained from the Ottawa Macdonald-Cartier International Airport weather station.

Annual probabilities were calculated for the baseline period (1981-2010) and the 2050s (2041-2070) for each climate parameter. The annual probabilities were then translated to study period probabilities by estimating the likelihood of occurrence over a 30-year period.

Table 1: Climate Projections Data Sources used in the 2019 Report and the 2023 Update

Climate Parameter	Threshold(s)	Climate Projections Data Source	
		2019 Report	**2023 Update**
Temperature – Extreme Heat	Tmax ≥ 25°C; Tmax ≥ 35°C	CMIP5 Projections Downscaled with Delta Approach	NCR Projections
	Tmax ≥ 30°C; Tmax ≥ 40°C; Tmean ≥ 30°C; Heat waves	CMIP5 Projections Downscaled with Delta Approach	CanDCS-U6 Projections
Temperature – Extreme Cold	Tmin ≤ -35°C	CMIP5 Projections Downscaled with Delta Approach	CanDCS-U6 Projections

Climate Parameter	Threshold(s)	Climate Projections Data Source	
		2019 Report	2023 Update
Rain (Short Intensity – High Duration)	50 mm in 1 hr	Historic IDF data adjusted using Clausius-Clapeyron rate	NCR Projections
Freezing Rain & Ice Storms	Ice accumulation of 25 mm; 40 mm	Literature	Literature
Snow	≥ 5 cm in 24 hrs; ≥ 30 cm in 24 hrs	Literature	Literature
	≥ 10 cm in 24 hrs	Literature	NCR Projections
High Winds	Wind speeds of 60 km/hr; 80 km/hr; 90 km/hr; 120 km/hr	Literature	Literature
High Winds	Wind speeds of 130 km/hr; 180 km/hr	N/A	Literature
Lightning	Flash density	Literature	Literature
Tornadoes	EF1+	Literature	Literature
Invasive Species	Emerald Ash Borer (kill temperature); Giant Hogweed (germination temperature requirement)	CMIP5 Projections Downscaled with Delta Approach	CanDCS-U6 Projections
Fog	≥ 50 fog days (Nov.-March)	Literature	Literature
Frost	Freeze-thaw cycles (Tmax Tmin fluctuation around 0°C)	CMIP5 Projections Downscaled with Delta Approach	NCR Projections
	Hard freeze-thaw cycles (Tmax Tmin fluctuation of ±4°C around 0°C)	CMIP5 Projections Downscaled with Delta Approach	CanDCS-U6 Projections

Climate parameter probabilities were assigned using the five-point scoring scale used in Hydro Ottawa's Asset Management System Risk Procedures (Table 2). This five-point probability scoring scale was used in the 2019 study and, therefore, maintains consistency and allows comparability between the 2019 study and the 2023 update.

Table 2: Probability Scoring Scaled Used in Hydro Ottawa's Asset Management System Risk Procedures

Probability Score	Descriptor	Detailed Description	Probability Range
1	Rare	May only occur in time period under exceptional circumstances	p ≤ 5%
2	Unlikely	Could occur in time period	5% < p ≤ 35%
3	Possible	Might occur in time period	35% < p ≤ 65%
4	Likely	Will probably occur in time period	65% < p ≤ 95%
5	Almost Certain	Is expected to occur	95% < p

2.2 Results

Updated projected frequency of occurrence, annual and 30-year probabilities, for each climate parameter assessed in the 2019 study, as well as baseline (1981-2010) and 1991-2020 data, are provided in Appendix A. Climate parameters for which the annual and/or 30-year probability changed as well as for the additional high wind thresholds (laminations) are presented in Table 3. Probabilities for any parameters from the 2019 study that did not change remain with the same ratings as were previously calculated. While tornadoes have impacted the Ottawa region more frequently in the last decade, the probability rating for tornado occurrence has not changed. Probability ratings were established for two scenarios: 1) the likelihood of a single point within Hydro Ottawa's service area being struck by a tornado and 2) the likelihood of a tornado occurring anywhere within the service area. In the risk assessment, the higher likelihood was carried forward and used to establish potential risk.

Table 3: Changes in Climate Parameter Probabilities and Additional Wind Threshold Probabilities

Climate Parameter	Threshold	2019 Study 2050s Probabilities (RCP8.5)				2023 Update 2050s Probabilities (RCP8.5/SSP5-8.5)			
		Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score	Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score
Rain	50 mm in 1 hr	4.5% (< 1 yr^{-1})	1	75%	4	32% (< 1 yr^{-1})	2	> 99%	5
Invasive Species: Emerald Ash Borer	Daily min. temp. of -30°C or colder (kill temp.)	3% (< 1 yr^{-1})	1	60%	3	4% (< 1 yr^{-1})	1	71%	4
Frost	Hard freeze-thaw cycles (Daily Tmax Tmin temp. fluctuation of ±4°C around 0°C) (30 cycles)	38% (< 1 yr^{-1})	3	> 99%	5	18% (< 1 yr^{-1})	2	> 99%	5
High Wind	Wind speeds > 130 km/hr	N/A	N/A	N/A	N/A	2.90% (<1 yr^{-1})	1	58%	3
	Wind speeds > 180 km/hr	N/A	N/A	N/A	N/A	1.25% (<1 yr^{-1})	1	31%	2

3 Review Workshop and Prioritizing Actions

Stantec organized an in-person (with a virtual option) climate risks and adaptation plan working session with Hydro Ottawa personnel on May 3, 2023. The workshop included a summary of the 2022 Derecho event forensic evaluation, the introduction of two additional thresholds for the high wind climate parameter, and a review of the consequence / risk scores. Additionally, Stantec sought input from attendees to determine the status of the 2019 climate adaptation and risk mitigation measures from the 2019 reports (Stantec, 2019a-b), and to determine their appropriateness for existing risk levels.

Revised consequence scores, where a change occurred, are presented in Section 4.2. Section 4 presents the updated adaptation recommendations for medium to very high risks, where a change has occurred.

4 Updates to Risk Assessment

4.1 2023 Methods

Each combination of climate parameter and infrastructure asset class is referred to as an interaction. To assess material changes in risk, Stantec calculated risk for the baseline (1981-2010) and 2050s (2041-2070) time horizons for each interaction. Risk is calculated following the approach outlined in the 2019 report, where ***Risk Score = Probability Score x Severity Score*** (Engineers Canada, 2011). Updated risk scores were only calculated for the following interactions:

- Interactions with climate parameters with a changed 2050s probability score,
- Interactions with the new high wind thresholds, or
- Interactions with updated consequence scores.

Consequence scores were assigned using a 1- to 25-point severity scale and performance descriptors extracted directly from Hydro Ottawa's Asset Management System Risk Procedures. The resulting risk matrix is presented in Table 4.

Table 4: Severity Ratings used in the Risk Assessment

Severity Score and Descriptor		Infrastructure Performance and Severity Rating			
		Level of Service: System Accessibility	Level of Service: Service Quality	Resource Efficiency	Asset Value - Financial
Insignificant	**1**	N/A	Service interruption resulting in <10,000 customer minutes interrupted. Service quality resulting in customer complaint, but meets CSA standards	Requires <10 hours of overtime to complete O&M work or undergo training. Requires <100 hours of overtime to complete capital work.	Financial risk resulting in an O&M expense of <$1k. Financial risk resulting in a capital expense of <$10k.
Minor	**4**	N/A	Service interruption resulting in >10,000 customer minutes interrupted. Service quality resulting in customer escalation, but meets CSA standards	Requires >10 hours of overtime to complete O&M work or undergo training. Requires >100 hours of overtime to complete capital work.	Financial risk resulting in an O&M expense of >$1k. Financial risk resulting in a capital expense of >$10k.
Moderate	**9**	Load demand/generation is exceeding planning limits.	Service interruption resulting in >500,000 customer minutes interrupted.	Requires >250 hours of overtime to complete O&M work or undergo training. Requires >2,500 hours of overtime to complete capital work.	Financial risk resulting in an O&M expense of >$50k. Financial risk resulting in a capital expense of >$500k.

Severity Score and Descriptor		Infrastructure Performance and Severity Rating			
		Level of Service: System Accessibility	**Level of Service: Service Quality**	**Resource Efficiency**	**Asset Value - Financial**
Extensive	**16**	Load demand/generation is exceeding thermal limits.	Service interruption resulting in >3,000,000 customer minutes interrupted.	Requires >1,500 hours of overtime to complete O&M work or undergo training. Requires >15,000 hours of overtime to complete capital work.	Financial risk resulting in an O&M expense of >$300k. Financial risk resulting in a capital expense of >$3M.
Significant	**25**	Unable to service new load/ERFs	Service interruption resulting in >10,000,000 customer minutes interrupted. Service quality resulting in not meeting CSA standards.	Unable to complete work with internal and/or external resources due to volume or skill gap.	Financial risk resulting in an O&M expense of >$1M. Financial risk resulting in a capital expense of >$10M.

Table 5: Hydro Ottawa Asset Management Risk Procedure Matrix

			Impact				
			1	4	9	16	25
			Insignificant	Minor	Moderate	Extensive	Significant
Likelihood	1	Rare	1	4	9	16	25
	2	Unlikely	2	8	18	32	50
	3	Possible	3	12	27	48	75
	4	Likely	4	16	36	64	100
	5	Almost Certain	5	20	45	80	125

Risk Score	Risk Rating
Low	≤10
Medium	11-30
High	31-60
Very High	≥60

Risk ratings for individual components were taken by summing the total consequence across all evaluated columns and multiplying by the event likelihood. For example, if consequence of 9 was assigned for all for categories for an event with a probability rating of 3, the resultant total cumulative risk would be calculated as:

Table 6: Sample Consequence and Cumulative Risk Rating Calculation

Level of Service: System Accessibility	Level of Service: Service Quality	Resource Efficiency	Asset Value - Financial	Likelihood of Event	Cumulative Risk
9	9	9	9	3	**108**

4.2 2023 Consequence and Risk Score Updates and Additions

Updates and additions to consequence scores occurred for the following parameters:

- For the wind threshold of 120 km/hr, consequence score updates included revising upward the consequence score of the Asset Value – Financial from a 9 to a 16 for Power Distribution – Overhead (N-S and E-W orientations) due to recent extreme wind experienced by Hydro Ottawa that led to more operational and capital expenses than previously rated in the 2019 study. During the workshop it was felt that the initial rating should be raised to reflect consequences reflective of extreme wind impacts that had not been felt by Hydro Ottawa prior to the derecho event.
- For the new wind threshold of 130 km/hr, consequence scores mirror the updated values for the 120 km/hr threshold. While there is a 17% increase in overall force, it was felt that the increase in consequence score for the 120 km/hr threshold would also be felt under a 130 km/hr event occurring in the service area.
- For the new 180 km/hr wind threshold, developed based upon the findings by UWO in the analysis of damage for the 2022 Derecho event, consequence scores of a 16 were assigned for system accessibility, service quality, and resource efficiency for Power Distribution lines and poles (N-S and E-W orientations). For financial, consequence scores were assigned a 25 due to the damage experienced by Hydro Ottawa in the 2022 Derecho event. These scores are reflective of severe damage and demand posed on Hydro Ottawa during and following the event, including challenges to restore power and the duration of the major event.
- For freezing rain, with ice accumulation of 25 mm, the consequence score for Asset Value – Financial was revised from a 4 to a 9 for Power Distribution – Overhead (N-S and E-W orientations), due to the impacts of recent freezing rain events that led to more operational and capital expenses than previously rated in the 2019 study.

A summary of the updated consequence scores and associated 2050s risk scores are presented in Table 7.

Table 7: Summary of Changes and Additions to Consequence and Risk Scores

Climate Parameter: Threshold	Infrastructure Performance Category	Consequence Update	2019 Study		2023 Update	
			Consequence Score	2050s Cumulative Risk Score	Consequence Score	2050s Cumulative Risk Score
High wind: 120 km/hr	Asset Value - Financial score for Power Distribution - Overhead (N-S and E-W orientations) Lines and Poles	Increased consequence scores from 9 to 16 due to recent extreme wind experienced by Hydro Ottawa that led to more operational and capital expenses	9	81	16	102
High wind: 130 km/hr	All categories	Consequence scores mirror those of the 120 km/hr threshold	N/A	N/A	16	102
High wind: 180 km/hr	System accessibility, service quality, and resource efficiency for Power Distribution - Overhead (N-S and E-W orientations) Lines and Poles	Consequence scores assigned a 16 based on UWO's analysis of damage for the 2022 Derecho event	N/A	N/A	16	114
	Financial for Power Distribution - Overhead (N-S and E-W orientations) Lines and Poles	Consequence scores assigned a 25 due to damage experienced by Hydro Ottawa in the 2022 Derecho event	N/A	N/A	25	
Freezing rain: Ice accumulation of 25 mm	Financial for Power Distribution - Overhead (N-S and E-W orientations) Lines	Increased consequence scores for 4 to 9 due to due to recent freezing rain events experienced by Hydro Ottawa that led to more operational and capital expenses	4	16	9	26

5 Updates to Adaptation Plan

This section presents additional recommendations to mitigate climate risk where a risk level has changed since the original scope of work. The recommendations in this section are made to supplement the original recommendations (Stantec, 2019b).

5.1 2019 Scope of Work

The development of the 2019 Adaptation Plan consisted of the following steps (Stantec, 2019b):

1. Validation of medium to very high risks to infrastructure and operations as well as the impacts in a workshop with Hydro Ottawa staff.
2. Selection of risk mitigation or adaptation measures to reduce the impacts of medium to very high future climate risks; developed through the workshop with Hydro Ottawa.
3. Prioritization of actions based on the risk levels, change in risk (current to future) and Hydro Ottawa's Asset Management System Risk Procedures.
4. Assignment of responsibilities and the development of indicators to track and monitor progress in the Enterprise Risk Management System (ERMS).

5.2 2023 Results

5.2.1 Executed Adaptation Actions

Hydro Ottawa has made significant progress on implementing the risk recommendations from the Adaptation Plan (Stantec, 2019b). A summary of work that was completed, the status update and next steps as provided by HOL is included in Appendix B.

5.2.2 Additional Suggested Adaptation Measures

Hydro Ottawa is progressing and moving forward on implementing climate change adaptation measures to build resilience from extreme events. It is recommended that HOL work to continue addressing climate change risk through ongoing work and consider additional adaptation measures brought forward during the review workshop to specifically address new climate and accelerating related risks. All new adaptation recommendations were related to the pole line systems and new measures are provided in Table 8. No additional recommendations for operations, underground systems or substations.

5.2.2.1 Pole Line System

Table 8: Updated Impacts and Adaptation Measures

Climate Parameter	System / Component Affected	Description of Impact	Current Risk Score	Future Risk Score	2023 Update to Future Risk Score	New Adaptation Recommendations
New Wind Thresholds from Derecho Event and Extreme Wind Speeds						• Consider a study on pole characteristics (i.e. age and guying locations) from the 2022 Derecho to determine potential vulnerability of pole tops. • Consider the impact of climate change on recently (or future) hydro poles being grown (i.e. wood density and strength) • Consider establishing additional supply capacity and storage for key components (e.g. poles) in the event that a major or catastrophic event impacts a large portion of the service area • Consider real-time or automated monitoring system for severe weather events or creating a staff position for a meteorologist to handle coordination between utilities and monitoring potential upstream outages before they impact HOL service area • Continue with planned adaptation planning actions already underway, including an undergrounding study, anti-cascading study and strategy, and asset hardening however, new risk should be utilized in decision making a cost/benefit studies underway. • Consider establishing a shared resource MoU with other utilities (e.g. Hydro One, Hydro Quebec) to work toward open data sharing of risks, opportunities, and best practices for handling extreme events. Other risk mitigation measures developed in the 2019 study remain relevant based on the conversations conducted at the 2023 reaffirmation workshop.
Annual wind speeds of 180 km/hr or higher (30-year occurrence)	Power Distribution: East-West lines and poles	Damage to poles and lines from high wind events.	114	114	114	
Annual wind speeds of 180 km/hr or higher (30-year occurrence)	Power Distribution: East-West lines and poles	Risk of damages from falling trees, broken tree limbs or flying debris.	114	114	114	
Annual wind speeds of 180 km/hr or higher (30-year occurrence)	Power Distribution: North-South lines and poles	Damage to poles and lines from high wind events.	132	146	146	
Annual wind speeds of 180 km/hr or higher (30-year occurrence)	Power Distribution: North-South lines and poles	Risk of damages from falling trees, broken tree limbs or flying debris.	132	146	146	
Annual wind speeds of 130 km/hr or higher (30-year occurrence)	Power Distribution: East-West lines and poles	Damage to poles and lines from high wind events.	102	102	102	
Annual wind speeds of 130 km/hr or higher (30-year occurrence)	Power Distribution: East-West lines and poles	Risk of damages from falling trees, broken tree limbs or flying debris.	102	102	102	
Annual wind speeds of 130 km/hr or higher (30-year occurrence)	Power Distribution: North-South lines and poles	Damage to poles and lines from high wind events.	129	129	129	
Annual wind speeds of 130 km/hr or higher (30-year occurrence)	Power Distribution: North-South lines and poles	Risk of damages from falling trees, broken tree limbs or flying debris.	129	129	129	
Revised Risk Scores Based on New Consequence Scoring						
Annual wind speeds of 120 km/hr or higher (30-year occurrence)	Power Distribution: East-West lines and poles	Damage to poles and lines from high wind events.	81	81	**102**	
Annual wind speeds of 120 km/hr or higher (30-year occurrence)	Power Distribution: East-West lines and poles	Risk of damages from falling trees, broken tree limbs or flying debris.	81	81	**102**	
Annual wind speeds of 120 km/hr or higher (30-year occurrence)	Power Distribution: North-South lines and poles	Damage to poles and lines from high wind events.	108	108	**129**	
Annual wind speeds of 120 km/hr or higher (30-year occurrence)	Power Distribution: North-South lines and poles	Risk of damages from falling trees, broken tree limbs or flying debris.	108	108	**129**	

Climate Parameter	System / Component Affected	Description of Impact	Current Risk Score	Future Risk Score	2023 Update to Future Risk Score	New Adaptation Recommendations
Ice accumulation (25 mm)	Power Distribution: North-South lines and poles	Damage from increased weight on overhead lines. Ice accretion on lines in excess of 12.5 mm (0.5 inches) accompanied by a 90km/h wind could result in structural failure and uneven ice accretion could cause swinging or 'galloping' in the lines Damages to lines from fallen trees or broken tree limbs. Damage to poles and other surface equipment from vehicles losing control on icy roads.	10	13	26	Complete an inventory of switches for critical equipment and consider looking at alternatives for implementing measures to prevent freezing.
Ice accumulation (25 mm)	Power Distribution: North-South lines and poles	Damages to lines from fallen trees or broken tree limbs.	8	16	26	

6 Limitations

The findings in this report are subject to several limitations. Section 2 discusses specific uncertainties associated with each climate parameter. Some overarching limitations are noted below.

Climate data is inherently uncertain. The climate parameter probabilities provided should be considered as high-level estimates of future conditions. The primary source of uncertainty in climate projections is the estimate of greenhouse gas emissions that will be observed over the current century. Additional sources of uncertainty include (but are not limited to) climate model parameterization, bias, and resolution.

Some of the climate parameters investigated are associated with very high degrees of uncertainty, because they are difficult to constrain using the outputs from climate models. Stantec has reviewed recently published scientific literature and guidance to provide an estimate of likely future conditions.

7 Conclusion

This Update to Distribution System Climate Vulnerability Risk Assessment and Climate Change Adaptation Plan was conducted by Stantec to provide Hydro Ottawa Limited (HOL) with updated climate parameter probabilities, consequence scores, risk levels, and adaptation plan. Recent extreme weather resulting in major weather events, specifically:

- September 21, 2018 – Tornadoes
- April 15, 2019 – Lightning storm and flooding
- July 5, 2019 – Windstorm
- June 14, 2021 – Summer/Lightning storm
- May 21, 2022 – Derecho storm
- December 23, 2022 – Winter storm

The findings in this report are based on the evaluation of impacts from the recent major weather-related events, a forensic analysis of the May 2022 Derecho event, and input from the review workshop.

The two main tasks completed within this study were to (1) update the list of climate parameters to include additional high wind thresholds representative of recent extreme weather events, update climate parameter probabilities, impact severity (based on input from Hydro Ottawa personnel), and risk scores, as well as completing a forensic analysis of the May 21, 2022 Derecho event; and (2) update where appropriate the adaptation and risk mitigation plan using input from the review workshop and where risk scores changed to medium-very high under current and future climate. For consistency, the same methods used in the 2019 report were also used in this reassessment.

Two additional high wind thresholds were established for this update based on updated Environment and Climate Change Canada (ECCC) criteria for severe thunderstorm winds and the damages observed by the Northern Tornadoes Project in surveys following the 2022 May Derecho event. The thresholds established included:

- Wind speeds > 130 km/h – Based on new ECCC severe thunderstorm winds and with 17% higher loading factor than the 120 km/h gust threshold used in the 2019 study
- Wind speeds > 180 km/h (Derecho event equivalent) – based on consistent EF-2 style observed damage in Ottawa region and Doppler Radar near surface wind speed recordings

Risk scores increased due to higher consequence ratings for current and future climate for higher threshold wind speeds (120 km/hr) and for newly established thresholds (130 km/hr and 180 km/hr). However, for most risks, no risk level change was observed.

To handle additional risks from higher wind thresholds, the following risk adaptation measures should be considered:

- Consider a study on pole characteristics (i.e. age and guying locations) from the 2022 Derecho to determine potential vulnerability of pole tops.
- Consider the impact of climate change on recently (or future) hydro poles being grown (i.e. wood density and strength)
- Consider establishing additional supply capacity and storage for key components (e.g. poles) in the event that a major or catastrophic event impacts a large portion of the service area
- Consider real-time or automated monitoring system for severe weather events or creating a staff position for a meteorologist to handle coordination between utilities and monitoring potential upstream outages before they impact HOL service area.
- Continue with planned adaptation planning actions already underway, including an undergrounding study, anti-cascading study and strategy, and asset hardening however, new risk should be utilized in decision making a cost/benefit studies underway.

Other risk mitigation measures developed in the 2019 study remain relevant based on the conversations conducted at the 2023 reaffirmation workshop.

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Appendices

Appendix A 2023 Climate Parameter Probability Update

Table A-1: Climate Parameter Probabilities and Additional Wind Threshold Probabilities in the Historical Baselines (1981-2010 and 1991-2020)

Climate Parameter	Threshold	2019 Study Historical Baseline (1981-2010)				2023 Update Historical Baseline (1991-2020)			
		Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score	Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score
Temperature – Extreme Heat	Daily max. temp. of 25°C or higher	100% (~62-63 yr^{-1})	5	100%	5	100% (~68-69 yr^{-1})	5	100%	5
	Daily max. temp. of 30°C or higher	100% (~14-15 yr^{-1})	5	100%	5	100% (~15-16 yr^{-1})	5	100%	5
	Daily max. temp. of 35°C or higher	50% (<1 yr^{-1})	3	>99%	5	80% (<1 yr^{-1})	3	100%	5
	Daily max. temp. of 40°C or higher	6% (<1 yr^{-1})	2	84%	4	6% (<1 yr^{-1})	2	84%	4
	Daily avg. temp. of 30°C or higher	3% (<1 yr^{-1})	1	60%	3	3% (<1 yr^{-1})	1	60%	3
	Heat waves: Consecutive days with max temp ≥ 30°C and min temp ≥ 23°C	7% (<1 yr^{-1})	2	89%	4	7% (<1 yr^{-1})	2	89%	4
	Heat waves: Consecutive days with max temp ≥ 30°C and min temp ≥ 25°C	~0% (~0 yr^{-1})	1	~0%	1	~0% (~0 yr^{-1})	1	~0%	1

Climate Parameter	Threshold	2019 Study Historical Baseline (1981-2010)				2023 Update Historical Baseline (1991-2020)			
		Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score	Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score
Temperature – Extreme Cold	Daily min. temp. of -35°C or colder	3% ($<1\ yr^{-1}$)	1	60%	3	~0% (rare)	1	~0%	1
Rain (Short Intensity – High Duration)	50 mm in 1 hr	1% ($<1\ yr^{-1}$)	1	~25%	2	1% ($<1\ yr^{-1}$)	1	~25%	2
Freezing Rain & Ice Storms	Ice accumulation of 25 mm	5% ($<1\ yr^{-1}$)	1	79%	4	5% ($<1\ yr^{-1}$)	1	79%	4
	Ice accumulation of 40 mm	2.5% ($<1\ yr^{-1}$)	1	>50%	3	2.5% ($<1\ yr^{-1}$)	1	>50%	3
Snow	Days with 5 cm of more of snowfall	100% ($\sim15\ yr^{-1}$)	5	100%	5	100% ($\sim15\ yr^{-1}$)	5	100%	5
	Days with 10 cm of more of snowfall	100% ($\sim5\text{-}6\ yr^{-1}$)	5	100%	5	100% ($\sim5\text{-}6\ yr^{-1}$)	5	100%	5
	Days with 30 cm of more of snowfall	13% ($<1\ yr^{-1}$)	2	98%	5	17% ($<1\ yr^{-1}$)	2	>99%	5
High Winds	Annual wind speeds of 60 km/hr	100% ($\sim14\text{-}15\ yr^{-1}$)	5	100%	5	100% ($\sim15\text{-}16\ yr^{-1}$)	5	100%	5
	Easterly winds of 60 km/hr or higher (warm season [April-September])	28.9% ($<1\ yr^{-1}$)	2	100%	5	47% ($<1\ yr^{-1}$)	2	>99%	5
	Easterly winds of 60 km/hr or higher	2.6% ($<1\ yr^{-1}$)	1	55%	3	3% ($<1\ yr^{-1}$)	1	60%	3

Climate Parameter	Threshold	2019 Study Historical Baseline (1981-2010)				2023 Update Historical Baseline (1991-2020)			
		Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score	Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score
	(summer [June-August])								
	Annual wind speeds of 80 km/hr	100% (~1-2 yr^{-1})	5	100%	5	100% (~1-2 yr^{-1})	5	100%	5
	Easterly winds of 80 km/hr or higher (cool season [October - March])	5.3% (<1 yr^{-1})	2	80%	5	5.3% (<1 yr^{-1})	2	80%	5
	Easterly winds of 80 km/hr or higher (winter [December - February])	2.6% (<1 yr^{-1})	1	55%	3	2.6% (<1 yr^{-1})	1	55%	3
	Annual wind speeds of 90 km/hr	23% (<1 yr^{-1})	2	>99%	5	23% (<1 yr^{-1})	2	>99%	5
	Annual wind speeds of 120 km/hr	2.5% (<1 yr^{-1})	1	53%	3	3.10% (<1 yr^{-1})	1	53%	3
	Annual wind speeds of 130 km/hr	2.5% (<1 yr^{-1})	1	53% (rare)	3	3.10% (<1 yr^{-1})	1	>60% (rare)	3
	Annual wind speeds of 180 km/hr	1.25% (<1 yr^{-1})	1	31% (rare)	2	1.25% (<1 yr^{-1})	1	31% (rare)	2
Lightning	Strikes near infrastructure (flashes/ km^2/ year)	1.1% (<1 yr^{-1})	1	28%	2	1.1% (<1 yr^{-1})	1	28%	2

Climate Parameter	Threshold	2019 Study Historical Baseline (1981-2010)				2023 Update Historical Baseline (1991-2020)			
		Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score	Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score
Tornadoes	EF1+ in Hydro Ottawa service area (City of Ottawa)	14.6% (<1 yr^{-1})	2	>99%	5	14.6% (<1 yr^{-1})	2	>99%	5
	EF1+ point probability (i.e., striking a specific asset in City of Ottawa service area)	0.02% (rare)	1	0.6%	1	0.02% (rare)	1	0.6%	1
Invasive Species: Emerald Ash Borer	Emerald Ash Borer (Daily min. temp. of -30°C or colder [kill temp.])	53% (<1 yr^{-1})	3	>99%	5	47% (<1 yr^{-1})	3	>99%	5
	Giant Hogweed (3 consecutive days of -8°C or colder [gemination requirement])	100% (25 yr^{-1})	5	100%	5	100% (9 yr^{-1})	5	100%	5
Fog	Season with ≥ 50 fog days (Nov.-March)	37% (~3-4 yr^{-1}	3	100%	5	37% (~3-4 yr^{-1})	3	>99%	5

Climate Parameter	Threshold	2019 Study Historical Baseline (1981-2010)				2023 Update Historical Baseline (1991-2020)			
		Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score	Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score
Frost	Freeze-thaw cycles – (Daily Tmax Tmin temp. fluctuation of ±1°C around 0°C) (30 cycles)	100% (~2-3 yr^{-1})	5	100%	5	100% (~2-3 yr^{-1})	5	100%	5
	Hard freeze-thaw cycles (Daily Tmax Tmin temp. fluctuation of ±4°C around 0°C) (30 cycles)	30% (<1 yr^{-1})	2	>99%	5	30% (<1 yr^{-1})	2	>99%	5

Table A-2: Climate Parameter Probabilities and Additional Wind Threshold Probabilities in the 2050s from the 2019 Study and the 2023 Update

Climate Parameter	Threshold	2019 Study 2050s Probabilities (RCP8.5)				2023 Update 2050s Probabilities (RCP8.5/SSP5-8.5)			
		Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score	Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score
Temperature – Extreme Heat	Daily max. temp. of 25°C or higher	100% (~99 yr^{-1})	5	100%	5	100% (~105 yr^{-1})	5	100%	5
	Daily max. temp. of 30°C or higher	100% (~42 yr^{-1})	5	100%	5	100% (~48 yr^{-1})	5	100%	5
	Daily max. temp. of 35°C or higher	100% (~6 yr^{-1})	5	100%	5	100% (~9 yr^{-1})	5	100%	5
	Daily max. temp. of 40°C or higher	100% (~1-2 yr^{-1})	5	100%	5	100% (~1-2 yr^{-1})	5	100%	5
	Daily avg. temp. of 30°C or higher	100% (~1-2 yr^{-1})	5	100%	5	100% (~4 yr^{-1})	5	100%	5
	Heat waves: Consecutive days with max temp ≥ 30°C and min temp ≥ 23°C	100% (~2 yr^{-1})	5	100%	5	100% (~3 yr^{-1})	5	100%	5
	Heat waves: Consecutive days with max temp ≥ 30°C and min temp ≥ 25°C	37% (<1 yr^{-1})	3	>99%	5	37% (<1 yr^{-1})	3	>99%	5
Temperature – Extreme Cold	Daily min. temp. of -35°C or colder	0.1% (rare)	1	3%	1	0.1% (rare)	1	3%	1

Climate Parameter	Threshold	2019 Study 2050s Probabilities (RCP8.5)				2023 Update 2050s Probabilities (RCP8.5/SSP5-8.5)			
		Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score	Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score
Rain (Short Intensity – High Duration)	50 mm in 1 hr	4.5% (<1 yr^{-1})	1	75%	4	32.0% (<1 yr^{-1})	2	>99%	5
Freezing Rain & Ice Storms	Ice accumulation of 25 mm	6% (<1 yr^{-1})	2	84%	4	6% (<1 yr^{-1})	2	84%	4
	Ice accumulation of 40 mm	3.8% (<1 yr^{-1})	1	~70%	4	3.8% (<1 yr^{-1})	1	~70%	4
Snow	Days with 5 cm of more of snowfall	100% (~15 yr^{-1})	5	100%	5	100% (~15 yr^{-1})	5	100%	5
	Days with 10 cm of more of snowfall	100% (~5 yr^{-1})	5	100%	5	100% (~4 yr^{-1})	5	100%	5
	Days with 30 cm of more of snowfall	10% (<1 yr^{-1})	2	>95%	5	10% (<1 yr^{-1})	2	>95%	5
High Winds	Annual wind speeds of 60 km/hr	100% (~16 yr^{-1})	5	100%	5	100% (~16 yr^{-1})	5	100%	5
	Easterly winds of 60 km/hr or higher (warm season [April-September])	32.4% (<1 yr^{-1})	2	>99%	5	32.4% (<1 yr^{-1})	2	>99%	5
	Easterly winds of 60 km/hr or higher (summer [June-August])	2.9% (<1 yr^{-1})	1	~60%	3	2.9% (<1 yr^{-1})	1	~60%	3

Climate Parameter	Threshold	2019 Study 2050s Probabilities (RCP8.5)				2023 Update 2050s Probabilities (RCP8.5/SSP5-8.5)			
		Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score	Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score
	Annual wind speeds of 80 km/hr	100% (~1-2 yr^{-1})	5	100%	5	100% (~1-2 yr^{-1})	5	100%	5
	Easterly winds of 80 km/hr or higher (cool season [October - March])	6.3% (<1 yr^{-1})	2	85%	4	6.3% (<1 yr^{-1})	2	85%	4
	Easterly winds of 80 km/hr or higher (winter [December - February])	3.2% (<1 yr^{-1})	1	>60%	3	3.2% (<1 yr^{-1})	1	>60%	3
	Annual wind speeds of 90 km/hr	29% (<1 yr^{-1})	2	>99%	5	29% (<1 yr^{-1})	2	>99%	5
	Annual wind speeds of 120 km/hr	3.1% (<1 yr^{-1})	1	61%	3	3.1% (<1 yr^{-1})	1	61%	3
	Annual wind speeds of 130 km/hr	N/A	N/A	N/A	N/A	2.90% (<1 yr^{-1})	1	58%	3
	Annual wind speeds of 180 km/hr	N/A	N/A	N/A	N/A	1.25% (<1 yr^{-1})	1	31%	2
Lightning	Strikes near infrastructure (flashes/ km^2/ year)	1.5% (<1 yr^{-1})	1	36%	3	1.56% (<1 yr^{-1})	1	38%	3
Tornadoes	EF1+ in Hydro Ottawa service	18.2% (<1 yr^{-1})	2	>99%	5	18.2% (<1 yr^{-1})	2	>99%	5

Climate Parameter	Threshold	2019 Study 2050s Probabilities (RCP8.5)				2023 Update 2050s Probabilities (RCP8.5/SSP5-8.5)			
		Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score	Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score
	area (City of Ottawa)								
	EF1+ point probability (i.e., striking a specific asset in City of Ottawa service area)	0.02% (rare)	1	0.7%	1	0.02% (rare)	1	0.7%	1
Invasive Species: Emerald Ash Borer	Emerald Ash Borer (Daily min. temp. of -30°C or colder [kill temp.])	3% (<1 yr^{-1})	1	60%	3	4% (<1 yr^{-1})	1	71%	4
	Giant Hogweed (3 consecutive days of -8°C or colder [gemination requirement])	100% (17 yr^{-1})	5	100%	5	100% (3 yr^{-1})	5	100%	5
Fog	Season with ≥ 50 fog days (Nov.-March)	Likely increase	4	100%	5	Likely increase	4	100%	5

Climate Parameter	Threshold	2019 Study 2050s Probabilities (RCP8.5)				2023 Update 2050s Probabilities (RCP8.5/SSP5-8.5)			
		Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score	Annual Probability	Annual Probability Score	30-Year Probability	30-Year Probability Score
Frost	Freeze-thaw cycles – (Daily Tmax Tmin temp. fluctuation of ±1°C around 0°C) (30 cycles)	100% (~2 yr^{-1})	5	100%	5	100% (~2-3 yr^{-1})	5	100%	5
	Hard freeze-thaw cycles (Daily Tmax Tmin temp. fluctuation of ±4°C around 0°C) (30 cycles)	38% (<1 yr^{-1})	3	>99%	5	18% (<1 yr^{-1})	2	>99%	5

Appendix B 2023 Adaptation Status, Next Steps, and Barriers

Western Engineering

Forensic Analysis of the May 21, 2022 Derecho for the Ottawa Area

Following the announcement of the reaffirmation study – consisting of an update of the 2019 Hydro Ottawa Climate Risk Assessment (Stantec, 2019), meteorologists from Western University's Northern Tornadoes Project (NTP) and Northern Hail Project (NHP) were retained to provide expert advice and analysis in the form of a forensic assessment of the May 21, 2022, severe windstorm. Termed a "derecho", this storm severely impacted Hydro Ottawa's infrastructure.

Doctor David Sills, Executive Director of the Northern Tornadoes Project (NTP), and Simon Eng, Research Meteorologist with the Northern Hail Project (NHP) and former consulting meteorologist on the original 2019 study, were asked to support the Hydro Ottawa reaffirmation study to address the following questions and concerns:

- *Significant concern regarding impacts associated with 120 km/h winds:* A peak wind gust reading of 120 km/h was recorded at Ottawa International Airport during the event. Wind speeds of this magnitude were included in the original climate risk assessment (Stantec 2019) but the May 21, 2022, storm generated impacts far greater than had been anticipated for winds of this magnitude.
- *The number and severity of weather-related outage events in recent years:* Several very high impact severe weather events have affected Hydro Ottawa's system since the late-2010s. This has triggered concerns that these events are increasing in frequency to such an extent that their effects may not be manageable.
  - *In particular, the southern-portion of the City has been severely affected by both the 2022 Derecho event and one of the September 2018 tornadoes:* This raised concerns that this specific region within Hydro Ottawa's service area was particularly vulnerable to severe thunderstorm-related wind events.
- *The May 21, 2022, storm indicated the need for identifying additional damage thresholds:* To help support future planning and continued efforts to increase resilience to current and future climate impacts, the risk assessment framework required the identification of additional, higher wind speed thresholds than had been previously identified in the original 2019 risk assessment (Stantec 2019).

Key **findings** from the NTP/NHP analysis are the following:

Evidence using damage-based wind speed estimates, coupled with a review of Doppler radar wind velocity information, as well as evidence from other locations

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along the derecho's path, strongly indicates that the 120 km/hr wind gust measured at Ottawa International Airport was *not* representative of the wind speeds experienced during the event in the most severely impacted portions of Hydro Ottawa's system. These pieces of evidence generally indicate much stronger winds which likely reached 180-195 km/h.

- Peak wind speed estimates obtained through damage assessment of buildings and trees using the Canadian version of the "Enhanced Fujita Scale" (EF-Scale; ECCC 2018) consistently indicated peak wind velocities in extreme south-eastern portions of the City of Ottawa were in the 180-195 km/h range – i.e., the lower-end of the "EF-2" range on the Enhanced-Fujita Scale.
- Winds of this magnitude were consistent with Doppler weather radar indicated values (Ibrahim et al., 2023), which showed winds in the area exceeding 160 km/h.
- Evidence also indicates that other locations along the storm's path that reported similar or higher instrumented wind gust measurements did *not* exhibit damage of the severity seen in the Ottawa area, either to electrical overhead systems or more broadly to buildings, infrastructure, and trees. These include:
    - Kitchener-Waterloo area – An initial peak gust of 131 km/h was recorded at Kitchener-Waterloo International Airport – while power outages and tree damage were reported in the area, damage to buildings, critical infrastructure and trees did not approach the magnitude of the impacts in the Ottawa area.
    - Toronto Pearson International Airport – A peak gust of 121 km/h was reported at Pearson International Airport, but damage to buildings and overhead systems in this region was again of much lesser magnitude then what had occurred in the Ottawa area. A ground survey of this area was conducted within hours of the event by one of the authors (S.Eng) and although notable damage to urban trees was documented, as well as the failure of a medium-voltage electrical distribution line near Lisgar GO Transit station, again damage was of much lower intensity than had been documented in the Ottawa area.
- For this reaffirmation study, *new* recommended wind gust thresholds of *130 km/h* and *180 km/h* were developed, corresponding to Environment and Climate Change Canada's (ECCC) "extreme" thunderstorm warning criteria, and the lower bound of EF2 damage, respectively.
- The direction of storm motion and damage to specific areas within the City of Ottawa should not be taken as indications that the motion and impact area of storms will be similar in future events. Historical events have shown that both the direction of storm motion and locations impacted will differ depending on specific weather conditions.
    - However, the preliminary historical assessment of derecho events indicates that storm motion will mostly likely have an eastward component, with storms approaching from the SSW through to the NNW.

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Note that the NTP conducted a thorough, multi-month study of the entire length of the derecho's track, which included numerous detailed ground surveys, satellite image review, and social and news media monitoring, documentation, and follow-up. Areas suffering similar (i.e., up to EF2 intensity) damage were indeed detected in other parts of the derecho damage path but did not include the regions near or around Kitchener-Waterloo and Toronto Pearson Airports.

Methodology and Definitions

Due to their highly localised and characteristically high intensity, specialised methods are needed to obtain wind speed estimates for severe thunderstorm winds (i.e., tornadoes, derechos, microbursts, etc.). This assessment used two methods in addition to instrumented measurements, to obtain wind speed estimates:

1) The Enhance Fujita or "EF" Scale uses damage to buildings, trees, and other infrastructure and objects to estimate wind speeds (ECCC 2018). Wind speeds are classified into 6 categories, from EF0 to EF5, of increasing intensity (Table 1). Consistency is achieved through comparing damage to adjacent objects and assets to determine if they indicated similar wind speeds. It is also achieved through careful inspection of the age, type, and quality of building construction.

Table 1 - Canadian EF-Scale and Associated Wind Speed (Gust) Ranges

EF-Scale Rating	Associated Wind Speed Range (Equivalent 3-second gust; km/h)
EF0	90 to 130
EF1	135 to 175
EF2	180 to 220
EF3	225 to 265
EF4	270 to 310
EF5	315 +

2) The EF-scale estimated wind speeds were supplemented through a Doppler weather radar analysis. The Franktown (CASFT) radar is located close to the Ottawa area and was used to assess wind speeds near the surface during the event.

3) Finally, instrumented measurements from anemometers – instruments used to measure wind speed – were also consulted. However, we note that measurements from such instruments may be missing or suppressed due to power failures, mechanical issues, debris impacts or obstructions, and other causes. The data they generate is also subject to errors in data capture and computer archiving.

The storm that produced the severe wind damage in the Ottawa area (and indeed across southern Ontario and western and southern Québec) is a special class of

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severe thunderstorm wind event referred to as a “derecho”. A derecho is defined as a long-lived “convectively” (i.e., thunderstorm) driven windstorm. “Damage must be incurred either continuously or intermittently over a swath of at least 650 km (~400 mi) and a width of approximately 100 km (~60 mi) or more.” (AMS, 2023)

Historical Derecho Climatology and Climate Change

A historical database of Canadian derechos is currently in development but is only in its infancy (see **Figure 1**). To properly assess the historical frequency and characteristics (e.g., path length, intensity, direction of motion) of derechos in Canada, the historical database needs to first be completed. Similarly, for a climate change projection of potential future changes in derecho activity, the historical baseline is first needed.

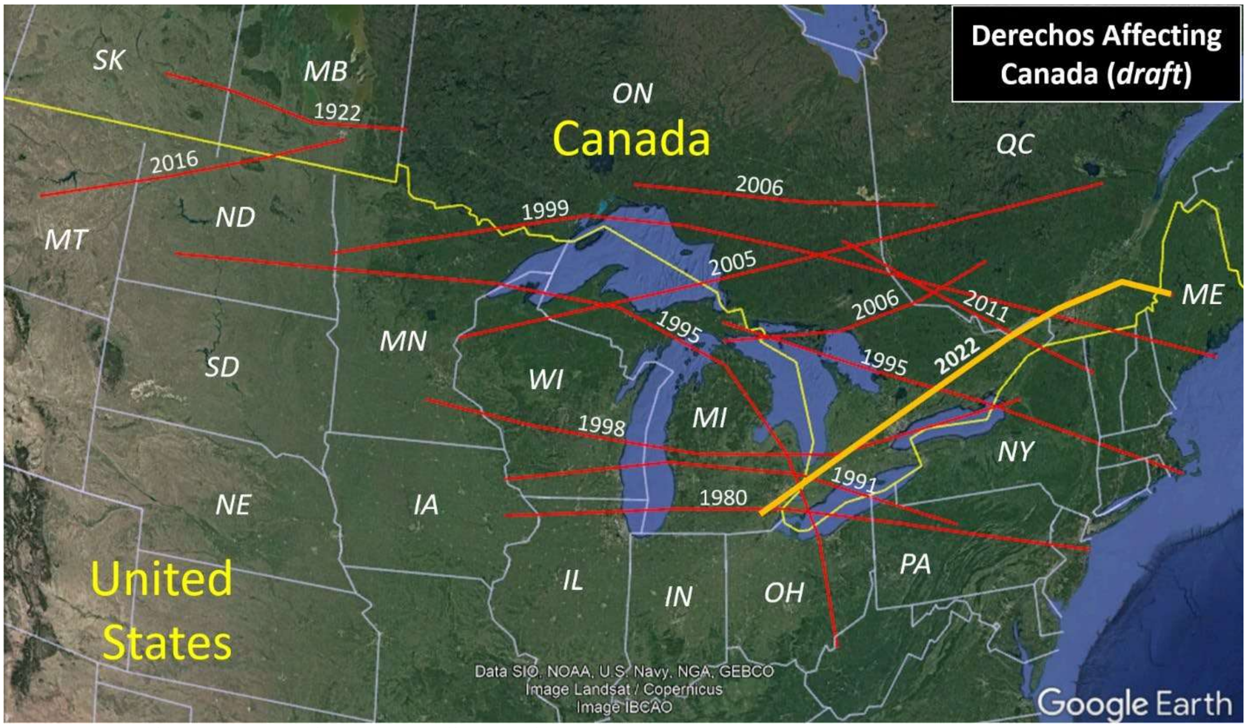

Figure 1 - Draft climatology of derechos affecting Canada (1922 to 2022).

Historical Events: July 17, 2011, Ottawa River Valley Derecho

The most recent derecho event preceding the 2022 storm affecting the Ottawa area occurred on July 17, 2011. The 2011 derecho event began at 2:45 PM in the Upper Ottawa Valley, affecting Allumette Island and Petawawa/Pembroke are before impacting the City of Ottawa at around 7:20 PM (CBC 2011). This storm resulted in four (4) injuries (including one serious) after it triggered a stage collapse at the

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Ottawa Blues Festival (CBC 2011), as well as one fatality at Ferme-Neuve, Québec. The storm continued to the southeast, affecting portions of Ontario, Québec, New York, and Vermont, ending at ~10:10 PM in Vermont. Unfortunately, no reliable wind speed estimates could be readily developed for this event in the Ottawa area. Ottawa International Airport reported a gust of “96E km/h”, with the letter “E” indicating the archived wind gust value is estimated and not an instrumented recording. No reliable wind speed estimate could be obtained from the stage collapse, either, since while the design wind speed for the stage should have been 80 km/h, subsequent investigations of the structure indicated it was not properly constructed and could easily have failed at a lower wind speed than the design requirement (CBC 2021). However, the storm did produce two instrumented measurements of gusts reaching 120 km/h, one at Pembroke, Ontario, the other at Chapeau, Québec.

Literature Assessment of Climate Change Effects on Derecho Activity

While no tailored climate change projection studies of derecho activity exist, the following considerations suggest that an increase is indeed possible:

- Climate change studies of the “storm track” – the boundary between air masses that generally represents where both the boundary between warm, moist air to the south and cooler arctic air to the north – and where large-scale low-pressure systems tend to travel, are shifting poleward (i.e., north in the northern hemisphere, e.g., Harvey et al., 2014).
    - Studies of derecho activity in the United States (e.g., Coniglio et al. 2004) have consistently indicated an area of maximum activity located immediate south of the Canadian border. Any poleward shift in this track would result in an increase in derecho events affecting southern Canada, especially in the Great Lakes basin.
- Derecho events tend to occur along the poleward side (i.e., northern fringe in the Northern Hemisphere) of so-called “heat domes”. These are features which result in extended extreme heat events for regions located underneath these domes. The frequency and intensity of heat events are projected to increase substantially, and therefore it is possible that severe thunderstorm events which favour the periphery of these extreme heat events will also increase in frequency and severity.

Engineering Risk Considerations

As is indicated on the preliminary map of historical Canadian derechos (Figure 1), the path of the May 2022 event was indeed anomalous. The 2011 storm impacted the City from the northwest, while other storms in the region resulted in paths with other directions, even changing direction in different segments. While the direction of motion will have an eastward component, this means that the *exact* direction of motion of the next event cannot be reliably anticipated.

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Summary of Findings

- Wind producing the worst impacts in southern and south-eastern portions of Hydro Ottawa's service area were due to winds in the 180-195 km/h range.
    - Indications from EF-scale damage analysis and Doppler radar derived winds strongly indicate that the wind gust measurement at Ottawa International Airport is not representative of winds which produced the most severe damage.
- A review of historical events indicates that the City of Ottawa has previously been affected by derecho events, and that the direction of motion and specific areas impacted have differed from the 2022 event. Therefore, the specific locations affected and the direction of storm motion experienced in the 2022 storm should not be explicitly relied upon as indicators of future events.
- While no derecho-specific climate change projection studies are available – for Canada or elsewhere – there are several indicators that suggest that derecho activity may increase in frequency for southern Canada under climate warming.

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Appendix C Forensic Analysis Derecho Event May 21, 2022

Priority Level	Asset Class	Initiative	Responsibility	Business Operation to Integrate Outcome	Climate Event Mitigated	Monitoring Strategy
PLS-1	Pole Line System	Develop anti-cascading strategies and standards for hardening of pole line systems to protect against wind and ice accumulation events, including: •Introducing break or stress points into the distribution lines. •Anchoring. •type of pole. Complete a cost-benefit review of the strategies at critical areas and/or strategic timelines (end of life).	Asset Planning	Asset Management Plan Pole, Fixtures and Primary Overhead Conductor	Wind, ice accumulation	Monitor power outages from cascading events year over year and track by climate event.
PLS-2	Pole Line System	Consider further updates to the vegetation management plan to account for the climate impacts and risks of increased invasive species and their potential to damage infrastructure or injure personnel during wind and ice events. Noting past program augmentations made in response to past storm events, evaluate feasibility of further augmentation with: •Trimming trees more often/aggressively or include heritage trees. •Include trees in the fall zone outside of Hydro Ottawa right away if condition assessment indicates vulnerability. •Working with the City of Ottawa and the Village of Casselman to choose tree species that will be more resistant to future climate.	Forestry Asset Planning	Vegetation Management Plan	Wind, ice accumulation	Review outage report as a result of tree damage on an annual basis and adjust Vegetation Management Plan as required.
PLS-3	Pole Line System	Complete a technology review and feasibility study of technology that may use reduce ice build-up through pulsing or vibration of distribution lines to prevent ice build-up and galloping of lines.	Standards	Asset Management Plan Pole, Fixtures and Primary Overhead Conductor	Ice accumulation	Line and pole damage and ice accumulation.
PLS-4	Pole Line System	Complete a study/analysis of potential methods to increase detection capabilities for downed lines to increase response time to repair damaged pole line system after damage from wind and/or ice accumulation.	Asset Planning	Asset Management Plan Pole, Fixtures and Primary Overhead Conductor	Wind, ice accumulation	Monitor power restoration response time to event.
PLS-5	Pole Line System	While likely cost prohibitive, where it may be warranted, complete a cost/benefit analysis to converting overhead lines to underground infrastructure when major damage has occurred, or when the infrastructure is nearing its end of life. Underground distribution lines and infrastructure would mitigate risk from wind, ice accumulation and fog.	Asset Planning	Asset Management Plan Pole, Fixtures and Primary Overhead Conductor	Wind, ice accumulation, fog	Outage reports for weather events and cost of damage estimates.

1 Initiative changed from the 2019 Hydro Ottawa Climate Change Adaptation Plan

Priority Level	Asset Class	Initiative	Responsibility	Business Operation to Integrate Outcome	Climate Event Mitigated	Monitoring Strategy
PLS-6	Pole Line System	Consider the feasibility of further increasing the frequency of pole washing and cost/benefit based on risk level (current/future) to prevent increase risk of fires related to an increase in anticipated fog days.	Asset Planning	Asset Management Plan Pole, Fixtures and Primary Overhead Conductor	Fog	Monitor pole fires and fog days on a year over year basis.
PLS-7	Pole Line System	Complete a cost/benefit analysis of expedited replacement of insulators and fused cut-outs with porcelain to prevent increase risk of fires related to an increase in anticipated fog days.	Asset Planning	Asset Management Plan Pole, Fixtures and Primary Overhead Conductor	Fog	Monitor pole fires and fog days on a year over year basis.
PLS-8 [1]	Pole Line System	Complete an inventory of switches for critical equipment and consider looking at alternatives for implementing measures to prevent freezing.	Asset Planning	Asset Management Plan Pole, Fixtures and Primary Overhead Conductor	Ice accumulation	Incidents and/or inability to correct issues related to immobile switches as a result of freezing rain.

1 Initiative changed from the 2019 Hydro Ottawa Climate Change Adaptation Plan

Priority Level	Asset Class	Initiative	Responsibility	Business Operation to Integrate Outcome	Climate Event Mitigated	Monitoring Strategy
ULS-1	Underground Line System	Complete an engineering review to identify if there are locations vulnerable to overheating (via a detailed assessment of locations that could be vulnerable to temperatures higher than 40°C) and complete a cost-benefit analysis for mitigation options, which may include: •Institute either operational constraints on how much power can be conveyed through cables to limit overheating of cables. •Cool ducts either actively or passively, for example, with thermal fill (a clay slurry).	Asset Planning Standards	Asset Management Plan UG Cable R0	Maximum Temperatures	Temperature runs within prescribed levels. Premature cable failure events and occurrences of 40°C days.
ULS-2	Underground Line System	Identify new technologies and processes through research and feasibility or pilot studies to reduce freeze thaw impacts. These may include: •Exploring the use of different materials for manholes instead of concrete that are less susceptible to freeze-thaw (e.g. fiber glass). •Redesign civil structure collars to move with the heading (e.g. telescopic collars).	Asset Planning Standards	Asset Management Plan - Civil Structures	Freeze-thaw events	Track freeze-thaw damage and annual freeze-thaw days.
SUB-1	Substations	Review additional requirements for sanding and gritting prior to site access.	Facilities	Maintenance Procedures	Ice accumulation	Delays due to inaccessibility.
SUB-2	Substations	Develop a policy to monitor and inspect substation building and structural components after an ice event to mitigate the risk of structural damage and loss of assets as a result of ice damage to substations.	Facilities Stations	Maintenance Procedures	Ice accumulation	Number of leaks or damages. Track maintenance costs.
SUB-3	Substations	Complete a cost-benefit analysis of installing protective covers on small exterior equipment, where feasible, to prevent damage/failure as a result of ice accumulation.	Facilities	Asset Management Plans	Ice accumulation	Number of failures of attached equipment due to ice.
SUB-4	Substations	Create an inventory of all critical equipment (e.g. switches) that could be impacted by ice accumulation, prioritize by criticality, and assess feasibility or practicality of covering with permanent or temporary covers without creating additional hazards [1].	System Operations Asset Planning Standards	Asset Management Plan - Station Switchgear and Breakers	Ice accumulation	Number of operational failures due to ice.

1 Initiative changed from the 2019 Hydro Ottawa Climate Change Adaptation Plan

Priority Level	Asset Class	Initiative	Responsibility	Business Operation to Integrate Outcome	Climate Event Mitigated	Monitoring Strategy
OPS-1	Operations	Refine and establish a policy on wind conditions when a lift bucket should not be used and when work should not be completed to mitigate the risk of injury related to wind.	Distribution Operations Health and Safety	Health and Safety Policy/Practice	Wind	Monitoring of the number of wind-related events and health and safety incidents associated with wind and lift buckets.
OPS-2	Operations	Consider a review of policies surrounding heat stress on outdoor workers and revise to include projected climate changes to mitigate the impacts of heat stress. Policies to consider should including: •A policy on work redistribution (scheduling) to avoid outdoor work during peak heat hours. •Where feasible and risk assessment permits, consider a policy around the adoption and use of modified PPE to improve cooling / ventilation.	Distribution Operations Health and Safety	Health and Safety Policy/Practice	Heat events	Monitor the number of heat-related incidents and daily max temperatures in excess of 35 °C and 40°C.
OPS-3	Operations	Work with Hydro One, and provincial regulators to ensure supply design and standards are aligned with climate risks.	Asset Planning System Operations	Various	Ice accumulation, wind	Track the frequency and scale of outages resulting from Hydro One service disruption.
OPS-4	Operations	Consider the cost-benefit of the following measures to reduce the risk of employee injuries related to ice accumulation events: •Review, and consider revising policy for requiring installation of winter tires on Hydro-owned vehicles to prevent injuries to personnel rather than through a request/approval process. •Installation and use of additional automated devices to limit need to travel during inclement conditions. •Introducing policies to include heated steps or walkways on Hydro Ottawa properties versus continued salting/sanding.	Fleet & Facilities Asset Planning	Health and Safety Policy/Practice	Ice accumulation	Monitor the number of ice-related incidents (near miss, incidents).
OPS-5	Operations	Develop a policy to monitor and inspect building and roofs after an ice event.	Facilities	Maintenance Procedures	Ice accumulation	Tracking of damage by weather event (if known). Track maintenance costs.
OPS-6	Operations	Consider updating the work from home policy to eliminate or reduce commuting during extreme weather events and hazardous road conditions, particularly ice accumulation.	Human Resources	Human Resources Policy	Ice accumulation	Safety bulletin for tracking number of slips, falls, and other ice-related incidents.

1 Initiative changed from the 2019 Hydro Ottawa Climate Change Adaptation Plan

Priority Level	Asset Class	Initiative	Responsibility	Business Operation to Integrate Outcome	Climate Event Mitigated	Monitoring Strategy
OPS-7	Operations	Consider future climate projections at end of life of current system when deciding to replace or rehabilitate building HVAC systems. Integrate requirement into Procurement Policy to size and design based on climate projections (heating and cooling requirements) in conjunction with critical needs (IT server requirements). By integrating future needs into procurement, the risk that cooling is not adequate during 40°C is minimized.	Facilities	Procurement Policy	Heat event	Monitor the efficiency and service requirements of the building's HVAC system and environmental controls.

1 Initiative changed from the 2019 Hydro Ottawa Climate Change Adaptation Plan

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10/24/2024

Pranav Pattabi, P.Eng
Supervisor, Maintenance and Reliability
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Subject: Hydro Ottawa Asset Condition Assessment Framework

Dear Pranav,

Hatch was engaged by Hydro Ottawa Ltd. (HOL) to review their Asset condition assessment (ACA) framework. The primary objective of this exercise is to validate the framework's calculation and methodology, providing suggestion on its alignment with HOL's broader asset management (AM) strategy and relevant standards. The ACA framework is employed by HOL to derive Asset Health Indices (HI), supporting efforts to enhance system reliability, optimize customer satisfaction, and improve operational efficiency. This approach integrates data from various maintenance programs such as visual inspections, testing and monitoring activities.

Hatch's review was structured into two aspects: 1) Examination of the provided information, including summaries of methodologies and raw data, to validate the ACA framework results for the assets in scope; 2) Evaluation of the ACA framework to ensure alignment with HOL's AM philosophy.

Hatch's review of HOL's ACA framework led to the following conclusions:

1. **<u>Desktop Review and Validation of Framework Results</u>**

Hatch has found HOL's ACA framework to be comprehensive, reflected by HOL's efforts to capture and utilize available data. The methodology document largely demonstrates transparency, consistency and alignment with the calculation model. Despite the volume of assets being assessed, the methodology ensures that data from different source is translated into meaningful metrics.

Hatch identified minor calculation gaps with minimal impact to the overall asset portfolio. HOL currently uses Microsoft Excel (Excel) for Health Index calculations. Some of the identified discrepancies rise from the manual handling of multiple Excel files. While Excel offers ease of use and flexibility, it is also prone to errors due to the intensive manual processes involved in managing and processing data. The reliance on manual data transfer, formula adjustments, and file imports increases the risk of human error, which can compromise the accuracy of health index calculations. Even minor mistakes, such as incorrect cell references or data misplacement, can potentially cascade into larger issues, leading to unreliable outputs. Additionally, the lack of built-in automation or advanced error-checking mechanisms within Excel makes it challenging to maintain consistency across large datasets. As data volumes grow, the effort required to validate entries and formulas manually becomes more time-consuming and error-prone. This increases the potential for inconsistencies, especially when multiple users are involved in updating and modifying asset data.

When Hatch identified this minor gap, HOL, acknowledges the challenges associated with Excel's manual processes and their impact on data accuracy. In response, HOL shared that they are actively exploring more streamlined solutions to address this limitation. Their goal is to implement a system that minimizes reliance on manual processes, offers analytics and dashboard capabilities, and has the potential to integrate with other enterprise solutions.

Hatch worked with HOL to identify the gaps and to find mitigation solutions, ultimately resulting in addressing all the calculation gaps a result of the project.

2. Assessment of Alignment with AM Philosophy and Relevant Standards:

Hatch has found HOL's ACA framework as overall comprehensive giving the limitation with available data. The framework also shows HOL's effort to balance complexity with practicality.

A key strength of HOL's ACA framework lies in its HI validation step, which ensures the integrity and robustness of all results. This step assesses if a sufficient number of parameters is available for each asset before proceeding with the ACA calculation, ensuring that the analysis is not only thorough but also meaningful. By setting this threshold, the framework prevents incomplete or unreliable assessments, maintaining consistency and precision across all evaluated assets.

Hatch proposed that additional criteria be incorporated for certain asset classes to provide a more comprehensive representation of the overall Health Index. HOL acknowledged the value of this suggestion and expressed agreement, noting that they are already in the process of gathering more data to support this enhancement. HOL confirmed that with this expanded dataset, they plan to implement some of the suggested criteria in the near future, further enhancing their ACA framework.

Hatch further recommended adopting a non-linear approach that can be closer aligned with HOL's Asset Management principles, emphasizing a shift from traditional linear models to more dynamic, data-driven methodologies. HOL has acknowledged the value of this suggestion and confirmed that they are actively exploring solutions to enhance their capabilities in advanced analytics. Their objective is to adopt a platform that offers better scalability, reduces reliance on manual processes, and minimizes the potential for human error inherent in Excel-based management. By moving toward a more automated and integrated system, HOL aims to streamline operations, improve data accuracy and ensure consistency across asset condition assessment as the framework evolves.

These efforts reflect HOL's commitment to continuous improvement, balancing the need for immediate enhancements with long-term strategies for operational efficiency. Their dual focus on expanding data collection and upgrading technology ensures that future phases will not only incorporate more robust criteria but also benefit from more reliable and scalable processes.

Key Takeaway

Hatch has reviewed HOL's Asset Condition Assessment calculations and methodologies. Hatch confirmed that the calculations are aligned with the methodologies and that the methodologies are generally aligned with industry best practices. Minor gaps were identified in the calculations, which HOL has acknowledged and addressed. Hatch also provided suggestions for enhancing the methodologies, which HOL recognized as valuable. HOL confirmed that they are in the process of gathering additional data and exploring solutions to support advanced analytics and meet evolving data requirements.

Yours faithfully,

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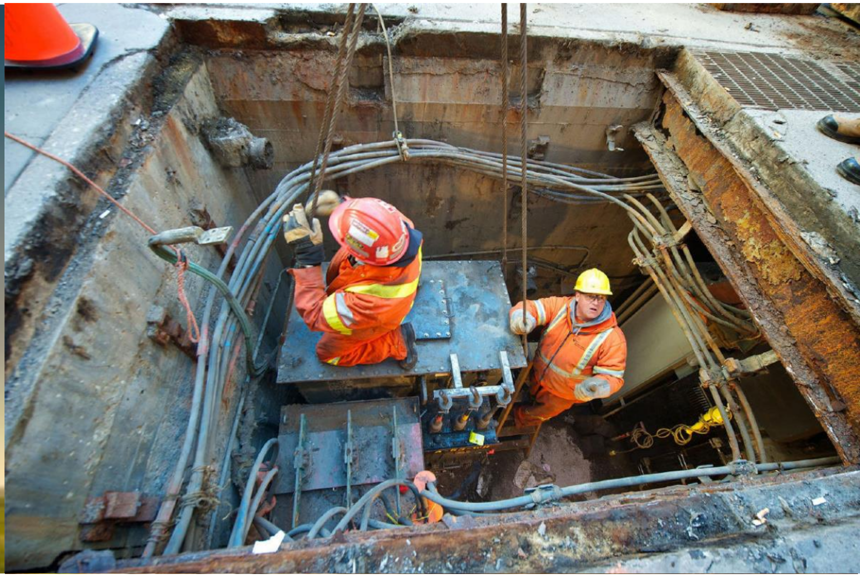
Distribution Asset Failure Curves





August 15, 2024

Hydro Ottawa Failure Curves

Hatch Project H372826

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Agenda

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Executive Summary

Overview

Hydro Ottawa Limited ("HOL") is looking to advance their asset failure curve intelligence to improve the risk- and value-based asset management processes. The overall objective of the project was to advance the existing failure curves from industry consensus-based to data-driven evidence based.

Through this project, Hatch has reviewed existing failure curves, provided data-driven failure curves and augmented HOL's current age-condition decay curves based on available asset records. Various data scenarios and methodologies were considered and verified by Hatch's SMEs to arrive at most accurate data-driven representation of the system. The purpose of this exercise was reviewing data availability, data quality, selecting the appropriate methodology and providing future recommendations.

This analysis was performed for 30 asset types across 9 asset classes:

- ✓ Transformers
- ✓ Poles
- ✓ Switches, Reclosers, Switchgear
- ✓ Cables, Relays, Maintenance Holes, Batteries

Evaluated Assets

Click on asset class to view detailed results

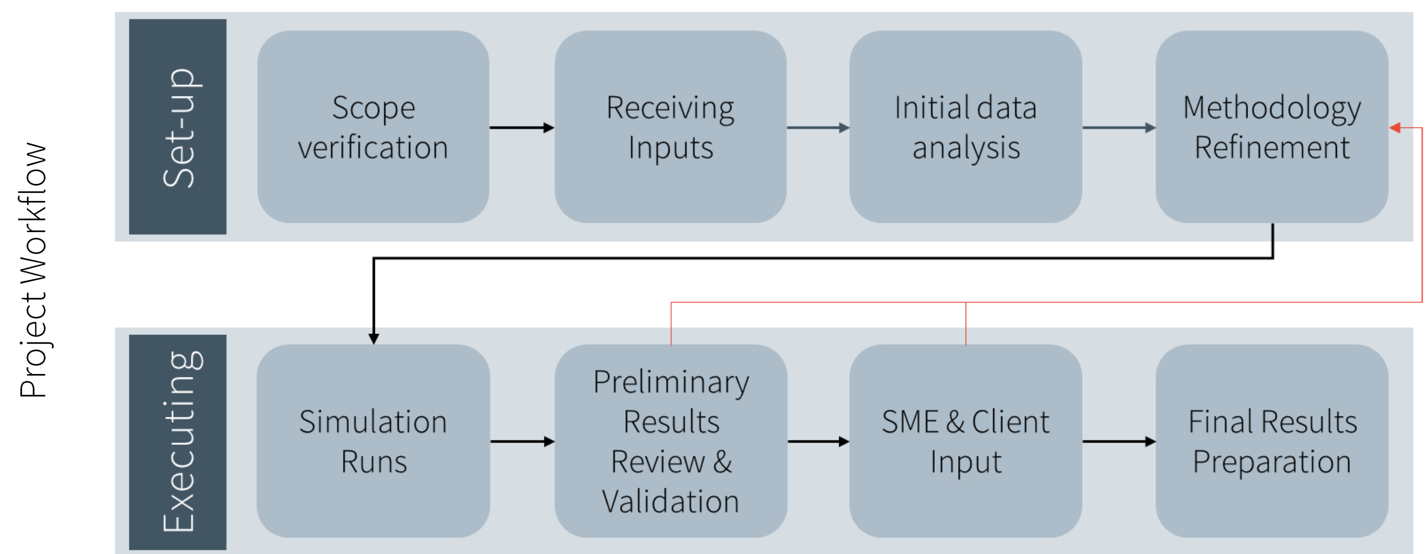
Transformers	1	Station Transformers
Transformers	2	Polemount Transformers
Transformers	3	Vault Transformers
Transformers	4	UG Transformers
Transformers	5	Station Tap Changers
Poles	6	Wood Poles
Poles	7	Concrete Poles
Poles	8	Metal Poles
Poles	9	Composite Poles
Switches/Reclosers	10	Station HV SF6 Breakers
Switches/Reclosers	11-A	Station Metalclad Air Breakers
Switches/Reclosers	11-B	Station Metalclad Vacuum Breakers
Switches/Reclosers	11-C	Station Metalclad Oil Breakers
Switches/Reclosers	11-D	Station Metalclad SF6 Breakers

Switches/Reclosers	12-A	UG Switchgear Air
Switches/Reclosers	12-B	UG Switchgear SF6
Switches/Reclosers	13-A	OH Manual Loadbreak Switch
Switches/Reclosers	13-B	OH SCADA Loadbreak Switch
Switches/Reclosers	14	OH Distribution Reclosers
Switches/Reclosers	15	Station Outdoor Reclosers
Switches/Reclosers	16	Station HV Circuit Switchers
Cables	17-A	UG Primary Cables – EPR
Cables	17-B	UG Primary Cables – XLPE
Cables	17-C	UG Primary Cables – PILC
Other	18	Protective Relays [EM, Electronic, Microprocessor]
Other	19	Maintenance Holes
Other	20-A	Station Batteries [VLA]
Other	20-B	Station Batteries [VRLA]

HydroOttawa HATCH

Highlights

- The team utilized an iterative process to examine the applicability of different reliability engineering methodologies and techniques to HOL's data, building upon Hatch's extensive experience in implementing reliability engineering methodologies within the T&D domain.
- Overall process flow was developed to address HOL-specific challenges and leverage different available inputs
- Continuous efforts were made to compare the results with industry and HOL Typical Useful Life values. The results were reviewed with SMEs for verification and further optimization of each step of the process.



HydroOttawa HATCH

Methodology

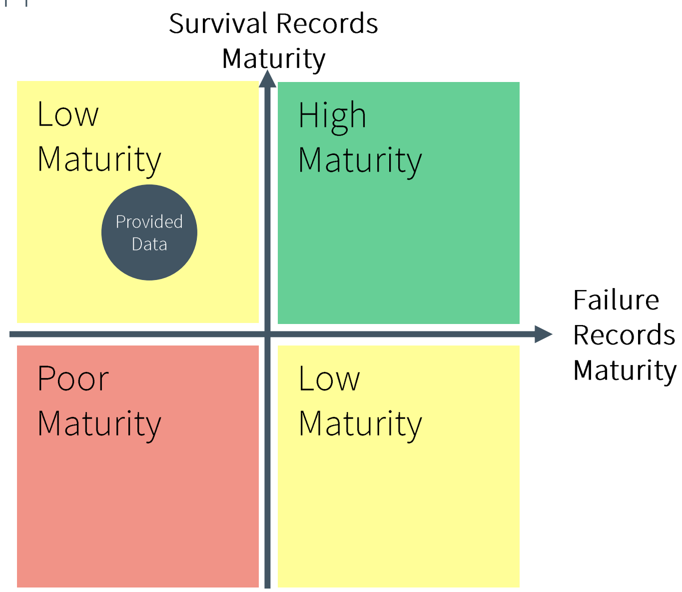
Data Driven Reliability Engineering

The accuracy of data-driven reliability engineering relies on the quality of existing data. The following are some of the data challenges within the reliability engineering for transmission and distribution utilities:

- General lack of survival and/or failure data.
- Minimal failure data compared to in-service assets. This leads to higher right censoring effect.
- Shorter data collection duration compared to the early assets' installation year and the overall study period. This leads to longer missing data duration and higher left truncation effect.

Based on these challenges, the data provided for this exercise would qualify on the second quadrant of the following reliability engineering maturity matrix. This highlights the fact that for the majority of asset classes, the data-driven results should be verified with internal SMEs before being applied.

The lack of asset failure data is the biggest challenge within the transmission and distribution asset management domain. This challenge, among other challenges, were addressed by utilizing extensive scenario-based simulations and probabilistic approaches to address the missing data.



Asset Simulation Methodology

Poisson bootstrapping and synthetic simulations

HOL Inputs

1. Asset Registry (no failures)

Estimated/actual install years for survivals

Health Index data where applicable

2. Corrective Renewal Data

# of corrective renewals due to failures for years 2016 to 2022

Analysis Set-up

Asset Registry Distribution

TUL Estimates

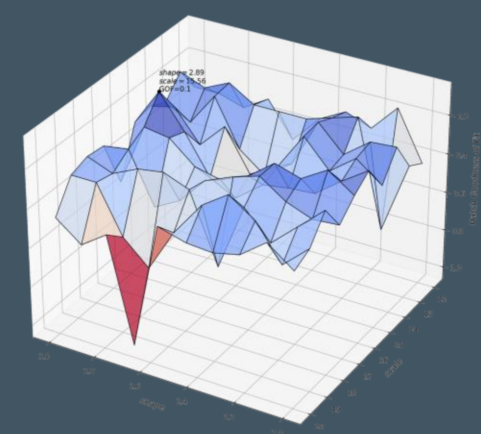
SME Input

Weibull Parameters

- Matrix of possible shape and scale values

Asset Simulation

Statistical analysis leveraging available data to arrive at best representative Weibull curve



Refine Boundary Conditions and Parameters if result is not satisfactory

Review Results

Synthetic Asset Registries

- Including Failures & Survivals

- Compare synthetic survival distribution to current asset registry
- Compare synthetic failure to replacement records
- Compare fitted Weibull distribution to TUL and SME inputs

Best Synthetic Registry & corresponding Weibull Curve

HydroOttawa HATCH

Result Review and Application

Simulation methodologies are designed to create simulated populations of assets under various initial conditions, including the probabilistic failure characteristics of these assets.

The outcome is then evaluated to ensure that the simulated population closely matches the current asset registry. If the simulated results consistently approach the distribution of the current asset registry, the simulation is considered to be converging. This convergence indicates that the methodology is reaching a stable state that accurately represents the current asset class population.

Converging at such a stable state is a common challenge when simulation methods are employed in management of utility assets. Various factors such as poor data quality can prevent a simulation from converging. In this exercise, the shape and scale parameters of a Weibull distribution were simulated across past several decades to arrive at virtual population of assets that shows maximum similarity to the current asset registry.

For 18 out of 30 asset classes (60% of the studied asset classes) the model did converge successfully. For the remaining 12 assets classes (40% of the studied asset classes) the model did not converge to specific stable results.

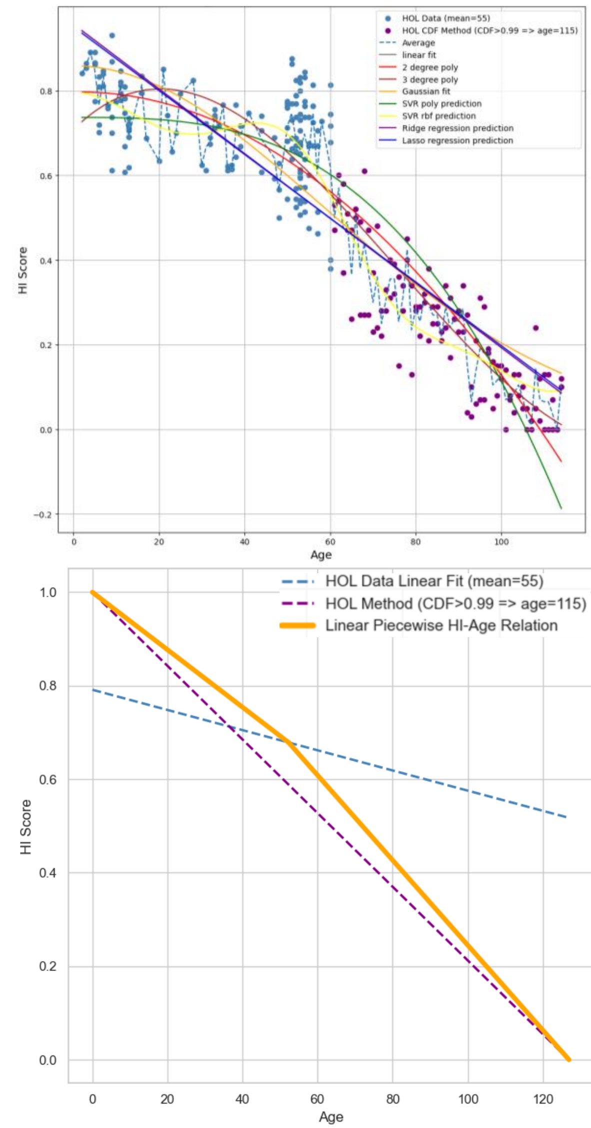
Three sets of results are reported for each asset class where applicable.

- Data Driven Results: The simulation results that most closely match the distribution of the asset registry are reported as data-driven results.
- TUL Adjusted Results: When data-driven results deviate from the industry's TULs, the similarity criterion is relaxed to include the top 10% of matches most closely resembling the current asset registry. From this selection, the results closest to the industry TUL are then provided.
- TUL Based Results are developed using industry recognized TUL, HOL specific historical TUL, and expert judgement.

When the simulation model did not converge, the corresponding cells within result tables for Data Driven Results and TUL Adjusted Results are gray shaded. Since the provided data is considered to be in the Low Maturity category, the simulation results for non-converging asset classes do not reflect their actual survival pattern. For these cases, SME verified shape was used to produce TUL Based results.

Age-Condition Degradation Curve

- Multiple statistical and machine learning methods were tested to model the health index degradation with time (including Linear, Polynomial, Sigmoid, Gaussian and Support Vector Machine regressions).
- The quality of data across all different asset classes would not allow for consistent regression model to work in majority of cases.
- The following criteria for a linear piecewise model was developed and proved robust based on data of 17 asset classes.
  - A segmented linear piecewise relationship was built to incorporate Health Index records where data shows less degradation than the current HOL health index degradation methodology.
  - First segment connects new assets with HOL health index data trend.
  - The fitted average useful life was used as inflection point.
  - Second segment connects inflection point to asset end of life as per the current HOL methodology.

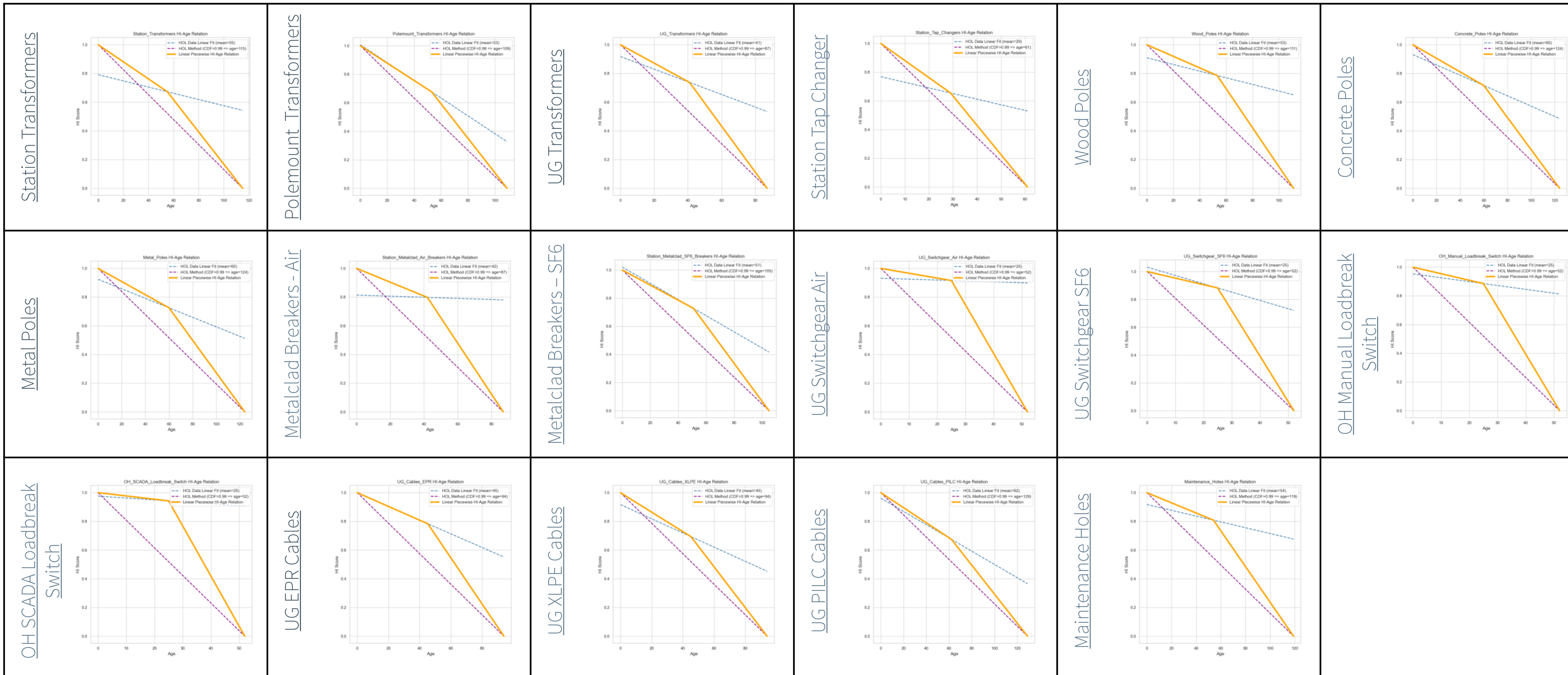


Station Transformers Age Condition Degradation

HydroOttawa HATCH

Results Overview
Age-Condition Degradation Curves

Results Overview: Age-Condition Degradation Curve



Results Overview – Failure Curves
Data Driven Results

Results Overview - Transformers

#	Asset	Data Driven			TUL Adjusted			TUL Based			Typical Useful Life (TUL)	*Comments*
		Shape	Scale	Mean	Shape	Scale	Mean	Shape	Scale	Mean		
1	Station Transformers	2.1	53	47	2.1	59	52	2.5	62	55	55	*Model converged successfully*
2	Polemount Transformers	3.2	76	68	3.7	59	53	2.5	59	53	53	*Model **did not** converge to a specific shape/scale combination*
3	Vault Transformers	2.6	69	61	2.3	60	53	2.5	59	53	53	*Model **did not** converge to a specific shape/scale combination*
4	UG Transformers	2.4	46	41	--	--	--	2.5	46	40	40	*Model converged successfully*
5	Station Tap Changers	2.0	27	24	2.4	32	29	2.5	34	30	30	*Model converged successfully*

Note: The red-highlighted results are recommended values confirmed during a workshop between HOL and Hatch SMEs. These recommendations were based on the convergence of the simulation model, the maturity of input data, and industry experience.

Results Overview - Poles

#	Asset	Data Driven			TUL Adjusted			TUL Based			Typical Useful Life (TUL)	*Comments*
		Shape	Scale	Mean	Shape	Scale	Mean	Shape	Scale	Mean		
6	Wood Poles	3	72	**64**	2.5	69	**61**	2.5	60	53	53	*Model **did not** converge to a specific shape/scale combination*
7	Concrete Poles	3.0	67	**60**	--	--	--	2.5	67	60	60	*Model **did not** converge to a specific shape/scale combination*
8	Metal Poles	2.6	69	**62**	2.0	67	**60**	2.5	67	60	60	*Model **did not** converge to a specific shape/scale combination*
9	Composite Poles	2.7	86	**76**	2.9	90	**80**	2.5	90	80	80	*Model **did not** converge to a specific shape/scale combination*

Note: The red-highlighted results are recommended values confirmed during a workshop between HOL and Hatch SMEs. These recommendations were based on the convergence of the simulation model, the maturity of input data, and industry experience.

Results Overview – Switches/Reclosers

#	Asset	Data Driven			TUL Adjusted			TUL Based			Typical Useful Life (TUL)	*Comments*
		Shape	Scale	Mean	Shape	Scale	Mean	Shape	Scale	Mean		
10	Station HV SF6 Breakers	3.0	50	45	--	--	--	2.5	51	45	45	*Model **did not** converge to a specific shape/scale combination*
11-A	Station Metalclad Air Breakers	2.2	52	46	2.2	45	40	2.5	47	42	42	*Model converged successfully*
11-B	Station Metalclad Vacuum Breakers	2.9	54	48	3.0	53	47	2.5	52	46	46	*Model converged successfully*
11-C	Station Metalclad Oil Breakers	2.7	45	40	2.6	58	51	2.5	62	55	55	*Model converged successfully*
11-D	Station Metalclad SF6 Breakers	2.4	53	47	2.9	60	53	2.5	57	51	51	*Model converged successfully*
12-A	UG Switchgear Air	3.0	26	23	2.9	38	34	2.5	28	25	25	*Model converged successfully*
12-B	UG Switchgear SF6	2.9	39	35	3.0	28	25	2.5	28	25	25	*Model **did not** converge to a specific shape/scale combination*

Note: The red-highlighted results are recommended values confirmed during a workshop between HOL and Hatch SMEs. These recommendations were based on the convergence of the simulation model, the maturity of input data, and industry experience.

Results Overview - Switches/Reclosers

#	Asset	Data Driven			TUL Adjusted			TUL Based			Typical Useful Life (TUL)	*Comments*
		Shape	Scale	Mean	Shape	Scale	Mean	Shape	Scale	Mean		
13-A	OH Manual Loadbreak Switch	2.3	39	**35**	2.0	36	**32**	2.5	28	25	25	*Model converged successfully*
13-B	OH SCADA Loadbreak Switch	2.6	41	**37**	2.3	31	**27**	2.5	28	25	25	*Model converged successfully*
14	OH Distribution Reclosers	2.6	44	**39**	3.0	44	**40**	2.5	45	40	40	*Model **did not** converge to a specific shape/scale combination*
15	Station Outdoor Reclosers	2.4	43	**38**	2.4	44	**39**	2.5	45	40	40	*Model **did not** converge to a specific shape/scale combination*
16	Station HV Circuit Switchers	2.2	58	**51**	--	--	--	2.5	57	50	50	*Model **did not** converge to a specific shape/scale combination*

Note: The red-highlighted results are recommended values confirmed during a workshop between HOL and Hatch SMEs. These recommendations were based on the convergence of the simulation model, the maturity of input data, and industry experience.

Results Overview - Cables

#	Asset	Data Driven			TUL Adjusted			TUL Based			Typical Useful Life (TUL)	*Comments*
		Shape	Scale	Mean	Shape	Scale	Mean	Shape	Scale	Mean		
17-A	UG Primary Cables – EPR	2.3	29	26	2.9	49	43	2.5	51	45	45	*Model converged successfully*
17-B	UG Primary Cables – XLPE	2.5	54	48	2.5	52	46	2.5	51	45	45	*Model converged successfully*
17-C	UG Primary Cables – PILC	2.0	67	60	2.6	69	62	2.5	70	62	62	*Model converged successfully*

Note: The red-highlighted results are recommended values confirmed during a workshop between HOL and Hatch SMEs. These recommendations were based on the convergence of the simulation model, the maturity of input data, and industry experience.

Results Overview - Other

#	Asset	Data Driven			TUL Adjusted			TUL Based			Typical Useful Life (TUL)	*Comments*
		Shape	Scale	Mean	Shape	Scale	Mean	Shape	Scale	Mean		
18-A	Protective Relays - EM	2.3	43	**38**	2.8	46	**41**	2.5	45	**40**	40	*Model converged successfully*
18-B	Protective Relays - Electronic	2.8	45	**40**	2.0	33	**30**	2.8	17	**15**	15	*Model converged successfully*
18-C	Protective Relays - Microprocessor	2.3	23	**21**	2.3	28	**25**	2.5	28	**25**	25	*Model **did not** converge to a specific shape/scale combination*
19	Maintenance Holes	2.3	61	**54**	2.6	67	**60**	2.5	68	**60**	60	*Model converged successfully*
20-A	Station Batteries [VLA]	2.9	16	**14**	2.3	19	**17**	2.5	28	**25**	25	*Model converged successfully*
20-B	Station Batteries [VRLA]	2.9	18	**16**	2.7	17	**15**	2.5	17	**15**	15	*Model converged successfully*

Note: The red-highlighted results are recommended values confirmed during a workshop between HOL and Hatch SMEs. These recommendations were based on the convergence of the simulation model, the maturity of input data, and industry experience.

Recommendations & Discussions

Summary and Recommendation

Project Highlights

- Utility companies face various data challenges in tracking and recording asset performance.
- It is instrumental to leverage any available information when data is not comprehensive.
- Available HOL information was utilized to developed a custom approach to address HOL-specific challenges

Recommendations

- Continue to improve failure data tracking and collection
  - Continue to track count of failures and renewals per year, in addition to replaced asset information, such as install year, age at renewal, and health index
  - For cables, continue to track failures/replacements by segment and feeder
- Continue to implement asset health index tracking
  - Continue to track and record asset health index information based on predetermined parameters

Confidential

Resilience Investment Business Case Report

Hydro Ottawa

Hydro Ottawa Resilience Investment Business Case Assessment
Project No. 156002

3/27/2024

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LIST OF ABBREVIATIONS

Abbreviation	Term/Phrase/Name
ANL	Argonne National Laboratory
BCR	Benefit Cost Ratio
C&I	Commercial & Industrial
CIS	Customer Information System
CMI	Customer Minutes Interrupted
COF	Consequence of Failure
Con Ed	Consolidated Edison
DC	District of Columbia
DOE	Department of Energy
Dominion	Dominion Energy
FPL	Florida Power & Light
FPSC	Florida Public Service Commission
GHG	Green House Gas
GIS	Geographic Information System
HILP	High impact lower probability
ICE	Interruption Cost Estimator
IEEE	Institute of Electrical and Electronics Engineers
LOF	Likelihood of Failure
MED	Major Event Day
NARUC	National Association of Regulatory Commissioners
NASEO	National Association of State Energy Officials
NIAC	National Infrastructure Advisory Council
NOAA	National Oceanic and Atmospheric Administration
OH	Overhead
OMS	Outage Management System

Abbreviation	Term/Phrase/Name
PC44	Public Conference 44
Pepco	Potomac Electric Power Company
PNNL	Pacific Northwest National Laboratory
PSEG	Public Service Electric and Gas
ROW	Right-of-Way
SQ	Status Quo
T&D	Transmission and Distribution
TECO	Tampa Electric Company
UG	Underground

1.0 EXECUTIVE SUMMARY

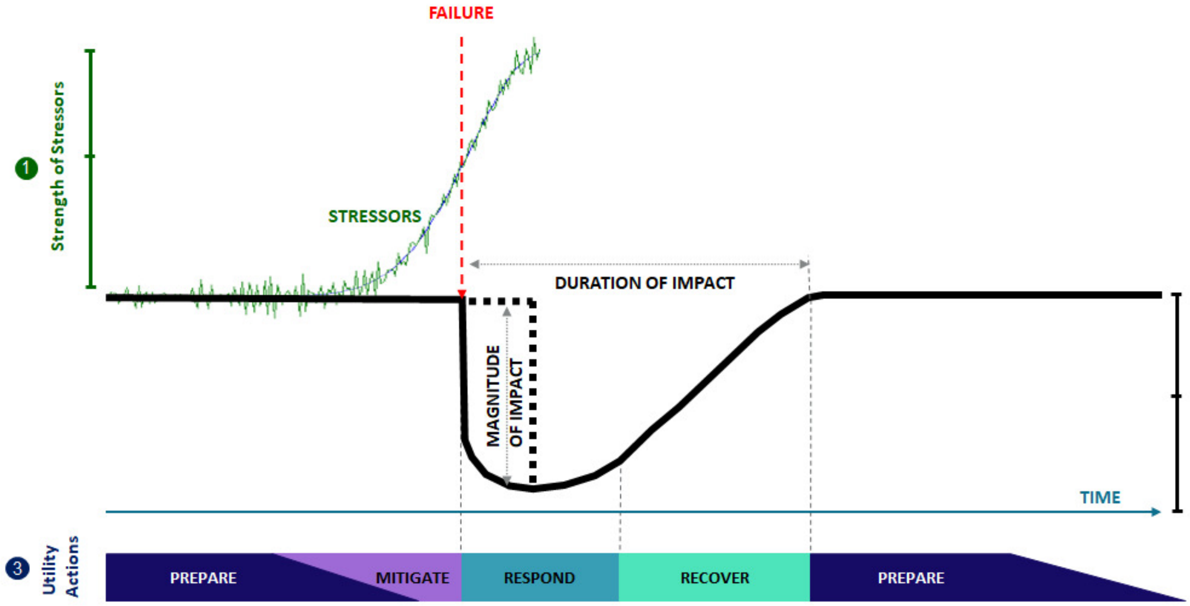
Resilience and its quantification within the utility industry, amongst others, is increasingly the topic of conversation for many electric grid stakeholders from commissions to planning engineers, from boardrooms to utility operations and beyond.

A utility's system resilience is a function of many factors but the two main functions are the frequency and types of events to impact the system, and the characteristics of the infrastructure. Obviously, more frequent and more intense events make grid resilience challenging. Second, the unique characteristics of a utility's system will change the overall outcome of the major events. The following are examples of key characteristics or vulnerabilities that will impact the resilience of the grid:

- Vegetation density
- Quantity of exposed infrastructure (Overhead vs Underground)
- Age and condition of exposed infrastructure
- Level of system sectionalization (Size of circuits, i.e. no. of customers fed off of each circuit)
- Mix of downstream customers

The combination of events and vulnerabilities provides additional challenges for grid resilience. 1898 & Co. utilizes a conceptual resilience framework to understand both of these factors (events and vulnerabilities) and how improvements to the grid can be executed to improve system resilience. Figure 1-1 represents this conceptual view of resilience. The framework is broken up into three components (stressor, state of the system, and utility actions). These three components of the framework are discussed in more detail in Section 2 of the report.

Figure 1-1: Conceptual Resilience Framework



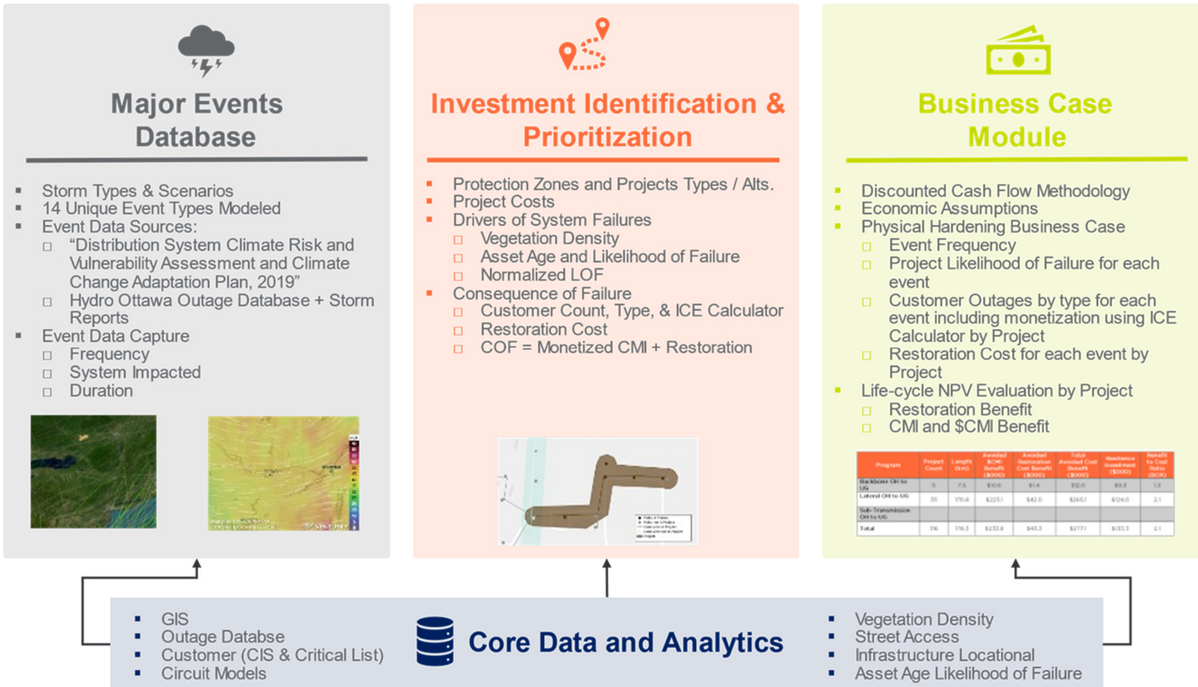
The conceptual frameworks are used throughout this report to:

- Make the case for how resilience investments benefit Hydro Ottawa's customers.
  - Impact to Customers: Outages - Section 3.2
  - Stressors - Section 3.3
  - Impact to Customers: Restoration Costs - Section 3.4
  - Elevated Safety Risks – Section 3.5
- Understand the benefits resilience investments have in avoiding or mitigating disruptive events.
- Anchor the resilience investment business case providing 'line-of-sight' from the theory to practice.

1.1 Resilience Investment Model Overview

Figure 1-2 provides an overview of the Resilience Investment Model to identify and prioritize hardening investments and calculate their customer centric business case.

Figure 1-2: Resilience Investment Model Overview



The Resilience Investment Model is foundationally data centric. It utilizes Hydro Ottawa enterprise data sources as well as external sources. From an internal enterprise perspective, the model utilizes Hydro Ottawa's Geospatial Information System (GIS) for the collection of assets and their attributes (age, type, etc.). This allows the resilience-based planning approach to be asset-centric. The model also utilizes Hydro Ottawa's Outage Database to understand the relationships between protection devices and the types of outage events, particularly larger events. The third core enterprise data set includes information from the Customer Information System (CIS). The fourth core dataset includes Hydro Ottawa distribution circuit models. 1898 & Co. linked these datasets to create the relationship between assets and customers and customer types. This allows the resilience-based planning approach to be customer-centric.

1898 & Co. also leveraged external data sources for the evaluation linking them to the internal data sources. The external data sources included satellite tree canopy for vegetation density analysis, and age deterioration analytics from 1898 & Co. own proprietary modeling. These external sources provided valuable information in identifying infrastructure that would more likely fail during events. Full details of the Resilience model are provided in Section 6.0

1.2 Resilience Investment Results

Hydro Ottawa and 1898 & Co. utilized a resilience-based planning approach to identify, prioritize, and justify o verhead to underground resilience investments in Hydro Ottawa's distribution system. Project benefits are shown in terms of the:

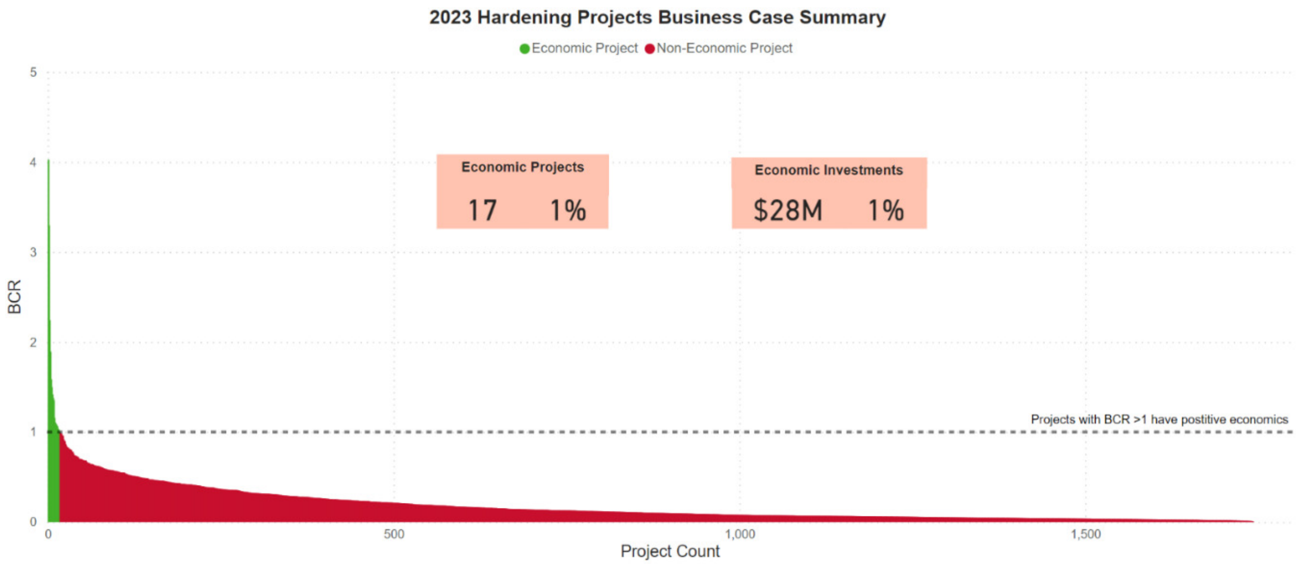
1. Decrease in the Storm Restoration Costs

2. Decrease in the customers impacted and the duration of the overall outage, calculated as CMI.

Additionally, the results are presented assuming monetization of the CMI using the DOE ICE Calculator, modified for resilience. The ICE Calculator is discussed in Section 6.2. The monetization of the CMI in conjunction with the storm restoration costs allows for the calculation of a benefit cost ratio for each potential overhead to underground project.

The resilience projects are prioritized based on the benefit cost ratio of each potential project. Figure 1-3 shows the resulting project resilience ranking, BCR per project cost, for all potential projects included in the evaluation with a historical baseline storm forecast.

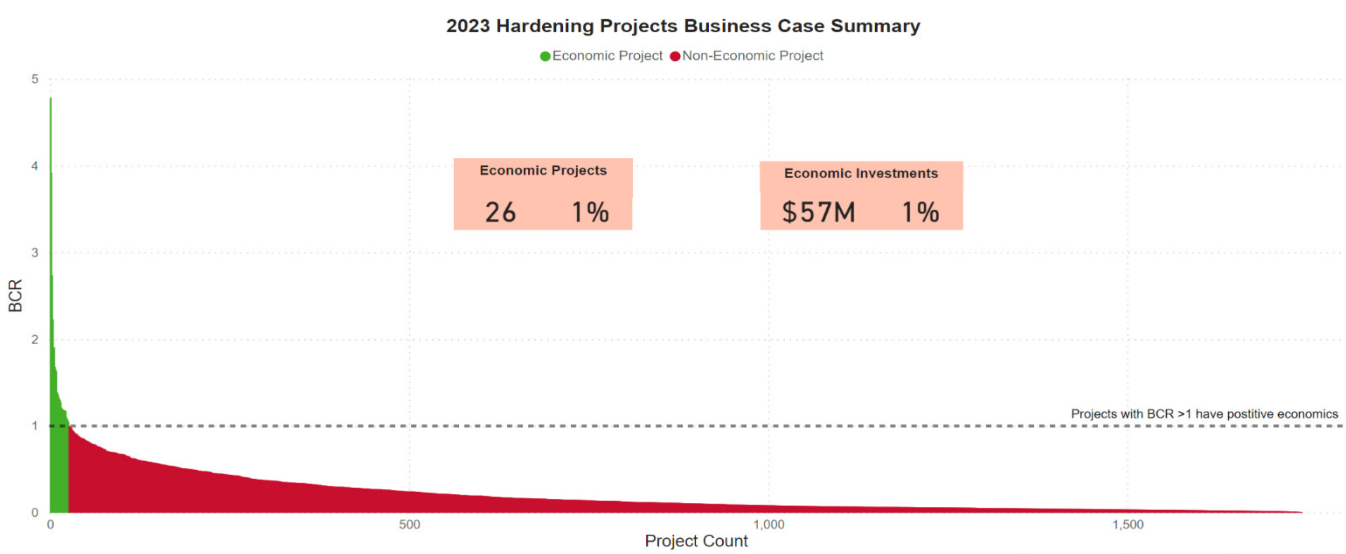
Figure 1-3: **Project Resilience Ranking by BCR for Historical Baseline Storm Forecast**



As the figure shows approximately 1 percent of the overhead to underground projects evaluated show a resilience benefit cost ratio value of more than one (28 million dollars). This metric is used to identify the most vulnerable parts of the system that yield the greatest return per dollar spent.

Figure 1-4 shows the resulting project resilience ranking, BCR per project cost, for all potential projects included in the evaluation with climate change storm forecast.

Figure 1-4: **Project Resilience Ranking by BCR for Climate Change Forecast**



As the figure shows approximately 1 percent of the projects evaluated show a resilience benefit cost ratio value of more than one (57 million dollars). This metric is used to identify the most vulnerable parts of the system that yield the greatest return per dollar spent.

1.3 Conclusions

The following include the conclusions of this resilience evaluation for Hydro Ottawa:

- The resilience of the grid is becoming increasingly important. The case for selective overhead to underground resilience investment is sound for Hydro Ottawa; resilience is at the cross section of major events, the modern customer and integrated society. The impact of major events to today's customer and society are much greater than in the past.
- There is opportunity to improve the resilience of Hydro Ottawa's grid for the benefit of customers over the long-term with strategic overhead to underground projects that have quantified benefits that outweigh the costs.
    - Approximately fifty million in total investment that will benefit customers depending on the event forecast assumed.
    - Over Twelve km of resilience circuit investment.
    - 17-26 of potential beneficial overhead to underground projects.
- The development of a Resilience Investment Strategy using the Resilience Investment Model results provides confidence to Hydro Ottawa grid stakeholders. The model provides confidence for the following reasons:
    - **Event-Based –** each project is evaluated against its event performance for 14 different weather events types that are based in the historical record and also climate forecasts with similar conclusions.
    - **Asset and Root-Caused Focused –** each project includes the relationship to their underlying assets. Asset likelihood of failures are based on the assets age and surrounding vegetation.
    - **Data-Centric –** the model utilizes Hydro Ottawa's GIS, OMS, CIS, distribution circuit models, and critical customer information.
    - **Customer-Centric –** the model links each asset to the impacted customer count and type.

- **Granular -** the granularity at the asset and project levels allows Hydro Ottawa to invest in portions of the system that provide the most value to customers from both a restoration cost reduction and avoided CMI perspective.
- **Comprehensive -** The approach is comprehensive and evaluates nearly all of the assets on Hydro Ottawa's overhead distribution systems.
- **Business Case Foundations -** The output of the model is the life-cycle resilience benefit and benefit cost ratio in financial terms.
- **Consistency**: The model calculates benefits consistently for all potential projects.

The assessment and modeling approach drives prudency for the comprehensive overhead to underground hardening evaluation on two main levels. First, the granularity of potential resilience projects allows Hydro Ottawa to target investment in the portions of the system that provide the most value to customers. Secondly, the customer-centric financial justification of project investments allows Hydro Ottawa to prioritize investments that provide significant customer 'bang for buck'.

The focus of this study was underground of overhead infrastructure, that is not the only resilience investment strategy available to mitigate the impact of future events. As Hydro Ottawa finalizes their resilience plan, other resilience investments could supplement the investment identified in this study.

2.0 RESILIENCE FRAMEWORK

Resilience and its quantification within the utility industry, amongst others, is increasingly the topic of conversation for many electric grid stakeholders from commissions to planning engineers, from boardrooms to utility operations and beyond. Following this industry movement, the Institute of Electrical Electronics Engineers (IEEE) has a working group committee focused on supporting the utility industry to develop metrics for measuring and normalizing resilience. These stakeholders recognize that major events are impacting critical infrastructure and disrupting our interconnected society with increasing consequences and devastation. Stakeholders also recognize that the impact of major events cannot be fully mitigated, but efforts can be made to decrease the overall impact and time for the grid to return to normal operations. Currently, measuring resilience for grid stakeholders is still evolving, as it is not a simple concept, and has many factors to consider. Section 2.0 of the report discusses the following resilience topics:

- Provides various definitions as a foundation for understanding resilience
- Offers a framework to understand resilience, the various factors related to it, and how it will be measured within this evaluation and report

2.1 Resilience Definition

The Merriam-Webster dictionary defines resilience as

> "1 : the capability of a strained body to recover its size and shape after deformation caused especially by compressive stress.
>
> 2 : an ability to recover from or adjust easily to misfortune or change."

Merriam-Webster elaborates on the definition, taking it from a "physics" definition and applying it more personally. It says:

> "In physics, resilience is the ability of an elastic material (such as rubber or animal tissue) to absorb energy (such as from a blow) and release that energy as it springs back to its original shape. The recovery that occurs in this phenomenon can be viewed as analogous to a person's ability to bounce back from a jarring setback."

Merriam-Webster also provides an etymology for resilience:

> "The word *resilience* derives from the present participle of the Latin verb *resilire,* meaning to "to jump back" or "to recoil". The base of *resilire* is *salire*, a verb meaning "to leap" that also pops up in the etymologies of such sprightly words as sally and somersault."

The definitions from Merriam-Webster provide a baseline for understanding resilience from a "physics" and "person" perspective, but additional exploration is needed for its application to infrastructure and electric grids specifically. While there is general agreement within the industry around the major elements of resilience, the definitions are not identical. Other definitions of resilience from grid stakeholders are:

- IEEE PES PES-TR83 Report—Resilience Framework, Methods, and Metrics for the Electricity Sector: "The ability to protect against and recover from any event that would significantly impact the grid."
- CIGRE WG C4.47: "Power system resilience is the ability to limit the extent, severity, and duration of system degradation following an extreme event."
- FERC: "The ability to withstand and reduce the magnitude and/or duration of disruptive events, which includes the capability to anticipate, absorb, adapt to, and/or rapidly recover from such event."
- DOE: "The ability of a power system and its components to withstand and adapt to disruptions and rapidly recover from them."

In a 2013 paper, the National Association of Regulatory Utility Commissioners (NARUC) offered its own definition of resilience in a manner that is simple and easy to understand.

> *"Robustness and recovery characteristics of utility infrastructure operations, which avoid or minimize interruptions of service during an extraordinary and hazardous event. In other words, it's the gear, the people and the way the people operate the gear immediately before, during and after a bad day that keeps everything going and minimizes the scale and duration of any interruptions."*

Before that, the National Infrastructure Advisory Council (NIAC) provided a definition that is often quoted, and which includes elements used in many other definitions. It states that resilience is the following:

> *"The ability to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event."*

The NIAC definition includes a system's ability to absorb and adapt. These important characteristics were also used by Argonne National Laboratory (ANL) in its work on state and social resilience and were incorporated into Pacific Northwest National Laboratory's (PNNL) work on the resilience impacts of transactive energy systems. The ANL approach can be used to break resilience into four phases that also align with NARUC's elegantly simple description – the difference being that ANL explicitly includes the ability of the system to recognize and mitigate potential failures before they happen. These four phases are described below:

- **Prepare (Before)**
  The grid is running normally but the system and its operators are preparing for potential disruptions.
- **Mitigate (Before)**
  The grid resists and absorbs the event until, if unsuccessful, the event causes a disruption.
- **Respond (During)**
  The grid responds to the immediate and cascading impacts of the event. The system is in a state of flux, and fixes are being made while new impacts are felt. This stage is largely reactionary (even if using prepared actions).
- **Recover (After)**
  The state of flux is over, and the grid is stabilized at low functionality. Enough is known about the current and desired (normal) states to create and initiate a plan to restore normal operations.

Sub-definitions include:

- *Vulnerability analysis*
  - *Lessons learned*
  - *Continued improvement*
- *Adaptability*
  - *To grid stresses*
  - *Switching flexibility/design*
  - *Robustness to absorb shocks and keep stable*
- *Changing conditions*
  - *Customer expectations*
  - *Climate change*
  - *Heavy distributed energy resources (DER) penetration*
- *Recovery*
  - *Includes preparedness like mutual assistance, SRP, spare inventory, etc.*
- *Extreme event*
  - *System Average Interruption Frequency Index (SAIFI) and Customer Average Interruption Duration Index (CAIDI) exclusions*
  - *Recordable storm*
- *Deliberate attacks*
  - *Cyber*
  - *Physical*
- *Accidents*
  - *Human performance*
  - *External*

Comparison of definitions to each other show significant alignment with respect to 1) disruptive events, 2) minimizing events, and 3) prepare, adapt, and recover.

For 1898 & Co. these definitions of resilience above can be used to form a conceptual framework in which to better understand and evaluate initiatives to improve grid resilience. This is discussed in the following sub-section.

2.2 Resilience Conceptual Framework

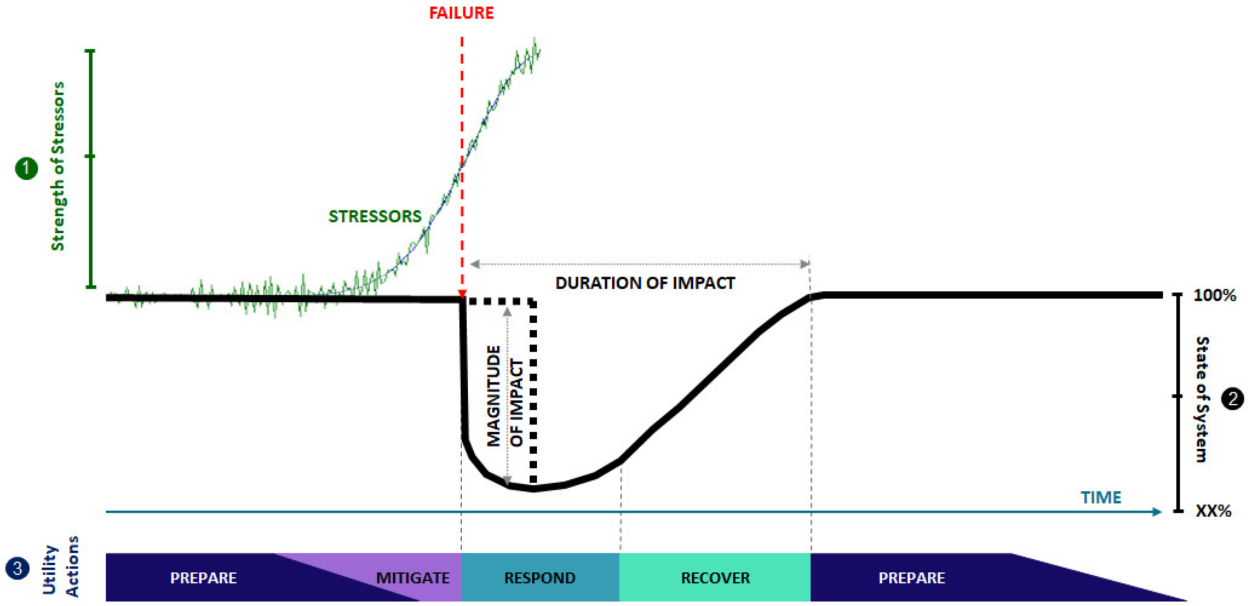
A utility's system resilience is a function of many factors but the two main functions are the frequency and types of events to impact the system, and the characteristics of the infrastructure. Obviously, more frequent and more intense events make grid resilience challenging. Second, the unique characteristics of a utility's system will change the overall outcome of the major events. The following are examples of key characteristics or vulnerabilities that will impact the resilience of the grid:

- Vegetation density
- Quantity of exposed infrastructure (Overhead vs Underground)
- Age and condition of exposed infrastructure
- Level of system sectionalization (Size of circuits, i.e. no. of customers fed off of each circuit)
- Mix of downstream customers

The combination of events and vulnerabilities provides additional challenges for grid resilience. Weather events by their nature are chaotic and do not impact an area evenly. Grid stakeholders could be 'lucky' or 'unlucky' depending on how weather events impact the grid. The power system will have a different resilience response to a thunderstorm with pockets of high winds in older, vegetation dense neighborhoods as opposed to newer neighborhoods which are typically underground (more likely in the suburbs). If a major event is more localized to the suburban area the grid may 'show' to be resilient, but should the event move 10 miles in a different direction it could cause significant outages in the older, vegetation dense neighborhood. The combination of these two factors - events and vulnerabilities - have profound impacts on a grid's measured resilience.

1898 & Co. utilizes a conceptual resilience framework to understand both of these factors (events and vulnerabilities) and how improvements to the grid can be executed to improve system resilience. Figure 2-1 represents this conceptual view of resilience. The framework is broken up into three components.

Figure 2-1: Conceptual Resilience Framework



The first component is the relative strength of a 'Stressor' or major event. The green line represents the underlying issue that is stressing the grid, which increases in magnitude until it reaches a point where it impacts the operation of the grid and causes an outage. The origin of the stress may be due to a failing component, or external due to storms or other events. Section 3.3 includes additional discussion on 'Stressors' and why investment is needed. Section 8.0 provides the application of 'Stressors' within this resilience framework for modeling resilience investment benefits. Each 'stressor' has a different expected frequency of occurrence and relative strength.

The second component is the 'State of System', represented by the black line. The line shows the status of the entire system or parts of the system (e.g., distribution circuits or substations). The "pit" depicted after the event occurs represents the impact on a system in terms of the magnitude of impact (vertical) and the duration (horizontal). For utilities this should be measured from a customer-centric perspective, mainly in the number of customer outages and the cost to restore the system to 'steady state'. The 'State of System' is driven by grid characteristics or vulnerabilities as outlined above. For utility overhead circuit infrastructure, the more aged and vegetation exposed assets with high downstream customer counts will cause a system to be less resilient against events.

The third component of the resilience framework is the utility actions as they prepare, mitigate, respond, and recover from the stressors that caused major disruptions to the grid. Within this third component, the utility has the ability to minimize the disruptions to the state of the system. The 'prepare' phase can be immediately before an event or well in advance of an event. In the case of immediately before an event, grid owners and operators may mobilize foreign utility crews and stage equipment to enable faster response during the event. Well before an event, grid owners and operators may invest in grid hardening initiatives to mitigate events. The focus of this report is on this prepare phase and the hardening investments that could be made to mitigate the impact of events. However, it should be noted that additional operation focused activities also impact major disruptions minimization but are not discussed as part of this evaluation. Additionally, technologies could be implemented to better understand the strain on the system to point grid operators to where failures could occur. For instance, utilizing enhanced weather prediction models against the system could identify likely areas of failure on the system. This would enable grid operators to reduce the time to respond. In the 'respond' phase grid operators are assessing damage and prioritizing response. This phase is often unpredictable, as efforts to assess the full impact can be delayed for safety reasons. In the 'recover' phase, grid operators understand the state of the system and how to restore it to normal operations. Section 8.0 outlines the resilience investment in the 'prepare' phase to decrease the impact of grid disruptions on customers.

Note that whether this is a specific or overall depiction of resilience, there is no quantification of time. Events may be measured in hours, or days, depending on the duration of the event.

The conceptual framework can be used to depict a specific distribution circuit, the whole distribution system, or the entire grid. If the figure is used to represent a specific distribution circuit, it represents the impact of the event on only that circuit. If the figure is used to represent the impact on the whole Hydro Ottawa system, it represents the aggregated impacts of the event (storm) and the outages that result from it.

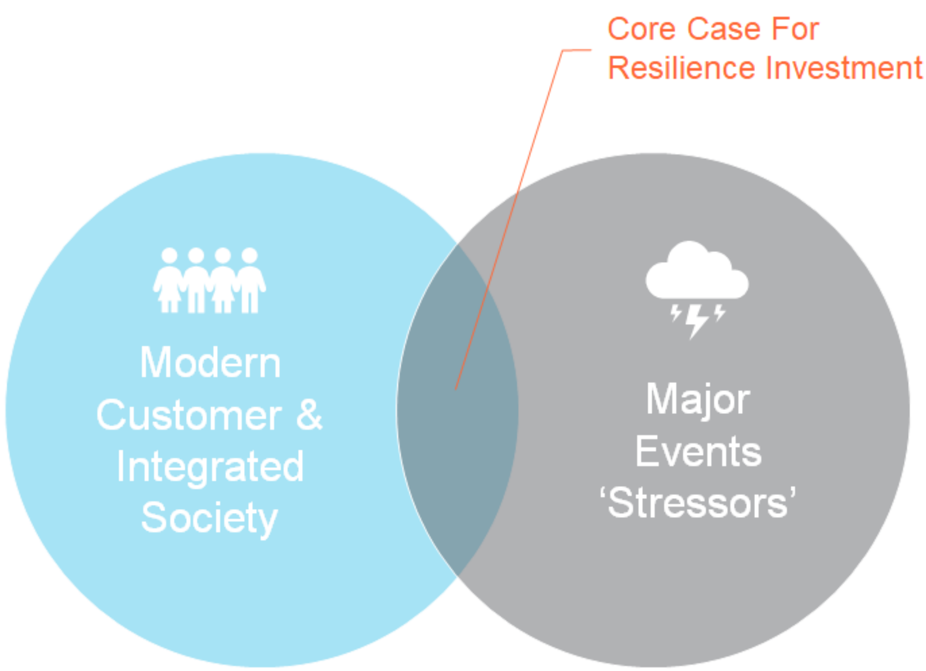
The conceptual frameworks are used throughout this report to:

- Make the case for how resilience investments benefit Hydro Ottawa's customers.
  - Impact to Customers: Outages - Section 3.2
  - Stressors - Section 3.3
  - Impact to Customers: Restoration Costs - Section 3.4
  - Elevated Safety Risks – Section 3.5
- Understand the benefits resilience investments have in avoiding or mitigating disruptive events.
- Anchor the resilience investment business case providing 'line-of-sight' from the theory to practice.

3.0 CASE FOR RESILIENCE

The case for resilience infrastructure improvements is where the modern customer and integrated society intersect with major events. This is depicted in Figure 3-1. While there are many factors, these two are the core case for improving grid resilience.

Figure 3-1: Core Case for Resilience Investment



The customer of today is much different than the customer of 25 years ago. Decades ago, grid outages were seen as inconveniences for customers. Today, these outages can cause real economic harm and stress, especially on society's most vulnerable. Additionally, today's society is far more integrated than in the past. The recent supply chain disruptions following the global pandemic have revealed to us just how interconnected our society and global economy has become.

The customer of today depends on the electric grid being consistently available for these reasons. Compounding the challenge is the expected trend toward more dependence on the grid with the acceleration of electrification such as home heating, commercial fleet electrification, transportation, electric vehicle adoption, to name a few. Additionally, distributed energy resources (DERs) are being contemplated by the customer base. The Canadian Net-Zero Emissions Accountability Act, which became law on June 29, 2021, enshrines in legislation Canada's commitment to achieve net-zero emissions by 2050. Electrification is seen as a key tool to achieve this goal. The acceleration of society's grid reliance due to electrification further establishes the need for the grid to be resilient. Delaying resilience investment will cause additional grid vulnerabilities as electrification accelerates to meet GHG targets.

History often shows that the catalyst for action is a major event that causes significant economic harm and/or stress for customers and society, while also placing societies most vulnerable at risk. A resilience focused and proactive organization considers these potential major events and the impact to customers and invests to mitigate their impact. As the modern customer and integrated society continue to rely more and more on the grid, it is important that grid stakeholders take proactive action to mitigate the impact of more regular events, as well as the major 1 in 100 year or 1 in 50-year type events.

The case for resilience starts by first exploring recent historical events that have impacted Hydro Ottawa customers, including memorable events, historical restoration costs, and historical customer outages. Second, the case for resilience provides additional context about the modern customer and expectations for grid reliance. The third element for the case for resilience is exploring major events outside recent memory to include the '1 in 100 hundred' year type events. As described above, the second and third items are the core case for resilience. While not always the primary focus of resilience investment, the high costs of system restoration and the increased levels of safety risk to society and crews of failed infrastructure during these events are also reasons to improve system resilience. These are also discussed in the following sub-sections. The sub-sections also show how these components fit into the resilience conceptual framework.

3.1 Historical Events Impacting Hydro Ottawa Customers

3.1.1 Recent Events of Note

The following are notable events that have impacted Hydro Ottawa's territory and left an impact on Hydro Ottawa and stakeholders. The review will include storms of note in 2022 and also recap some high impact storms over the last 25 years.

3.1.1.1 May 2022 Derecho

On May 21, 2022 a historic derecho swept through Hydro Ottawa's service territory. This derecho was one of the most destructive storms in Canadian history with winds up to 190 km/h.[1] The storm resulted in over 400 poles that needed to be replaced. In addition, approximately 180,000 customers lost power. Approximately 50 percent of these customers were without power for multiple days. Some customers were without power for over two weeks. The restoration efforts included utilization of 335 contractors[2]. The storm impacted the entire service territory with wind equivalent to either an EF1 (138-177 km/h) or EF2 (178-217 km/h)winds.

[1] Northern Tornadoes Project: https://ntpopendata-westernu.opendata.arcgis.com/apps/westernu::on-qc-derecho-may-21-2022-event-summary-map/about

[2] Derecho: Our biggest storm yet | Hydro Ottawa

Figure 3-2: May 2022 Derecho[3,4]

Storm Name: May 2022 Derecho

Year: 2022

Top Wind Speed: 190 km/h

Outage Duration: 7+ days

Customers Impacted: ~180,000

Time to restore 50% of Customers: 48 hours

System Damage: Poles Replaced – 400

3.1.1.2 December 23, 2022 Winter Storm

Before the storm hit Ottawa, the northeastern United States faced down wild weather with blizzards, damaging winds and freezing temperatures causing havoc for holiday travelers. Thousands of flights were cancelled and highways were closed with stranded motorists and multi-vehicle pile-ups.

Customers with email addresses on file received Weather Watch notification in their inbox the afternoon of Wednesday, December 21, warning them that fierce winds and power outages were expected due to the severity of the incoming storm. As predicted, the storm arrived late Thursday evening.

The storm impacted Hydro Ottawa's distribution system starting on December 23 with the first outage taking place at 1:01 a.m. A total of 67,710 customers sustained interruptions. Ninety percent of the customers were restored within 12.5 hours.[5]

[3] https://www.uwo.ca/ntp/blog/2022/ntp_extends_may_21st_ottawaarea_ef2_downburst_eastward.html
[4] https://hydroottawa.com/en/blog/what-year-top-five-outages-2022
[5] https://hydroottawa.com/en/about-us/regulatory-affairs/major-events/december-23-2022

Figure 3-3: December 23, 2022 Winter Storm[6]

Storm Name:
Dec 23, 2022 Winter Storm

Year: 2022

Outage Duration:
2 days

Customers Impacted:
~67,710

Time to restore 90% of Customers: 12.5 hours

3.1.1.3 Sept 2018 Tornados

On Sept 21, 2018 multiple tornados impacted Hydro Ottawa's service territory. These tornados were destructive with winds at 265 km/h. The storm resulted in 88 poles that needed to be replaced as well as 4 km of powerlines that needed to be replaced. In addition, approximately 165,000 customers were without power. Approximately 95 percent of these customers were restored within 72 hours. The restoration efforts included utilization of 86 contractors[7].

[6] https://hydroottawa.com/en/blog/what-year-top-five-outages-2022
[7] https://hydroottawa.com/en/blog/weathering-storm-look-back-september-2018-tornadoes

Figure 3-4: Sept 2018 Tornadoes[8]

Storm Name:
Sept 2018 Tornadoes

Year: 2018

Top Wind Speed:
265 km/h

Outage Duration:
7+ days

Customers Impacted:
~165,000

Time to restore 50% of Customers: 36 hours

System Damage:
Poles Replaced – 88
Powerlines – 4km

Several poles collapsed along Greenbank Road and Hunt Club Road after a tornado hit Ottawa on Sept. 22, 2018. (Leah Hansen/CBC)

3.1.1.4 Great Ice Storm of 1998

While this was approximately 25 years ago, it give insights into resiliency planning. On January 5, 1998, ice started forming and ice thickness up to 85 mm were measured with unofficial report of up to 100 mm were reported. The storm was very large in extent with considerable damage throughout Ontario and Quebec. Employees from Gloucester Hydro, Goulbourn Hydro, Kanata Hydro, Nepean Hydro and Ottawa Hydro come together as one team to repair the extensive damage. Overall, Environment Canada estimates "the storm claims as many as 35 lives, downs millions of trees, 1,000 transmission towers, 30,000 utility poles and enough wires and cable to stretch around the world three times.[9]

[8] https://www.cbc.ca/news/canada/ottawa/tornadoes-one-year-anniversary-city-response-1.5291134
[9] https://hydroottawa.com/en/about-us/our-company/our-history

Figure 3-5: Great Ice Storm of 1998[10,11,12]

Storm Name:
Great Ice Storm of 1998

Year: 1998

Maximum Ice Thickness:
85 mm

Customers Impacted (Ontario):
~1,500,000

Time to restore 95% of Customers: ~48 hours

Last Customer Restored:
33 days

Total Storm Damage (Ontario):
Poles Replaced – 300,000
Powerlines – >100,000km

Ice storm in Ottawa. Postmedia

3.1.1.5 Other Major Events

The following table summarizes other weather Events:

Table 3-1: Other Major Weather Event Summary[13]

Start Date	Storm Description	Total Customers Interrupted	Time to restore 90% of Customers
July 1, 2016	Thunderstorm	32,934	2 hours
January 4, 2017	Freezing Rain	19,130	11.3 hours
September 27, 2017	Thunderstorm	14,051	24 hours
April 16, 2018	Freezing Rain/Wind	56,146	36 hours
May 4, 2018	High Wind	60,811	12 hours
July 5, 2019	Thunderstorm	70,069	6.5 hours
November 1, 2019	High Winds	14,228	6 hours
June 14, 2021	Thunderstorm	17,441	8.5 hours
April 5, 2023	Freezing Rain	163,448	40.5 hours

10 https://www.cbc.ca/news/canada/ottawa/ice-storm-ottawa-20-years-later-1.4470067
11 https://ottawacitizen.com/news/local-news/the-great-ice-storm-of-1998-by-the-numbers
12 https://hydroottawa.com/en/about-us/our-company/our-history
13 https://hydroottawa.com/en/about-us/regulatory-affairs/major-events

3.1.2 Historical Restoration Costs

Table 3-2 shows the historical Hydro Ottawa storm costs for major storms. The table shows the costs in the dollars of the day (nominal) and then escalated to 2023. The values were provided by Hydro Ottawa. The average major storm cost is approximately $7.6 million per storm in 2023 dollars. These costs are eventually passed on to customers.

Table 3-2: Hydro Ottawa Historical Storm Costs

Date	Strom Type	O&M (Nominal$)	Capital (Nominal$)	Total (Nominal$)	Total (2023$)[14]
2018-04-15	Ice Storm	$400,000	$900,000	$1,300,000	$1,579,572
2018-05-04	Wind Storm	$100,000	$800,000	$900,000	$993,673
2018-09-21	Tornado	$800,000	$2,300,000	$3,100,000	$3,422,650
2022-05-21	Derecho	$8,700,000	$15,300,000	$24,000,000	$24,480,000

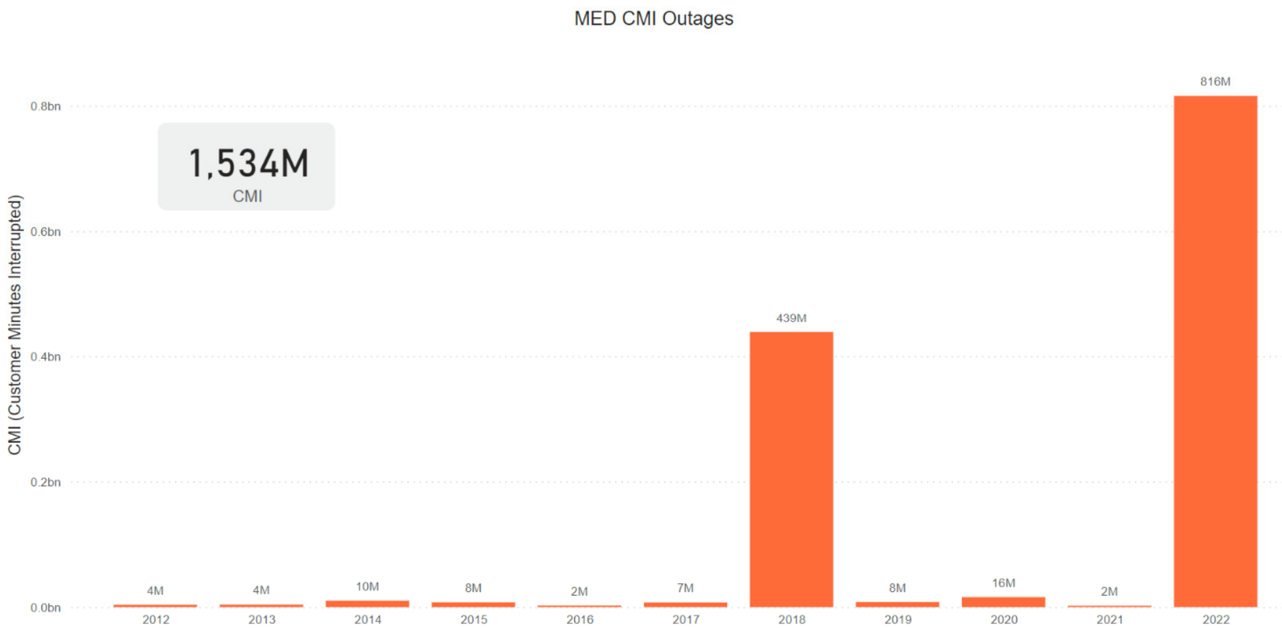
3.1.3 Historical Major Event Day Customer Outages

Figure 3-6 shows the historical Hydro Ottawa major event (Major Event Day)[15] customer minutes interrupted (CMI) from July 2012 through February 2023. This information was captured from Hydro Ottawa outage database. The figure shows a total 11-year CMI of 1.53 billion, with an annual average of 128 million CMI. This means each customer was without electrical service an average of 366 minutes per year over the 11-year time horizon. The figure also shows that a single event can impact an 11-year time horizon significantly as the May 2022 Derecho 816 million CMI comprise a significant portion of the 11-year total CMI.

[14] Inflation Calculator | Find US Dollar's Value from 1913-2022 (usinflationcalculator.com)

[15] A Major Event Day (MED) is a day where the impacts on system reliability have exceeded a threshold which is no longer considered business as usual. Definitions vary by jurisdiction, but typically adhere to some variation of the 2.5-β method defined in IEEE 1366-2022. MED outages are typically excluded from reporting to help compare reliability performance between utilities.

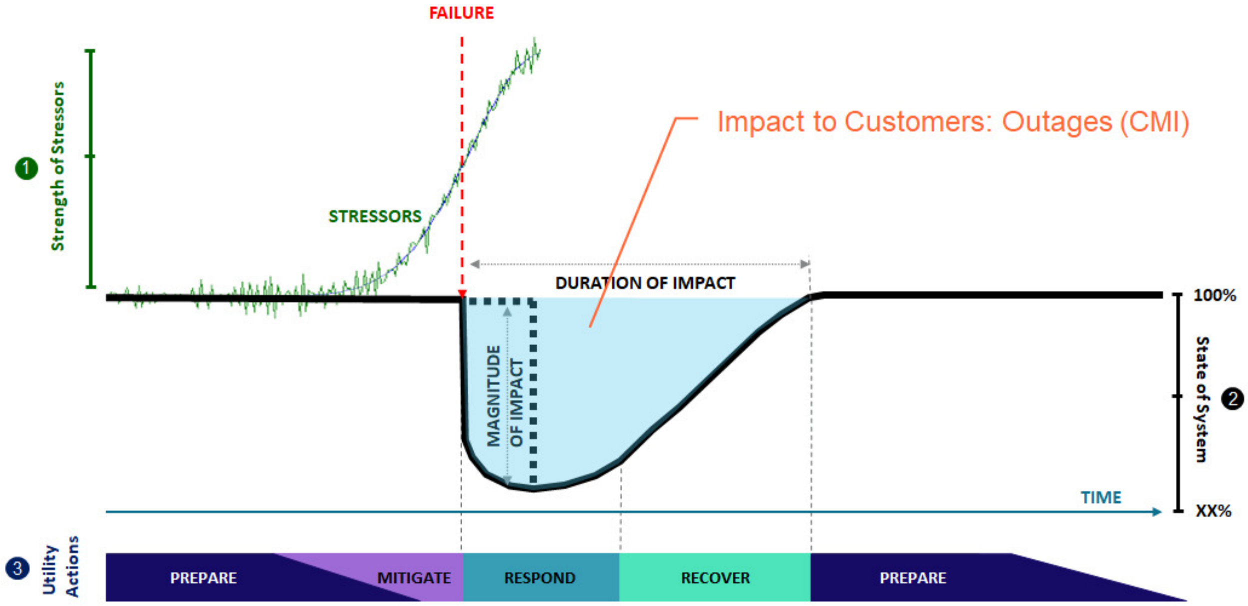
Figure 3-6: Hydro Ottawa Historical CMI



3.2 The Impact of Customer Outages

The core case for resilience starts with the impact to customers and grid stakeholders. Figure 3-7 demonstrates the impact to customers from an outage perspective, within the Resilience Conceptual Framework. The area in blue represents the overall customer outage time. Within the utility industry, this is quantified by CMI. Within the blue-shaded portion of Figure 3-7, CMI is the impact of magnitude in terms of customers without service at each minute of time summed together.

Figure 3-7: Resilience Framework & Customer Outages



The CMI outage metric is not new for utilities. It has been used for several decades to understand utility performance and calculate the impact of grid outages. What has changed over the decades is the impact to customers and society of grid outages. Twenty-five years ago, grid outages used to be seen as an inconvenience or nuisance to life; today grid outages cause serious stress and economic harm for customers depending on the duration and time of the event. Extended outages caused by major events are a real concern for the health and safety of society's most vulnerable.

Several factors have caused the outages of today to be more impactful than the outages of decades past. These changes for customers and society are a key reason for why resilience investment in the electric grid is needed. The following sub-sections outline many of these customer and societal changes.

3.2.1 Critical Customers

Hydro Ottawa serves many different customer types, including some customers that are highly dependent on an uninterrupted, infrequent, and resilient power supply as possible. This includes customers with life sustaining medical devices, critical function customers (such as nursing homes, hospitals, and police stations), and warming centers.

Critical customers who serve the community in a service or healthcare role, among other necessary functions. There is a total of 1,061 critical customer facilities served by Hydro Ottawa, including but not limited to the following customer types:

- Ambulance Depot
- Ambulance Facility
- Child-care Center
- Community Police Center
- Fire Station
- Hospital
- Long Term Care Facility
- Police Station
- Public Works Garage/Community Police Station
- Recreational Facility
- School
- Veterinary Facility

Investing in grid resilience has a crucial impact on customers whose health is tied to power dependent medical devices, and critical customers whose purpose is to provide public, or healthcare services rely on resilient power to serve the community effectively and efficiently. Disrupted power interferes with their ability to provide care and assistance, especially during critical times.

3.2.2 Work from Home

Today, the largest number of the workforce is working from home than in history. Ottawa has the nation's highest percentage of the workforce who work from home (40% in December 2022) [16]. The catalyst for increased work from home was spurred by the COVID-19 pandemic. This compares to a Canadian national average of approximately 4% in 2016[17].

For this population, insulating against outages and fluctuations in power supply directly impacts a customer's bottom line. When power is interrupted from the home

[16] https://www.thestar.com/business/opinion/2023/05/10/working-from-home-10-surprising-facts-that-complicate-everything.html
[17] https://www.statista.com/topics/7816/remote-work-in-canada/#topicOverview

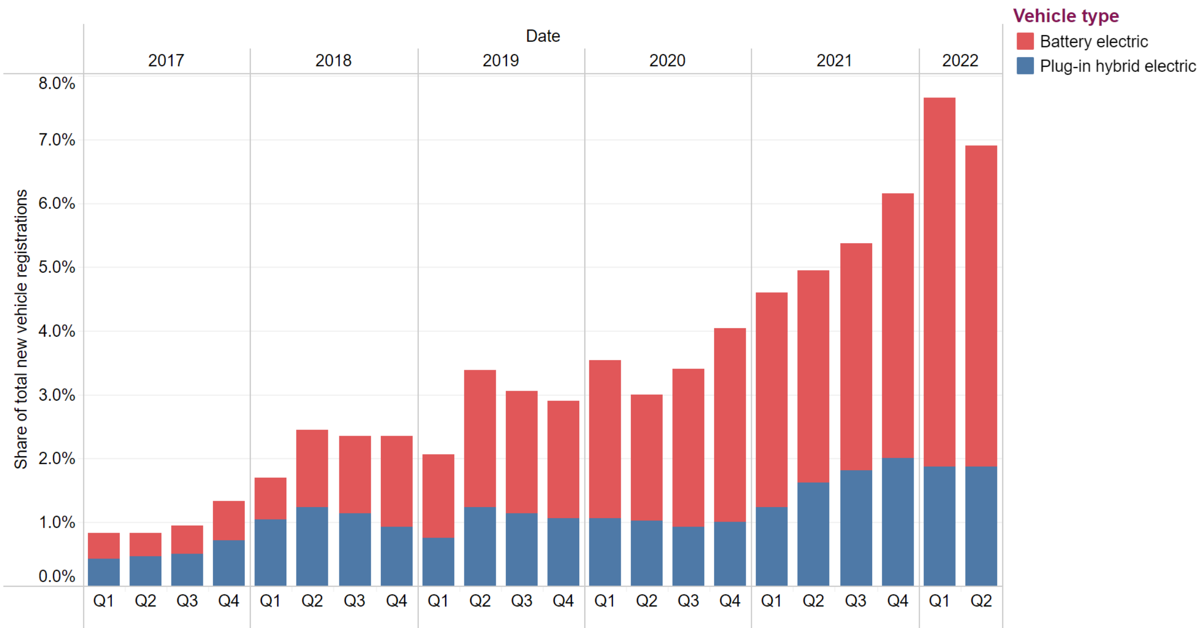
working space, this may cause an employee to use paid or unpaid leave, or incur additional costs to outsourced support in the form of additional childcare, commuting costs, etc. For the modern employee and business, power resilience is critical to maintain operations and lower business risk.

3.2.3 Electrification and Decarbonization

As mentioned in Section 3.0, Canada has very aggressive decarbonization plans which center around electrification of traditionally fossil fuel intensive activities. As the country plans to move the majority of activities that require power to electric power, the reliability and resiliency of the electric grid become critical. While this shift will affect many industries and activities, this section focuses on transportation electrification as an example, but the plan to decarbonize includes electrification of residences, commercial locations, industrial equipment, industrial processes, and agriculture to name a few.

This shift to electrification will cause growth in demand on the distribution system as an increased number of systems and services become electrified. Customers will expect the distribution grid to handle the new technology and subsequent increased load in real time. To illustrate this concept, EV adoption in Canada is a prime example. As customers continue to adopt electric vehicles, demand for decreased grid instability is at the forefront of customer's minds. For the customers that commute or otherwise rely on vehicles to perform daily tasks, it is expected that they are able to drive after a night of charging. Figure 3-8 shows the adoption of EVs within Canada as a percentage of total sales through mid 2022.

Figure 3-8: EV Vehicle Adoption in Canada[18]



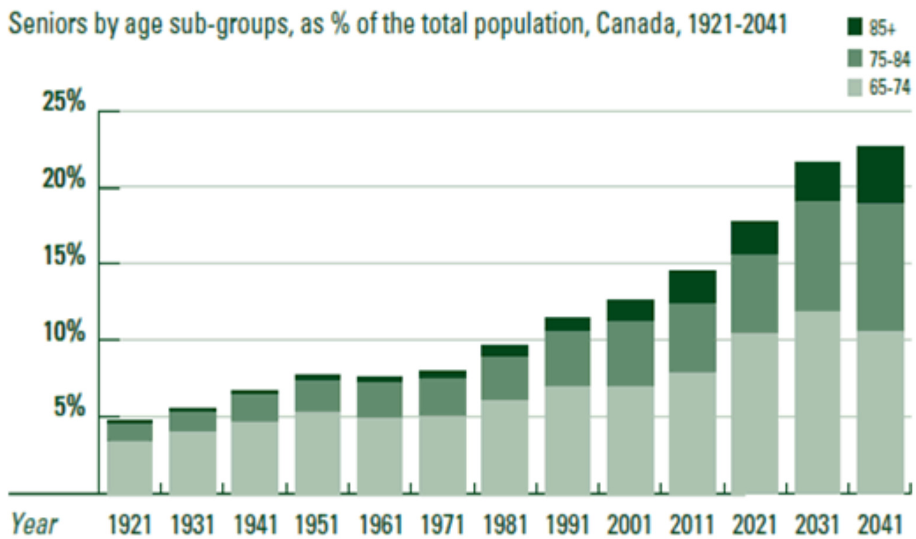
Residential customers are not the only customers affected by this change. Since residential customers work at industrial and commercial customers, these larger customers will see reduced productivity and revenue when their employees can't commute to work (for those that can't work virtually). Additionally, those with commercial vehicles for shipping or local delivery would be heavily impacted by a significant disruption in power.

3.2.4 Aging in Place

Nearly 90 percent of Canadians state their preference is to remain in their current homes as they age.[19] The number of Canadian residents that are over 65 are trending up, as shown in Figure 3-9.

[18] https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2022/market-snapshot-record-high-electric-vehicle-sales-canada.html
[19] https://www.readersdigest.ca/health/healthy-living/aging-in-place/

Figure 3-9: Population of Canadian Over 65 from 1921-2041[20]



For seniors who plan to age in their current homes, the decreasing of long-lasting and widespread power outages, and increased time to power restoration are critical to independence and their overall health and safety. During the Texas blackouts of February 2021, 246 people died when power was lost to large portions of the state in freezing weather. Of those deaths, 67% were due to hypothermia and the rest were due to pre-existing illness, vehicle accidents, carbon monoxide poisoning, fires, and falls[21]. Of these fatalities, approximately 60% were over the age of 60.[22]

3.2.5 Integrated Society

Decade over decade society is evolving and becoming more and more reliant on electrical power. Consider just 25 years ago when the personal computers were starting to emerge as a business necessity, but widespread adoption in homes had not begun yet. The internet was a fascination, but not central to how customers lived life. On-line shopping for essentials was not yet a mainstream concept. Networking was by telephone landlines or in-person, with "virtual" mediums of communication, such as video calling, not yet possible. Modern electrical vehicles with practical

[20] https://www.elections.ca/content.aspx?section=res&dir=rec/part/sen&document=index&lang=e
[21] https://www.texastribune.org/2022/01/02/texas-winter-storm-final-death-toll-246/
[22] https://www.courthousenews.com/wp-content/uploads/2022/02/texas-state-health-services-department-report-on-winter-storm-uri-death-toll.pdf

ranges were not at the prototype stage. Productivity was not as intertwined with electric power availability as it is today, since work and personal functions were still done in person.

Energy resilience is now business-critical and is having a higher impact on people's lives as society continues to become more integrated. Our society today is highly intertwined on both the macro and micro scale. We have grown to understand this integration from the supply-chain disruption following the global pandemic, and personal experience with productivity interruptions in daily life. A real-life example helps prove the point – a utility consulting engineer recently had to take a day off unexpectedly because of a power outage at his child's daycare in Austin, TX. This engineer was part of a larger group, based in Kansas City. The Kansas City team had to re-arrange their day to cover for this engineer's time out, causing decreased productivity and efficiency for the team as a whole. In an efficient society with 'just-in-time everything' and families where all heads of households are employed, minor disruptions in the utility grid can cause economic harm and stress.

Industries, large and small, work cohesively to allow society to function at the level of productivity and financial success currently achieved. If one of these falls due to unavailable power, the ripple effect is not contained to just one employee, business, or industry.

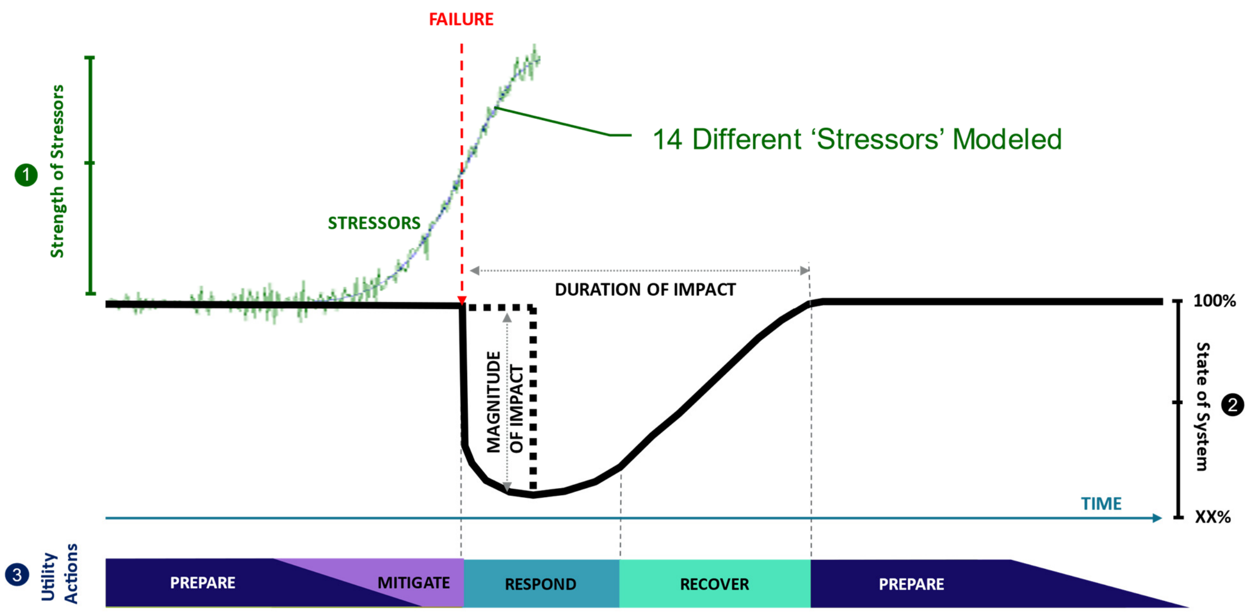
3.3 Major Events 'Stressors'

The case for resilience continues with disruptive events or 'stressors'. The types of events and their frequency is key to understanding the grid's resilience, measuring it, and performing the business case for investments.

Because of this, measuring a grid's current resilience is forward looking. This forward-looking nature causes challenges in measuring resilience since the future needs to be modeled and the future is uncertain. While it may be tempting and much easier to measure resilience from a historical perspective, this leaves grid stakeholders, especially customers, at high risk. For instance, grid stakeholders may have a false sense that their grid is resilient by comparing their customer outages to their peers. However, this may only be because the stakeholder's grid did not experience many events in the last 5 or 10 years as their peers. Section 8.0 shows that Hydro Ottawa's service territory has had periods of very low major events and periods of high major events. A historical focus provides a misleading measure for grid resilience and leaves grid stakeholders exposed to disruptive events.

As discussed above, the level of grid resilience is firstly based on the number and type of events. Within the resilience conceptual framework, Figure 3-10 shows that this evaluation includes 14 different stressors or major events. Section 8.0 outlines each of these 'stressors' in more detail and the approach to estimating their future frequency.

Figure 3-10: Resilience Framework 'Stressors'



Since grid resilience is foundationally based on potential future stressors, it is critical to formulate the 'universe' of events that could impact the grid. Several factors need to be considered. Firstly, the type of events, such as natural disasters (e.g. tornados, ice storms) or human driven disruptions (e.g. cyber/physical infrastructure attacks). This evaluation covers the range of weather-based natural disaster events in the modeling of resilience. Second is the level of impact. This evaluation includes a wide range of events, from the upper bound impact events (strong thunderstorm/derecho) to the lower bound impact events (regional weather events). The type of events included in measuring resilience is based on the goals grid stakeholders have for mitigating disruption. This evaluation mainly leverages historical events as a guide for the future as a conservative assumption.

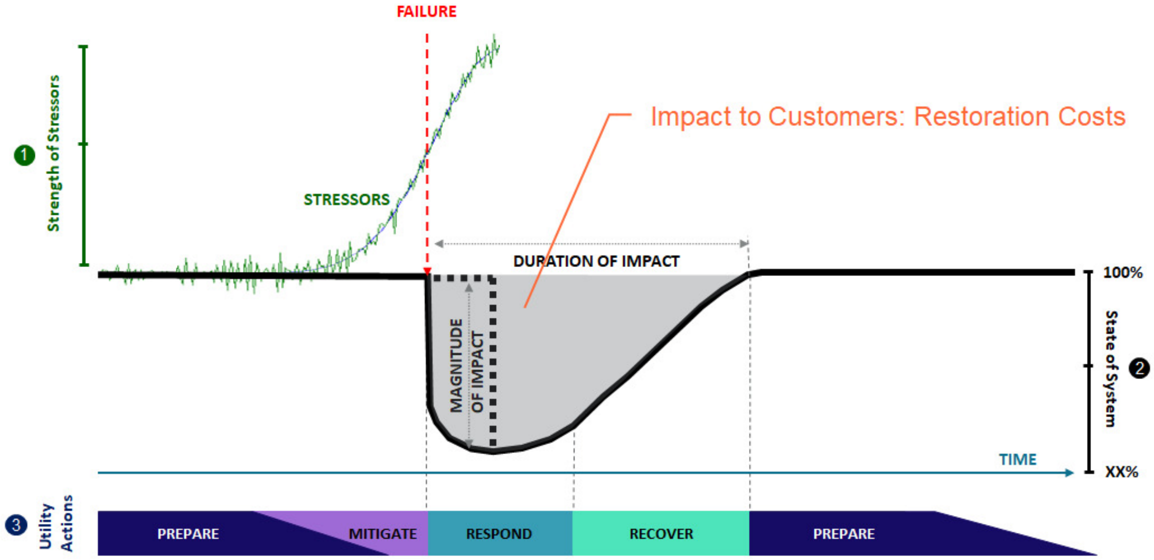
Within this evaluation, system resilience is a sum of all the events weighted by their expected future probability. Specifically, the resilience measurement is done for each of the 14 identified event types multiplied by their expected future probability, then totaled together. The entire system worth of assets do not fail, so the resilience impact is a double failure calculation, 1. Probability of an event 2. Probability an asset fails.

The range and type of 'stressors' outlined in Section 8.0 is the key driver for the case for resilience investment. The historical record shows a wide range of event types to impact the Hydro Ottawa service territory. As the effects of climate change are expected to increase over time, these types of events could increase in relative frequency in the future.

3.4 Restoration Costs

While the foundation of the case for resilience is the overlap of the modern customer and integrated society with the range of major events, restoration costs are a further driver. Figure 3-11 shows this customer impact within the Resilience Conceptual Framework. It should be noted that the cost represented in the 'grey' area includes both the immediate cost to restore the system during the event and the costs to rebuild the grid to standard following the event.

Figure 3-11: Resilience Framework & Restoration Costs



Over time, the cost to replace infrastructure has increased. This is especially the case during major events. Replacing infrastructure during a failure event typically requires overtime and more resources than for a proactive approach. It also includes ‘patches’ during the respond and recover phases, which are followed on by rebuilds to appropriate standards after the event, sometimes weeks or months later. This causes reactive infrastructure rebuilds for a disruptive event to be 1.5 to 2.0 times higher than for similar planned activities. Depending on the size of the event, utilities may leverage mutual assistance from other outside utilities in the restoration effort. These costs can be 3.0 to 5.0 times higher than using local crews. These higher multipliers are due to the double time, per diems, mobilization and de-mobilization, equipment fees, and general higher inefficiencies in managing a high level of resources all at one time. The urgency to speed up recovery times results in a premium price for services, and these costs eventually get passed on to the customer.

Proactive resilience investment can mitigate some of these costs. If enough resilience investment is completed, a utility will have less infrastructure failures during events, therefore will use less resources and crews in the restoration process.

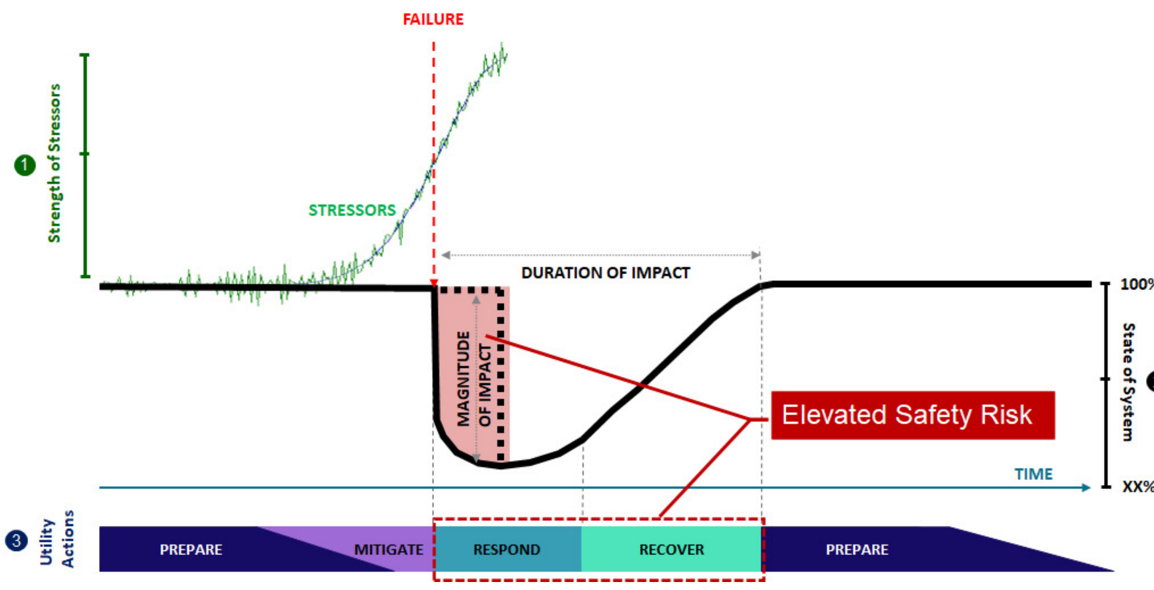
With smart resilience investment, the grid can be rebuilt to not only withstand major events but also enable the customer of the future’s demand for electrification and

DER penetration. Given the current expectations for the future customer, a fully reactive approach could cause infrastructure rebuilds to be 2.5 to 4.0 times more than a proactive approach. To date, the level of infrastructure rebuilds at this higher life-cycle cost has been low, but with the increasing age of the system the percentage of the system that would be rebuilt at these levels will be much higher.

3.5 Safety Risks

Similar to restoration costs, mitigating safety risks is another additional driver of resilience. This is done on two fronts. Firstly, during an event, infrastructure failures expose the general public to elevated levels of safety risks. Additionally, utilities crews during the respond and recover phases are rebuilding the grid in a more unpredictable situation. Often times, the rebuilding efforts can be late into the evening, in the dark, and in conditions that are potentially hazardous. The long hours and maneuvering around debris, broken infrastructure, and hard to reach places increases safety risks. These elevated levels of safety risk are shown within the Resilience Conceptual Framework in Figure 3-12.

Figure 3-12: Resilience Framework & Elevated Safety Risk



Rebuilding resilient infrastructure will help to mitigate the safety risks. As discussed in more detail below, this benefit stream is not overtly quantified in this evaluation.

However, this benefit stream should not be ignored within the resilience business case framework.

4.0 RESILIENCE OBJECTIVE

As the utility industry has yet to develop an agreed upon definition for resilience, establishing an ultimate objective for resilience and measuring how to achieve it are further behind. Nevertheless, electric utilities are taking action to harden the grid (see Section 5.0) while the industry evolves on defining resilience, setting an objective for it, and establishing metrics to grade progress and achieving the objective of resilience.

4.1 Measuring Resilience Conceptual Framework

Resilience metrics are in their infancy and relatively immature within the utility industry. Some utilities are exploring resilience metrics through derivations from reliability metrics. In developing metrics for resilience, 1898 & Co. has leveraged the conceptual resilience framework from Section 2.2, to measure resilience for electric utilities. This framework provides the underlying design philosophy and basis for the Resilience Investment Model (see Section 6.0). 1898 & Co.'s guiding principles for measuring resilience are:

- **Customer-Centric –** Since the case for resilience is founded on the impact to customers, metrics need to have direct 'line-of-sight' to customer impacts. Where possible, metrics should take into account differences in customer and community types. 1898 & Co. has included an initial recommendation for the value of customer outages in this report (see Section 6.2).
- **Incorporate the 'universe' of events –** The other foundation for the case for resilience is the range of events. This includes the typical events that occur several times a year through High Impact Low Probability (HILP) events that may have a frequency of '1 in 100' years or even '1 in 500' years. This may mean including events that are not part of the historical record. Similar to the value of various customer types and communities, the process of identifying the 'universe' of events should include various grid stakeholders. Additionally, the unknown unknowns of climate change make it vital to collaborate with a larger stakeholder group. 1898 & Co.'s evaluation for this resilience investment evaluation included both forecast based on historical information as well as a climate change forecast.

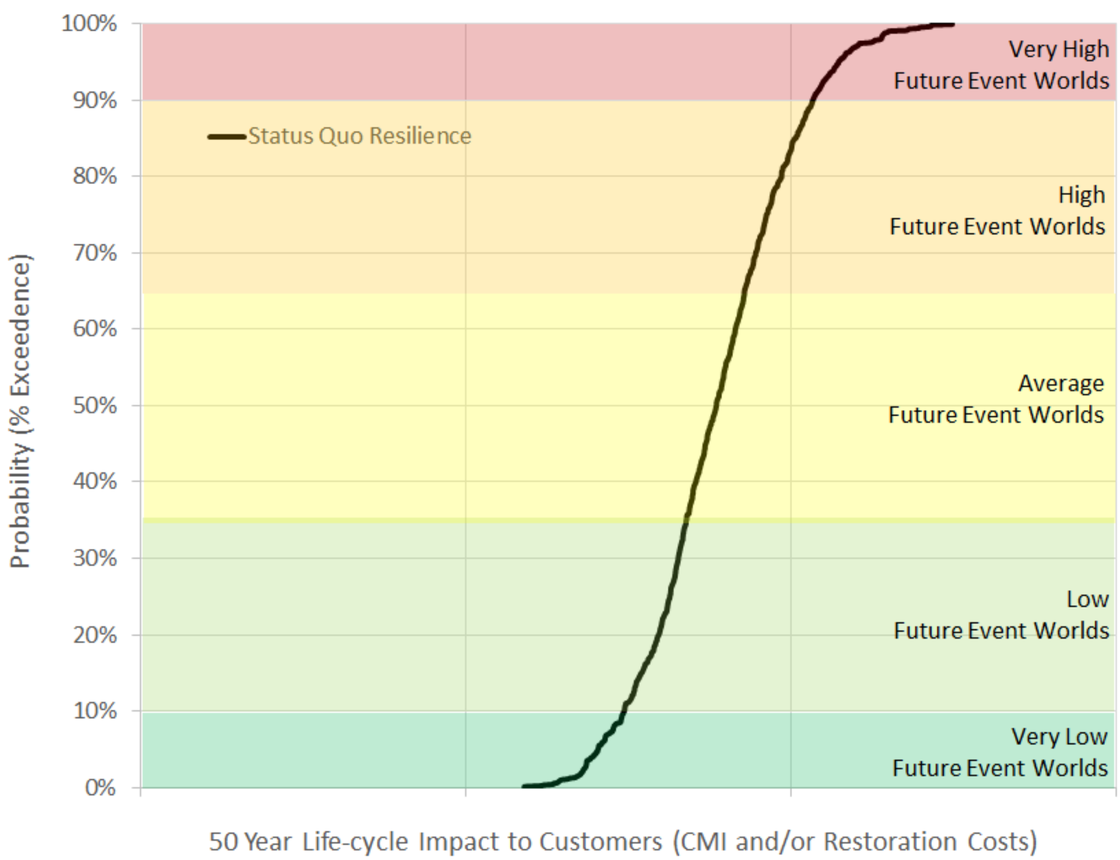
- **Future-focused –** Since resilience is about mitigating future disruptive events, metrics should aim to focus on potential future events. While capturing historical performance is objective and rooted in data, solely focusing on them may provide a false sense of actual resilience depending on the time horizon. Future-focused allows for the inclusion into a resilience metric the HILP events, historical only metrics may exclude HILP events since they have not occurred in the recent past. If only historical metrics are used to evaluate a grids resilience, it may leave stakeholders with a false sense of system resilience. This is often why a major event 'catalyst' occurs before real change happens. For this reason, it is vital that metrics include a future focus to understand the real risks exposed to grid stakeholders.
- **Encompass the arc of time –** Recency bias is a real concern for resilience metrics. The historical records show periods of time with few events and periods of time with higher-than-average number of events. If resilience metrics only include a short time horizon, it may provide a false sense of a system's actual resilience. Metrics should strive to include decades long time horizons if possible.
- **Integrate system characteristics / vulnerabilities –** Disruptive events, especially weather, are unpredictable. For instance, major wind events can have gusts of 50 mph winds in one part of the service territory, and only 15 mph winds 5 miles away. Focusing only on event-based metrics would exclude the fact that all parts of the system are not the same in age, vegetation density, etc. For example, the infrastructure impacted by the 15 mph winds may be much older, with high vegetation density compared to the infrastructure hit with 50 mph winds. For this reason, it is critical that resilience metrics focus on the vulnerable parts of the system agnostics of events.
- **Range of potential outcomes (stochastic modeling) –** While there is uncertainty around future events, this uncertainty is not unbounded. Bounds or confidence bands can be developed through stochastic modeling (generally Monte Carlo techniques). Time horizons of interest can be modeled and better understood by utilizing the historical record to statistically characterize and forecast the range of future system outcomes.

- **Data-Driven with Industry Experience Insights-** Data availability and quality are continually improving. As data availability grows, more effective and insightful indicators can be developed and explored. This will not happen in a vacuum as both the frontier of data science and industry insights are continuing to evolve.
- **Simplicity –** Resilience is a multifaceted and complex topic as outlined above. In measuring resilience, there is balance between metrics that are simple and easy to communicate, and metrics that are complex and include all necessary details.
- **Enables Effective Prudency Evaluation-** The cost of mitigation measures is often considerable. Metrics and investment evaluations need to ensure limited resources are being deployed effectively and providing value to the utility's customers. Metrics that produce financial justification results provide more direct alignment for stakeholders in evaluating investment prudency.

The conceptual framework, discussed above in Section 2.2, is useful as a starting point to develop a framework for measuring resilience. The conceptual framework for resilience is for a specific event and shows the customer impacts in terms of CMI (see Section 3.2) and restoration costs (see Section 3.4). A whole system resilience metric can be estimated by summing the impacts of all events weighted by their expected frequency over the arc of time. In other words, sum the conceptual framework figures for the 'universe' of events multiplying each by their expected future frequency.

The result of this approach produces the life-cycle customer impact for the 'universe' of events as represented in Figure 4-1. The figure shows the range of potential impacts to customers for all events and their range of frequencies over the next 50 years. The figure shows several potential event 'worlds' from very high to very low. It also incorporates the range of events permutations that could occur over the time horizon. The 50-year time horizon is recommended as it is the minimum of a '1 in 100' year type of event and the average expected life of utility infrastructure, 50 years. This conceptual approach to measuring resilience meets many of the guiding principles outlined above with the exception of complexity in understanding and enabling effective prudency evaluation. It is also the foundation for understanding the goal of resilience.

Figure 4-1: Measuring Resilience Framework



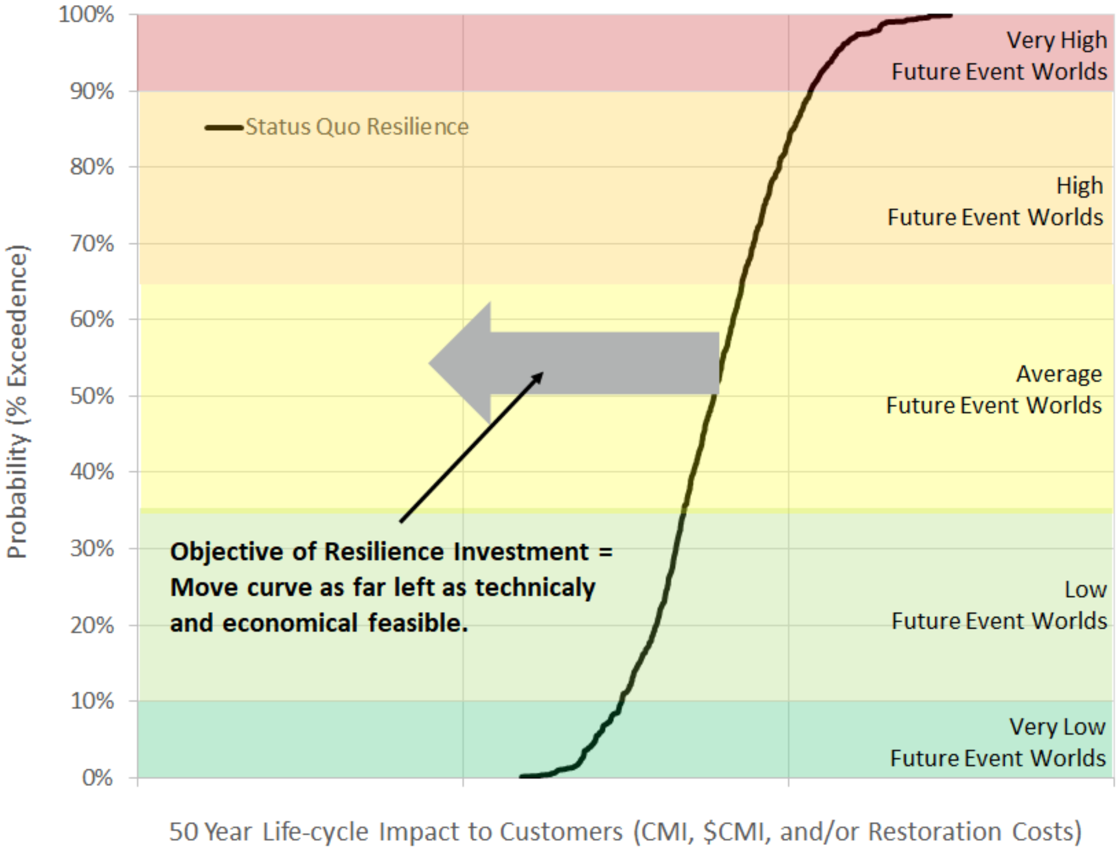
4.2 The Objective for Grid Resilience

The objective for grid resilience investment is two-fold:

1. Minimize to the extent technically feasible the impact of disruptive events to customers over the life-cycle of infrastructure
2. Invest in resilience upgrades with a positive business case, benefit to cost ratio >= 1

This is depicted within the resilience measuring framework in Figure 4-2.

Figure 4-2: Resilience Investment Objective



This two-fold objective for resilience investment seems simplistic enough on the surface but a deeper evaluation is needed to fully understand its implications.

- **Minimize to extent feasible –** Investments over time should be made to a level that they provide meaningful change in event impact. Since events impact all over a utility service territory, resilience investments will need to be substantial over the long term to provide meaningful change. Meaningful change being decreasing all system major event outages and restoration costs by over 30 to 40 percent. This approach allows for all customers to benefit through significantly shorter event's durations and restoration costs. For example, 4 day events before a long-term resilience plan could be a 2.5 day event after a resilience plan is implemented on the system. This also means that the impact of events cannot be fully mitigated. There will always be residual risk.
- **Investments with a positive business case –** The substantial level of investment is balanced or constrained by only including investments with a

positive business case. Over investment is also a risk with achieving a goal of resilience. Because customers ultimately pay for both proactive and reactive system costs, it is important that over investment risk be managed. Limiting investments to those with a positive business case helps utilities to not overinvest in resilience measures.

- **Measuring the impact to customer** – Customers are impacted in terms of restoration costs which eventually get passed along through rates and outages. Minimizing outages and restoration costs should be included in the objective for resilience. In fact, the Florida legislature outlined this two-fold objective for evaluating investments of decreasing customer outages and restoration costs as the focus for Florida electric utilities in developing their 10-year Storm Protection Plans. It should be noted that a specific metric was not proposed, rather utilities metrics need to be aligned to this two-fold objective. The impact of customer outages is complex in that different customers and communities have significantly different impacts to them based on the type of event and duration of the event. Measuring resilience will require grid stakeholders to place a value on different customer and community types and the duration of events. This is critical to identifying direct investments for customers and building the business case for investments. While restoration savings is part of the business case, the main component is the value of avoided outages. For this reason, 1898 & Co. shows CMI, monetized CMI ($CMI), and restoration cost for measuring resilience investments. The valuing of societal costs for different event durations is currently a gap for electric utilities stakeholders. In other words, what is the societal cost of a 4-day outage for a residential customer versus a 2 day outage. 1898 & Co. has included its baseline approach for the value of outages, sometimes referred to as the value of lost load, in Section 6.2.

Before exploring specific metrics to evaluate resilience and improving it, it is important to understand how it can be improved through infrastructure upgrades. The following section discusses this topic.

4.3 Improving System Resilience

There are several approaches to mitigating the impacts of major disruptive events and improving the overall resilience of the system. From an infrastructure enhancement perspective, there are three main approach types to improving system resilience:

1. **Resistance** – the ability of the system to retain its service, to completely or partially fend off the effects of a major event.
2. **Absorptive Capacity** – the ability of the system to mitigate the effects of a major event by implementing contingency measures that restore all or part of the system.
3. **Recoverability** – the ability of the system to more quickly return to full service.

Each of these three approaches is targeted at the 'prepare' phase. The following sub-sections describe each of these approaches in relation to the Resilience Conceptual Framework. The sections use example infrastructure improvements for each of the three approaches. The focus of this evaluation is undergrounding, but other resilience investment alternatives will be discussed for completeness. Undergrounding is expected to be part of a larger Resilience Investment Plan. In developing a resilience investment plan, it is important to use all three of these approaches for a multi-prong approach to improve resilience, prioritizing those investments that provide the most resilience 'bang-for-buck'. This is discussed in Section 6.0.

4.3.1 Resistance Investments and Resilience Impact

Resistance investments aim to strengthen the system so that major events do not impact the system or have minimal impact on the system. Examples of these types of grid investments include:

- Stronger Structures / Poles
  - Wood to Steel (or other manufactured) Conversions
  - Wood Pole Upgrades (e.g. Class 3 conversion to Class 1 or Class C or B construction to Class B+ or A)
- Rebuild with Tree-wire
- Overhead to Underground Conversions

- Substation Elevation

The focus of this evaluation is undergrounding, but other resilience investment alternatives will be discussed for completeness. The level of improvement in system resilience for each of these investment types is dependent on the level of penetration of the investment across the system and the types of stressors to impact the system. Figure 4-3 shows the impact of resilience improvement assuming weaker stressors with the entire system having been rebuilt with much stronger structures or poles. For the weaker stressors, the figure shows that this type of investment can nearly fully mitigate the impact of events.

Figure 4-3: Resilience Improvement and Hardening All Infrastructure (Weaker Event)

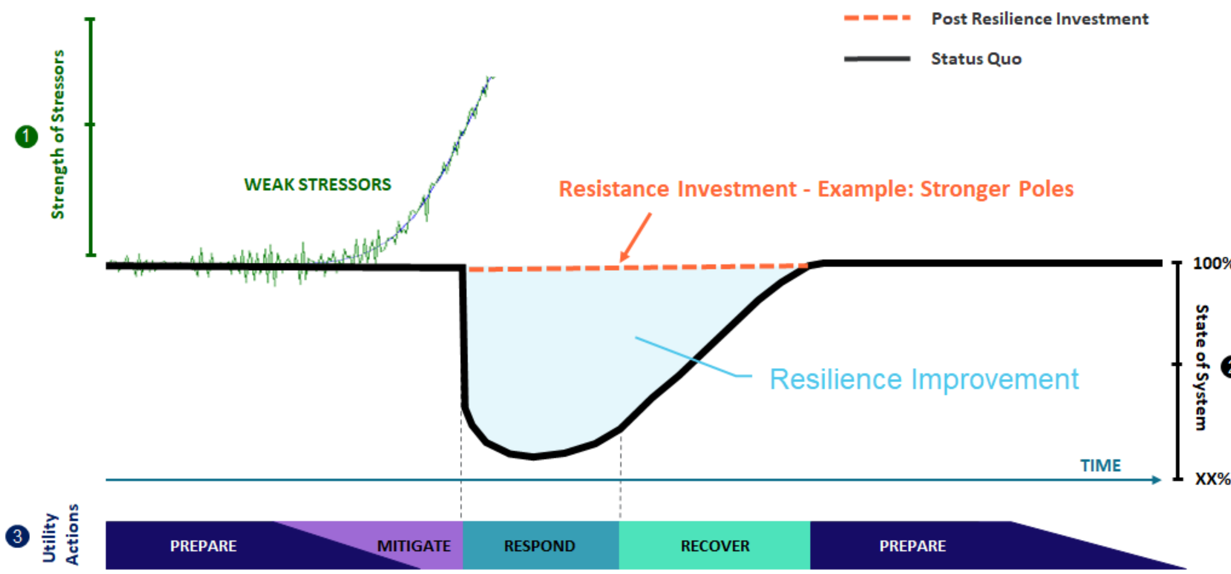


Figure 4-4 shows the resilience improvement for this same investment strategy, stronger poles across the entire system, for the stronger stressors. With the stronger infrastructure, it now takes a stronger or more intense stressor to cause asset failures. This is represented in the figure by failure now occurring at point ‘B’ as opposed to point ‘A’ without the infrastructure upgrade. The hardening did not prevent failures but delayed it and shortened the outage duration. While it might take more work to erect the stronger, and bigger, poles, fewer structures fail in this scenario. Fewer asset failures means that more crews will be able to work on the assets that do fail, which can have a beneficial multiplying effect on outage reduction time. Of course, if only a small fraction of the structures are hardened the overall resilience improvement is small.

Figure 4-4: Resilience Improvement and Hardening All Infrastructure (Stronger Event)

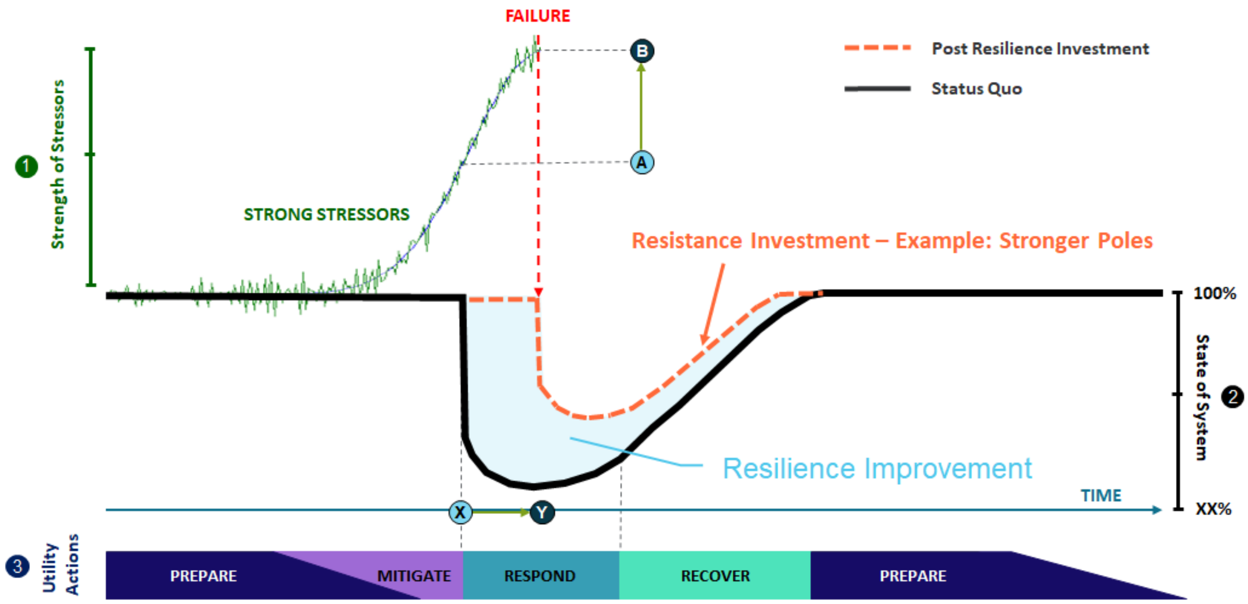


Figure 4-3 and Figure 4-4 show the range of resilience improvement for utilizing stronger structures or poles for the resistance investment approach. The cost effectiveness of this strategy is dependent on the relative mix of weaker and stronger stressors. Undergrounding infrastructure, while expensive, does provide maximum resilience benefit, nearly fully mitigating the impact of the range of stressors. Figure 4-5 visualizes the resilience benefit within the Resilience Conceptual Framework. The figure is based on a fictitious scenario where the entire system is undergrounded. Figure 4-6 provides a more realistic resilience improvement scenario with partial system undergrounding.

Figure 4-5: Resilience Improvement and Undergrounding All Infrastructure

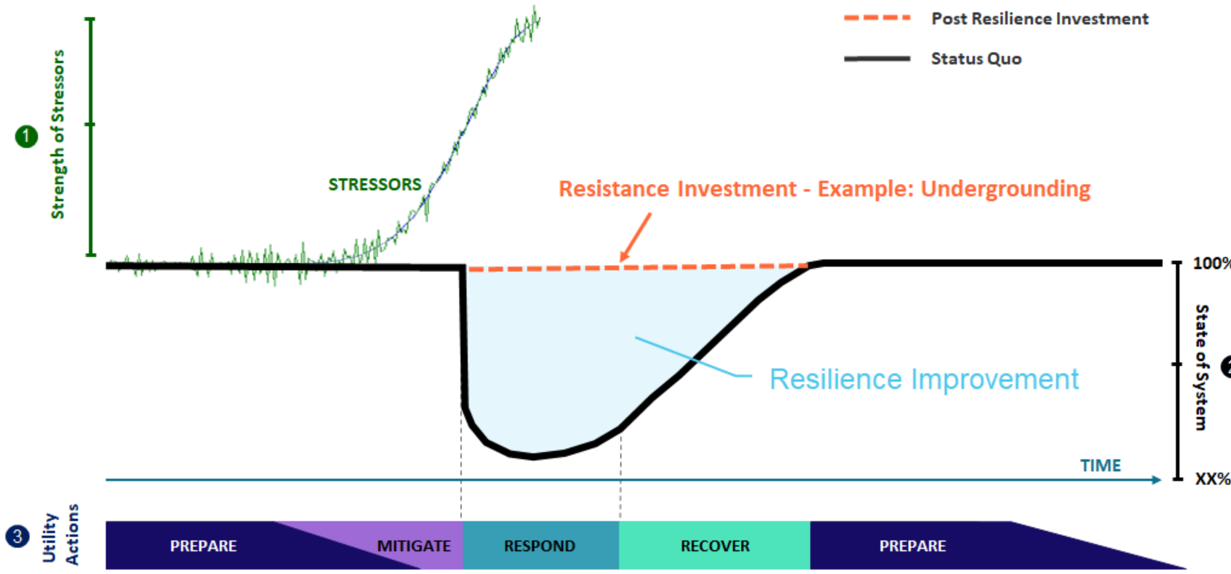
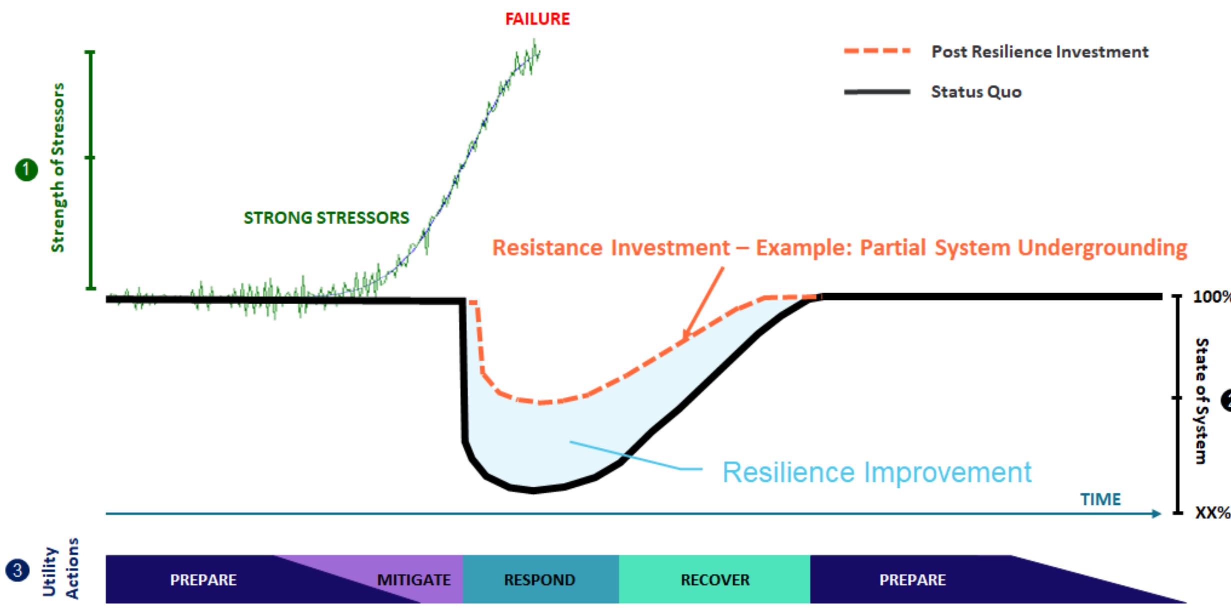


Figure 4-6: Resilience Improvement and Partial System Undergrounding



The resistance investment approach can provide significant benefits for all grid customers. Firstly, directly for the customers whose infrastructure has been hardened or undergrounded. These customers directly benefit from the hardening activities. Secondly, even customers whose upstream infrastructure was not hardened achieve benefits from this strategy. As Figure 4-4 and Figure 4-6 both show, the overall duration of the major disruptive stressors are less than a status quo approach. With less infrastructure to rebuild after a major event, crews can rebuild the failed infrastructure much faster. Additionally, depending on the severity of the storm, there could be additional benefits of needing less costly foreign crews to restore the system.

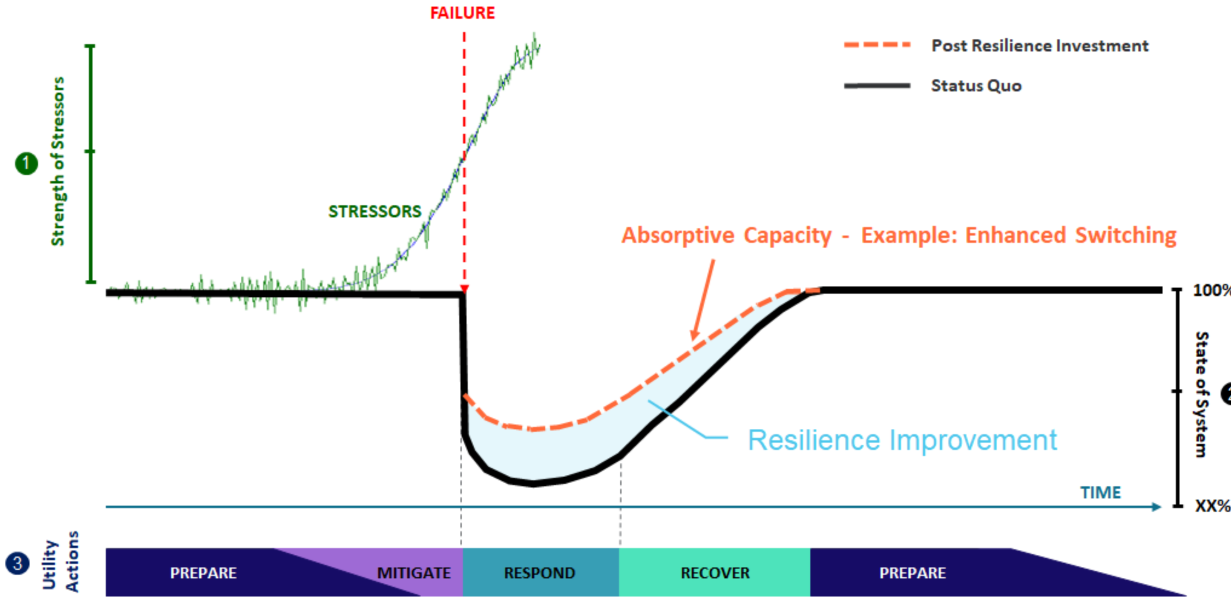
4.3.2 Absorptive Capacity Investment and Resilience Impact

Absorptive capacity investments aim to mitigate the impact of the event by implementing contingency measures that restore part of the system. Examples of these types of grid investments include:

- Enhanced Switching
  - Distribution Automation
  - Adding more circuit ties
- Looping and diverse paths

The focus of this evaluation is undergrounding, but other resilience investment alternatives will be discussed for completeness. Figure 4-7 shows the impact of resilience improvement from absorptive investment strategies, specifically enhanced switching capabilities. While this type of investment does not mitigate asset failures, it does mitigate the impact to customers. In the case of enhanced switching, customers can be swapped over to parts of the system that have not failed, decreasing the number of customers impacted. For enhanced switching, the overall duration of the event is not mitigated making the overall resilience improvement less than a resistance strategy. However, the cost of these approaches relative to resistance investment approaches can be significantly less.

Figure 4-7: Resilience Improvement and Enhanced Switching



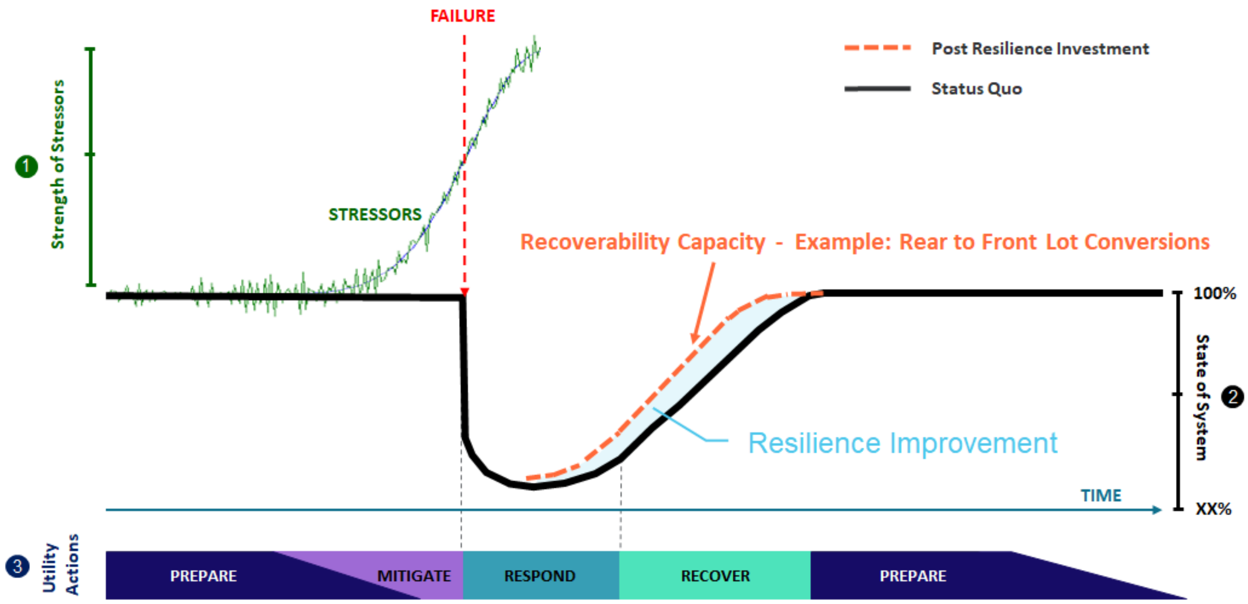
4.3.3 Recoverability Capacity Investment and Resilience Impact

Recoverability is the ability of the system to quickly return to full service. Typically, recoverability for major events is achieved through operational strategies like number of crews, staging of equipment, and optimization of crew development to name a few. From an infrastructure investment perspective, a main approach to improving recoverability is to enhance access to the infrastructure. Assets in deep right-of-way are far more challenging to rebuild as access for crews and trucks is challenging. Examples of these types of grid investments include:

- Improving Access to Right-of-ways
- Bridge and Road Access
- Rear lot to Front Lot Conversions (all else equal)

The focus of this evaluation is undergrounding, but other resilience investment alternatives will be discussed for completeness. Figure 4-8 shows the impact of resilience improvement from recoverability investment strategies, specifically rear lot to front lot conversions. As the figure shows, the absolute impact on the system is not mitigated, rather the overall duration is decreased to improve the overall resilience. In the long-term, this investment strategy does not mitigate asset failures, unless the infrastructure is built to a stronger standard with the conversion, it does allow crews to get access to and fix the infrastructure much faster. Recoverability only based investment strategies are not typically done at scale since the cost can be significant. Rather, this strategy is more on an opportunistic basis or done at the same time with cost efficiencies with a resistance or absorptive investment strategy.

Figure 4-8: Resilience Improvement and Rear to Front Lot Conversions



5.0 RESILIENCE INVESTMENT PLANS WITHIN THE INDUSTRY

Across the United States, Canada, and around the world, utilities are pursuing resilience investment plan filings in response to the greater impact major events have on the electrical system. While some states have strong stances on resilience requirements (Florida, New York), others have chosen to provide recommendations for utilities to consider. As seen with New York's recent move from resilience recommendations to codified filing requirements, resilience investment requirement levels are in a state of flux. Many Public Service Commissions (PSC) are recognizing the importance of resilience but there are still a wide range of regulatory environments out there. The following section is an initial review of resilience investment across the United States and Canada.

5.1 Maryland & Virginia

In 2012, a derecho storm impacted Maryland during a sustained heat wave, and together resulted in the 47 fatalities according to NOAA[23]. In response, Executive Order 01.01.2012.15 directed the State Energy Advisor, in conjunction with other agencies including the Maryland Energy Administration (MEA), to solicit recommendations from industry experts on how to improve the resilience and reliability of the distribution system – resulting in the formation of the Grid Resiliency Task Force. This group included almost 50 experts who evaluated the effectiveness and feasibility of undergrounding power lines, options for improving grid resilience infrastructure investments, and alternative financing and cost recovery for capital investments. The resulting *Weathering the Storm* report included 11 recommendations, including to implement a ratemaking structure that aligns customers and utility incentives by rewarding reliability that exceeds established reliability metric and penalizes failure to meet those metrics.

In 2016, MDPSC initiated a proceeding titled Public Conference 44 (PC44)[24] to review electric distribution systems in Maryland, aiming to explore issues that will

[23] National Oceanic and Atmospheric Administration (NOAA). (2013 January). *The Historic Derecho of June 29, 2012*. U. S. Department of Commerce

[24] https://www.psc.state.md.us/transforming-marylands-electric-grid-pc44/

maximize benefits and choice to Maryland electric customers and assess how the evolving grid impacts low- and moderate-income ratepayers. In the first notice, seven topics were considered for the proceeding, including the following:

- Rate design
- Electric Vehicles
- Competitive Markets and Customer Choice
- Interconnection Process
- Energy Storage
- Distribution Planning

Building on the information from the Task Force on Comprehensive Electricity Planning (compromising of the NARUC and NASEO), MDPSC created the Distribution System Planning Work Group in 2021 with the goal of aligning planning processes with state goals and proliferation of distributed energy resources through comprehensive examination of distribution system planning in Maryland[25].

In 2019, the MEA sponsored an incentive program called Resilient Maryland, aimed at growing the adoption of microgrid and other distributed generation systems. This pilot program provides competitive grants to stakeholders in the development of microgrids, combined cycle heat and power, and resilience hubs in the state. The program disbursed $297,000 in 2019, $1.03 million in 2020, $1.59 million in 2021, and $1.58 million in 2022. Applications for 2023 are currently open[26].

The MDPSC approved a request from Potomac Electric Power Company (Pepco) to include a "Grid Resilience Charge" on customer's monthly bills in Montgomery and Prince George countries. This charge allowed Pepco to secure $24 million from ratepayers in Case No. 9311, in order to replace priority distribution feeders in 2014. In 2016, Pepco requested approval under Case No. 9418 for an additional $31.6 million under the same program.

[25] https://news.maryland.gov/mea/2021/02/11/maryland-announces-plan-for-electric-grid-of-the-future/
[26] https://energy.maryland.gov/business/Pages/ResilientMaryland.aspx

Pepco and Dominion Energy (Dominion) are utilities with similarities to Hydro Ottawa. A summary of efforts by these utilities is summarized Table 5-1 below:

Table 5-1: Pepco and Dominion Resilience Efforts to Date

Utility	Resilience Program	Area	Projects	Time Horizon	Budget
Pepco	DC Plug Projects	District of Columbia (DC)	Undergrounding distribution feeders – Wards 3, 4, 5, 7, and 8.	2012-Present	$500M*
	Capital Grid Projects	DC & Maryland	Substation upgrades, new substations, 10 miles of undergrounding transmission lines	2020-2028	$1.1B
Dominion	Strategic Underground Program	Virginia & North Carolina	Undergrounding tap lines most prone to outages over the last 10-years	2019-2026	$179M per year
	Grid Improvement Programs	Virginia	Hardening main feeders, vegetation management for ash tree mortality due to invasive insects.	2018-2030	$3B

*This program is funded by Pepco, and the District of Columbia.

Additionally, MEA (along with 12 other states), declared commitment to a more efficient and resilient energy future in February of 2011, following the conclusion of the two-year initiative hosted by the NARUC and the National Association of State Energy Officials (NASEO).

5.2 Florida

In 2006, the Florida Public Service Commission (FPSC) passed a requirement for electric utilities to develop storm protection plans. In 2019, this became codified by the Florida legislature, also allowing utilities to recover the costs of approved plans through a charge separate and apart from base rates. Each utility must file a petition with the Commission for approval of a T&D Storm Protection Plan (SPP) that covers the utility's immediate 3-year planning period and their longer 10-year planning horizon. Per the legislation and SPP rule, each utility is required to provide an updated SPP at least every 3 years. The SPP rule following the legislation lays out requirements for plans. From a benefits perspectives, the plans are required to show benefits in terms of avoided customer outages and avoided storm restoration costs.

In November 2022, FPSC approved 4 plans submitted by power company utilities for efforts to harden the state's power grid over the next 3 years. The FPSC approved nearly all of the investments over the next 3 years for each of the four electric utilities; Florida Power and Light (FPL), Duke, Florida Public Utilities and Tampa Electric Company (TECO).

5.2.1 Florida Power & Light

FPL requested approval for plan totaling $13.77B. The commission approved nearly all of the requested funding for programs for the first 3 years of the 10-year plans. Table 5-2 provides an overview of their SPP filing.

Table 5-2: FPL Storm Hardening Estimated Categories and Spends

Program	Annual Cost	Timeframe (Years)
Distribution Inspection	$66.9M	10
Transmission Inspection	$67.2M	10
Distribution Feeder Hardening	$270.8M	9
Distribution Lateral Hardening	$939M	10
Transmission Hardening	$50.4M	10
Distribution Vegetation Management	$76.6M	10
Transmission Vegetation Management	$14.4M	10
Substation Storm Surge/Flood Mitigation	$16M	2
Distribution Winterization (withdrawn)	$22.3M	2
Transmission Winterization (withdrawn)	$22.3M	2
Transmission Access Enhancement	$11.70	10
Total	**$1.54B**	

5.2.2 Duke Florida

Duke Florida requested approval for plan totaling $7.17B. Table 5-3 provides an overview of their SPP filing. Duke Florida's Plan programs include the following:

Table 5-3: Duke Storm Hardening Estimated Categories and Spends

Program	Annual Cost	O&M Cost	Timeframe (Years)
Feeder Hardening	$2.0B	$49M	10
Lateral Hardening	$2.9B	$74M	10
Underground Flood Mitigation	$15M		10
Distribution Vegetation Management	$23M	$517M	10
Transmission Structure Hardening	$1.6B	$34M	10
Substation Flood Mitigation	$38M		10
Loop Radially-Fed Substation	$82M		10
Substation Hardening	$133M		10
Transmission Vegetation Management	$126M	$127M	10
Self-Optimizing Grid (3yrs)	$340M	$11M	10
Total	**$7.257B**	**$812M**	

5.2.3 Florida Public Utilities

Florida Public Utilities requested approval for plan totaling $243.1M. The plan includes Distribution Overhead Feeder Hardening, Distribution Overhead Lateral hardening, Distribution Overhead Lateral Undergrounding, T&D Vegetation Management, Future T&D Enhancements, Transmission/Substation Resiliency, Transmission Inspection and Hardening, and SPP Program Management. Table 5-4 provides an overview of their SPP filing. Florida Public Utilities Plan programs include the following:

Table 5-4: Florida Public Utilities Storm Hardening Estimated Categories and Spends

Program	2022 Cost	2023 Cost	2024 Cost
Overhead Feeder Hardening	$300,000	$3.01M	$3.07M
Lateral Feeder Hardening	$60,000	$580,000	$1.01M
Lateral Undergrounding	$110,000	$1.12M	$1.67M
Distribution Inspection and Replacement	$1.2M	$1.52M	$1.62M

Transmission System Inspection and Hardening	$620,000	$620,000	$620,000
Transmission & Substation Resiliency	-	-	$9.35M
Transmission & Distribution Vegetation Management	$9.5M	$11.5M	$14M
Future Transmission & Distribution Enhancements	-	-	-
Total	**$11.81**	**$18.35M**	**$31.34M**

5.2.4 TECO

TECO requested approval for a plan totaling $1.45B for Distribution lateral Undergrounding, Substation Extreme Weather (Distribution & Transmission), Distribution Overhead Feeder Hardening, Transmission Access Enhancement, along with things like environmental management and future maintenance. Table 5-5 provides an overview of their SPP Filing.

Table 5-5: TECO Storm Hardening Estimated Categories and Spends

Program	Annual Cost	Timeframe (Years)
Distribution Lateral Undergrounding	$105M	3
Supplemental Distribution Circuit Vegetation Management	$60,200	10
Mid-Cycle Distribution Vegetation Management	$58,100	10
69kV Vegetation Management Reclamation	$2,185	1
Transmission Asset Upgrades	$53.1M	3
Substation Extreme Weather Hardening	$5M	3
Distribution Overhead Feeder Hardening	$94.8M	3
Transmission Access Enhancements	$3M	3
Wood Pole Inspections	$1.1M	10
Transmission Inspections	$430,000	10
Groundline Inspections, ground Patrol, Aerial Infrared Patrol, Above Ground Inspections, Substation Inspections	$150,000	10
Disaster Preparedness & Recovery Plan	$300,000	Annually
Distribution Pole Replacements	$82.9M	10
Total	**$345.9M**	

5.3 Louisiana

The state of Louisiana saw two storm resilience plans filed in 2022, both from Entergy. The filings were the results of two major category 4 hurricanes impacting the Entergy service territory in 2020 and 2021 (Laura and Ida, respectively). First, Entergy New Orleans enacted a grid hardening and resilience filing with the New Orleans City Council (their applicable regulator). The plan detailed nearly $1.3 billion in spending over 10 years and asserted 890 grid resilience projects were identified in the plan. These projects include distribution and transmission projects involving over 33,000 structures and 650 line-miles. The annual plan costs are shown in Table 5-6.

Table 5-6: Entergy New Orleans Resiliency Estimated Spends by Year

Year	Approx. Investment
2023	$0
2024	$20M
2025	$36M
2026	$47M
2027	$197M
2028	$200M
2029	$205M
2030	$188M
2031	$230M
2032	$154M
Total	**$1.276B**

The second filing in Louisiana was done by Entergy Louisiana, with a proposed plan capital investment for approval by the commission of approximately $5 billion for the first five years of the 10-year plan. The total 10-year plan investment level is nearly $9 billion. This plan proposes the following resilience programs, as shown in Table 5-7.

Table 5-7: Entergy Louisiana Resiliency Estimated Spends by Year and Category[27]

Year	Distribution Feeder Hardening (Rebuild)	Distribution Feeder OH to UG Conversion	Lateral Hardening (Rebuild)	Lateral OH to UG Conversion	Transmission Rebuild	Substation Control House Remediation	Substation Storm Surge Mitigation	Total
2023	$0	$0	$54,700	$0	$0	$700	$3,800	**$59,200**
2024	$48,000	$0	$252,700	$26,648	$11,800	$3,100	$16,900	**$359,148**
2025	$382,100	$0	$281,900	$68,260	$80,500	$5,000	$40,900	**$858,660**
2026	$556,200	$25,800	$257,600	$61,062	$258,400	$3,400	$51,200	**$1,213,662**
2027	$364,000	$5,800	$241,300	$29,273	$271,300	$0	$27,800	**$939,473**
2028	$532,200	$0	$269,100	$49,533	$326,900	$0	$5,000	**$1,182,733**
2029	$555,300	$0	$319,900	$42,690	$217,500	$0	$5,600	**$1,140,990**
2030	$513,300	$0	$250,000	$58,223	$226,200	$0	$5,300	**$1,053,023**
2031	$419,700	$0	$166,000	$50,045	$133,100	$0	$3,600	**$772,445**
2032	$222,100	$0	$261,900	$25,311	$12,200	$0	$0	**$521,511**
2033	$441,100	$0	$74,800	$20,403	$0	$0	$0	**$536,303**
2034	$183,900	$7,800	$15,900	$1,210	$0	$0	$0	**$208,810**
Total	**$4,217,900**	**$39,400**	**$2,445,800**	**$432,659**	**$1,537,900**	**$12,200**	**$160,100**	**$8,845,959**

Both Entergy filings proposed to recover costs through a resiliency and storm hardening cost recovery rider, to permit timely recovery of the Resilience Plan's revenue requirements due to the level and pace of spending through the plan.

5.4 New York

The state of New York has seen multiple named events in recent years, most notably Hurricane Sandy. In response, the Columbia Center for Climate Change Law filed a formal petition with the New York PSC requesting all utilities under its jurisdiction be required to develop climate change adaptation plans, which in turn led Consolidated Edison (Con Ed) to file a plan of the same name in 2014. The initial plan

[27] **Source:** Application of Entergy Louisiana, LLC For Approval of the Entergy Future Ready Resilience Plan (Phase 1), Table 8-1

investment level was $1 billion and was recoverable through its own recovery rider. This same year, a group of NGOs and academic centers were ordered by the PSC to continue the Storm Hardening and Resiliency Collaborative in the form of four working groups with the scope of addressing storm hardening design standards, alternative resiliency strategies, natural gas system resiliency and risk assessment/cost benefit analysis. Additionally, the PSC required Con Ed's commitment to conduct a Climate Change Vulnerability Study, which was performed in 2013, and again in 2019.

The New York State Senate passed Bill S4824A in 2021, which requires electrical corporations to submit a storm hardening system resiliency plan to the PSC, authorizes utility companies to petition the PSC for a waiver of reimbursement requirements, requires utility companies to reimburse customers for certain widespread prolonged outages, and prohibits utility companies from recovering costs incurred due to power outages from customers. The bill, named the Soil Health and Climate Resilience Act, went into effect in 2022 and requires utilities to perform climate change vulnerability studies by 2023. An updated plan must be filed five years after the approval of an original plan, and utilities can make an annual filing to recover costs associated with the preparation of the plan. Additionally, each utility must establish a climate resilience working group no later than 2023, and include in the group representatives from the PSC, municipalities, customer advocacy groups, and energy and environmental advocacy groups.

5.5 New Jersey

Public Service Electric and Gas (PSEG) was granted approval of the $550 million "Energy Strong" infrastructure hardening and resiliency plan in 2014 and $207 million in 2019. The cost recovery for this plan was a new recovery rider, for both gas and electric investments. The program spends by phase are detailed in Table 5-8.

Table 5-8: PSEG Energy Strong Program Investment Levels by Phase

Program	Approx. Investment
Phase 1	
Substation Flood Hardening	$400M
Grid Modernization	$150M
Phase 2	
Distribution Circuit Hardening	$100M
Communication and ADMS Upgrades	$107M
Total	**$757M**

5.6 California

California is currently executing plans to mitigate the impact of wildfires in the state. California's investor-owned utilities plan to spend over $10 billion to mitigate the risk. The investments are aimed at reducing the risk of wildfires in their service territories. These programs employ several strategies, including inspecting and repairing equipment, trimming back trees and other vegetation that could fall into power lines, and investing in grid technologies and system hardening.

5.7 Texas

In response to very disruptive natural disaster events that cause disruption throughout the midwestern portion of the United States, Texas has passed House bill 2555 that creates a new cost recovery mechanism to allow transmission and distribution investments to harden those systems. Specific rules to implement House Bill 2555 are expected from the Texas Public Utility Commission by the end of 2023.

5.8 IEEE Resilience Working Group

The Institute of Electrical and Electronic Engineers (IEEE) created a working group in 2019 dedicated to the discussion, defining, and quantification of resiliency in the electric distribution system. The group's scope includes capturing common methods and applications utilities may use prior to and following extreme natural events and/or environmental conditions to improve distribution system resiliency. The topics covered by the group include but are not limited to the following:

- System design and implementation
- Hardening Efforts
- Inspections and maintenance activities
- Response consideration
- Quantitative measurements

This group does not consider events surrounding cybersecurity or deliberate physical security attacks. The work group is comprised of 27 industry professionals, contributing to seven different chapters, with each chapter's scope as follows:

- Chapter 1: Literature Review
- Chapter 2: Resilience Goal/Objectives
- Chapter 3: High Impact Weather/Storm Event Risk Identification
- Chapter 4: Quantification of Resiliency
- Chapter 5: System Modeling and Storm Simulation
- Chapter 6: Guide for Infrastructure and Operational Improvements
- Chapter 7: Use Cases and Resiliency Study

Currently, the work group's goals through 2023 include building a consensus on resilience metrics between the following factors: common tools among utilities, common tools among research, and bringing a consensus among available data to utilities, data infrastructure, and research methods. Through 2024, the group aims to create a common framework for quantitative metrics of resilience with a focus on available data by starting a risk-benefit analysis of investments on both new infrastructure and grid hardening.

5.9 Ontario Energy Board Resilience Policy Analysis[28]

[28] https://engagewithus.oeb.ca/sectorresilience

In 2023, the Ontario Energy Board engaged London Economics International LLC to analyze and define resilience and explore related policy questions as they apply to electric distributors in Ontario. The result was a comprehensive report "Resilience in the electricity distribution sector and related policy questions" that outlined an initial road map that could be used to guide strategy and tactics related to resilience initiatives aimed at mitigating threats to the electrical distribution system. While the report concludes that resilience investment are warranted to best serve the needs of electrical customers and financial justification should be required before specific investments are funded, it leaves some key elements unresolved around the areas of the appropriate evaluation framework, the funding mechanism to support resilience investment, and how to measure the effectiveness of the investments after implemented.

6.0 RESILIENCE INVESTMENT MODEL

Hydro Ottawa and 1898 & Co. utilized a resilience-based planning approach to identify, prioritize, and perform a business case for resilience investment in the distribution system. The resilience-based planning approach utilizes 1898 & Co.'s Resilience Investment Model. The Resilience Investment Model leverages the Conceptual Resilience Framework outlined in Section 2.0 and was designed based on the guiding principles outlined in Section 4.1. The model takes the "theory" of the frameworks and develops an actional investment plan that prioritizes resilience investments based on available data, analytics models, and a business case methodology. The approach calculates the resilience improvement at the asset, project, and program level. For the purposes of this evaluation, resilience benefits for projects are estimated from a customer centric perspective. The customer benefits are shown in terms of the:

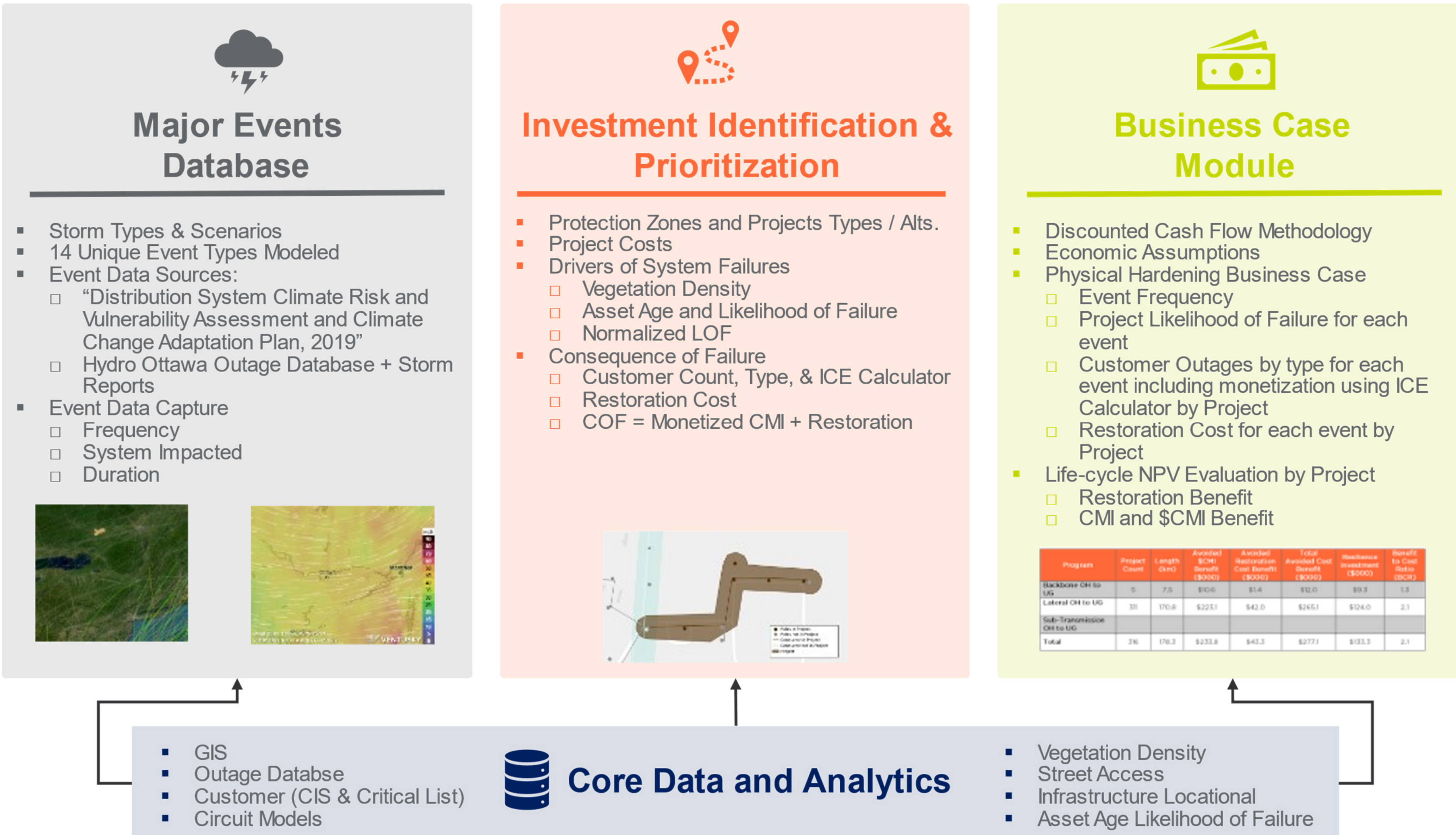
1. Decrease in the Event Restoration Costs
2. Decrease in the customers impacted and the duration of the overall outage, calculated as CMI and monetizing the CMI (discussed in Section 6.2)

The Resilience Investment Model employs a data-driven, decision-making methodology using robust and sophisticated algorithms to calculate the resilience benefits. The following sections provide an overview of the model, the approach to monetizing customer outages, and why modeling using this approach is important and necessary.

6.1 Resilience Investment Model Overview

Figure 6-1 provides an overview of the Resilience Investment Model to identify and prioritize hardening investments and calculate their customer centric business case.

Figure 6-1: Resilience Investment Model Overview



6.1.1 Core Data and Analytics

The Resilience Investment Model is foundationally data centric. It utilizes Hydro Ottawa enterprise data sources as well as external sources. From an internal enterprise perspective, the model utilizes Hydro Ottawa's Geospatial Information System (GIS) for the collection of assets and their attributes (age, type, etc.). This allows the resilience-based planning approach to be asset-centric. The model also utilizes Hydro Ottawa's Outage Database to understand the relationships between protection devices and the types of outage events, particularly larger events. The third core enterprise data set includes information from the Customer Information System (CIS). The fourth core dataset includes Hydro Ottawa distribution circuit models. 1898 & Co. linked these datasets to create the relationship between assets and customers and customer types. This allows the resilience-based planning approach to be customer-centric.

1898 & Co. also leveraged external data sources for the evaluation linking them to the internal data sources. The external data sources included satellite tree canopy for vegetation density analysis, and age deterioration analytics from 1898 & Co. own proprietary modeling. These external sources provided valuable information in identifying infrastructure that would more likely fail during events.

6.1.2 Major Event Database

Since the magnitude of the restoration cost decrease and CMI decrease is dependent on the frequency and magnitude of future major events that may impact the Hydro Ottawa service area, the Resilience Investment Model starts with the 'universe' of major weather events that could impact Hydro Ottawa's service area. The Major Event Database provides the high-level impact to the system of the storm stressor. The major events database includes the following:

- Event Type
- Frequency of an event occurring
- Percentage of the system impacted
    - Sub-Transmission Protection Devices
    - Backbone Protection Devices
    - Lateral Protection Devices

- Duration of the event
- Restoration Cost

6.1.3 Investment Identification

The Investment Identification develops the list of potential underground hardening projects and their costs. The evaluation is comprehensive in evaluating nearly the entire system. Underground hardening investments are defined based on a customer-centric perspective at the protection zone level for distribution circuits. The module also estimates the costs for each of the projects.

6.1.4 Resilience Business Case Module

The Resilience Business Case Module calculates the business case for each project with total benefit per dollar invested from the Investment Identification Module. The business case is based on a discounted cash flow methodology over a 50-year time horizon. The business case for each project is a sum of the avoided reactive costs and avoided monetized customer outages for each of the events within the Major Events Database.

The output of the Resilience Business Case Module is:

- Resilience Business Case for highest resilience improvement projects
  - Project Cost and High Level Scope
  - Life-Cycle Net Present Value (NPV) Benefits
  - Benefit to Cost Ratio (BCR)

6.2 Societal Impacts & Monetizing Outages

Society's reliance on electricity continues to expand from one decade to the next. This includes the increasing number of connected devices, aging in place, working from home, and electrification to highlight some of the more obvious drivers of an increased reliance on the grid. Section 3.2 provides further discussion of the many societal impacts tied to the loss of electrical power. From a customer's perspective, there is a real impact to their lives, and these impacts should be considered and factored into the development of a business case for each proposed resiliency project. .

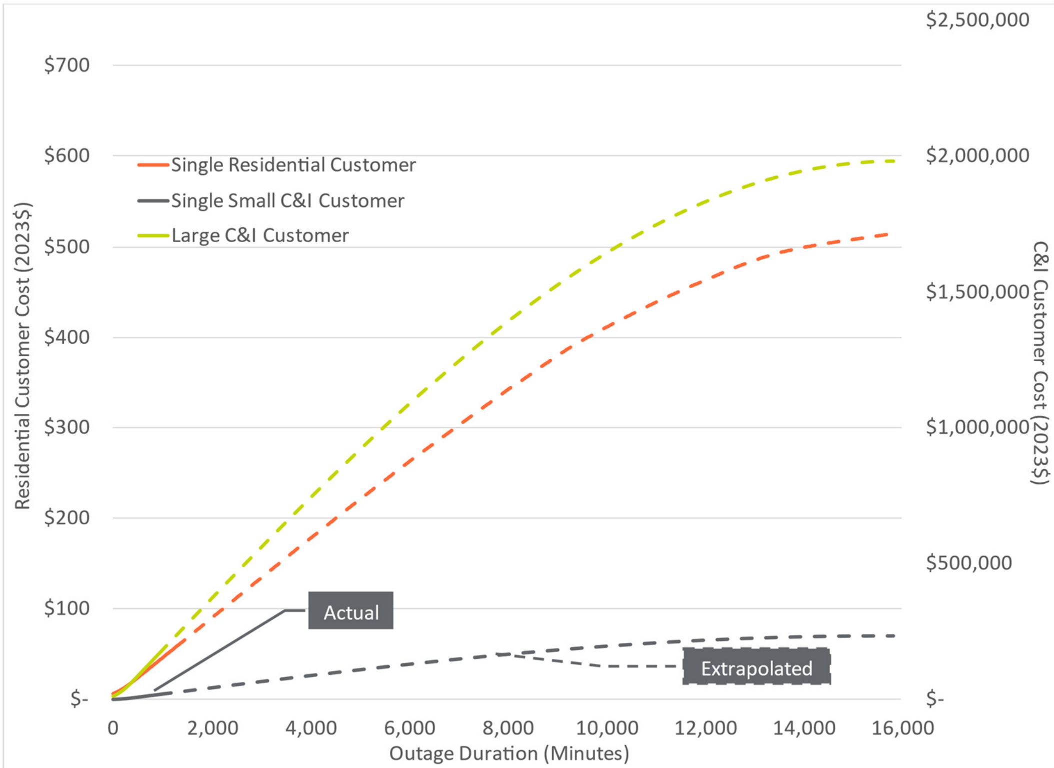
The DOE ICE calculator provides a third-party independent estimate of the value of eliminating or partially mitigating an outage. While there are some known deficiencies that generally result in underestimating the monetized customer impact, it is still the most recognized and utilized approach for the monetization of customer outages.

The ICE Calculator is an electric reliability planning tool developed by Freeman, Sullivan & Co. and Lawrence Berkeley National Laboratory. This tool is designed for electric reliability planners at utilities, government organizations, or other entities interested in interruption costs and/or the benefits associated with reliability improvements in the United States. The ICE Calculator was funded by the Office of Electricity Delivery and Energy Reliability at the DOE.

The value of interruption costs within the calculator are based on customer surveys from 15 research efforts conducted by 10 utility companies resulting in 34 different data sets totaling over 105,000 observations from 1989 to 2012. Greater than 44 thousand Medium to Large C&I customers, greater than 27 thousand small C&I customers, and over 34 thousand residential customers. The developers of the ICE calculator have also noted significant advancements in societal use of devices and other technologies including a higher number of people working from home. With most of the surveys being done before these advancements in the last 10 to 15 years, the developers of the ICE Calculator consider the current cost of interruptions to be conservative. The developers of the calculator have received additional funding to update the surveys which would reflect these key changes, especially the value of interruptions in a post-pandemic society. As this update will not be reflected until 2024, this business case evaluation does not attempt to normalize the ICE Calculator for these factors, rather the evaluation utilizes the result directly from the current calculator to be conservative.

The calculator includes the estimated interruption costs for residential, small commercial and industrial (C&I), and large C&I customers for a range of durations. The calculator was extrapolated for the longer outage durations for storm-based outages. Figure 6-2 shows the cost of interruptions for New York (closest US state to Ottawa) customers for each customer class in Canadian dollars. The figure also shows the extrapolation for longer outages. Hence a customer interruption monetized value can be derived for an outage of any duration for each of the listed customer classes.

Figure 6-2: ICE Calculator Monetized Cost of Outage Summary



6.3 Resilience Investment Model – 'The Why'

The Resilience Investment Model was designed and developed for the purpose of identifying and ranking T&D resilience investments to provide the most benefit for customers. For Hydro Ottawa, it was utilized only for the distribution system. The resilience-based planning approach described within this report are appropriate to model resilience investment for the following reasons:

- **Event-Based -** The benefits of resilience projects are wholly dependent on the number, type, and overall impact of future events to impact the region served by Hydro Ottawa. Different events have dramatically different impacts to Hydro Ottawa's distribution system. For this reason, the resilience-based planning approach includes 14 different potential major events that could impact Hydro Ottawa over the next 50 years capturing event forecasts provided within the "Distribution System Climate Risk and Vulnerability Assessment and Climate Change Adaptation Plan" produced by Stantec Consulting Ltd. (additional details in Section 8.0) and Hydro Ottawa's outage records. The evaluation is not limited to only recent events to minimize recency bias, but rather includes data going back 170 years.

- Asset and Root-Caused Focused - Major events cause assets to fail, and assets collectively serve customers. Moreover, it only takes one asset failure to cause customer outages. The cost to restore the failed assets is dependent on the extent of the damage and resources used to fix the system. The duration to restore affected customers is dependent on the extent of the asset damage and the extent of the damage on the rest of the system. It may only take 4 hours to fix the failed equipment, but customers could be without service for 4 days if crews are busy fixing other parts of the system for 3 days and 20 hours. All of this is dependent on the type of storm to impact the system. Modeling this series of events for the entire system at the asset and project level for both a "Status Quo" and "Hardened" scenarios is needed to accurately model resilience project benefits. Therefore, the resilience-based planning approach calculates the phases of asset and project resilience for each of the 14 storm events for both scenarios.
- Data-Centric - By breaking down the entire distribution system by protection zone, the resilience-based planning approach is foundationally data centric and links the appropriate assets to each possible resiliency project. The model utilizes Hydro Ottawa's GIS, outage database, CIS, distribution circuit models, and critical customer information. It also utilizes satellite tree canopy data and road layers.
- Customer-Centric - By breaking down the entire distribution system by protection zone, the resilience-based planning approach is foundationally customer centric. Each protection zone has a known number of customers and type of customers such as residential, small or large commercial and industrial, and critical customers. The objective is to harden each asset that has a higher risk of failing, which would result in a customer outage. Since only one asset needs to fail downstream of a protection device to cause a customer outage in that zone, failure to harden all the necessary assets still leaves vulnerable

components that could potentially fail in an event. Rolling assets into projects at the protection device level allows for hardening of all vulnerable components in the project zone and for capturing the full benefit for customers.

- Granular - The granularity at the asset and project levels allows Hydro Ottawa to invest in portions of the system that provide the most value to customers from both a restoration cost reduction and avoided CMI perspective. For example, a circuit may have 10 laterals that come off a feeder, and the resiliency investment model may determine that only 3 out of the 10 should be hardened. Without this granularity, a suboptimal or inefficient level of investment could occur. The adopted approach provides confidence that the final overall plan is investing in parts of the system that provide the most value for customers.
- Comprehensive - The approach is comprehensive and evaluates nearly all of the assets on Hydro Ottawa's distribution systems. By considering and evaluating those systems on a consistent basis, the results of the final underground hardening plan provide confidence that portions of Hydro Ottawa's distribution assets are not overlooked for potential resilience benefit.
- Business Case Foundations - The output of the model is the resilience benefit of each project for each of the 14 storm types. The life-cycle resilience benefit for each resilience project is dependent on the probability of each storm and the mix of storm events to occur over the life of the resilience projects. A project's resilience value comes from mitigating outages and associated restoration costs not just for one storm event, but from several over the life-cycle of the assets. For this evaluation, the future of major storm events is assumed to be equal to the historical frequency based on 170 years of weather data. The number of storm scenarios is significant given there are 14 unique types of storm events that could impact grid infrastructure.
- Consistency: The model calculates benefits consistently for all projects. The model carefully normalizes for more accurate benefits comparison between asset types. For example, the model can compare an overhead rebuild resilience project to a lateral undergrounding project to a distribution

automation project. This is a significant achievement allowing the assessment to accurately compare a wide range of investment types.

- Drives Prudency: The assessment and modeling approach drives prudency for the final comprehensive hardening plan on two main levels. First, the granularity of potential resilience projects allows Hydro Ottawa to invest in the portions of the system that provide the most value to customers. Without granularity, there is risk that parts of the system “ride the coat-tails” of needed investment causing inefficient allocation of limited capital resources. Secondly, the customer-centric financial justification of project investments allows Hydro Ottawa to prioritize investments that provide significant customer ‘bang for buck’.

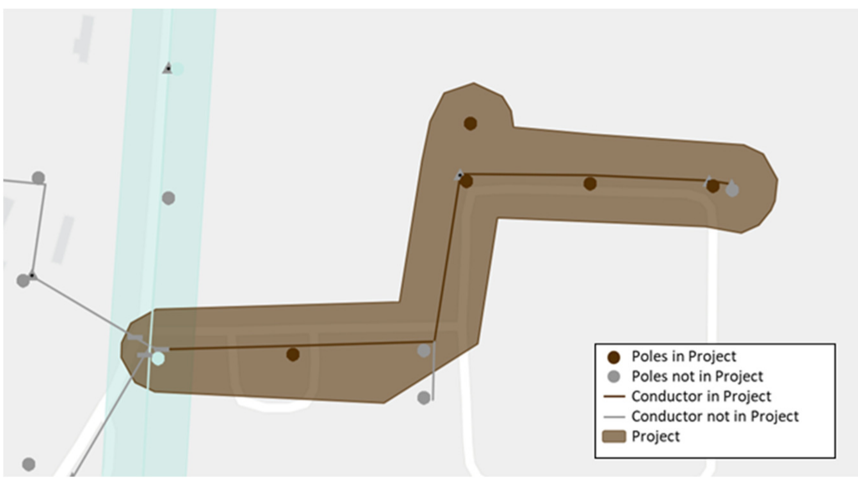
7.0 CORE DATA AND ANALYTICS

The resilience-based approach and methodology is data driven. This section outlines the core data sets and base algorithms employed within the Resilience Investment Model. This section includes both data from Hydro Ottawa's systems and external data sources.

7.1 Geographical Information System

The GIS provides the list of assets in Hydro Ottawa's system and how they are connected to each other. Since the resilience-based approach is fundamentally an asset management bottom-up based methodology, it starts with the asset data, then rolls all the assets up to projects, and all projects up to programs, and finally the programs up to the Resilience Investment Plan. The relationship between assets and projects is illustrated in the geospatial figure below.

Figure 7-1: Asset to Project Relationship



The Resilience Investment Plan created by 1898 & Co. only modeled overhead to underground projects, therefore all underground assets were removed from the evaluation. The existing underground system makes up 56% (3,463 km) of the total length of primary conductor. In addition to removing underground assets 22% (600 km) of overhead conductor was excluded from review for being 4 kV conductor which was outside the scope of this project.

In alignment with this methodology, 1898 & Co. utilized the connectivity within Hydro Ottawa's GIS to link each distribution voltage asset up to a lateral (fuse protection device) or feeder (breaker or recloser protection device). This linkage of assets to protection zones provides a granular evaluation of the distribution system that allows projects to be created to target only portions of a circuit for resilience investment. Through this approach, 1898 & Co. was able to use the asset level information from Table 7-1 and convert it to the project level summaries in Table 7-2. It is important to note that each asset in Table 7-1 is tied to one of the projects listed in Table 7-2, which provides a bottom-up analysis.

Table 7-1: Hydro Ottawa Asset Base

Asset Type	Units	Value
Sub-Transmission Circuits	[count]	72
Poles / Structures	[count]	3,387
Conductor Length	[kilometers]	312.5
Distribution Circuits (OH)	[count]	203
Feeder Poles	[count]	20,916
Lateral Poles	[count]	14,577
Feeder OH Primary	[kilometers]	1,178
Lateral OH Primary	[kilometers]	644

Table 7-2: Projects Created from Hydro Ottawa Data Systems

Count	Program	Project Count
1	Backbone OH to UG	324
2	Lateral OH to UG	1,338
3	Sub-Transmission OH to UG	81
	Total	1,743

7.2 Outage Database

The outage database includes detailed outage information by cause code for each circuit and protection device over the last 11 years. The Storm Resilience Model utilized this information to understand the historical storm related outages for the various distribution laterals and feeders on the system.

7.3 Customer Type Data

Hydro Ottawa provided customer count and type information with database relationships to the GIS and OMS. Using connectivity from the distribution circuit to the breaker, the customer relationship to the substation was also established. This data allowed the Resilience Investment Model to directly link the number and type of customers impacted to each protection device. Types of customers include residential, small C&I, and large commercial and industrial. This customer information is used in concert with the estimated event duration to estimate the CMI for each project which is monetized using the DOE ICE Calculator. This is foundational for the customer-centric business case approach. Figure 7-2, Figure 7-3, and Figure 7-3 show the customer counts for trunk backbone, lateral and subtransmission protection zones.

Figure 7-2: Customers by Backbone Protection Device

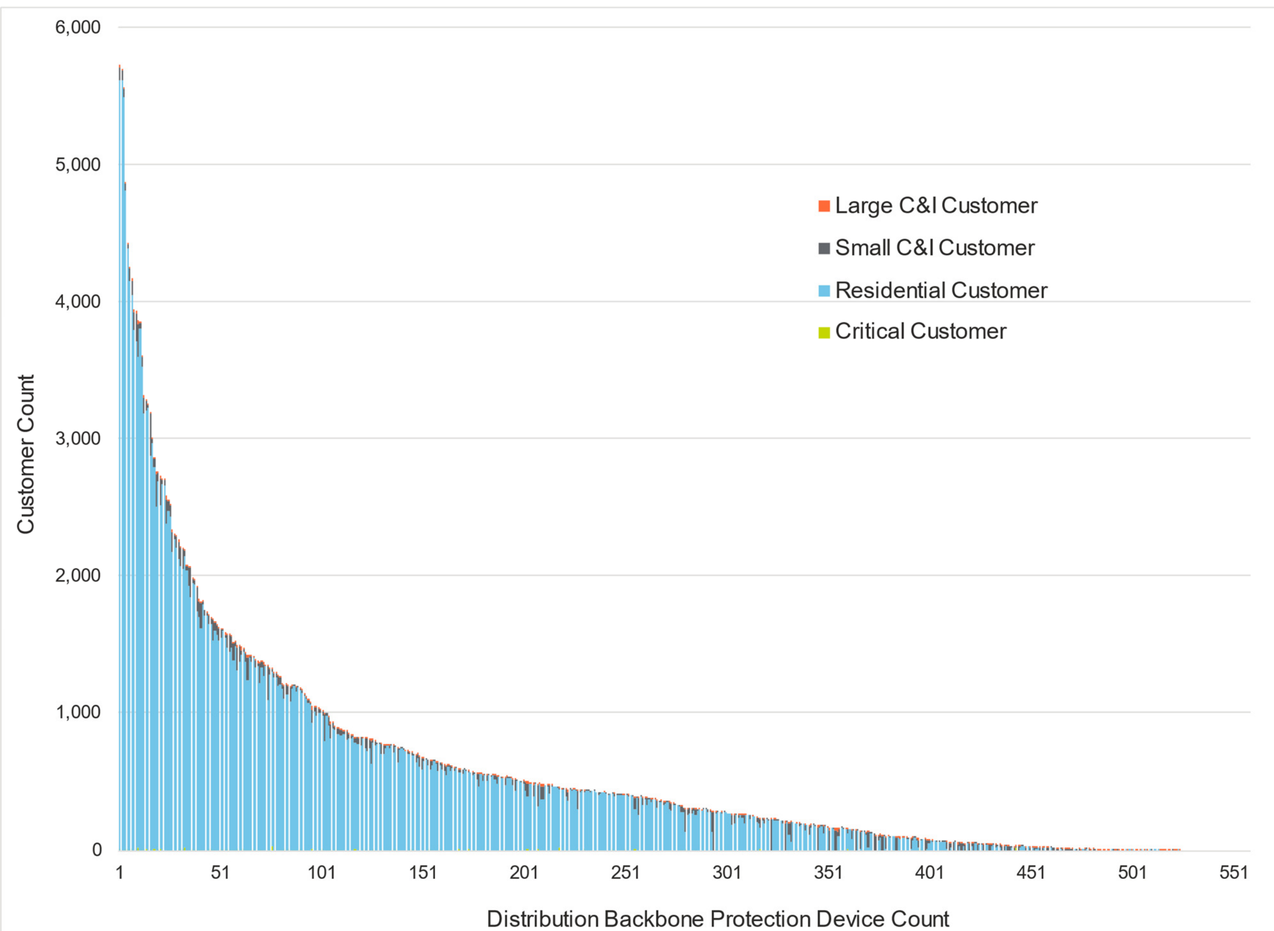


Figure 7-3: Customers by Lateral Protection Device

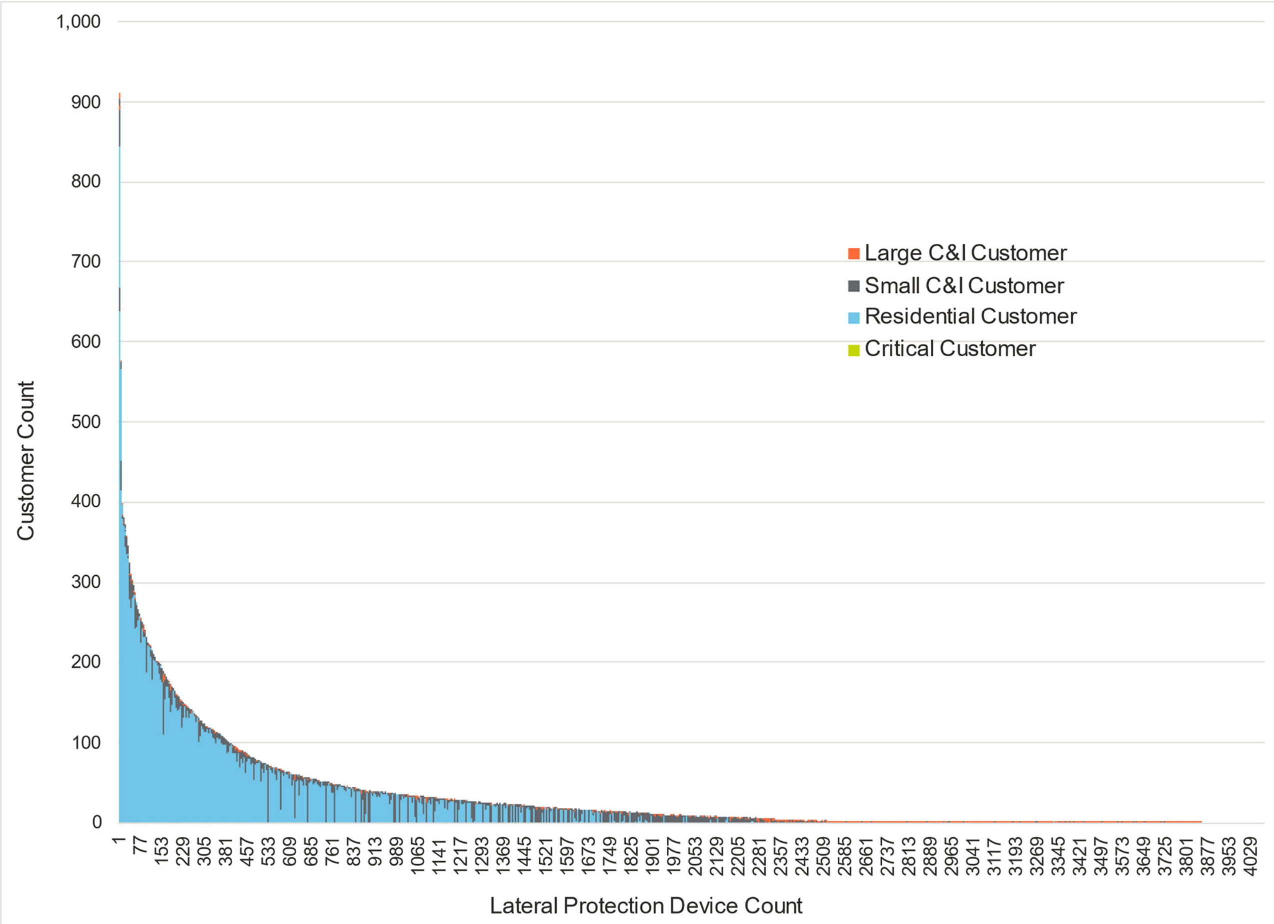
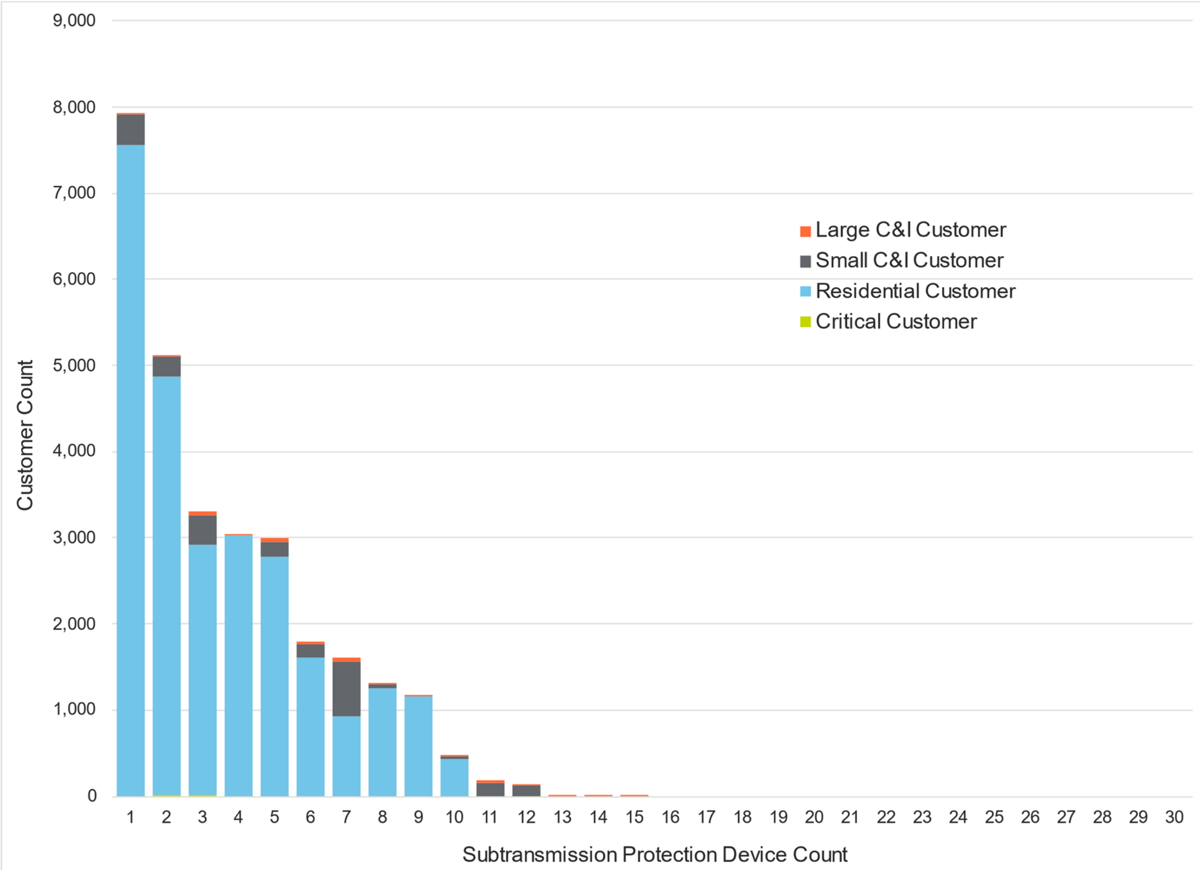


Figure 7-4: Customers by Subtransmission Protection Device

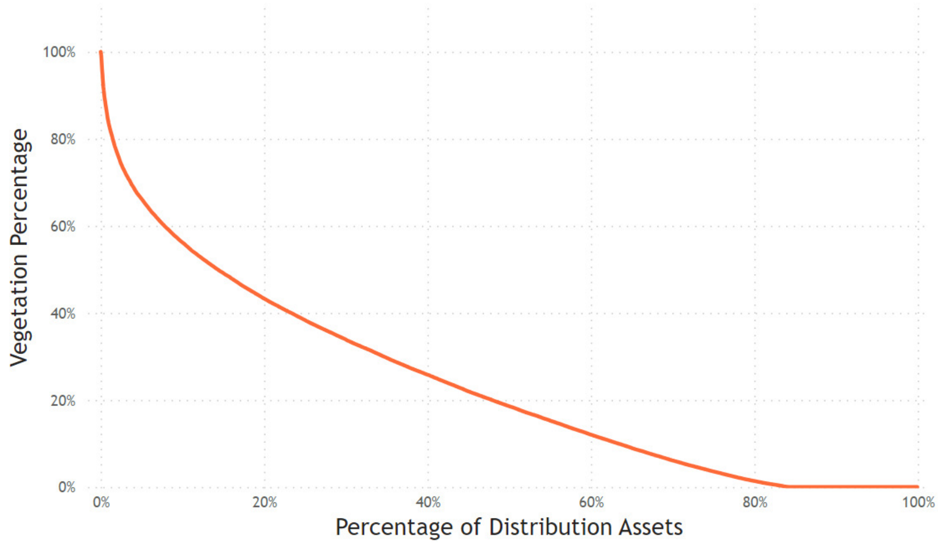


7.4 Vegetation Density Algorithm

The vegetation density for each overhead conductor is a core data set for identifying and prioritizing resilience investment for the circuit assets because vegetation, both inside and outside of the trim zone, blowing into conductor is a significant cause of outages during major storm events. The Resilience Investment Model calculates the vegetation density around each distribution overhead conductor. The model utilizes satellite tree canopy data to calculate the percentage of vegetation within the entire Hydro Ottawa system. The ± 6 meters on either side of the conductor is indicative of the vegetation density on the system from a major storm perspective. For each span of conductor (approximately 54,466) a vegetation density is assigned based on the vegetation density surrounding the conductor. This information is used to identify the portions of the system most likely to have an outage for each type of storm.

Figure 7-5 shows the range of vegetation density for OH Primary. The figure ranks the conductors from highest to lowest level of vegetation density. As shown in the figure, approximately 20 percent of the conductor spans (not weighted by length) for OH Primary have near zero tree canopy coverage, while approximately 60 to 70 percent have some level of coverage all the way up to 90 percent coverage.

Figure 7-5: Vegetation Density on Hydro Ottawa Primary Conductor



7.5 Age

As poles age, they lose some of their original design strength. Therefore, aged poles (all else equal) will fail at lower dynamic load levels than poles with their original design strength. The Resilience Investment Model utilizes 1898 & Co.'s asset management solution, AssetLens Solutions, to estimate the age based LOF for each wood pole and structure. 1898 & Co.'s AssetLens Solutions utilizes industry standard survivor curves with an asset class expected average service life and the asset's age to estimate the age based LOF over the next 10 years.

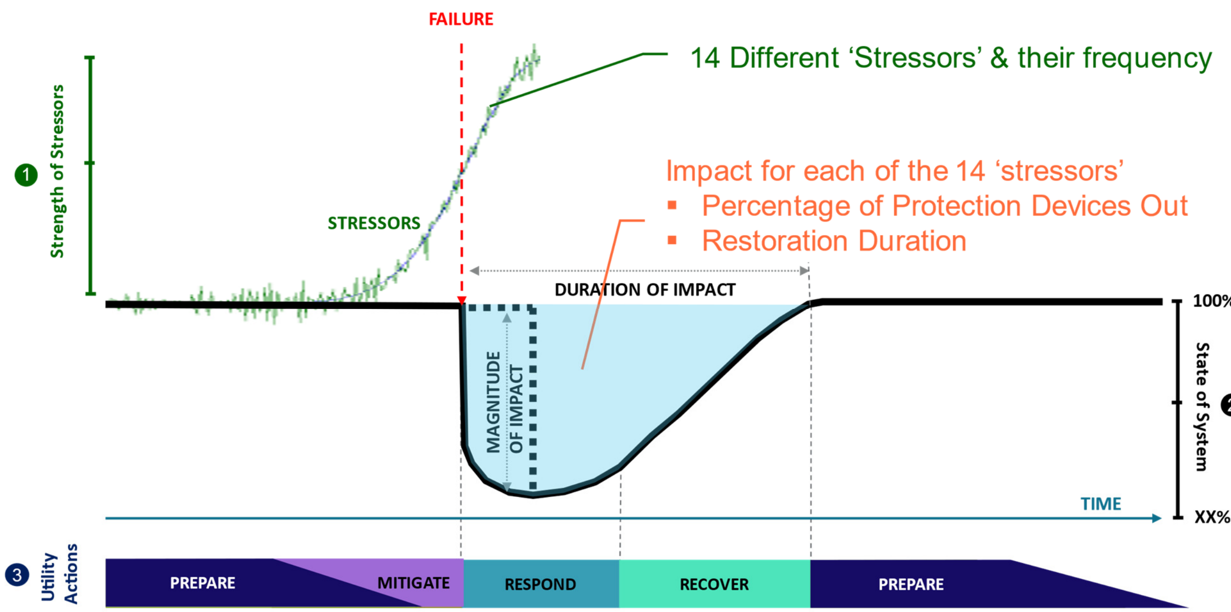
7.6 Accessibility

The accessibility of an asset has an impact on the duration of the outage and the cost to restore that part of the system. Rear lot structures take much longer to restore and cost more to restore than front lot structures. To take differences in accessibility into account, the Resilience Investment Model performs a geospatial analysis of each structure against a data set of roads. Structures within a certain distance of the road were designated as having roadside access; others were designated as in the deep right-of-way (ROW). This designation was used when calculating restoration and resilience project costs in the Resilience Investment Model. Approximately 73 percent of the Hydro Ottawa structures have road access while 27 percent are in the deep right-of-way.

8.0 MAJOR EVENT ('STRESSORS') DATABASE

The first component of the Resilience Investment Model is the Major Storms Event Database. The database includes the probabilities for each of the events as well as range of impacts to the distribution system while also outlining the duration and customers impacted. Figure 8-1 shows the Major Event Database within the Resilience Framework. The database outlines from a top-down perspective the type of events that impact the grid, their frequency, and high-level impact.

Figure 8-1: Resilience Framework & Major Events Database



This section describes the data sources and approach used to develop the database. Since the benefits of resilience projects are directly related to the frequency and impact of major storm events, the resilience-based planning approach starts with developing the range and frequency of storm types that could impact Hydro Ottawa's service area.

8.1 Event Database Evaluation

1898 & Co. reviewed several event data sources to determine the range of major events and the future frequency of events to impact the Hydro Ottawa service territory.

8.1.1 Event Database Review

The National Oceanic and Atmospheric Administration (NOAA) includes a database of major named-storm events over the past 170 years, beginning in 1852. The database includes Category 1 through 5 hurricanes, Tropical Storms, and Tropical Depressions. This database was mined to evaluate the different types and frequency of major storms to impact the Hydro Ottawa service area.

NOAA also includes a database of non-named major storm events over the past 26 years, beginning in 1996. The database includes the rain, wind and winter types of storm types organized by high-level and low-level types. Unlike the hurricane data that reports storm paths, these events are recorded at the county or sub-county level. 1898 & Co. mined this data for Saint Lawrence County in New York which was very close to the Hydro Ottawa service territory.

Additional relevant information is an update to the "Distribution System Climate Risk and Vulnerability Assessment and Climate Change Adaptation Plan, 2019". Hydro Ottawa retained Stantec Consulting Ltd. (Stantec) to provide an independent third party assessment to better understand system risk posed by weather events. Within the report forecasts were developed based on both historical frequencies and also proposed climate change forecasts. This provides a basis for helping to develop a resilience strategy for two different risk tolerance levels. One with a 50 year forecast based on historical frequencies and one based on an independent climate change forecast. This can be helpful information to discern the appropriate level of investment as part of a resilience plan to appropriately mitigate resilience risks associated with weather events. 1898 & Co. utilized the study forecasts to understand storm types and frequencies that have the largest impact on the Hydro Ottawa service territory.

Hydro Ottawa's Outage database characterizes some outages as a Major Event Day (MED). The database also includes the duration, cause, date, and customer impact for each outage listed. 1898 & Co. mined this data for frequency and impact of major event days that impacted the Hydro Ottawa service territory.

8.1.2 Event Database Considerations and Selection

1898 & Co reviewed multiple weather event data sources as part of the evaluation. Each data set contained unique information pertaining to the frequency and strength of various weather events. However, after reviewing NOAA major named storms, non-named events, and the "Distribution System Climate Risk and Vulnerability Assessment and Climate Change Adaptation Plan", 1898 & Co. determined the weather forecasts contained in the study provided the best basis for evaluating the business case for converting overhead sub-transmission and distribution lines to underground. While NOAA provided some regional insights, the data was not specific for Ottawa as the focus is generally contained to the United States. In contrast the "Distribution System Climate Risk and Vulnerability Assessment and Climate Change Adaptation Plan" was commissioned by Hydro Ottawa and specific to Hydro Ottawa' service territory. Therefore, the alignment to the Hydro Ottawa outage data was better than other event data sources.

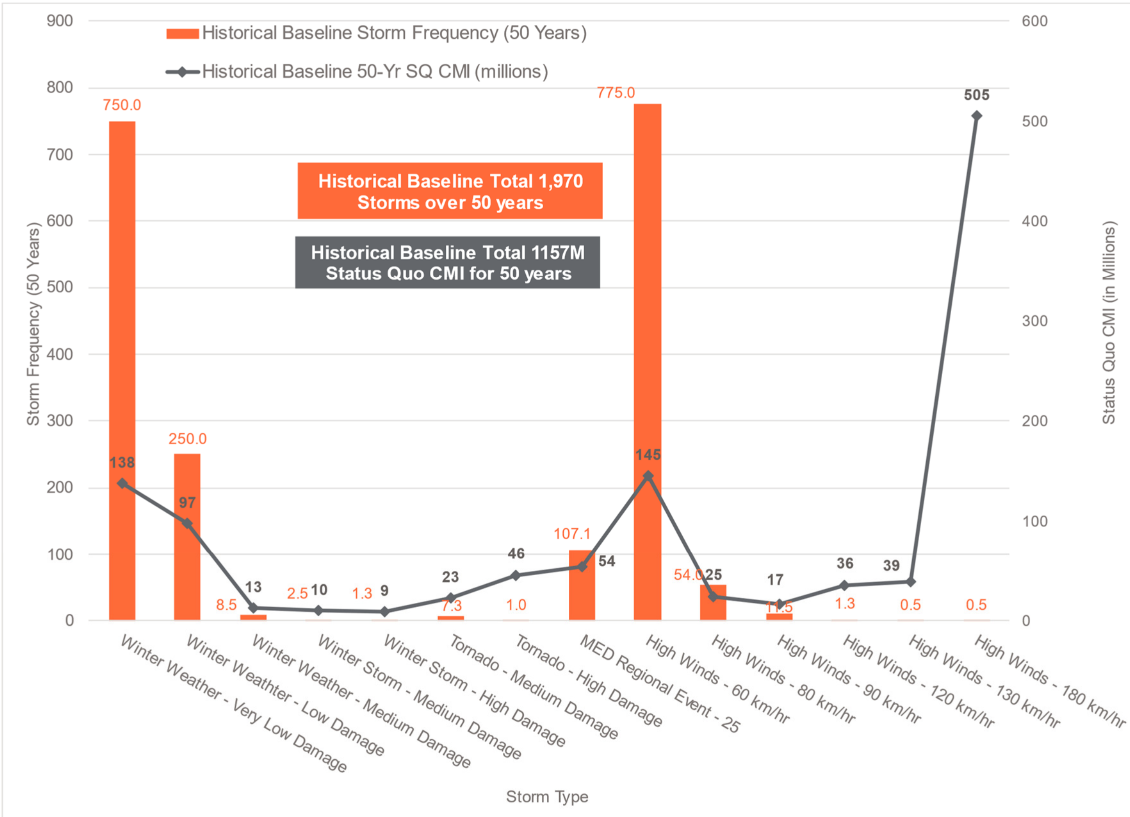
8.2 Major Event Forecast

One of the critical elements of the Major Event Database is the frequency and severity of the storms' impact on the system. As outlined in Section 8.1 the basis for frequency and severity comes from the "Distribution System Climate Risk and Vulnerability Assessment and Climate Change Adaptation Plan, 2019". 1898 & Co. then did analysis for both the baseline historical and climate change forecasted frequencies in the evaluation.

8.2.1 Baseline Historical

Historical frequencies were put together by Stantec using external data sources as outlined in the "Distribution System Climate Risk and Vulnerability Assessment and Climate Change Adaptation Plan, 2019". Figure 8-2 shows the frequency forecasted for each storm type over the next 50 years in orange and the status quo (SQ) CMI value for each storm type over the next 50 years in grey that was used in the Resilience Investment Model. The figure shows the storm with the highest CMI impact, High Winds – 180 km/hr, has some of the lowest frequencies in the next 50 years with a 50% chance of that size storm hitting in the next 50 years. While this is a high impact low probability event, 2022 demonstrated that the threat is credible and real.

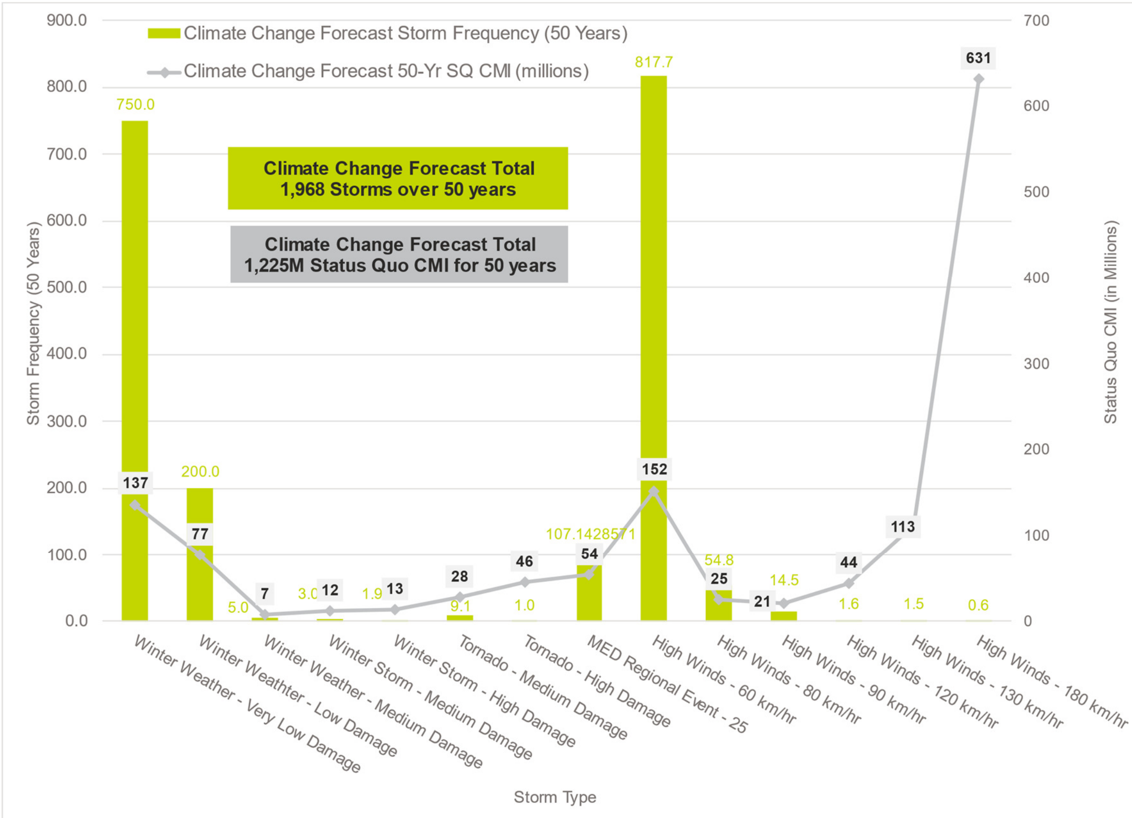
Figure 8-2: Baseline Historical 50 Year Storm Frequency and SQ CMI



8.2.2 Climate Change Forecast

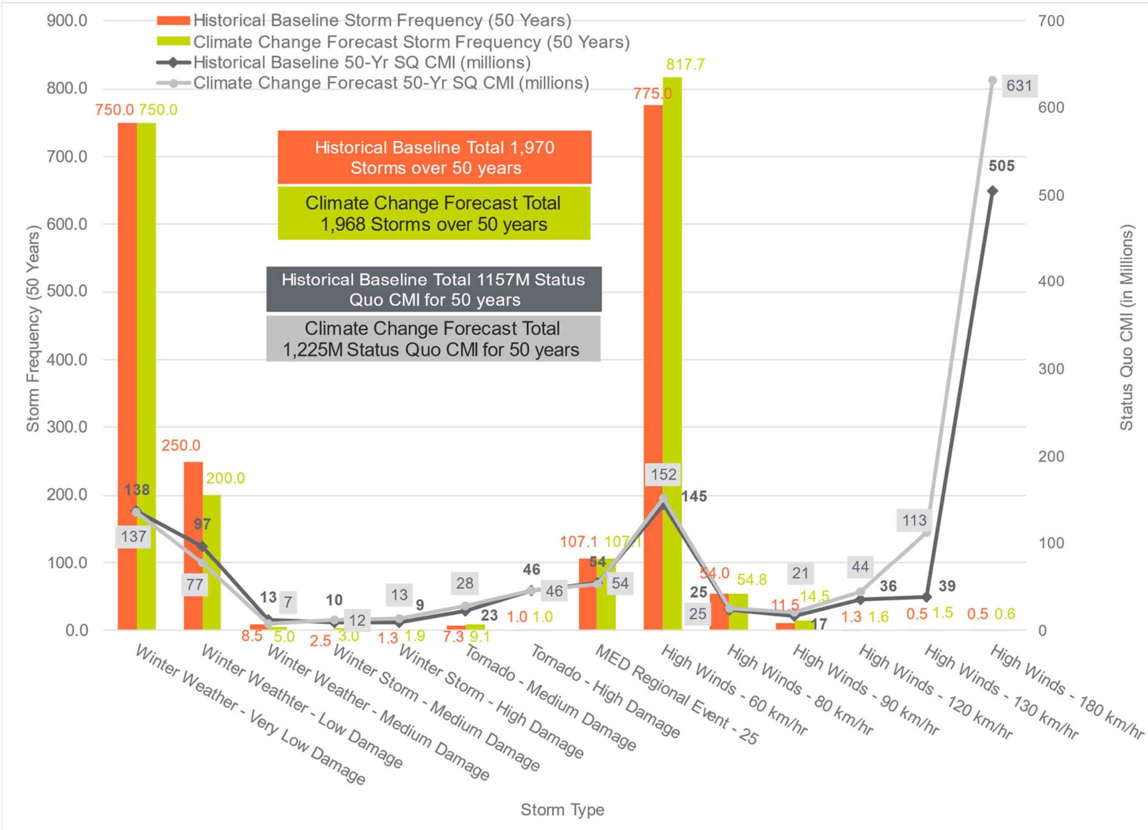
Climate change forecasted frequencies were put together by Stantec using external data sources as outlined in the "Distribution System Climate Risk and Vulnerability Assessment and Climate Change Adaptation Plan, 2019". Figure 8-3, similar to Figure 8-2 for the baseline historical frequencies, shows the frequency of each storm type over the next 50 years in green and the status quo CMI value for each storm type over the next 50 years in light grey that was used in the Resilience Investment Model.

Figure 8-3: Climate Forecast 50 Year Storm Frequency and SQ CMI



The figure shows a very similar trend and outcome as seen in Figure 8-2 with the historical data. A comparison of the two forecasts is shown in Figure 8-4. In Figure 8-4 the estimated storms to hit in the next 50 years according to historical baseline is 1,970. According to the climate change forecast storm frequency, it is estimated to be less with 1,968 as the winter weather storms are on a slight downward trend. However, there is an estimated 68M CMI increase in the climate change forecast as higher impact storms are forecasted to be more frequent.

Figure 8-4: Baseline Historical 50 Year Storm Frequency and SQ CMI



8.3 Hardening Investment Types

In developing the types of hardening and resilience investments to include in the evaluation, 1898 & Co. leveraged the following:

- Current state of the Hydro Ottawa system and types of impact to customers based on operational experience.
- Balance of investment strategies to improve system resilience: resistance, absorptive capacity, and recoverability (see Section 4.3). Additionally, how various investment types would provide benefits on 'blue-sky' days.
- Types of events to impact the Hydro Ottawa service territory (see Section 8.0).
- Types of resilience investments other utilities within North America are making (see Section 5.0).
- Feedback from utilities on recent evaluation of recent major events.

Based on these items, Hydro Ottawa and 1898 & Co. identified the following investment types to include in the evaluation:

- Trunk / Backbone Hardening - converting overhead to underground. OH undergrounding for each protection zone is based on the level of vegetation density around the infrastructure.
- Lateral or Tap – converting overhead to underground. OH rebuilding or undergrounding for each protection zone is based on the level of vegetation density around the infrastructure and if the infrastructure has street access.
- Sub-Transmission Hardening - converting overhead to underground.

8.4 Major Events Database Overview

Table 8-1 shows the Major Events Database included within the Resilience Investment Model. The database includes 14 event types, the expected future annual frequency, and the impact of the event. The impact of the event is characterized by the percent of the sub-transmission, backbone, and lateral protection devices out and the duration to restore those devices. The database is sorted by the highest percentage of laterals protection devices out. It is based on the data sources and assessment described above.

Table 8-1: Major Events Database

Event No.	Major Event Type (Impact Level & Distance)	Annual Future Frequency (Historical Baseline)	Annual Future Frequency (Climate Forecast)	Percent of Protection Devices Out		Outage Duration (Minutes)	
				Backbone / Sub-T	Lateral	Backbone / Sub-T	Lateral
1	High Winds - 180 km/hr	0.01	0.01	28.39%	49.69%	13,500	17,190
2	High Winds - 130 km/hr	0.01	0.03	4.87%	9.30%	1,600	3,300
3	Tornado - High Damage	0.02	0.02	3.04%	5.17%	1,350	2,750
4	High Winds - 120 km/hr	0.03	0.03	1.81%	3.88%	1,350	2,750
5	Winter Storm - High Damage	0.03	0.04	0.23%	1.94%	1,350	2,750
6	Winter Storm - Medium Damage	0.05	0.06	0.13%	1.29%	1,400	3,000
7	High Winds - 90 km/hr	0.23	0.29	0.13%	1.29%	750	1,200
8	Winter Weather - Medium Damage	0.17	0.10	0.13%	1.29%	830	1,190
9	Tornado - Medium Damage	0.15	0.18	0.13%	1.29%	1,200	1,700
10	MED Regional Event - 25	2.00	2.00	0.06%	0.32%	830	1,190
11	High Winds - 80 km/hr	1.08	1.10	0.06%	0.26%	830	1,190
12	Winter Weather - Low Damage	5.00	4.00	0.06%	0.19%	500	1,400
13	High Winds - 60 km/hr	15.50	16.35	0.03%	0.13%	207	1,350
14	Winter Weather - Very Low Damage	15.00	15.00	0.03%	0.13%	165	1,315

9.0 INVESTMENT IDENTIFICATION & PRIORITIZATION MODULE

The Investment Identification and Prioritization Module develops the list of potential resilience projects, their costs, then prioritizes them based on the benefit cost ratio. The evaluation is comprehensive in evaluating nearly the entire system. Hardening investments are defined based on a customer-centric perspective at the protection zone level. The module also estimates the costs for each of the projects. The prioritization of each project is based on their benefit cost ratio. The results of the module are:

- Project scope and cost
  - Original pole count
  - Length of under grounding (km)
  - Estimated overhead to underground project cost (Can 2023$)
- Project Benefits
  - 50 year CMI reduction
  - Monetized CMI (50 year PV)
  - Restoration savings (50 year PV)

9.1 Evaluated System for Resilience Investment

The Resilience Investment Model is comprehensive in that it evaluates nearly all of Hydro Ottawa's overhead distribution system. Table 9-1 shows the asset types and counts included in the Resilience Investment Model.

Table 9-1: Hydro Ottawa Asset Base Modeled

Asset Type	Units	Value
Sub-Transmission Circuits	[count]	72
Poles / Structures	[count]	3,387
Conductor Length	[kilometers]	312.5
Distribution Circuits (OH)	[count]	203
Feeder Poles	[count]	20,916
Lateral Poles	[count]	14,577
Feeder OH Primary	[kilometers]	1,178
Lateral OH Primary	[kilometers]	644

9.1.1 Distribution Projects Identification

For distribution projects, assets were grouped by their most upstream protection device, which was either a breaker, recloser, or a fuse. This approach focuses on reducing customer outages. The objective is to harden each asset that could fail and cause a customer outage. Since only one asset needs to fail downstream of a protection device to cause a customer outage, failure to harden all the necessary assets still leaves vulnerable components that could potentially fail in an event and result in an outage. Rolling assets into projects at the protection device level allows for hardening of all vulnerable components in the circuit and for capturing the full benefit for customers including avoidance or mitigation of an outage.

For distribution circuit projects (laterals and feeders), undergrounding was the hardening option considered. Overhead hardening rebuilds are generally lower cost than undergrounding projects, but they generally provide fewer resilience benefits than undergrounding since the hardened overhead infrastructure is still exposed to wind and debris from vegetation and other materials.

9.1.2 Sub-Transmission Project Identification

The 44 kV and 13 kV sub-transmission circuits primarily supply distribution substations and large customers. Sub-Transmission circuits behave more like transmission than distribution since they are often looped and built with redundancy. However, very damaging events like very high damage thunderstorms and named storms cause enough damage to several circuits leaving 10,000+ customers without power. Due to the looped nature of the sub-transmission system, rebuilding smaller protection zones is not an option, and the entire sub-transmission circuit must be considered for resilience hardening.

9.1.3 Potential Resilience Projects Evaluated

Table 9-2 contains a list of potential resilience projects based on the methodology outlined above. Section 9.3 outlines the approach to selecting the resilience projects that provide the most value to customers from a perspective of reducing both restoration cost and CMI.

Table 9-2: Potential Resilience Projects Included in Evaluation

Count	Program	Project Count
1	Backbone OH to UG	324
2	Lateral OH to UG	1,338
3	Sub-Transmission OH to UG	81
	Total	1,743

For the resilience evaluation, 1898 & Co. evaluated each protection zone as independent from others. In other words, 1898 & Co. assumed each electrically connected protection zone was not physically connected to another protection zone on shared structures. Given the complexities of shared infrastructure within the GIS models, this simplifying assumption was made.

9.2 Project Cost

Project costs were estimated for the projects in the Resilience Investment Model. Project costs were estimated using the asset level data within the Resilience Investment Model to estimate scope (length and project type: lateral, backbone, sub-transmission) and then multiplying by unit cost estimates to calculate the project costs. See Table 9-3 for the estimates used per kilometer for lateral, backbone, and sub-transmission.

For each project, Hydro Ottawa's GIS data was used to determine the length of overhead conductor to be converted to underground, and additional GIS analysis determined adjustments that were made for downtown circuits and protection zones that were in the deep right of way.

Table 9-3: Hydro Ottawa Unit Costs

Project Type	Voltage	Cost per Kilometer
Lateral	All voltages	$718,000
Backbone	8kV, 12kV, and 28kV	$1,259,000
Backbone	13kV	$935,000
Backbone	13kv - Downtown	$1,485,000
Sub-Transmission	44kV	$1,459,000

9.3 Project Prioritization

For each of the projects outlined in Table 9-2, 1898 & Co. estimated a 50 year present value benefit. The benefits are based on a 50 year forecast of both likelihood of failure (LOF) and consequence of failure (COF) for each of the storm types. The calculation is done at the potential resilience project level, estimating the likelihood and consequence of failure of the existing infrastructure in the project during an event.

9.3.1 Likelihood of Failure (LOF)

Based on the event types and resilience upgrades 1898 & Co. developed a framework to estimate each asset's likelihood of failing during the events. The LOF values are based on the drivers of failure. Often the wind speeds can cause vegetation outside the typical trim zone to come into contact with the overhead lines. For more minor events, the consequence is simply vegetation coming into contact with electrical lines causing the protection device to lock out. Very little infrastructure may need to be replaced. For more major events, the dynamic loading of the vegetation in the lines and wind against the wires and structure can cause the structure top or structure to fail. These failures can be costly to fix. Compromised structure or older assets are more likely to fail given their internal strength is weakened.

Since vegetation and structure age / condition are the main drivers of what would cause infrastructure to fail given an event, the overhead infrastructure LOF is based on the vegetation density around the infrastructure and the age based remaining life of the asset. As described in Section 7.4, 1898 & Co estimated the vegetation density for each span of conductor in Hydro Ottawa's system. Additionally, as described in Section 7.5, 1898 & Co. estimated the age based LOF for each structure based on end-of-life curve and expected remaining life. The combination of these factors is the LOF for each overhead asset.

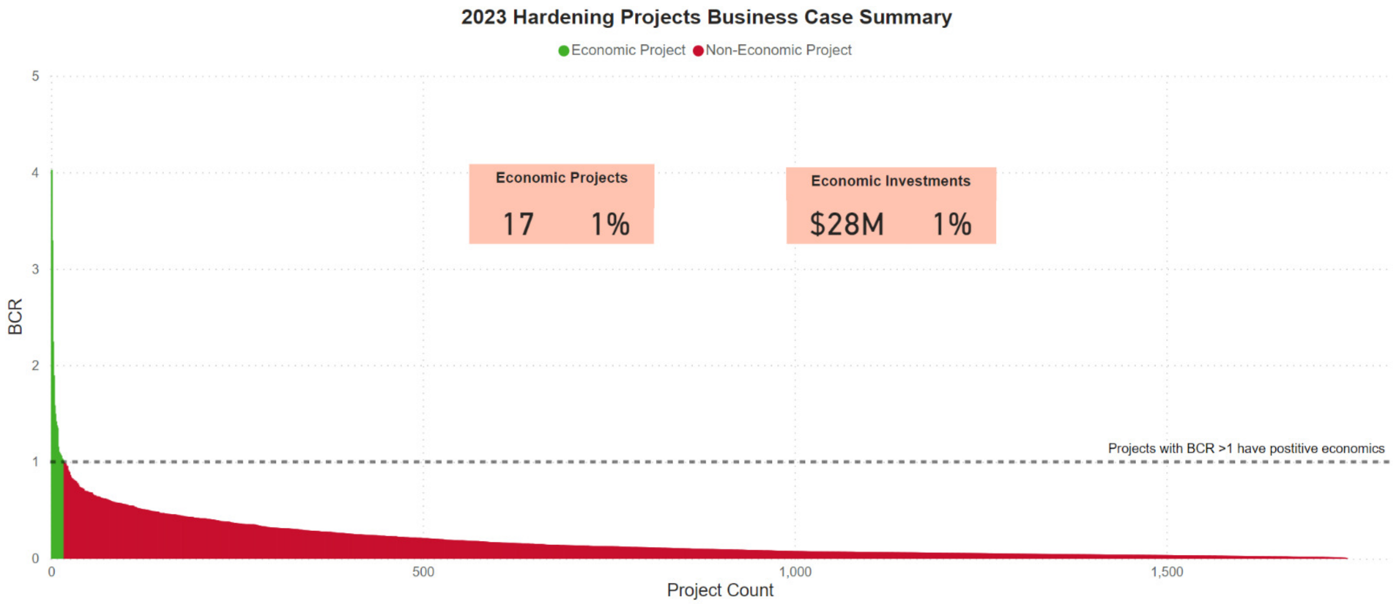
9.3.2 Consequence of Failure (COF)

The consequence of failure for each overhead asset is based on their downstream customers. As described in Section 7.3, 1898 & Co. linked each asset to their downstream customer count and type. The consequence of each asset is based on the monetization of the outage duration based on the customer outage from the DOE ICE Calculator (see Section 6.2) for the customers impacted should that asset fail.

9.3.3 Resilience Prioritization

The resilience projects are prioritized based on the benefit cost ratio of each potential project. Figure 9-1 shows the resulting project resilience ranking, BCR per project cost, for all potential projects included in the evaluation with a historical baseline storm forecast.

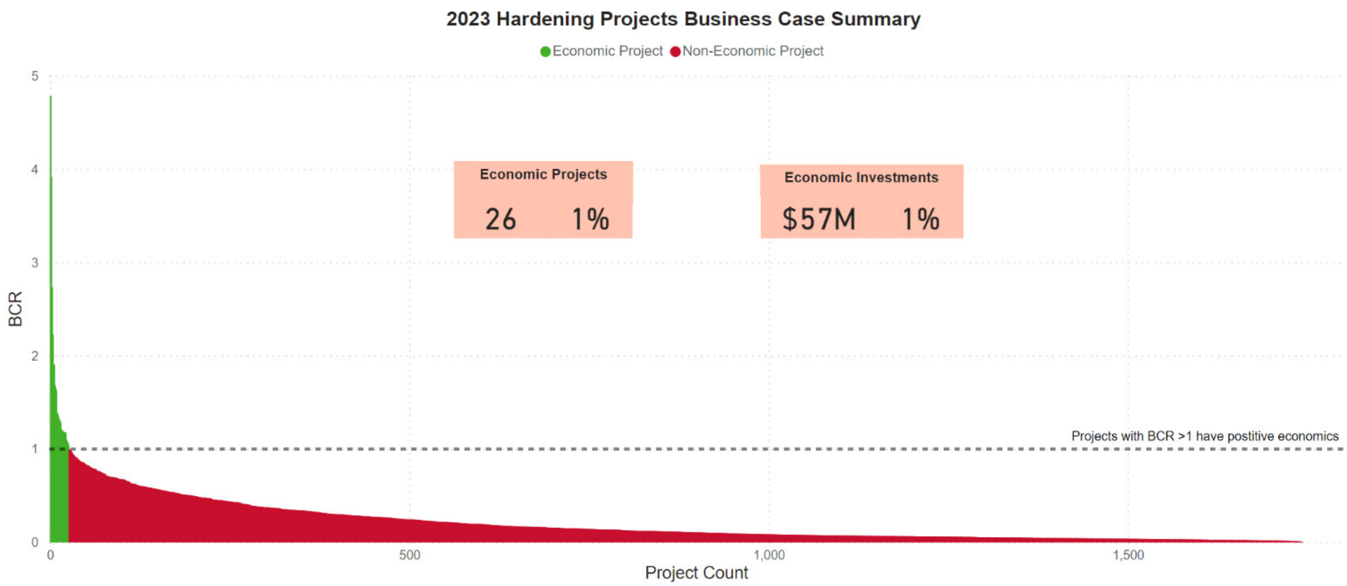
Figure 9-1: **Project Resilience Ranking by BCR for Historical Baseline Storm Forecast**



As the figure shows approximately 1 percent of the projects evaluated show a resilience benefit cost ratio value of more than one. This metric is used to identify the most vulnerable parts of the system that yield the greatest return per dollar spent.

Figure 9-2 shows the resulting project resilience ranking, BCR per project cost, for all potential projects included in the evaluation with climate change storm forecast.

Figure 9-2: **Project Resilience Ranking by BCR for Climate Change Forecast**



As the figure shows approximately 1 percent of the projects evaluated show a resilience benefit cost ratio value of more than one. This metric is used to identify the most vulnerable parts of the system that yield the greatest return per dollar spent.

These results are based on a 60 year time horizon with 2.0% escalation and a discount rate of 6.0%. The business case for each project is a sum of the avoided reactive costs and avoided monetized customer outages for each of the events within the Major Events Database. The output of the Resilience Business Case Module is:

- Resilience Business Case for highest resilience improvement projects
  - Project Cost and High Level Scope
  - Life-Cycle Net Present Value (NPV) Benefits
  - Benefit to Cost Ratio (BCR)

10.0 RESULTS & CONCLUSIONS

Hydro Ottawa and 1898 & Co. utilized a resilience-based planning approach to identify, prioritize, and justify resilience investments in Hydro Ottawa's distribution system. Project benefits are shown in terms of the:

1. Decrease in the Storm Restoration Costs
2. Decrease in the customers impacted and the duration of the overall outage, calculated as CMI.

Additionally, the results are presented assuming monetization of the CMI using the DOE ICE Calculator, modified for resilience. The ICE Calculator is discussed in Section 6.2. The monetization of the CMI in conjunction with the storm restoration costs allows for the calculation of a benefit cost ratio for each potential overhead to underground project.

10.1 Resilience Business Case Results for Beneficial Projects

The Resilience Investment Model calculates the Resilience Benefit Cost Ratio for each potential overhead to underground project. The Resilience BCR is the sum of the present value of avoided restoration costs and the present value of the monetized avoided customer outages divided by the project cost. Table 10-1 shows the summary business case results for resilience investments within Hydro Ottawa's system with a resilience benefit to cost ratio greater than or equal to 1. The table shows:

- There is significant opportunity to improve the resilience of Hydro Ottawa's grid for the benefit of customers with strategic projects that have quantified benefits that outweigh the costs.
  - Approximately $27.5 million in total investment when using historical baseline forecasts and approximately $57.3 million in total investment when using climate change forecasts
  - A range between 12.6 – 28.4 kilometers of resilience overhead to underground investment, depending on the scenario being evaluated.

- For both the historical forecast scenario and climate change forecast, over 15 potential projects were identified where benefits outweigh their costs, note 1898 & Co. organized Hydro Ottawa system into over a thousand projects that were evaluated within the Resilience Investment Model.

- Each of the programs have robust business cases results with benefit to cost ratios in the range of 1.0 to 4.03 with an average of 1.60 based on the historical forecast scenario. Similarly, for the climate change forecast scenario, the benefit to cost ratios range is 1.0 to 4.78 with an average of 1.66.
- Most of the benefits come from the monetized avoided customer outages benefit. This is an alignment for the main case for resilience investment, the integration of the modern customer and integrated society and major events.
- Avoided restoration costs cover approximately 6 percent of the resilience investment level, the remaining benefit stream to cover the resilience investment is the monetization of customer outages.

It is expected that any initial resilience plan budget would be based on a subset of the provided list. Each project was evaluated based on appropriate planning assumptions, however, upon detailed review and walkdowns, Hydro Ottawa may discover technical challenges that dramatically impact the business case of a project. For instance, Hydro Ottawa may discover that underground rock conditions are much worse than anticipated or easement costs or other costs will be much higher than planned. These discovered challenges would cause the project cost to increase significantly. In this situation, Hydro Ottawa would swap out the project for another from the provided Excel project list. It should be noted that the projects in the table can be filtered such that the quantified benefits are equal to or greater than the costs (BCR ≥ 1).

Table 10-1: Historical Baseline Resilience Business Case Summary Results

Program	Project Count	Length (km)	Avoided $CMI Benefit ($000)	Avoided Restoration Cost Benefit ($000)	Total Avoided Cost Benefit ($000)	Resilience Investment ($000)	Benefit to Cost Ratio (BCR)
Backbone OH to UG	3	3.34	$7.6	$0.27	$7.6	$6.6	1.15
Lateral OH to UG	13	6.82	$26.7	$1.9	$28.6	$16.4	1.75
Sub-Transmission OH to UG	1	2.47	$4.7	$0.3	$5.0	$4.6	1.10
Total	**17**	**12.64**	**$38.7**	**$2.5**	**$41.2**	**$27.5**	**1.50**

Table 10-2: Climate Change Forecast Resilience Business Case Summary Results

Program	Project Count	Length (km)	Avoided $CMI Benefit ($000)	Avoided Restoration Cost Benefit ($000)	Total Avoided Cost Benefit ($000)	Resilience Investment ($000)	Benefit to Cost Ratio (BCR)
Backbone OH to UG	3	3.34	$9.2	$0.27	$9.5	$6.6	1.43
Lateral OH to UG	18	8.93	$37.9	$2.3	$40.2	$22.0	1.83
Sub-Transmission OH to UG	5	16.11	$31.8	$3.1	$34.9	$28.7	1.22
Total	**26**	**28.38**	**$78.9**	**$5.7**	**$84.6**	**$57.3**	**1.48**

10.2 Conclusions

The following include the conclusions of this resilience evaluation for Hydro Ottawa:

- The resilience of the grid is becoming increasingly important. The case for selective overhead to underground resilience investment is sound for Hydro Ottawa; resilience is at the cross section of major events, the modern customer and integrated society. The impact of major events to today's customer and society are much greater than in the past. Much of this is due to:
    - Number of critical customers
    - Number of people working from home
    - Aging in place
    - Electrification and Decarbonization
    - Integrated society

  Major grid disruptions due to major events now cause real economic harm to customers, increases customer stress levels, and puts societies' most vulnerable at risk to life. This is evident from recent events in 2022. Proactive investment today and over the next decade is needed to mitigate the impact of these events. With the expectation of an even more integrated and connected society with electrification and decarbonization causing greater reliance on electricity in the Ottawa area, the resilience of the grid becomes increasingly important. Additionally, the case for resilience effectively mitigates reactive costs and safety risks.
- There is opportunity to improve the resilience of Hydro Ottawa's grid for the benefit of customers over the long-term with strategic overhead to underground projects that have quantified benefits that outweigh the costs.
    - Approximately fifty million in total investment that will benefit customers.
    - Over Twelve km of resilience circuit investment.
    - 17-26 of potential beneficial overhead to underground projects.
- The development of a Resilience Investment Strategy using the Resilience Investment Model results provides confidence to Hydro Ottawa grid stakeholders. The model provides confidence for the following reasons:

- **Event-Based –** each project is evaluated against its event performance for 14 different weather events types that are based in the historical record and also climate forecasts with similar conclusions.
- **Asset and Root-Caused Focused –** each project includes the relationship to their underlying assets. Asset likelihood of failures are based on the assets age and surrounding vegetation.
- **Data-Centric** – the model utilizes Hydro Ottawa's GIS, OMS, CIS, distribution circuit models, and critical customer information.
- **Customer-Centric** – the model links each asset to the impacted customer count and type.
- **Granular -** the granularity at the asset and project levels allows Hydro Ottawa to invest in portions of the system that provide the most value to customers from both a restoration cost reduction and avoided CMI perspective.
- **Comprehensive -** The approach is comprehensive and evaluates nearly all of the assets on Hydro Ottawa's overhead distribution systems.
- **Business Case Foundations** - The output of the model is the life-cycle resilience benefit and benefit cost ratio in financial terms.
- **Consistency**: The model calculates benefits consistently for all potential projects.
- **Drives Prudency**: The assessment and modeling approach drives prudency for the comprehensive overhead to underground hardening evaluation on two main levels. First, the granularity of potential resilience projects allows Hydro Ottawa to target investment in the portions of the system that provide the most value to customers. Secondly, the customer-centric financial justification of project investments allows Hydro Ottawa to prioritize investments that provide significant customer 'bang for buck'.

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FINAL REPORT

HYDRO OTTAWA DECARBONIZATION STUDY

Prepared by Black & Veatch

PREPARED FOR

15 OCTOBER 2024

Disclaimer

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1.0 Executive Summary

1.1 REPORT BACKGROUND AND OBJECTIVES

In June 2021, the Canadian Net-Zero Emissions Accountability Act became law and codified the country's commitment to Net Zero Emissions by 2050 in alignment with the Paris Agreement. The City of Ottawa has made a similar commitment with interim emissions reductions targets in the near-, mid-, and long-term. These goals will have far-reaching implications for the energy sector, particularly for the infrastructure, assets, and systems of utilities.

Hydro Ottawa Limited (HOL), the primary electric distribution utility for the City of Ottawa, has prioritized and is embarking on an important initiative to evaluate the complex impacts of these decarbonization policies on their distribution system. HOL engaged with Black & Veatch to explore the implications of decarbonization initiatives and the relative impact of decarbonization-driven electrification on future load and the HOL distribution system. The results of this study are provided in this comprehensive narrative final report. While broader decarbonization-driven impacts are expected, this study specifically and intentionally does not explore changes in the electricity generation mix or downstream customer impacts.

More specifically, this study examines the changes in load curves resulting from decarbonization-driven electrification of buildings and transportation between 2024 and 2050. Decarbonization load projections, rough-order-of magnitude (ROM) capital costs, and insights from this study are provided to inform how Hydro Ottawa's distribution assets could change to serve these increasing and evolving load requirements.

This report provides a directional overview of when and where new infrastructure investment will be required, the forecasted impact of electrification on the resiliency of the HOL grid, and the role of non-wires solutions (NWS) to maintain reliability and resiliency of HOL-owned assets. This report summarizes the methodology and results of this study, including key policy drivers and uncertainties that should be considered in future-looking assessments. This study and results summarized herein were guided by the following objectives:

1. Evaluation and understanding of the main variables impacting electrification in the HOL service territory.
2. Evaluation of the impact of the future decarbonized load projections on the HOL distribution system.
3. Consideration of the NWS that may be leveraged in the short-, mid-, and long-term to defer traditional wires upgrades.
4. Development of directional ROM investments for the necessary NWS and traditional wires upgrades forecasted to maintain reliability on the HOL grid.

Decarbonization In Ottawa: Policy Context and Trends

Electrification is expected to dramatically increase across the globe as end-users, utilities, and corporations transition from carbon-intensive fuels such as oil, diesel, and natural gas to low carbon solutions. As interim decarbonization targets quickly approach, distribution utilities like HOL need to be prepared to fully plan for the dramatic increases of electricity needs on their system.

It is well documented that global temperatures are increasing, and Canada is no exception to this global increase. According to Canada's Changing Climate Report, Canada is warming at double the rate of the rest of the world.[1] The Canadian government has taken serious strides to ensure that their global emissions impact actively declines. As an example, the Canadian Net-Zero Emissions Accountability Act sets a legally binding target for Canada to achieve net-zero greenhouse gas emissions by 2050, which means that any remaining emissions would need to be balanced by removing an equivalent amount of emissions from the atmosphere. The Act also requires the Canadian government to set interim emissions reduction targets for 2030, 2035, and 2040, and to report on progress towards these targets every five years.[2]

Similarly, the Greenhouse Gas Pollution Pricing Act imposes a federal price on carbon pollution, incentivizing the adoption of low carbon energy sources and electrification.[3] The 2030 Emission Reduction Plan complements these efforts by promoting electric vehicle adoption and setting targets for zero-emission vehicle sales. Ottawa's Climate Change Master Plan further outlines strategies for emission reduction and resilience building. Together, these policies strive to expedite the transition to a low carbon economy, foster renewable energy uptake, and address the impacts of climate change in Ottawa and throughout Canada.

An increase in electricity demand across Canada and in Ottawa can further be expected in part due to the incentives outlined in the 2030 Emission Reduction Plan. This plan aims to facilitate the transition to electric vehicles by allocating $900 million CAD towards the installation of an additional 50,000 Zero-Emission Vehicle chargers nationwide.[2] Moreover, the Canadian government is providing $1.7 billion CAD to extend incentives for the Zero-Emission Vehicles (iZEV) Program, making it more affordable and convenient for Canadians to purchase and operate new electric light-duty vehicles.[2]

The goal of the iZEV funding is to ensure that, by 2026, at least 20% of new light-duty vehicle sales will be zero-emission vehicles, with at least 60% by 2030, and 100% by 2035. It is important to note that the medium- and heavy-duty vehicle (MHDV) market will also be affected, as the Government intends to develop an MHDV ZEV regulation requiring 100% of MHDV sales to be ZEVs by 2040 for a subset of vehicle types.[2]

The City of Ottawa, in addition to aligning with the required Canadian Net-Zero Emissions Accountability Act, has also aligned with the Intergovernmental Panel on Climate Change (IPCC). Through new short-, mid-, and long-term targets, the Canadian capital intends to reduce both community and corporate

[1] Canada Changing Climate Report, 2019.
[2] Canada's 2030 Emissions Reduction Plan targets reducing emissions by 40-45% from 2005 levels. The 2030 plan was public in March of 2022, building on the existing 2020 climate plan, and the Pan-Canadian Framework from 2016.
[3] Greenhouse Gas Pollution Pricing Act, 2019.

emissions by 100% by 2050 and 2040, respectively.[4] This decarbonization of buildings and vehicles will undoubtedly impact the demand on HOL's distribution grid, potentially necessitating upgrades or even new wire networks to supply power to locations across the city.

In continuation of the plans and investment areas stated in the larger 2021 Canadian Net-Zero Emissions Accountability Act and the 2030 Emission Reduction Plan, the City of Ottawa's Climate Change Master Plan lays out the city's objectives for both its corporate and residential residents. The City of Ottawa's Climate Change Master Plan includes eight priority action areas to achieve its ambitious net-zero emissions target. These areas will impact the energy market, reliability, resiliency, and electrification within Ottawa. The plan includes initiatives such as implementing a Community Energy Transition Strategy, applying a climate lens to asset management and capital projects, exploring carbon sequestration methods, and developing a governance framework for tackling climate change.

These strategies and initiatives have already resulted in significant energy savings, with conservation initiatives creating an estimated cumulative annual utility savings of approximately 5.9 million kWh of electricity, 297,909 m^3 of natural gas, and 48,662 m^3 of water.[4] As the city continues to implement these strategies and invest in energy-saving projects, it will help reduce the total load of carbon emissions generated by current development, leading to a more sustainable and electrified future.

Canada's policies and regulations demonstrate a proactive approach to combating climate change and promoting sustainability. The Canadian Net-Zero Emissions Accountability Act, Greenhouse Gas Pollution Pricing Act, and 2030 Emission Reduction Plan in particular incentivize decarbonization and renewable energy sources. These legislative frameworks, coupled with Ottawa's Climate Change Master Plan, outline a comprehensive approach to address climate challenges, promote electrification, and enhance resilience.

By embracing these measures, critical stakeholders like HOL can adapt to evolving regulatory landscapes through forward-looking decarbonization studies like this one to ensure their organizations are prepared for the expected shifts in demand from decarbonization-driven electrification.

1.2 SUMMARY METHODOLOGY & APPROACH

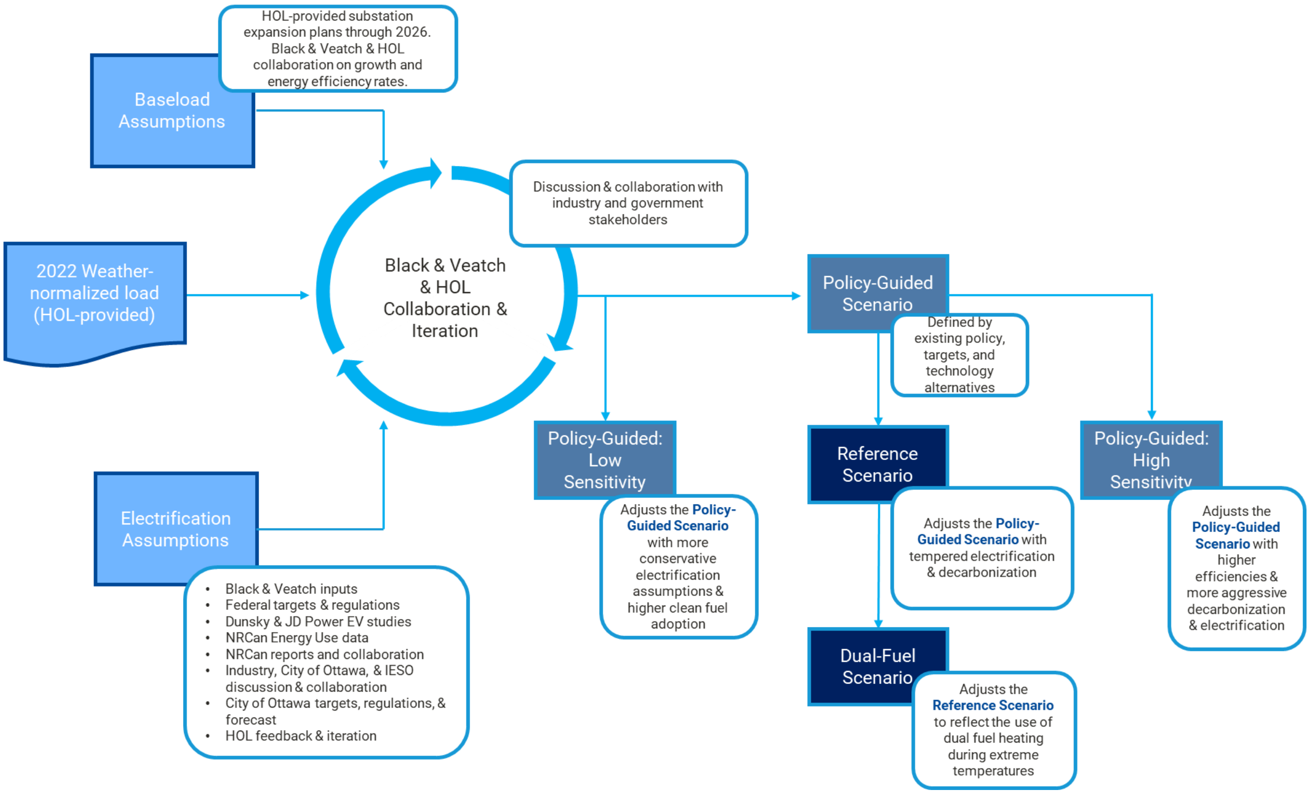
To accomplish these objectives, HOL and Black & Veatch leveraged a scenario-based approach to model a future decarbonized system load. The team considered known policy drivers and trends, reviewed and examined existing decarbonization and emissions reduction studies, and leveraged subject matter expertise to forecast and evaluate the impact of decarbonization initiatives on the HOL service territory and distribution system.[5] Black & Veatch and HOL reviewed these assumptions on an ongoing basis with external stakeholders to ensure transparency in the assumptions development process and also to ensure

[4] Ottawa Climate Change Master Plan, 2020.

[5] Section 5: References provides an extensive list of public studies and resources reviewed in this assessment. The Electrification and Energy Transition Panel report titled "Ontario's Clean Energy Opportunities" was published after study assumptions were finalized. However, it is not expected that findings from that report would significantly alter assumptions used in this study.

input in a robust and thoughtful assumptions set. An overview of the study methodology approach is provided in Figure 1.

Figure 1. Study Summary Methodology and Approach



Once a primary base decarbonization load projection (referenced throughout this report as the Policy-Guided Scenario) had been completed, observed trends in load growth and electrification were paired with short-term planning projections to create a "most-likely" Reference Scenario. Two alternative decarbonization scenario load projections were modeled in addition to two sensitivities to capture a full range of plausible outcomes. Each load projection was evaluated through the lens of a possible decarbonized future in Ottawa and what that means for the HOL service territory. Further detail on the development of load projection scenarios can be found in Section 2.2.

This study explores the impact of decarbonization-driven load increases on HOL assets. Focusing on the Reference Scenario, it evaluates the opportunity of NWS as a mitigation strategy when compared to traditional infrastructure upgrades. Once the decarbonization load was projected, a mitigation strategy to manage increases in load was developed in two steps:

(1) an overload analysis to determine which substations are overloaded on an hourly basis; and

(2) review of strategies to manage the overload conditions at specific substations. Overload strategies consistent of either wires only upgrades at each substation or NWS at each substation.

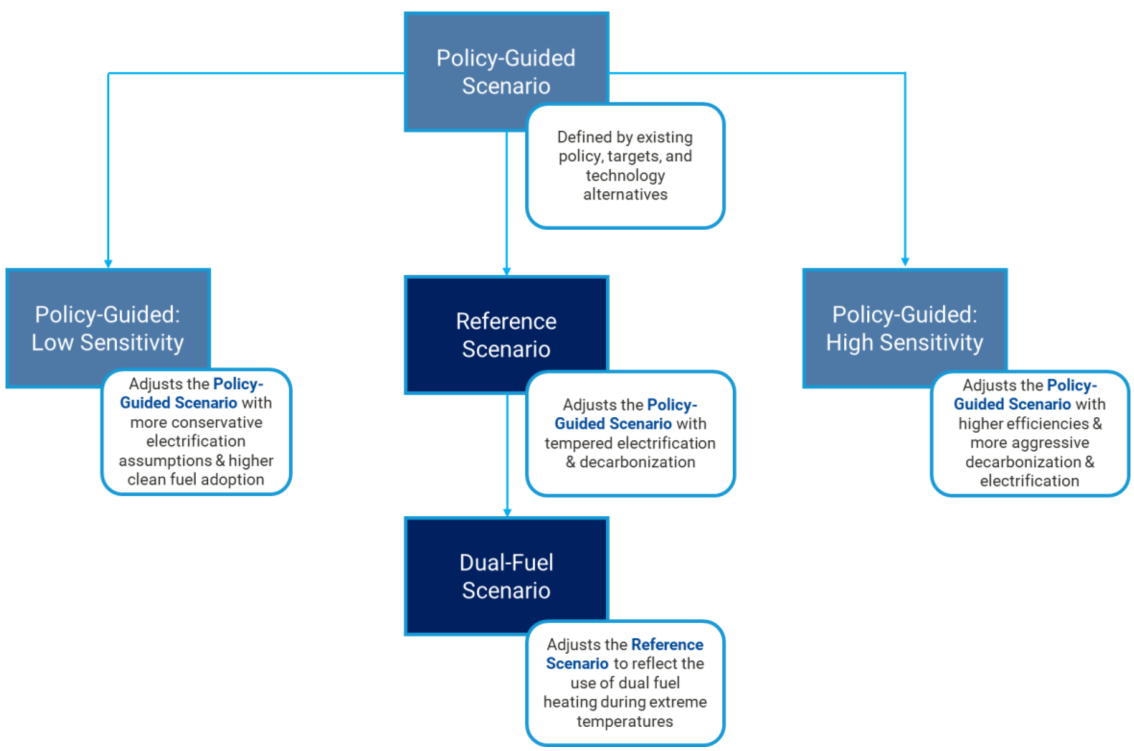
Once the potential for NWS was evaluated, an analysis was conducted to determine the optimal system upgrade solutions based on cost, safety, reliability, resiliency, and environmental factors. The overload analysis was done for the years 2035 and 2050. These two years were selected as 2035 would indicate a lower, but more certain load case in the short term, where the 2050 load case would indicate a higher, but more uncertain load case in the long run. These two cases are used to set lower and upper bounds for needed investments to address the new load profiles on the distribution system. Further detail on this analysis can be found in Section 3.2 in the main narrative of this report.

1.3 KEY FINDINGS

Decarbonization Load Projections

As with any projections, uncertainties around the rate of decarbonization-driven electrification, new technology adoption, technology cost variables, supply chain considerations, and changing political dynamics impact how electrification will change between now and 2050. Given these variations, this study leveraged a scenario-based approach in which one primary Reference Scenario was modeled and evaluated, with two alternative decarbonization scenarios complemented by two sensitivities. The primary and alternative scenarios, as well as the sensitivities, are characterized below.[6,7] The relationship between each projected scenario and sensitivity is shown in Figure 2.

Figure 2. Load Projection Scenario & Sensitivity High-Level Relationship & Descriptions



[6] A deep dive into each scenario is provide in Sections 2.2 and 2.3.

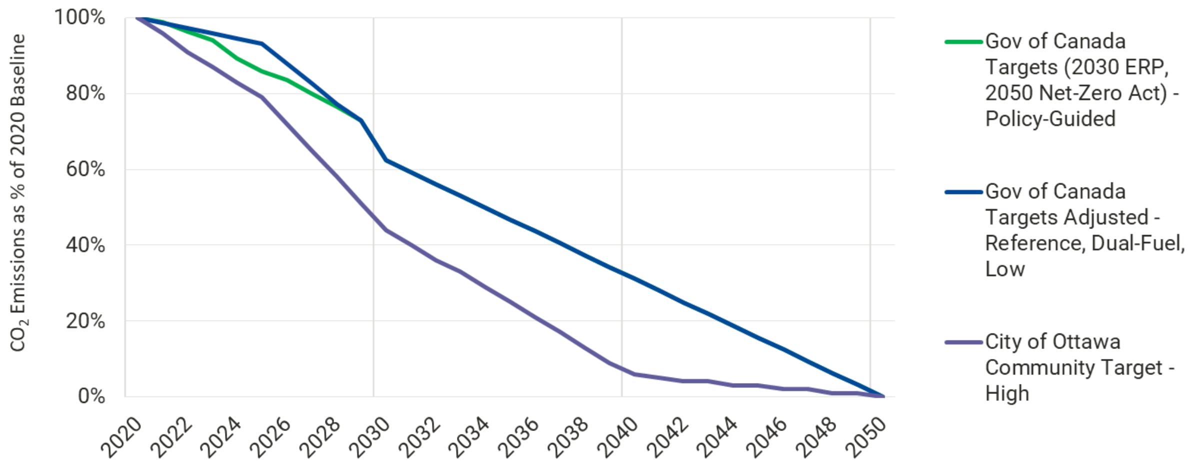
[7] Detailed findings in this report focus primarily on the three scenarios rather than the sensitivities, consistent with project scope and alignment with internal HOL forecasts.

Leveraging inputs from ongoing decarbonization trends, existing policy, other published reports and subject matter expertise, the final scenarios and sensitivities evaluated are described in greater detail below.

- The **Policy-Guided Scenario**: characterized by strict adherence to Canada's 2030 Emissions Reduction Plan and the Canadian Net-Zero Emissions Accountability Act. This scenario is defined by existing policy, targets, and technology alternatives. All future scenarios and sensitivities were adjusted off this baseline scenario.
- The **Reference Scenario**: encapsulates the most likely scenario based on observed HOL load projection trends, electrification adoption trends, and subject matter expertise. These inputs position this scenario with tempered electrification in the short-term, as optimal to inform short- to mid-term investments required to maintain reliability on the HOL distribution power grid. For example, peak load on HOL's system has remained mostly flat for the past 15 years with a maximum of 1,518 MW in 2010, a minimum of 1,308 MW in 2014, and a most recent peak of 1,348 MW in 2022. In the mid- to long- term, this scenario assumes increasing policy-driven electrification.
- The **Dual-Fuel Scenario**: applies a space heating and water heating sensitivity during extreme temperatures to the Reference Scenario.
- The **High Case Sensitivity**: provides a sensitivity on more aggressive decarbonization and electrification than the Policy-Guided Scenario.
- The **Low Case Sensitivity**: provides a sensitivity on less aggressive decarbonization and electrification than the Policy-Guided Scenario.

The scenarios evaluated in this study explore different rates of decarbonization in the HOL service territory informed from three primary sources. The Policy-Guided Scenario in this assessment leveraged the Government of Canada's stated goals in the 2030 Emissions Reduction Plan and 2050 Net-Zero Act, which target a 40% reduction in emissions by 2030 and net-zero emissions by 2050. The Reference and Dual-Fuel Scenarios, reflect a decarbonization curve adjusted from federal targets to capture short-term trends observed in HOL service territory. This adjusted curve still meets federal targets albeit at a slower pace in the next 3-5 years before ramping up ahead of the 2030 target date. These targets were used to inform the emissions targets and rates of electrification among each scenario. A comparison of these decarbonization targets is provided in Figure 3.

Figure 3. Scenario Decarbonization Targets



Decarbonization levers were adjusted within each scenario and sensitivity to further inform scenario decarbonization load projections. Decarbonization levers are defined in this study as the primary key inputs and assumptions that inform efficiency and volume of load impact. Though not every single driver of load change is included in the high-level summary below, this study identified these levers as having the highest impact on decarbonization load projections for HOL.[8] Section 2.1 Methodology & Assumptions outlines the following levers in much greater detail:[9]

- HOL service territory population growth
- Energy efficiency assumptions
- Electric vehicles adoption, efficiency, and charging assumptions
- Residential, commercial, and federal building heating and cooling assumptions; technologies and efficiencies
- The future role of low carbon fuels and natural gas
- Adoption and generation from distributed photovoltaics (PV)

[8] Black & Veatch understands that there are numerous other assumptions that could be considered for the purposes of this analysis. The assumption categories provided above were identified as the most impactful and necessary to complete this scope of work.

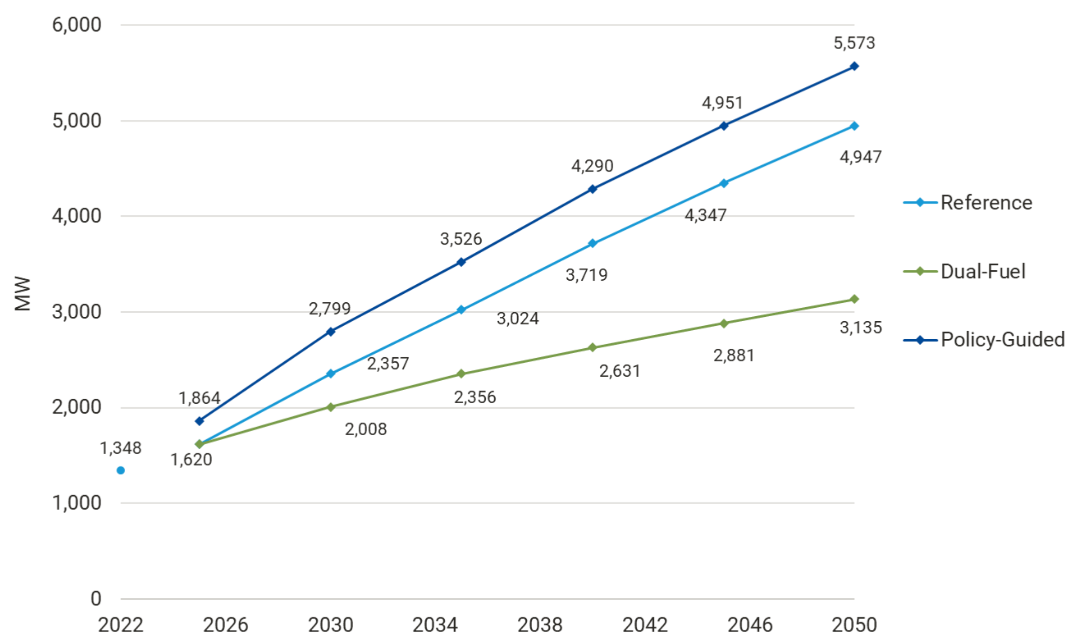
[9] Of important note, this study does not explore or evaluate changes in electric generation portfolios in Canada or Ottawa, or the impacts of decarbonization from the perspective of electric generation. Further this study did not explore the future of natural gas in Canada nor the Hydro Ottawa service territory. Both are outside of the scope of this study.

Figure 4 provides a peak demand comparison of the decarbonization scenarios modeled. In 2022, HOL's weather-normalized peak reached 1,348 MW.[10]

- The Reference Scenario projected a 2050 peak of 4,947 MW, 267% higher than the 2022 HOL weather normalized peak. Decarbonization-driven electrification, particularly associated with heating electrification assumptions drove this load increase.
- The Policy-Guided Scenario was developed to capture the impact of full electrification in meeting decarbonization goals without any load mitigation measures, resulting in a projected peak of 5,573 MW in 2050, or a 313% increase from 2022.
- The Dual-Fuel Scenario represents a future where gas (assumed to be low carbon) continues to provide a portion of space heating needs, especially in extreme cold temperatures. Even with this prevalence of dual-fuel heating systems, peak demand grows by 133% to 3,135 MW in 2050.

In each of these three scenarios, HOL would expect significant impacts to their distribution system and parallel investment needed to maintain reliability and resiliency.

Figure 4. Decarbonization Scenario Peak Demand Comparison of Primary Scenarios



Distribution System Impact Assessment

As part of this study, Black & Veatch evaluated different wires and NWS to ensure that substations facing future overload conditions could meet the required demand. The purpose of this assessment was twofold:

[10] At the time of this study, 2022 load data was the most current available.

(1) to evaluate the directional costs of a wires only solutions scenario to meet project load growth in the Reference Scenario, and

(2) to identify the system-wide combination of wires and NWS that could provide a lower system-wide cost.

Two primary overload solutions scenarios were developed to compare the system-wide cost over both study horizons described above: a wires only solution scenario and a cost optimized solutions scenario. These two primary solution scenarios were developed to inform future detailed feasibility studies in which HOL can use to determine the highest priority substations to upgrade and solutions in which should be considered. The primary solution scenarios are defined as follows:

- The Wires Only Solution Scenario – This scenario assumes that only traditional wires solutions are considered to addressed substation overload conditions. Wires only solutions include upgrades to existing substations and/or the addition of new substations.
- The Cost Optimized Solutions Scenario – This final scenario considered the lowest cost option to each qualified overloaded substation to determine the lowest system-wide rough order of magnitude (ROM) cost assumptions over the horizon. This scenario leverages a mix of wires, Battery Energy Storage Systems (BESS) (if feasible), and reciprocating engines (RECIPs) to address substation overloads.

To account for uncertainty of the decarbonization load projection and limitations of the system model used to determine station overload conditions, each scenario was evaluated at two different years and two different load transfer conditions for a total of four investment model sensitivities. First, each scenario was evaluated using the decarbonization load projection of 2035 and the decarbonization load projection of 2050; 2035 provides a lower but more certain load projection, and 2050 provides a higher but less certain load projection. Then, within each year, the potential to transfer the load to another substation is evaluated. The combined result is four different investment profiles for each scenario. The year 2035 with all potential load transfers assumed to be possible provides the lowest bound of investment required, and the year 2050 load projection with none of the potential load transfers assumed to be possible provided the upper bound of investment required.

In order to develop the cost optimized solutions scenario, two NWS technology assessments were completed: a wires and BESS solution assessment and a RECIP solution assessment. The outcomes of these two assessments, combined with the wires only solutions scenario, directly informed the development of the cost-optimized scenario. The two NWS technology assessments are described below.

- Wires + BESS Solution Technology Assessment – This assessment evaluated the role of BESS as an NWS to address substation overloads over the study horizon. If the substation had enough capacity during non-overload hours to sufficiently charge a BESS to discharge during an overload condition, the substation was determined to be eligible for a BESS. If there was not sufficient power available to charge a BESS prior to the overload, a BESS was not used and the wires only solution was applied.

- RECIP Solution Technology Assessment– This assessment evaluates the role of RECIPs as an NWS to address substation overloads. Each overloaded substation was evaluated to determine the required size and directional cost of the RECIP required.

While the outcome of these technology assessments was necessary in developing the cost optimized solutions scenario, this study dives into the results of these assessments from the perspective of the cost optimized solutions scenario only. Importantly, the two assessments (wires and BESS and RECIPs) are intended as a screening assessment only, meaning that they do not consider BESS and RECIP size limitations, land availability and other important considerations that should be evaluated in future phases of work. Thus, the results provided should be viewed through such lens.

To evaluate the two primary solution scenarios, as well as the NWS, five key measures were identified and evaluated. Each measure was scored on a scale of one to ten, with one being the least desirable and ten being the most desirable. The total score represents the sum of each measure's independent score. The intent of this scoring matrix is to review and evaluate each of the solution scenarios against one another. The measures are defined as follows:

- Solutions Scenario Cost: Represented as the total net present value (NPV) of system-wide capital expenses (CAPEX) and operating expenses (OPEX). Rough order of magnitude (ROM) directional pricing estimates were developed for each solution scenario. The two solutions scenario NPVs were compared against one another, and the lowest cost solution was evaluated as the most desirable.
- Safety: Evaluated as how safe the proposed solutions is and potential risk it could pose to the surrounding area.
- Reliability: Evaluated as to how much power and for how-long an overload could be served by the evaluated solutions. Scenario solutions leveraging dispatch limited solutions were measured as less favorable.
- Resiliency: Evaluated as the total capacity of the wires or NWS assets as well as vulnerabilities to external pressures such as grid outages or fuel limitations.
- Environmental: Evaluated considering greenhouse gas (GHG) considerations, noise, and land use considerations.

The two solution scenarios were evaluated through both the mid-term and long-term lens. The solutions scenario matrix assessment was applied to the 2035 findings to inform shorter-term investment strategies. Figure 5 shows the summary findings of the solutions scenarios in the matrix assessment. Black & Veatch applied quantitative cost metrics from its directional investment modeling results and a mix of qualitative and quantitative expertise to inform a high-level assessment of safety, reliability, resiliency, and environmental considerations. A deep dive into these findings and methodology can be found in Section 3.1 Methodology & Assumptions and 3.2 Substation Overload Results & Solution Scenarios.

Figure 5. Solutions Scenario Comparison Matrix (2035 Horizon Considerations)[11]

Measures	WIRES ONLY	COST OPTIMIZED
Cost	5	9
Safety	10	7
Reliability	10	9
Resiliency	5	8
Environmental	5	5
Total Score (Sum)		
Overall Score	35	38

Measures Scoring

1 2 3 4 5 6 7 8 9 10

Least Desirable → Most Desirable

Conclusion & Summary Recommendations

This study evaluated the potential for increases in system load in the HOL distribution system based on various decarbonization and end use electrification scenarios. Additionally, impacts to the system were assessed and potential methods to mitigate those impacts were developed. The model analysis reveals that the electrification of energy end use cases such as transportation and heating will result in a significant increase in system load and is projected to require significant expenditures to address.

The main body of this narrative final report provides a deep-dive into the methodology and assumptions of each decarbonization load scenario, as well as scenario-based comparison of each scenario decarbonization load projection. The impact on peak, load profiles, and total demanded are summarized in great detail in an effort to provide a comprehensive comparison of the impact of different decarbonization levers. Further, a detailed overview of the methodology and approach and resulting findings of the system substation overload analysis, as well as recommended next steps for considerations are provided in Section 3.0 Decarbonization Load Impacts to HOL's Distribution System.

[11] Individual measures were scored on a scale of one to ten. The overall score is the sum of all scores. Discussion regarding each measure score is provided in Section 3.2.

This study provides a robust analysis and thorough examination of potential adjustments needed between now and 2050 for HOL to effectively address future decarbonization-driven load impacts. Though this study provides robust and comprehensive analysis into the possibility of the impact of decarbonization initiatives in the HOL service territory, additional considerations, studies, and analyses should be considered. The analysis performed in this study should be leveraged and built upon to further assess and finalize mitigation strategies to optimize capital investment. In addition to the results provided within this narrative final report, an additional appendix is included titled "Appendix A: HOL Provided Substation Data." The appendix includes a table which outlines all of the substation assumptions included in the overload analysis provided by HOL. These inputs were used in the assessment of substation overloads from the Reference Scenario load profiles over the study horizon.[12] All public sources used to inform assumptions in this analysis are also provided in Section 5: References.

[12] In additional to the two appendices summarized, Black & Veatch completed and provided extensive data analysis and financial modeling not included herein but used to determine the outcome of this analysis.

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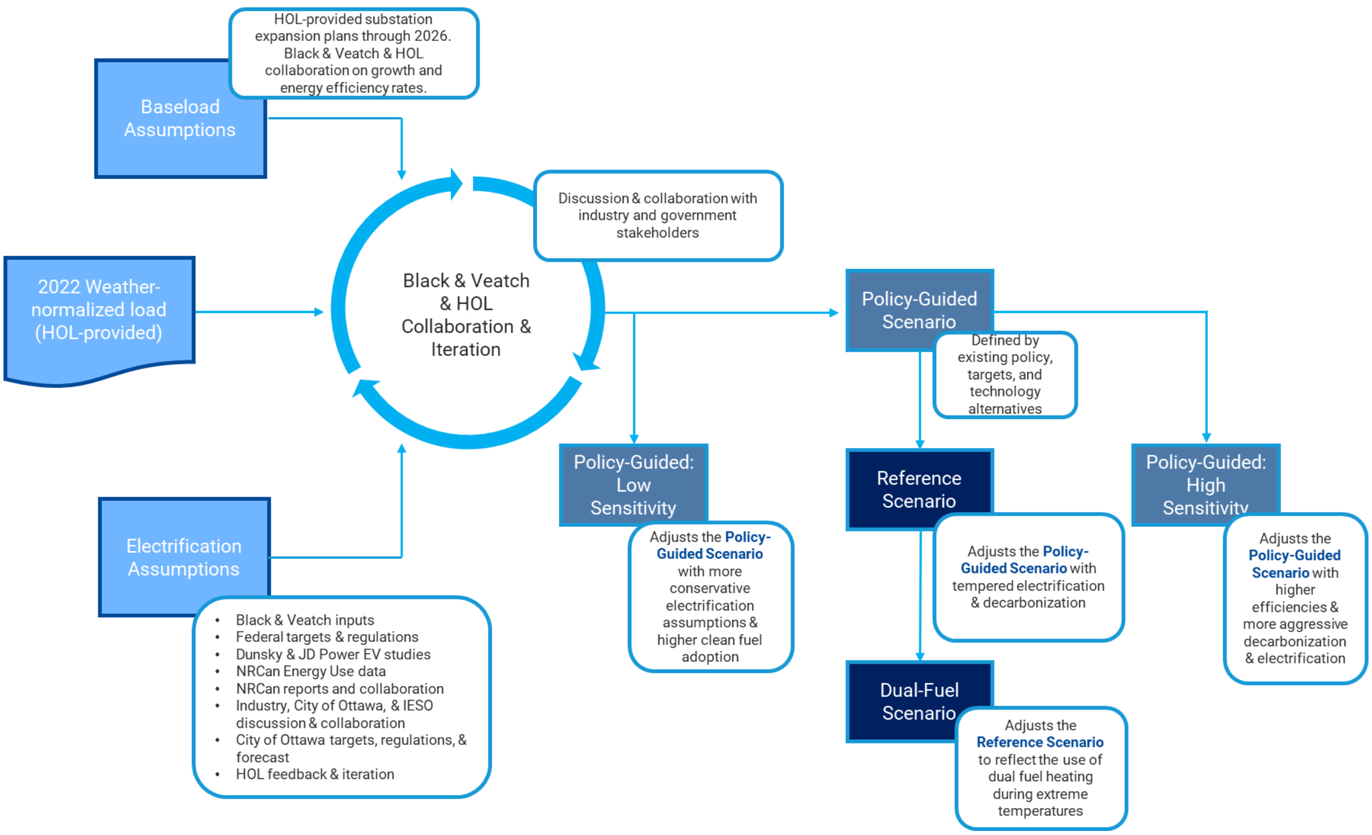
2.0 Decarbonized Load Projections

2.1 METHODOLOGY AND ASSUMPTIONS

In developing the decarbonization load scenarios used in this analysis, Black & Veatch leveraged a combination of public and proprietary HOL data to inform decarbonization assumptions and load trends. This data included historical load profiles at the substation level, weather normalization techniques, short-term system upgrade plans, growth forecasts, distributed energy resources (DER) information, and publicly available decarbonization plans and goals. Black & Veatch and HOL collaborated to define decarbonization load scenarios to inform decarbonization load projections. An overview of the study methodology and approach is provided in Figure 6.

Figure 6. Study Summary Methodology and Approach



As part of the methodology, load modeling was broken into two load categories (baseload and new electrification load). This methodology allows for greater visibility into the drivers of the decarbonization-driven new electrification load, specifically. All decarbonization load projections were completed in 5-year increments for each scenario for the following six years: 2025, 2030, 2035, 2040, 2045, and 2050. The baseload and new electrification load categories are defined as follows:

- **Baseload:** Considers the existing hourly electric consumption at the system level for all end use customer types. It does not include flow transfers between substations and derives from the actual 2022 weather-normalized electric load at the system level. The baseload is projected through 2050 considering growth rates and energy efficiency measures defined for each customer segment, such as residential, commercial, large customers, and federal. The short-term growth rate between 2023 and 2026 was informed by HOL planned capacity expansion at the substation level; and post-2026, the growth rate at the substation level varies by customer segment. The baseload projection is the same across all scenarios and sensitivities modeled.

- **New Electrification:** Includes six segments: Transportation Electrification, Residential Electrification, Commercial Electrification, Federal Building Electrification, Large Customer Electrification, and Distributed PV Generation. Each category was projected using a decarbonization curve and additional assumptions specific to each category, such as space heating, water heating, and technology adoption. Of note, in several scenarios some buildings continue using gaseous fuels through 2050.[13] For the purposes of ensuring that Canada's climate targets are met, this gas was assumed to have net-zero emissions intensity.

Load Category 1: Baseload Methodology

The baseload projection was developed by estimating growth of existing load on HOL's distribution system. Beginning with 2022 weather-normalized hourly electric load, organic load growth was estimated for 2023-2026 based on known capacity expansion plans at the substation level. New substation plans and enhancement projects for existing substations were used to create growth rates that were then applied to specific substation loads.

Beyond 2026, projections were estimated for each of the following customer segments using segment-specific growth and energy efficiency rates: residential, commercial, federal, street lighting, and large customers.

The **Residential** customer segment was created from the Residential HOL rate category, and load growth was projected based on population growth[14]. Energy efficiency gains were estimated at 0.5% per year based on the Independent Electricity System Operator's (IESO's) Gatineau Corridor End-of-Life Study.[15]

The **Commercial** customer segment was created from the following HOL rate categories: Commercial, 50-1,000 kW, 1,000-1,500 kW, and 1,500-5,000 kW. Load growth was projected based on population growth, and energy efficiency gains were estimated at 1% per year based on the IESO's Gatineau Corridor End-of-Life Study.[15]

The **Federal** customer segment was created by mapping 130 federal facilities in the Ottawa region to Canada's 2021 Greenhouse Gas Emissions Inventory to measure annual energy consumption. For federal customers who were also large customers, metered electricity was used instead. Load growth was projected based on historic growth, and energy efficiency gains were estimated at 1% per year based on

[13] A detailed assessment of the role of the data centers was not included as part of this decarbonization study scope but should be considered in future load projection assessments.
[14] City of Ottawa Growth Projections for the New Official Plan – Medium Projection, 2019. Extrapolated from 2047 to 2050.
[15] IESO Gatineau Corridor End-of-Life Study, 2022.

the IESO's Gatineau Corridor End-of-Life Study.[15] It was assumed that federal buildings with plans to transition to commercial or residential use would maintain similar consumption profiles and growth rates.

The **Large Customer** segment was created from the metered data of 28 of HOL's largest customers. This segment was broken down into subsegments with specific assumptions for each.

- Office Building large customers: growth and energy efficiency were the same as the Commercial customer segment.
- Hospital large customers: growth and energy efficiency were informed by the Commercial customer segment.
- University large customers: growth estimates informed from other university decarbonization and sustainability plans, energy efficiency assumed equal to commercial segment.
- Water Treatment Plant large customers: growth based on population growth and energy efficiency estimated at 0.5% for the industrial segment from IESO's Gatineau Corridor End-of-Life Study.[15]

The **Street Lighting** customer segment was created from the Street Lighting HOL rate category, and load growth was projected based on population growth. No energy efficiency gains were estimated due to the high existing penetration of LED street lighting in Ottawa.

Load Category 2: New Electrification Methodology

Transportation Electrification

Transportation Electrification includes the load from charging electric light-duty, medium-duty, and heavy-duty vehicles (LDV, MDV, HDV). LDVs are projected to comprise the vast majority of EV charging load in the HOL service territory and the following parameters were developed and defined to estimate annual electricity consumption of electric vehicles.[16]

- Number of electric vehicles: informed from existing regulations and public forecast adoptions
- Electric vehicle electric consumption per distance (efficiency rating): utilized the IESO Annual Planning Outlook (APO)[17] estimate of 0.2 kWh/km
- Distance traveled per EV per year: 16,196 km[18]
- Charger efficiency: estimated at 0.85[17]

Annual consumption from EVs was allocated to hourly load profiles at the substation level via:

- Hourly charging profiles developed for different types of residential (L1, L2) and public chargers (L3)
- Residential charging allocated based on population/number of residential customers at the substation

[16] Unless otherwise noted LDV assumptions leveraged proprietary Black & Veatch analysis and research. A detailed study of LDV efficiencies, miles traveled and charging efficiency were outside the scope of this assessment.
[17] IESO Annual Planning Outlook, 2022.
[18] IESO Annual Planning Outlook, 2022, modified slightly by Black & Veatch subject matter experts.

- Public charging allocated based on historical locations (indicative of demand at the location)
- Seasonality of consumption accounted for by using EV consumption data from climates similar to Ottawa

The significant impact of new LDV load is expected to be tempered by rate structures designed to incentivize customers to charge when electricity demand is low, lessening the impact on system-level peaks. From 2023 to 2030, some adoption of the Ontario Government's ultra-low overnight (ULO) rate was assumed. [19] After 2030, new rate structures optimized to flatten future system-level load curves were assumed to be implemented as HOL adapts to the changing load profile of its system. Adoption rates for these rate incentives differ by scenario.

For City of Ottawa's buses, a separate load projection was created using the following assumptions:

- Full electrification of fleet by 2040
- Observed data from the existing OC Transpo Zero Emission Bus Program, including:
    - Distance traveled per bus
    - Electric efficiency of buses
    - Charging load profiles

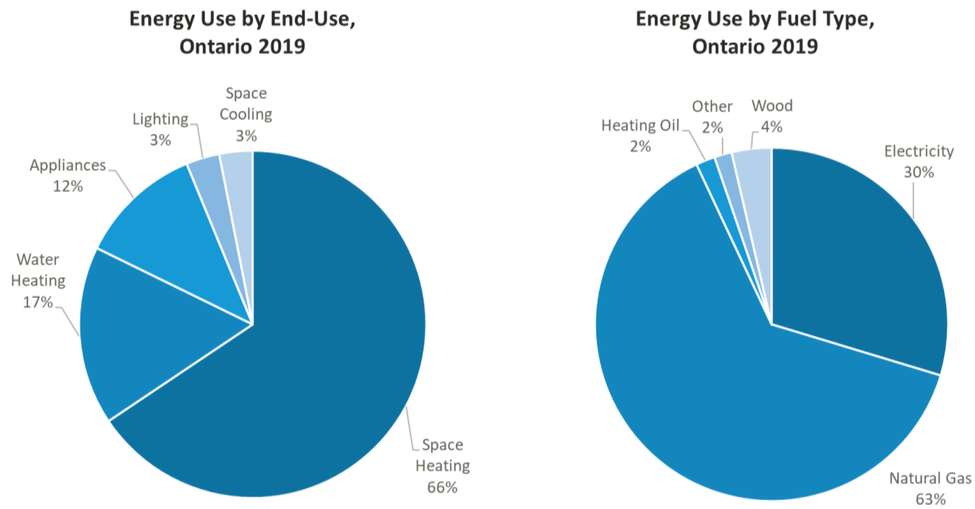
Outside of LDVs and city buses, MDV and HDV load was estimated as a proportion of LDV load using a combination of public and proprietary Black & Veatch sources. Projected MDV and HDV load was then added to the total LDV load.

Residential Electrification

Residential Electrification includes potential electrification load from space heating, water heating, and appliances in the residential sector. According to Natural Resources Canada (NRCan) data, space cooling and lighting in the residential sector are already 100% electric. [20] NRCan data was used to quantify energy consumption by end use (space heating, water heating, appliances) and energy end use fuel type, as shown in Figure 7. Black & Veatch applied a decarbonization curve based on Federal or local climate targets to the entire residential sector. For each energy end use, specific electrification assumptions were developed.

[19] Ontario Ultra-Low Overnight Rate
[20] NRCan Residential Sector Energy Use, Ontario.

Figure 7. Residential Energy Use in Ontario, *Natural Resources Canada*



Space heating and water heating were electrified based on expected technology share (heat pumps, electric resistance, gas) at the end of the study's horizon. These target technology shares leveraged existing publicly available forecasts such as Canada Energy Regulator's (CER) Canada's Energy Future, Enbridge's Pathways to Net Zero Emissions in Ontario, and the City of Ottawa's Energy Evolution GHG Modeling to inform forecasts for this study. For example, the Reference Scenario utilized the forecast in Canada's Energy Future report to arrive at 50% heat pumps, 26% electric resistance heating, and the remainder served by low carbon gas by 2050.

From these technology adoption assumptions, Black & Veatch applied a blended coefficient of performance (COP) to convert the amount of energy used by natural gas to electricity or low carbon fuels such as hydrogen or RNG. Black & Veatch utilized historical weather data in Ottawa to project electrified space heating load curves over the course of a year. For water heating, efficiency metrics (COP) were applied to known energy demand from natural gas-fired residential water heating (NRCan) and known load profiles from similar climates to create annual hourly load projections.[20]

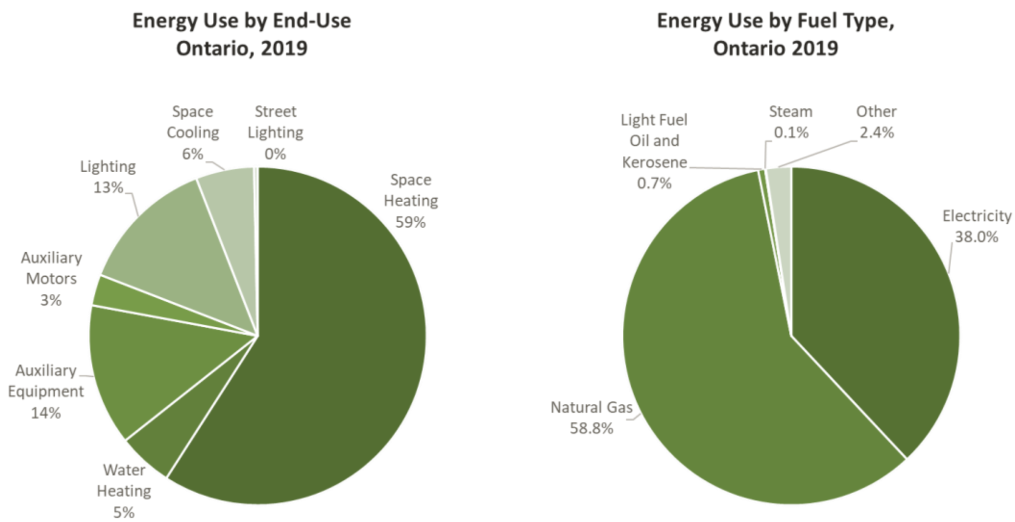
Roughly 63% of energy used in household appliances is provided by natural gas, consistent with NRCan data.[20] In this assessment, the natural gas portion was assumed to be electrified based on scenario-specific decarbonization curves.

Importantly, blended efficiency metrics for both space heating and water heating were reduced in all scenarios for hours at or below -10°C based on historical weather data. This was to account for the assumed diminished efficiency of air-source heat pump technology in extreme temperatures sometimes experienced in Ottawa's climate.

Commercial Electrification

Commercial Electrification includes potential electrification load from space heating, water heating, space cooling, and auxiliary equipment in the commercial sector. Like the residential sector, NRCan data was used to quantify energy consumption by end use (space heating, water heating, etc.) and energy end use fuel type as shown in Figure 8.[21] Black & Veatch applied a decarbonization curve based on federal or local climate targets to the entire commercial sector. For each energy end use, specific electrification assumptions were developed.

Figure 8. Commercial Energy Use in Ontario, *Natural Resources Canada*



Space heating, space cooling, and water heating were electrified based on fuel share (electric vs. low carbon gas) at the end of the study horizon. These target fuel shares leveraged publicly available forecasts such as Canada Energy Regulator's (CER) Canada's Energy Future, Enbridge's Pathways to Net Zero Emissions in Ontario, and the City of Ottawa's Energy Evolution GHG Modeling to inform projections for this study.[22,23,24] Based on the electrification options available for commercial buildings and the minimum performance of alternatives from the National Energy Code of Canada for Buildings, Black & Veatch applied a blended coefficient of performance (COP) to convert the amount of energy used by natural gas to electricity.[25] Black & Veatch utilized historical weather data in Ottawa to project electrified space heating load curves over the course of a year. For water heating, efficiency metrics (COP) were applied to known energy demand from natural gas-fired commercial water heating (NRCan) and load profiles from similar climates to create annual hourly load projections.[21]

Roughly 17% of energy used in auxiliary commercial equipment (e.g., clothes dryers, cooking appliances) is provided by natural gas. [21] Similar to the residential sector, the natural gas portion was assumed to be electrified based on scenario-specific decarbonization curves.

Like the residential sector, blended efficiency metrics for both space heating and water heating were reduced in all scenarios for hours at or below -10°C based on historical weather data. This was to account

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[21] NRCan Commercial Sector Energy Use, Ontario.
[22] Ottawa Energy Evolution Modelling Ottawa's Greenhouse Gas Emissions to 2050.
[23] CER Canada's Energy Future, 2023.
[24] Enbridge Pathways to Net-Zero Emissions in Ontario, 2022.
[25] National Energy Code of Canada for Buildings, 2020.

for the assumed diminished efficiency of existing air-sourced heat pump technology in extreme temperatures sometimes experienced in Ottawa's climate.

Federal Building Electrification

The government of Canada publishes annual Greenhouse Gas Emissions (GHG) Inventories which include all federal facilities in the country. One hundred thirty (130) federal facilities were identified from this inventory in the Ottawa region; each facility was mapped to a substation on HOL's distribution system based on the facility address. From the GHG Inventory, Black & Veatch determined the annual energy consumption at the substation level. For large federal users, metered electricity was used instead (see next section on Large Customer Electrification). Due to similar consumption profiles, commercial electrification assumptions around space heating & cooling, water heating, and auxiliary equipment were applied to federal buildings. These assumptions were applied to scenario-specific decarbonization curves. Black & Veatch assumed these facilities would either remain operational as federal buildings or transition to commercial use cases with similar consumption profiles and growth rates.

Large Customer Electrification

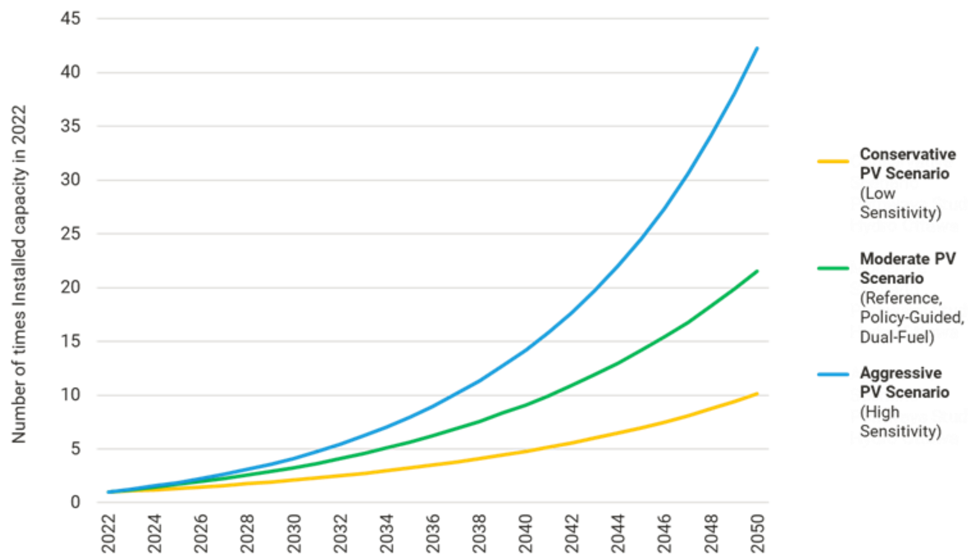
As in the baseload projection, Black & Veatch created a specific set of electrification assumptions for 28 large customers broken into 6 subsegments. Large Customer Electrification did not vary by scenario. Of important note is that the intent of this study was not to develop and project large customer specific or custom decarbonization trends and trajectories, but to understand the directional impact of decarbonization on the HOL distribution system. Thus Black & Veatch leveraged publicly available information to inform assumptions of these large customer groups.

Distributed PV Generation

Black & Veatch completed a load projection of distributed photovoltaic (PV) solar generation growth given its ability to significantly influence system-level peaks, especially during summer months. HOL provided current installed capacity estimates of roughly 42 MW as well as generation profile data observed at selected substations. Substation-level generation profiles and capacity factors were applied to growing capacity load projections. Black & Veatch leveraged forecasts from the City of Ottawa's Pathway Study on Solar Power to apply growth patterns by scenario.[26] Each solar scenario from this study assumes different levels of local effort to encourage rooftop PV and global inputs such as improved economics and technology performance. Figure 9 shows the different distributed PV projections leveraged for this analysis.

[26] City of Ottawa's Pathway Study on Solar Power in Ottawa, 2017.

Figure 9. Distributed PV Projection Assumptions



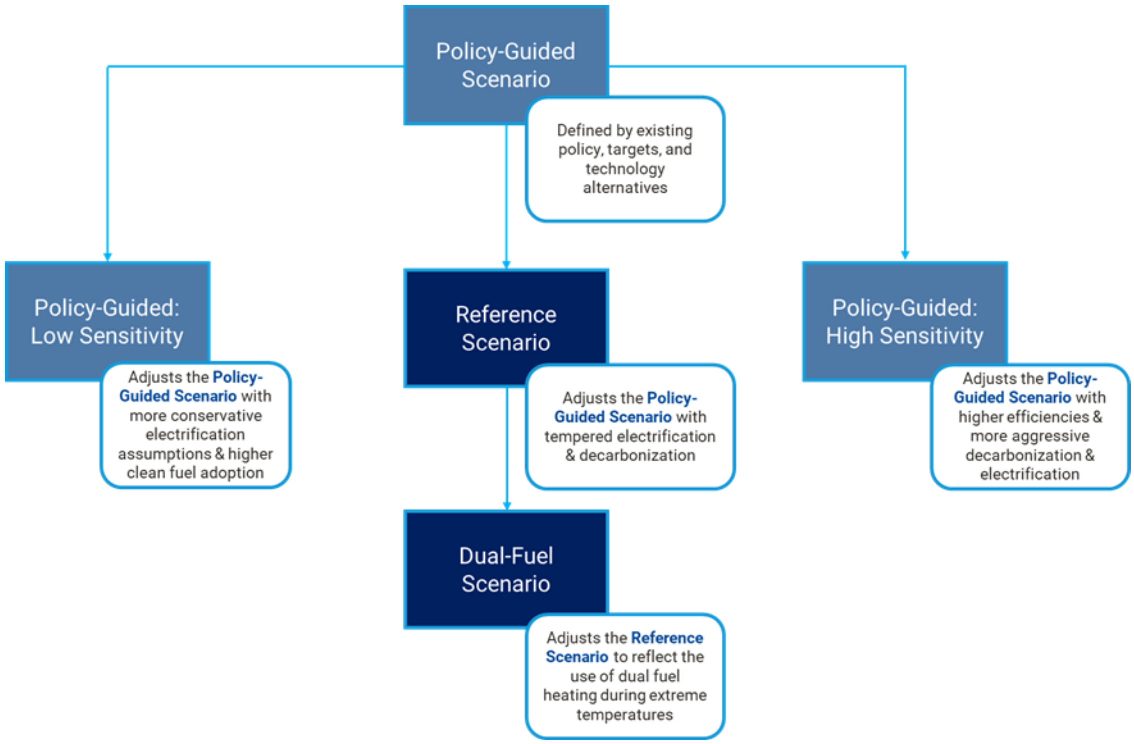
Substation-level Projection Methodology

To apply all new electrification assumptions to HOL substations, Black & Veatch conducted a thorough analysis of customer segmentation. Utilizing both publicly available and proprietary HOL data, Black & Veatch created an estimated customer segment breakdown for all 92 substations in HOL's distribution system. Customer segment-specific new electrification growth factors were applied proportionally based on these customer breakdown estimates. The end result was both system- and substation-level load projections for each load category for each scenario.

2.2 OVERVIEW OF LOAD SCENARIOS

In order to capture a range of possible outcomes to HOL's distribution system resulting from decarbonization, Black & Veatch developed one primary reference decarbonization scenario, two alternative decarbonization scenarios, and two sensitivities. This section defines each scenario, presents an overview of assumptions, and examines customer segment-level results. In Section 2.3 Results Summary and Comparison, system-level results for the three scenarios are presented and analyzed comparatively. Each scenario's development and influences are described below, along with the scenario-specific results of each load category. Figure 10 shows the logical flow of developing these scenarios.

Figure 10. Load Projection Scenario & Sensitivity High-Level Relationship & Descriptions



Leveraging inputs from ongoing decarbonization trends, existing policy, other published reports and subject matter expertise, the final scenarios and sensitivities evaluated are described in greater detail below.

- The **Policy-Guided Scenario**: characterized by strict adherence to Canada's 2030 Emissions Reduction Plan and the Canadian Net-Zero Emissions Accountability Act. This scenario is defined by existing policy, targets, and technology alternatives. All future scenarios and sensitivities were adjusted off of this baseline scenario.
- The **Reference Scenario**: encapsulates the most likely scenario based on observed HOL load projection trends, electrification adoption trends, and subject matter expertise. These inputs lead Black & Veatch and HOL to assert this scenario, with tempered electrification in the short-term, is optimal to inform short-to-mid term investments required to maintain reliability on the HOL distribution power grid. For example, peak load on HOL's system has remained mostly flat for the past 15 years with a maximum of 1,518 MW in 2010, a minimum of 1,308 MW in 2014, and a most recent peak of 1,348 MW in 2022. In the mid- to long- term, this scenario assumes increasing policy-driven electrification.
- The **Dual-Fuel Scenario**: applies a space heating and water heating sensitivities during extreme temperatures to the Reference Scenario.
- The **High Case Sensitivity**: provides a sensitivity on more aggressive decarbonization and electrification than the Policy-Guided Scenario.

- The **Low Case Sensitivity**: provides a sensitivity on less aggressive decarbonization and electrification than the Policy-Guided Scenario.

Load Projection Assumptions

Each of these scenarios contain the *same baseload projection* but utilize levers of electric vehicle (EV) adoption, building heating and cooling, water heating, decarbonization curves, and distributed PV adoption to measure the impact of decarbonization policy on load modeling. This section describes the methodology used and variables accounted for to build each portion of the decarbonized load projections. A number of assumptions remained the same in each load projection scenario. A list of those shared common assumptions is provided in Table 1.

Table 1. Common Assumptions Across Scenarios

Load Category	**Shared Assumptions** (assumptions were identical in each scenario & sensitivity)
Baseload	• All baseload assumptions, including historical load profile, growth rates & energy efficiency
Residential	• Energy efficiency • Load profile • Space cooling & appliance electrification
Commercial	• Energy efficiency • Load profile • Space cooling & auxiliary equipment electrification
Federal	• Energy efficiency • Load profile
Transportation	• EV efficiency • Vehicles miles traveled • Charger efficiency • City bus electrification
Large Users	• All large user assumptions, including historical load profile, growth rates & energy efficiency
Distributed PV	• Generation profile • Capacity factor

Importantly, the five load categories used as levers for scenarios were Transportation Electrification (LDV specifically), Residential Electrification, Commercial Electrification, Federal Electrification, and Distributed

PV Generation. A summary of the scenarios and each level assumption is provided in Table 2. The baseload projection and Large Customer Electrification results are presented here outside individual scenarios, as they remained constant across all five scenarios and sensitivities.

Table 2. Scenario and Sensitivity Assumptions Comparison[27]

	Dual Fuel Scenario	Reference Scenario	Policy-Guided Scenario	High Sensitivity	Low Sensitivity
Scenario Description	Defined by adjusting the Reference Scenario with dual fuel heating during extreme temperatures	Defined by adjusting the Policy-Guided Scenario with tempered electrification & decarbonization	Defined based on existing policy, targets, and technological alternatives	Defined by greater efficiency and more aggressive decarbonization & electrification assumptions	Defined by more conservative decarbonization assumptions, with greater clean fuel adoption
Decarbonization Curves & Targets	Government of Canada Targets (tempered in short-term)	Government of Canada Targets (tempered in short-term)	Government of Canada Targets (2030 ERP, 2050 Net Zero Act)	City of Ottawa Climate Change Master Plan Community Target	Government of Canada Targets (tempered in short-term)
Electric Vehicles	EV adoption to meet federal targets	EV adoption to meet federal targets	EV adoption to meet federal targets	Faster EV adoption than federal targets	Slower EV adoption than federal targets
Residential, Commercial & Federal Buildings	Partial electrification with moderate heat pump adoption Dual-fuel heating assumptions Remaining pipeline gas assumed as low-carbon fuels	Partial electrification with moderate heat pump adoption Remaining pipeline gas assumed as low-carbon fuels	Complete electrification Second highest heat pump adoption	Most aggressive electrification Highest heat pump adoption, highest efficiency assumptions	Least aggressive electrification with higher remaining load served from low-carbon fuels Lowest heat pump adoption
Distributed PV	Moderate PV Growth	Moderate PV Growth	Moderate PV Growth	Most aggressive PV growth	Most conservative PV growth

Baseload Results

As described in Section 2.1, the baseload projection is driven by a combination of existing substation plans, population growth forecasts, and energy efficiency assumptions. After beginning at 1,348 MW in 2022 and increasing to 1,737 MW in 2030 baseload levels out and decreases on the back end of the study horizon due to energy efficiency projections outpacing load growth from the increasing population. By 2050 the baseload peak is 1,797 MW, only 3.4% higher than 2030 (0.17% annualized growth). As demonstrated in Figure 11, the baseload projection utilizes the same load profile as HOL's system today.

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[27] Assumptions detailed are discussed in greater detail later in this section.

The baseload peak and load profile are identical across all scenarios. Figure 12 shows baseload peak demand projections.

Figure 11. Baseload Annual Load Profile

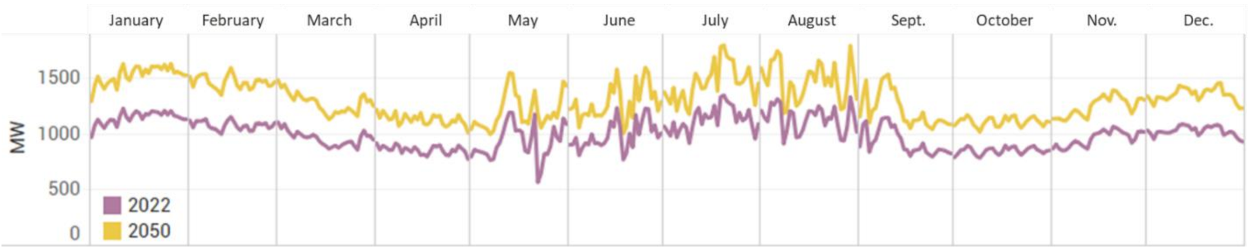
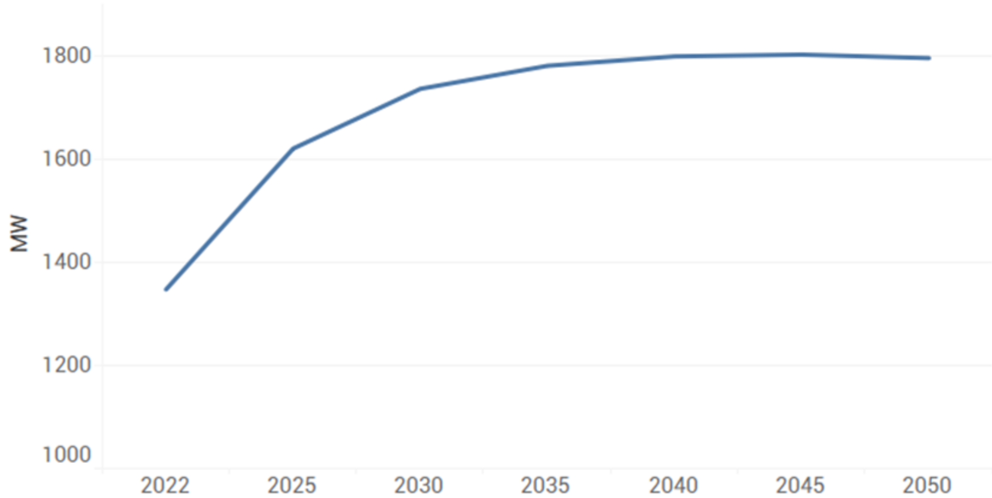


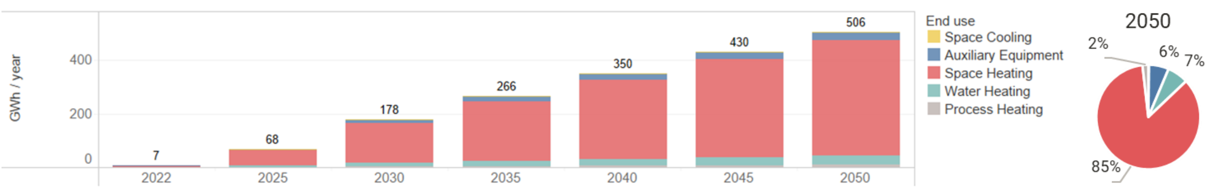
Figure 12. Baseload Peak Demand Projection



Large Customer Electrification

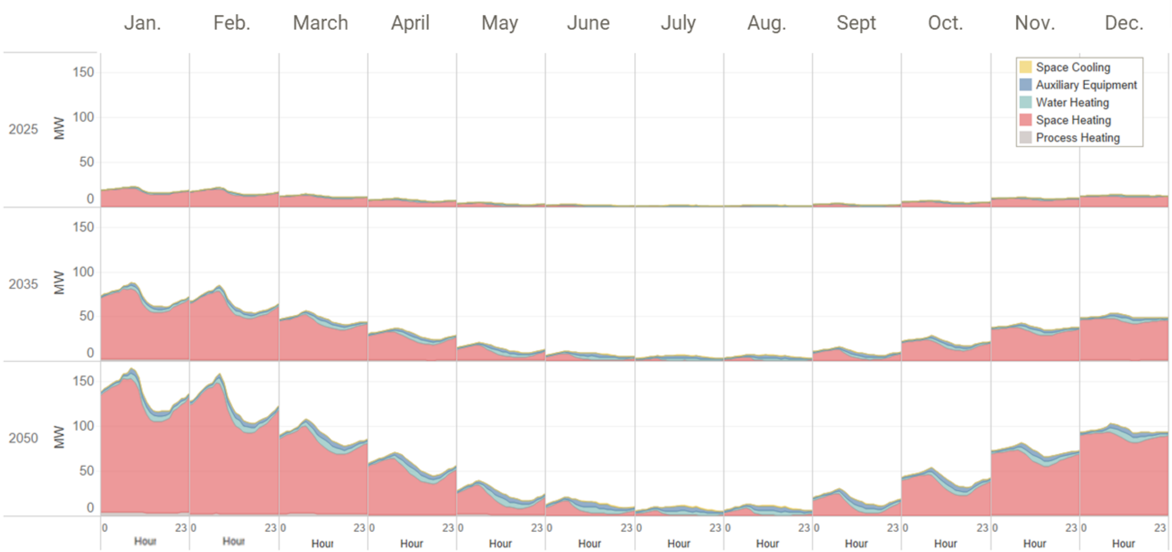
The Large Customer Electrification load projection (as seen in Figure 13) includes specific assumptions for each subsector of customer. Space heating electrification is the primary driver of this load projection, as seen by the increased load in winter comparative to summer months. By 2050, 85% of the 506 GWh consumed by large customers annually is for space heating. Overall, Large Customer electrification represents a relatively small proportion of system load (3% in the Reference Scenario) – outpaced by load growth in Residential, Commercial, and Transportation sectors. The Large Customer Electrification load projection did not vary across scenarios.

Figure 13. Large Customer New Electrification Load Projection by End-Use



As expected, space heating load is highly seasonal (as seen in Figure 14), dropping dramatically between winter months and summer months. Though noticeable in 2025, by 2035 and 2050 the seasonality and associated peaks will become increasingly severe. The associated increase of spacing heating related electricity demand is tied to a transition away from gas heating.

Figure 14. Large Customer Hourly Electricity Load Profile (Average Day Per Month)



Reference Scenario and Dual-Fuel Scenario

The Reference Scenario in this study reflects the most likely short-to-mid-term load projection expected in the HOL service territory. Based on historical data and existing trends, Black & Veatch and HOL believe this scenario is optimal to inform short-to-mid term investments required to maintain reliability on the HOL distribution power grid. Thus, the Reference Scenario is the decarbonization load projection in which distribution modeling and ROM investment estimates were performed. A narrative of those findings is provided in more detail in Section 3. Decarbonization Impacts to HOL's Distribution System.

In the Reference Scenario, the new electrification load projection is characterized by a tempered pace of decarbonization in the short-term but still meeting Canada's 2030 Emissions Reduction Plan and Canada's wider 2050 decarbonization goals. This curve was developed from the existing Government of Canada targets adjusted for slower electrification in the near-term informed by observed trends in HOL's service territory. Further, this scenario assumes full electrification of most buildings, with a minority continuing to utilize gas distribution networks by 2050. However, to meet decarbonization targets in this scenario, pipeline fuel is assumed to be decarbonized via adoption of low carbon fuels. While identical to the Policy-Guided Scenario in EV adoption and PV generation, these cases differ in the implementation and adoption of EV charging rate incentives.

Alongside the Reference Scenario, Black & Veatch assessed a Dual-Fuel Scenario in which all assumptions match the Reference Scenario except for space heating and water heating. In this sensitivity, it was assumed that the majority of buildings that adopt heat pumps also maintain their gas space heating and water heating as back-up allowing for the use of gas-fired heating during extreme cold weather.

Reference Scenario and Dual-Fuel Scenario: Transportation Electrification

Transportation Electrification assumptions for these two scenarios are shown in Table 3. From 2023 to 2030 a rate design similar to the Ontario Government's existing ULO rate is assumed.[19] Beyond 2030, Black & Veatch assumed charging rate incentives would be adapted to provide optimal load flattening (i.e., incentivizing charging during times when demand from other load sectors is low.) These scenarios assume a rate incentive adoption rate of 75%, informed by the reference case of BC Hydro's Optional Residential Time-of-Use 2023 Rate Application.[28] Charging profiles in the Reference Scenario were informed by the Electric Vehicle User Behavior: An Analysis of Charging Station Utilization in Canada report. [29]

Table 3. Reference Scenario Transportation Electrification Assumptions

METRIC	ASSUMPTION	INFORMED BY
% of New Electric LDV Sales	2026 – 20% of new LDVs 2030 – 60% of new LDVs 2035 – 100% of new LDVs	Canada Zero-Emission Vehicle Sales Targets
Charger Types	Residential L1 or L2 – 80% Public L2 – 17% Public DCFC – 3%	Dunsky & NRCan,[30] J.D. Power,[31] Black & Veatch analysis
Rate Incentive Adoption	75%	BC Hydro's Optional Residential Time-of-Use 2023 Rate Application[28]
MDV/HDV Load as a Percentage of total LDV load	2050 – 10% (increases incrementally up to 10% by 2050)	Black & Veatch analysis. MDV/HDV load should be assumed as an addition to LDV load

As expected, EV-related load increases dramatically over the study horizon, growing from approximately 492 GWh/year in 2030 to 3,624 GWh/year in 2050, as shown in Figure 15. Peak EV load sees similarly dramatic increases, from 55 MW in 2030 to 772 MW in 2050. LDV related load makes up the majority of this increase, as expected given the assumed compliance of Canada's Zero-Emission Vehicle Sales Target of reaching 100% of new LDVs by 2035. Annual consumption growth from Transportation Electrification averages 123% between 2025 and 2035 as federal EV sales mandates ramp up before slowing to 11% per year between 2035 and 2050.

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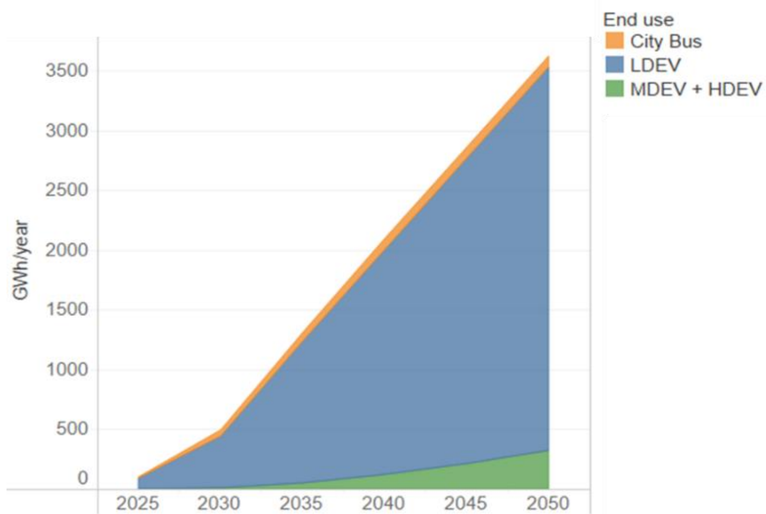
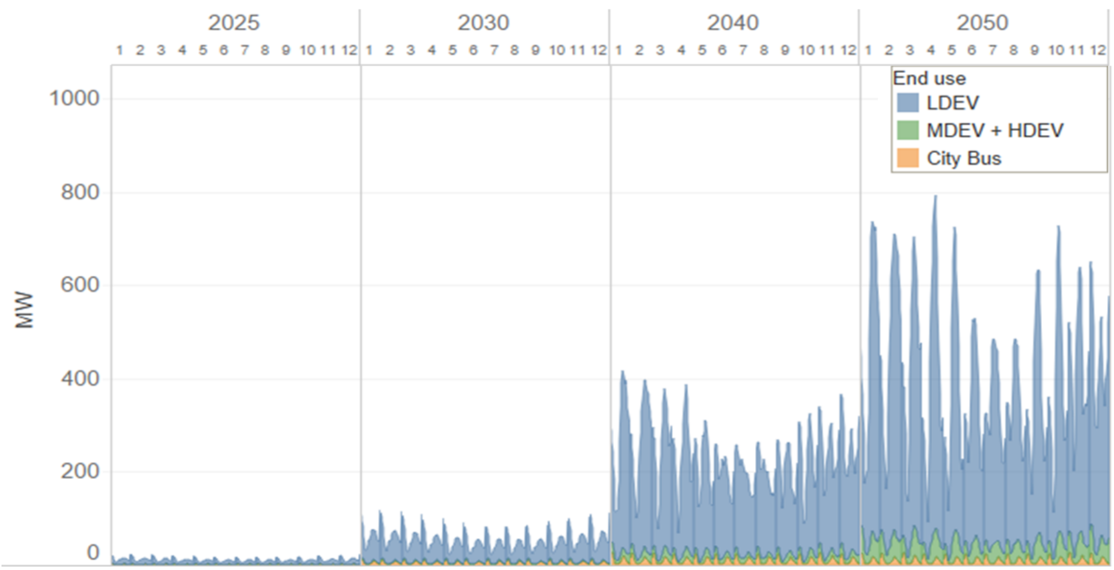
[28] BC Hydro Optional Residential Time-of-Use Rate Application, 2023.
[29] Electric Vehicle User Behavior: An Analysis of Charging Station Utilization in Canada, 2023.
[30] Dunsky & NRCan Updated Projections for Canada's Public Charging Infrastructure Needs, 2022.
[31] J.D. Power Electric Vehicle Experience Home Charging Study, 2023.

Figure 15. Reference Scenario Transportation Electrification Annual Load



The impact of a rate or other EV charging incentives is modeled as effective in shifting EV charging load from high-demand times (typically in early morning and evenings in the winter when heating load is at the highest) to lower demand hours. This trend is demonstrated in Figure 16.

Figure 16. Reference Scenario Transportation Electrification Load Profile



Reference Scenario and Dual-Fuel Scenario: Residential Electrification

Residential energy use in the Reference Case & Dual-Fuel Scenario was projected based on the adjusted decarbonization curve to account for slower progress in the near term while electrification technologies reach greater adoption in Ottawa. By 2050, the Reference Scenario assumes that residential buildings are mostly electrified, with space heating and water heating provided by heat pumps and electric resistance heating. However, roughly a quarter of heating needs are projected to be provided by gas distribution networks in 2050 (assumed to be low carbon such as RNG or hydrogen to meet Canada's decarbonization goals.) In the Dual-Fuel Scenario, a majority of households that adopt heat pumps also maintain their connection to gas distribution networks for use during extreme low temperatures. These technology forecasts were informed by CER's Canada's Energy Future report and collaboration with the team who authored the report.[23]

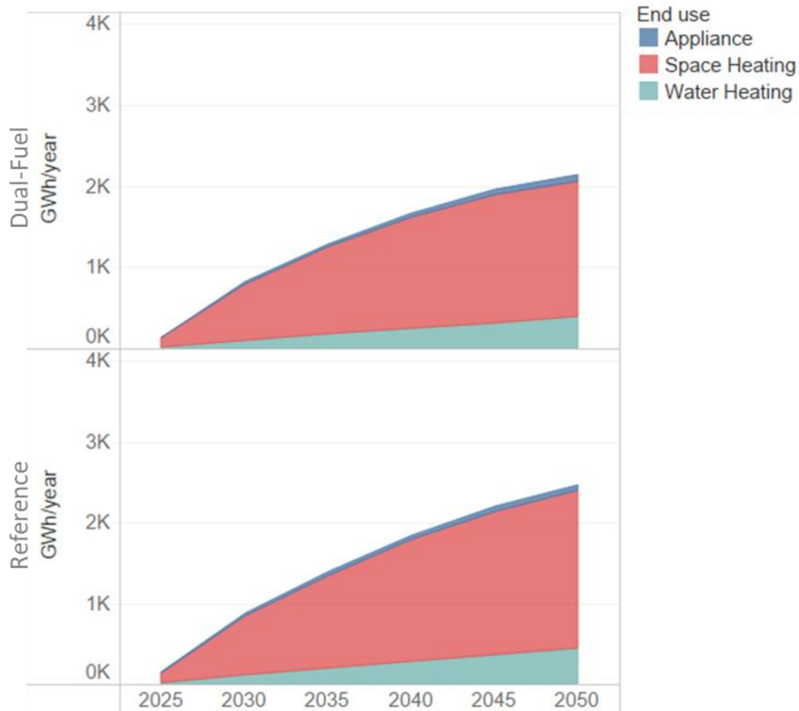
In both the Reference Scenario and the Dual-Fuel Scenario, space heating and water heating was assumed to be more efficient than in the Policy-Guided Scenario to accommodate expected technological advancement in heating technologies over the duration of the study horizon. During the hours in which temperatures remained above -10° C, water and space heating efficiencies remained the same between the Reference Scenario and the Dual-Fuel Scenario. During extreme cold hours (-10°C or lower), the efficiency of electric space heating was assumed to decline given the limitations of certain heat pumps technologies' ability to maintain efficiency during extreme cold temperatures. Table 4 provides a summary of the residential and commercial electrification assumptions used in each load scenario.

Table 4. Residential & Commercial Segment Electrification Assumptions

METRIC	REFERENCE SCENARIO	DUAL-FUEL SCENARIO	INFORMED BY
Space Heating Electrification Target (Achieved by 2050)	76% electric heating (combination of heat pumps and electric furnaces)	76% electric heating (combination of heat pumps and electric furnaces)	Canada's Energy Future report[23]
Heat Pump Space Heating COP	Residential - 3.94 Commercial – 3.65	Residential - 3.94 Commercial – 3.65	• Weighted average electric heating efficiencies • Canada's Energy Future report[23] • National Energy Code of Canada for Buildings[25]
Extreme Temperature (-10°C) Space Heating COP	Space Heating – 1.36	Space Heating – 10.14	Black & Veatch & HOL analysis
Water Heating Electrification Targets	76% electric	76% electric	Canada's Energy Future report[23]

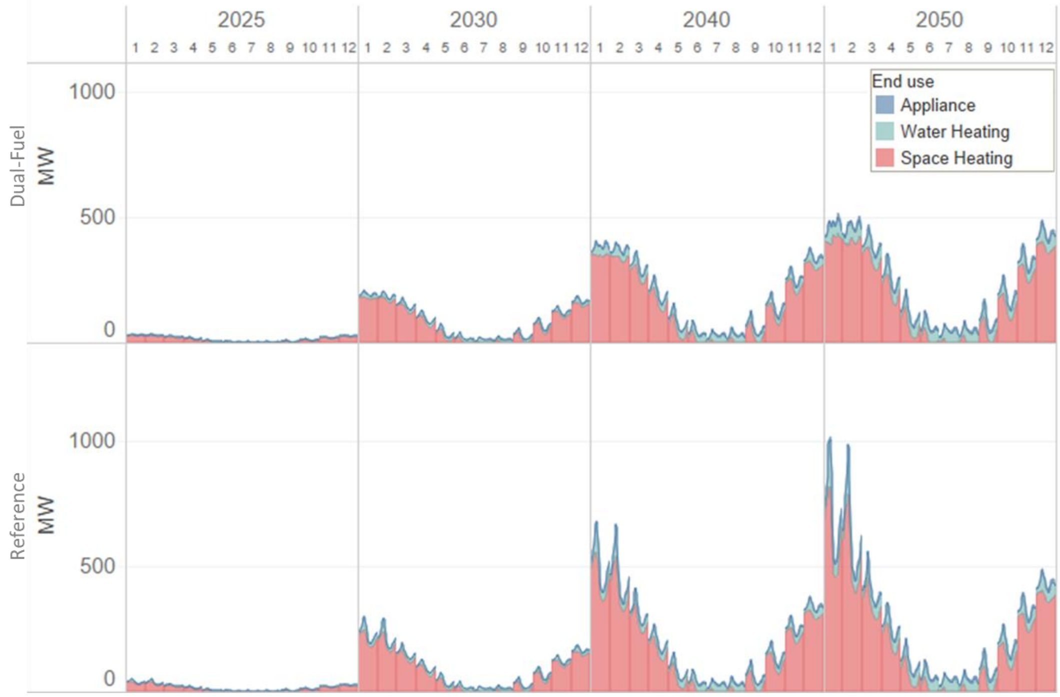
As demonstrated in Figure 17, the revised decarbonization curve slows load growth in the short-term when compared to the Policy-Guided Scenario (summarized in the Policy-Guided Scenario section). Lower space heating and water heating loads drive lower residential loads due to higher efficiency from increased heat pump penetration and continued use of low carbon gas in some buildings.

Figure 17. Reference Scenario Residential Electrification Annual Load



As shown in Figure 18, the use of dual-fuel systems significantly decreases load when comparing the sensitivity to the Reference Scenario. This trend becomes increasingly noticeable in 2035 when Reference Scenario customer electrification reaches 1,389 GWh per year, compared to 1,285 in the Dual-Fuel Scenario. By 2050 the gap increases to 2,472 GWh and 2,147 GWh in the Reference Scenario and Dual-Fuel Scenario, respectively. When extreme temperatures cause heat pump efficiency to drop below a certain threshold, gas-fired heating will ramp up, nearly eliminating electric space heating demand from households with these heating systems. For the purposes of this analysis, that extreme temperature was assumed to be at or below -10°C.

Figure 18. Reference & Dual-Fuel Scenarios Residential Electrification Load Profile

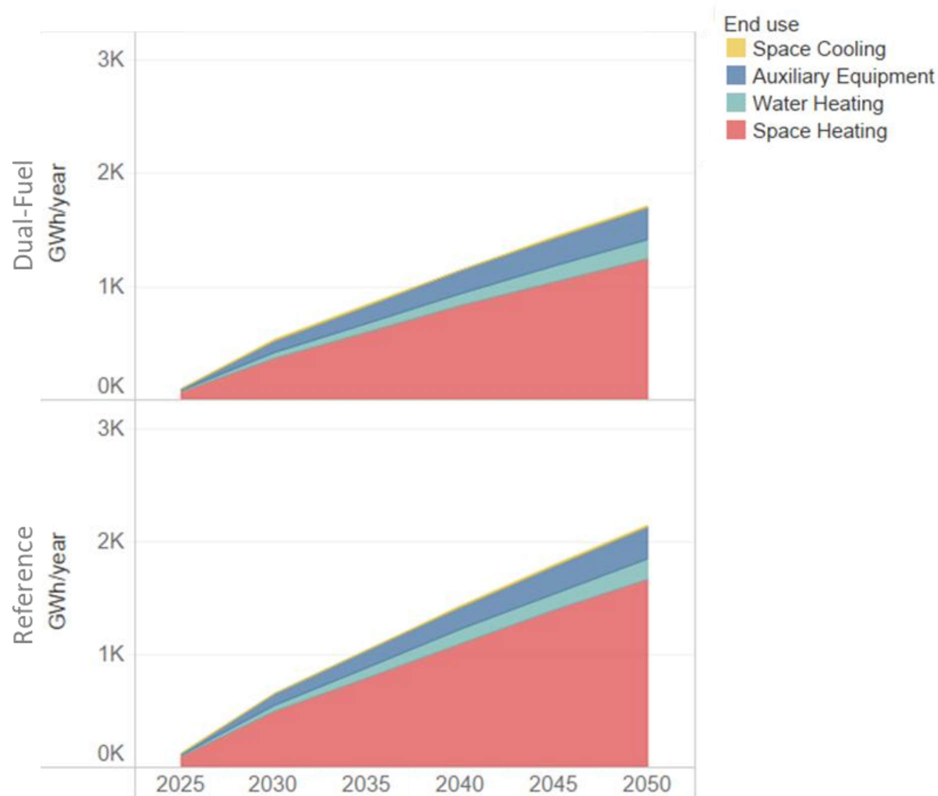


Seen in Figure 18, the seasonal impacts of dual-fuel heating compared to electric-only heating are clear. The most extreme examples occur in early January 2050, when Reference Scenario heating load exceeds 1,000 MW compared to 471 MW during that same hour in the Dual-Fuel Scenario.

Reference Scenario and Dual-Fuel Scenario: Commercial & Federal Building Electrification

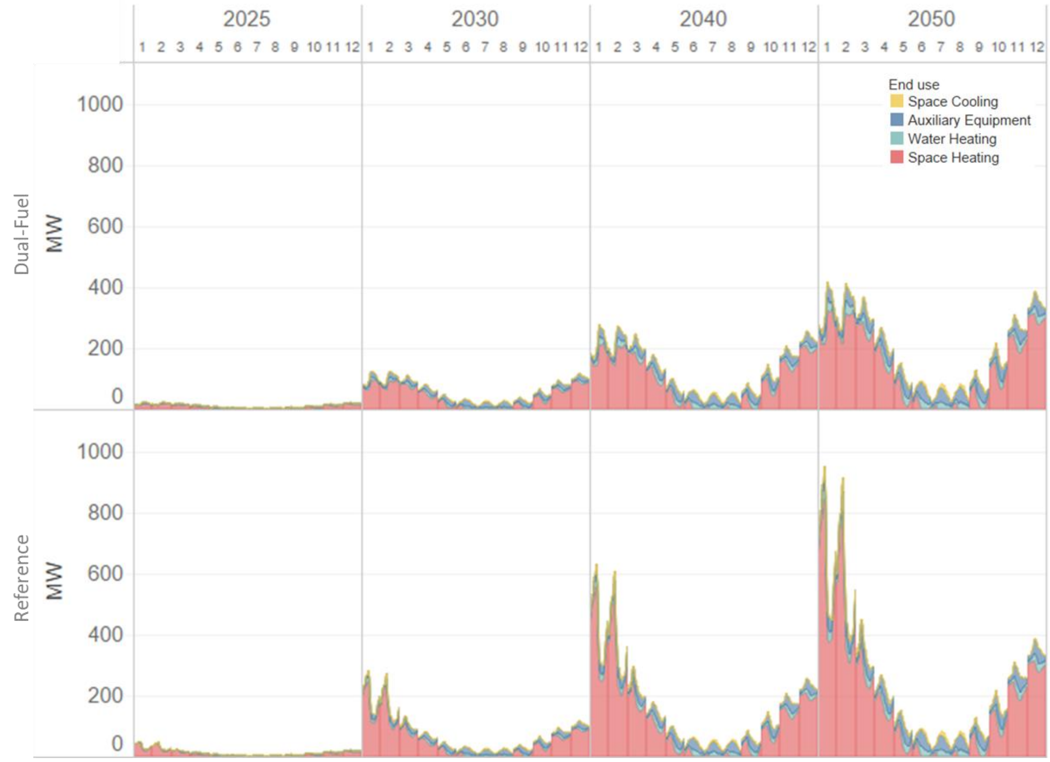
Commercial electrification in the Reference Scenario and Dual-Fuel Scenario follows similar assumptions as residential electrification. Like residential electrification, the adjusted short-term decarbonization curve was used to account for slower progress in the near term to align more closely to observed short-term trends. By 2050, buildings are assumed to be mostly electrified, with space heating and water heating provided by heat pumps and electric resistance heating. These trends are displayed in Figure 19. Roughly a quarter of heating needs are assumed to be provided by gas distribution networks in 2050 (assumed to be low carbon alternatives such as RNG or hydrogen to meet Canada's decarbonization goals). In the Dual-Fuel Scenario, most commercial buildings that adopt heat pumps are assumed to maintain their connection to gas distribution networks for use during extreme low temperatures. These technology forecasts were informed by CER's Canada Energy Future Net-Zero report and collaboration with the team who authored the report.

Figure 19. Reference & Dual-Fuel Scenarios Commercial Electrification Annual Load



The same trends projected in residential electrification are also exhibited in the commercial projections. As observed in Figure 19, the revised decarbonization curve slows load growth in the short term. Higher efficiency from increased heat pump penetration and some continued use of low carbon gas offset the load growth from electrification in later years. In the residential electrification sector, the use of dual-fuel systems significantly decreases load when comparing the sensitivity to the Reference Scenario, as can be observed in Figure 20. When extreme temperatures cause heat pump efficiency to drop below a certain threshold, gas-fired heating will ramp up, nearly eliminating electric space heating demand from buildings with these heating systems.

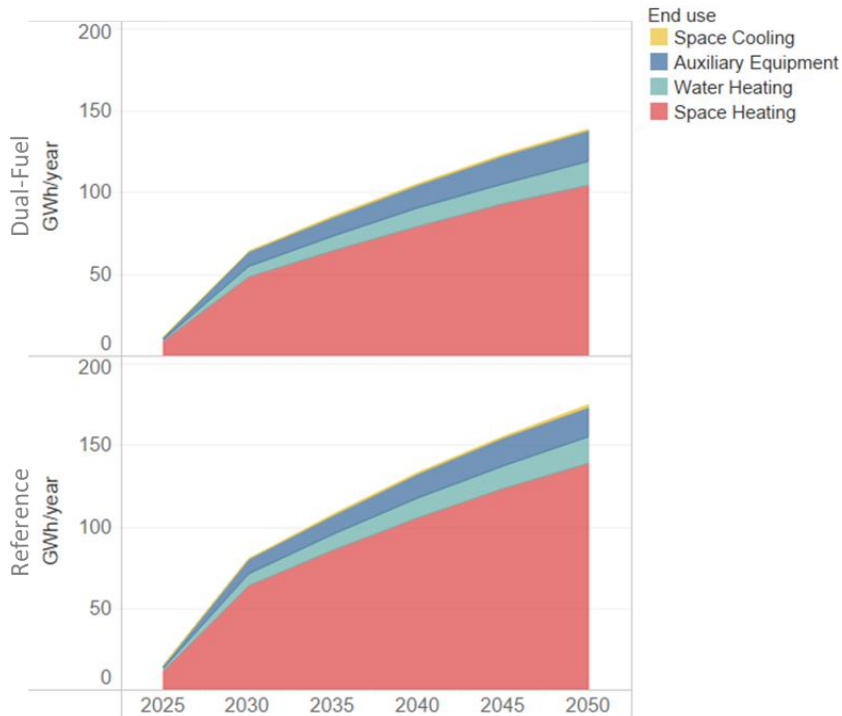
Figure 20. Reference & Dual-Fuel Scenarios Commercial Electrification Load Profile



As observed in the residential sector, seasonal impacts of dual-fuel heating compared to electric only heating are equally observed in the commercial sector. The most extreme examples occur in early January 2050, when Reference Scenario heating load exceeds 900 MW compared to 237 MW during that same hour in the Dual-Fuel Scenario.

Federal Building Electrification in the Reference Scenario and sensitivity utilized the same assumptions as Commercial Electrification, thus the results displayed in Figure 21 represent results consistent with that sector.

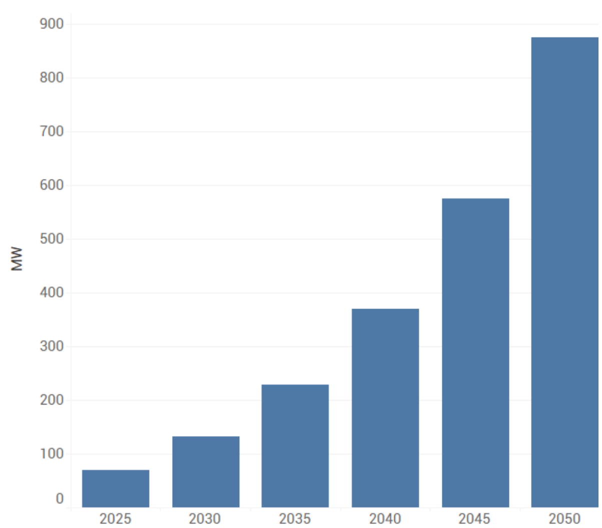
Figure 21. Reference Case Federal Electrification Annual Load



Reference Scenario and Dual-Fuel Scenario: Distributed PV Generation

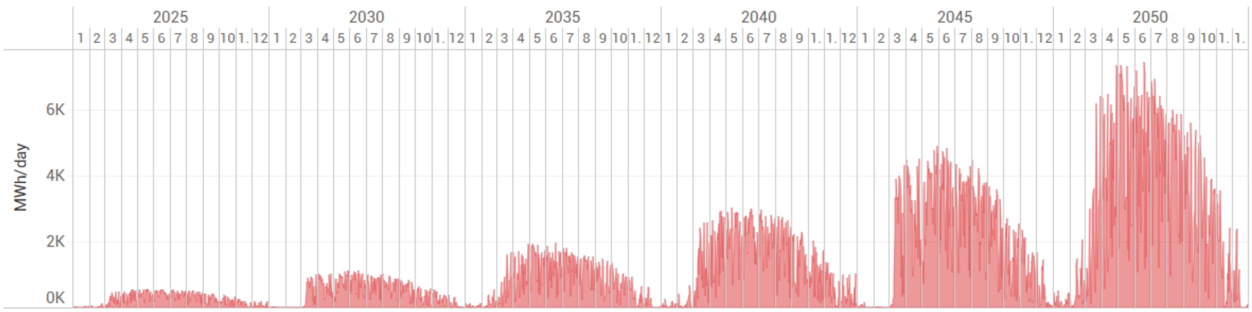
The moderate solar growth scenario from the City of Ottawa's Pathways Study on Solar Power was applied to project the Reference Scenario PV generation.[26] As a result, installed PV capacity grows incrementally throughout the projection horizon from 42 MW in 2022 to 875 MW in 2050, as shown in Figure 22. This same growth is observed in the Dual-Fuel Scenario given that this baseline assumption was unchanged.

Figure 22. Reference Case Distributed PV Installed Capacity



By 2050, distributed PV is projected to provide 5 to 6 GWh of generation on summer days. While this significantly offsets total load, it does not counteract evening peaks driven primarily from residential, commercial, and transportation electrification. Further, distributed PV generation also does little to offset winter evening peaks caused by space heating and water heating, as shown in generation profiles in Figure 23. This dynamic is important as HOL considers the impacts of NWS on the distribution system given that the system shifts from a summer peak to winter peak by 2030 in both the Reference Scenario and the Dual-Fuel Scenario. The role of solar and its ability to be paired with other NWS to increase reliability and resilience at substations is described in greater detail in Section 4.

Figure 23. Reference Scenario Distributed PV Generation Profile



Policy-Guided Scenario

The Policy-Guided Scenario was defined and projected assuming strict adherence to Canada's 2030 Emissions Reduction Plan and the Canadian Net-Zero Emissions Accountability Act. Decarbonization curves and EV adoption curves in this scenario were built based on these policies and targets**.** In doing so, buildings across all sectors were projected to be fully electrified by 2050, phasing out natural gas use to reach zero emissions targets. This scenario represents significant potential impacts to HOL's grid if climate goals are successfully met and there is little done to address the electrification impacts.

Policy-Guided Scenario: Transportation Electrification

Table 5 provides a summary of the transportation electrification assumptions and the sources which informed such assumptions. Unlike the Reference Scenario and Dual-Fuel Scenario, no charging incentives were assumed, resulting in charging profiles that reflect no load-flattening effects driven from incentives. Charging profiles in the Policy-Guided Scenario were informed by the Electric Vehicle User Behavior: An Analysis of Charging Station Utilization in Canada report.[29]

Table 5. Policy-Guided Scenario Transportation Electrification Assumptions

METRIC	ASSUMPTION	INFORMED BY
% of New Electric LDV Sales	2026 – 20% of new LDVs 2030 – 60% of new LDVs 2035 – 100% of new LDVs	Canada Zero-Emission Vehicle Sales Targets
Charger Types	Residential L1 or L2 – 80% Public L2 – 17% Public DCFC – 3%	Dunsky & NRCan,[30] J.D. Power,[31] Black & Veatch analysis

METRIC	ASSUMPTION	INFORMED BY
Rate Incentive Adoption	0%	No load mitigation efforts in the Policy-Guided Scenario
MDV/HDV Load as a Percentage of total LDV load	2050 – 10% (increases incrementally up to 10% by 2050)	Black & Veatch analysis. MDV/HDV load should be assumed as an addition to LDV load

Annual consumption from transportation electrification increases at a compound annual growth rate (CAGR) of 29.5% between 2025 and 2035 as federal EV sales mandates ramp up before slowing to 7% CAGR between 2035 and 2050. Peak load occurs on average around 6:00 pm, driven by the existing trend of commuters getting home and plugging in for the evening. Energy consumed by electric vehicles is greater in the winter than in the summer because of decreased charging efficiency in colder months. This can be seen most pronounced in 2050 where winter peak approaches 1 GW while summer peak is about 650 MW. Figure 24 shows the amount of transportation electrification end use, followed by Figure 25 which shows the transportation load profiles over the study horizon.

Figure 24. Policy-Guided Scenario Transportation Electrification by End-Use

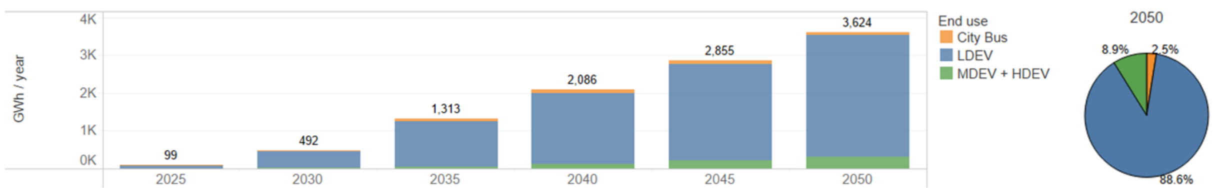
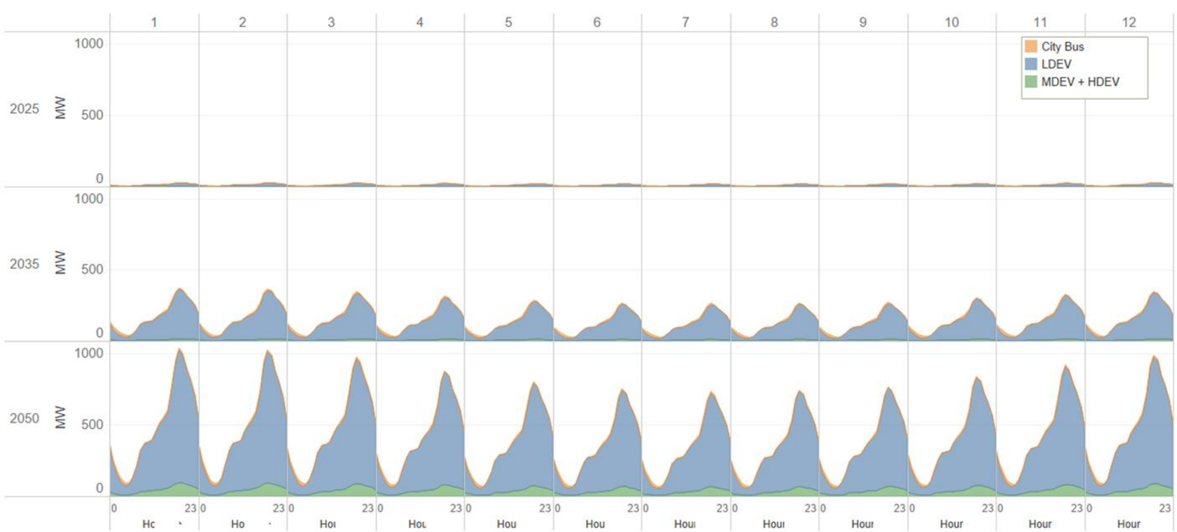


Figure 25. Policy-Guided Scenario Transportation Electrification Load Profile



Policy-Guided Scenario: Residential Electrification

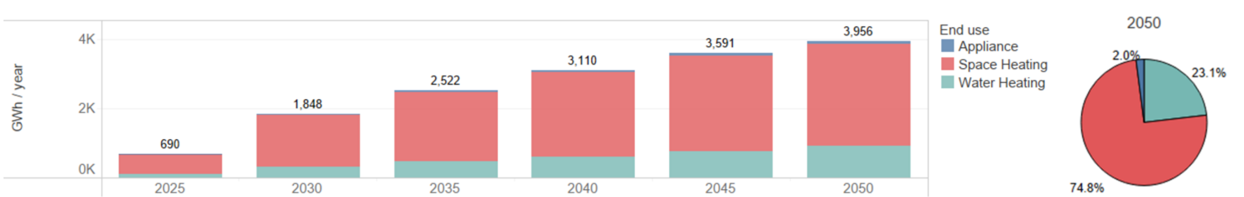
Residential energy use in the Policy-Guided Scenario was decarbonized based on Canada's 2030 Emissions Reduction Plan and the Canadian Net-Zero Emissions Accountability Act. Buildings are assumed to be completely electrified, with space heating and water heating provided by heat pumps and electric resistance heating. Residential heating (both water heating and space heating) was projected to be 100% electrified by 2050, consistent with decarbonization targets leveraged in this scenario. Black & Veatch used a mix of publicly available sources to develop weighted average heating efficiencies. Coefficients of performance (COPs) of both water and space heating declined during hours in which temperature reached below -10°C. Table 6 provides a summary of the residential and commercial electrification assumptions incorporated in this scenario analysis.

Table 6. Residential & Commercial Segment Electrification Assumptions: Policy-Guided Scenario

METRIC	POLICY-GUIDED SCENARIO	INFORMED BY
Space Heating Electrification Target (Achieved by 2050)	100% electric heating (combination of heat pumps and electric furnaces	Scenario assumption that federal targets are met via full building electrification
Heat Pump Space Heating COP	Residential – 3.24 Commercial – 3.00	• Weighted average electric heating efficiencies • Canada's Energy Future study[23] • City of Ottawa Energy Evolution[22] • National Energy Code of Canada for Buildings[25]
Extreme Temperature (-10°C) Space Heating COP	Residential Space Heating – 1.76 Commercial Space Heating – 1.76	Black & Veatch & HOL analysis leveraging combination of datasets above
Water Heating Electrification Targets	100% electric	National Energy Code of Canada for Buildings[25]

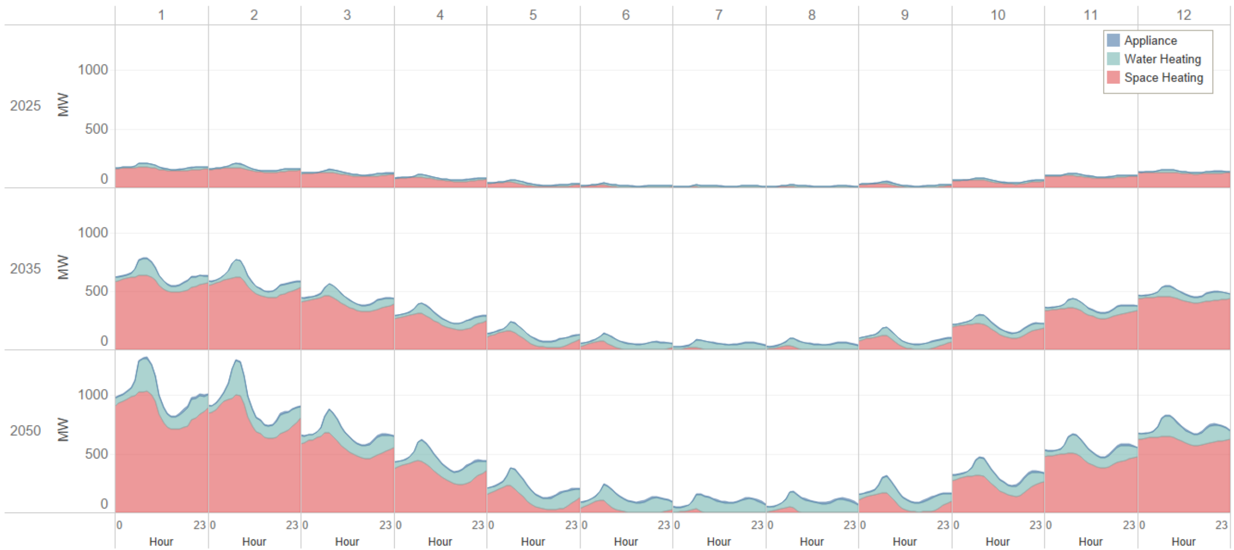
Annual new electrification load from residential electrification increased to 1,848 GWh in 2030 and to 3,110 GWh in 2040, an increase of 68% in that 10-year period. While electrification-driven growth slows past 2040 it still grows a considerable 27%, reaching 3,956 GWh/year in 2050. The high electrification growth in the near- to mid-term is driven by the more aggressive decarbonization curve assumed in that period to meet interim Canadian emissions targets. Load growth, while still significant between the 2040 and 2050 period, slows due to a projected heating load comprised of more efficient heating technologies such as air- and ground-source heat pumps. Figure 26 shows residential electrification load increase by end-use over the study horizon.

Figure 26. Policy-Guided Scenario Residential Electrification by End-Use



Space heating and water heating dominate residential electrification, accounting for a combined 98% of new electrification residential load. Space heating drives early morning peaks while water heating has both an evening and early morning peak. This is due to typical residential behavior turning on heating and hot water first thing in the morning and at the end of the workday. Heating efficiency significantly impacts load, and the relatively high penetration of electric resistance heating causes higher residential values than other scenarios. Figure 27 shows residential electrification profiles by end-use.

Figure 27. Policy-Guided Scenario Residential Electrification by End-Use



Policy-Guided Scenario: Commercial Electrification & Federal Building Electrification

Similar to the residential sector, commercial energy use was decarbonized based on the Target for Buildings from the Government of Canada. In line with residential electrification assumptions, commercial buildings are assumed to be completely electrified, with space heating and water heating provided by various commercial technologies that meet the National Energy Code of Canada. Commercial heating (both water heating and space heating) was projected to be 100% electrified by 2050, consistent with decarbonization targets leveraged in this scenario. Black & Veatch leveraged a mix of publicly available sources to develop weighted average heating efficiencies. Coefficients of performance (COPs) of both water and space heating declined during hours in which temperature reached below -10°C.

Like the residential sector, commercial load is dominated by space heating and water heating, as displayed in Figure 28. However, auxiliary equipment such as dryers and ovens play a significant role as well, accounting for 10% of new load by 2050. Unlike residential load profiles, commercial electrification peaks only in the morning. This coincides with the beginning of the workday and trails off in the evening as the workday concludes, as shown in Figure 29.

Figure 28. Policy-Guided Scenario Commercial Electrification by End-Use

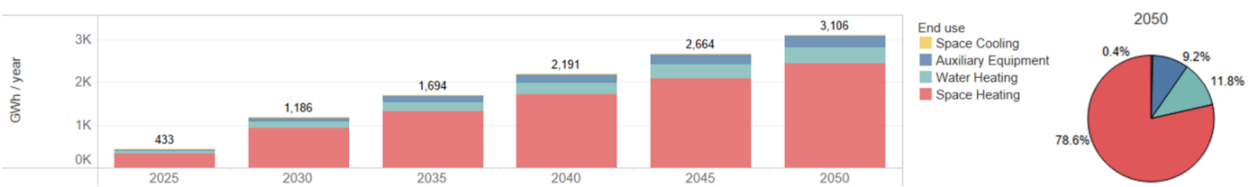
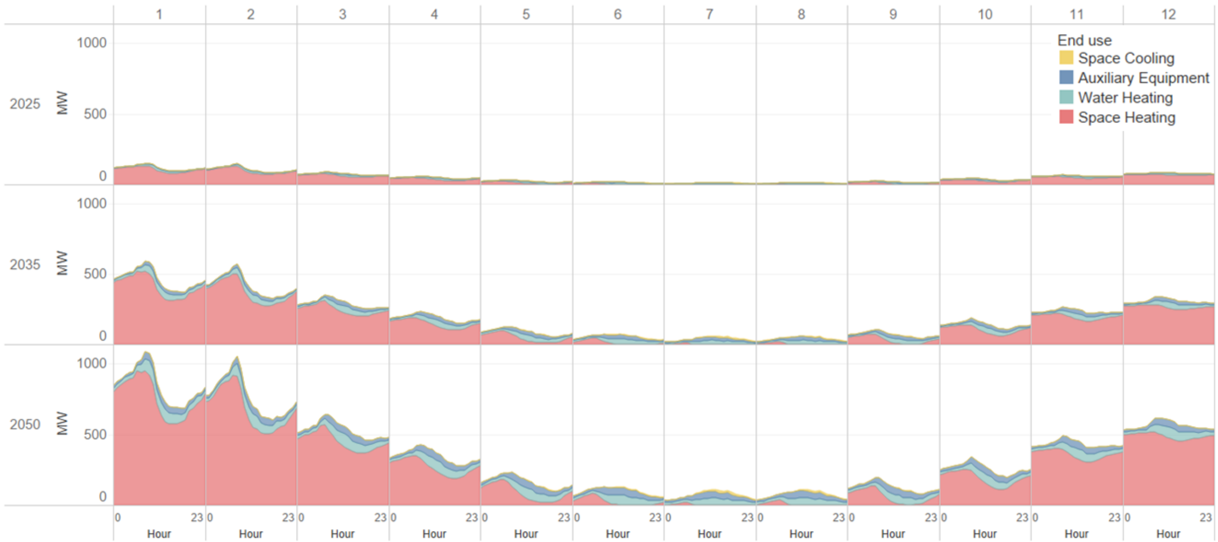
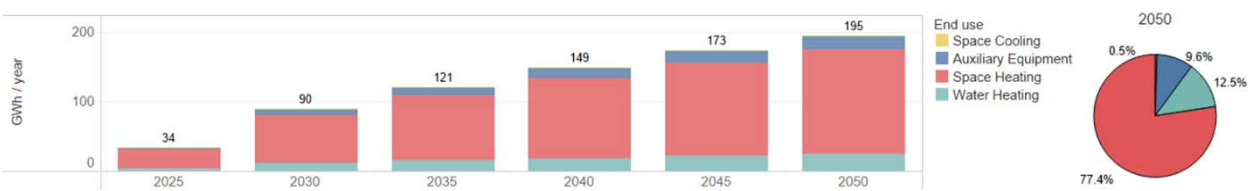


Figure 29. Policy-Guided Scenario Commercial Electrification Load Profile



The same decarbonization assumptions and energy uses for Commercial buildings were used for the 130 Federal buildings, however decarbonization targets were applied to each facility's estimated energy consumption rather than the sector's energy consumption as a whole. Because of these assumptions, results from Federal building electrification mirror those of commercial buildings, as shown in Figure 30.

Figure 30. Policy-Guided Scenario Federal Electrification by End-Use



Policy-Guided Scenario: Distributed PV Generation

The moderate growth scenario from the City of Ottawa's Pathways Study on Solar Power[26] was also applied to project the Policy-Guided Scenario PV generation. As a result, installed PV capacity increases incrementally throughout the horizon from 42 MW in 2022 to 875 MW in 2050, identical to the Reference and Dual-Fuel Scenarios, as shown in Figure 31 and Figure 32.

Figure 31. Policy-Guided Scenario Distributed PV Installed Capacity

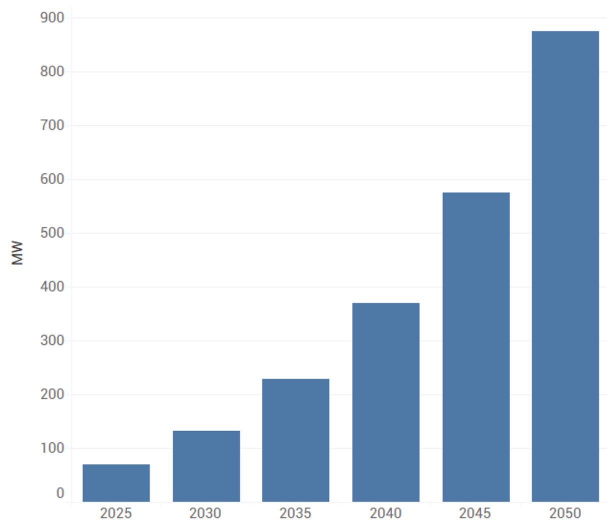
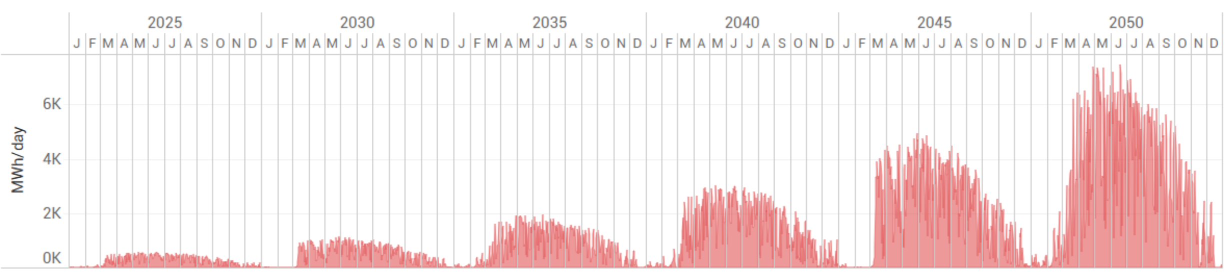


Figure 32. Policy-Guided Scenario Distributed PV Generation Profile



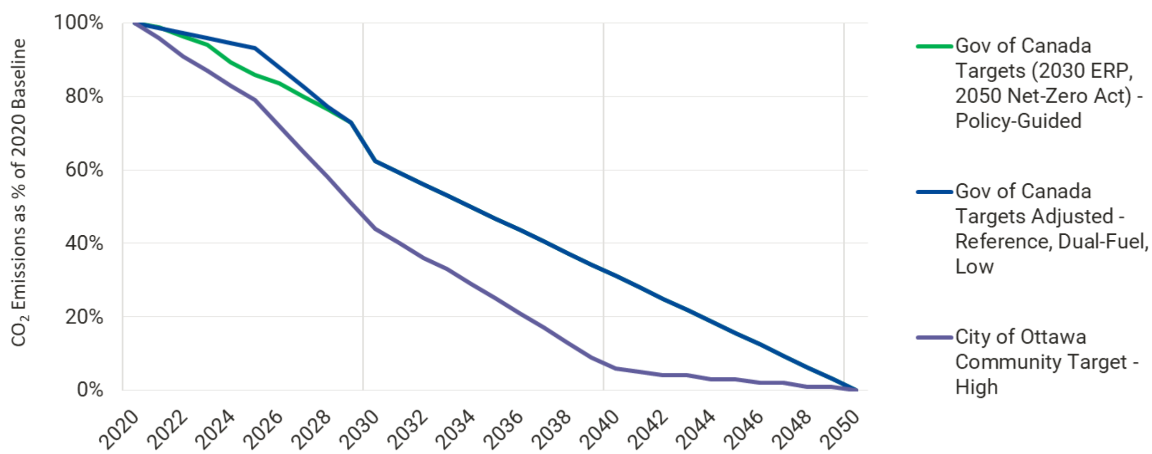
Given the use of the same solar projections and curves, solar projections in the Policy-Guided Scenario are identical to the Reference and Dual-Fuel Scenarios as summarized. By 2050, distributed PV contributes 5-6 GWh of generation on summer days. While this significantly offsets total load, it does not counteract evening peaks driven primarily from residential, commercial, and transportation electrification. Further, distributed PV generation also does little to offset winter evening peaks caused by space heating and water heating.

High & Low Sensitivities

The High Case Sensitivity and Low Case Sensitivity were developed to examine more aggressive and less aggressive decarbonization pathways, respectively, than current climate goals and expectations. Each sensitivity is meant to show possible high and low extremes in each customer segment and thus faster or slower progress towards climate goals.

To track with these trends, the High Case assumes a general societal shift towards a decarbonization mindset, where electrification not only happens faster but efficiencies of electrification technologies improve due to significant focus on research & development. Most notably, the High Sensitivity assumes the achievement of near-complete decarbonization by 2040, the most aggressive of all scenarios and sensitivities modeled in this study (see Figure 33). Conversely, electrification technologies are adopted slower in the Low Case and a higher proportion of households and commercial buildings continue to rely on decarbonized gaseous fuels.

Figure 33. Scenario & Sensitivity Decarbonization Profile Comparison



High & Low Sensitivities: Transportation Electrification

The primary differentiator in the sensitivities when compared to previously discussed transportation electrification is the rate of EV adoption (i.e., growth of new EV sales). In the High Sensitivity, EV adoption accelerates even faster than Canada's federal targets, reaching 90% of new vehicle sales by 2030 and 100% by 2035. Conversely, the Low Sensitivity models a significantly slowed pace of EV adoption, whether that be driven by societal resistance, lack of charging infrastructure build-out, or long-term supply chain issues. In the Low Sensitivity, EVs reach 40% of new sales by 2035 and 90% by 2050, indicating that a significant portion of the overall vehicle stock will remain gasoline or diesel powered past 2050. Table 7 shows the full list of assumptions specific to these sensitivities.

Table 7. High & Low Sensitivities Transportation Electrification Assumptions

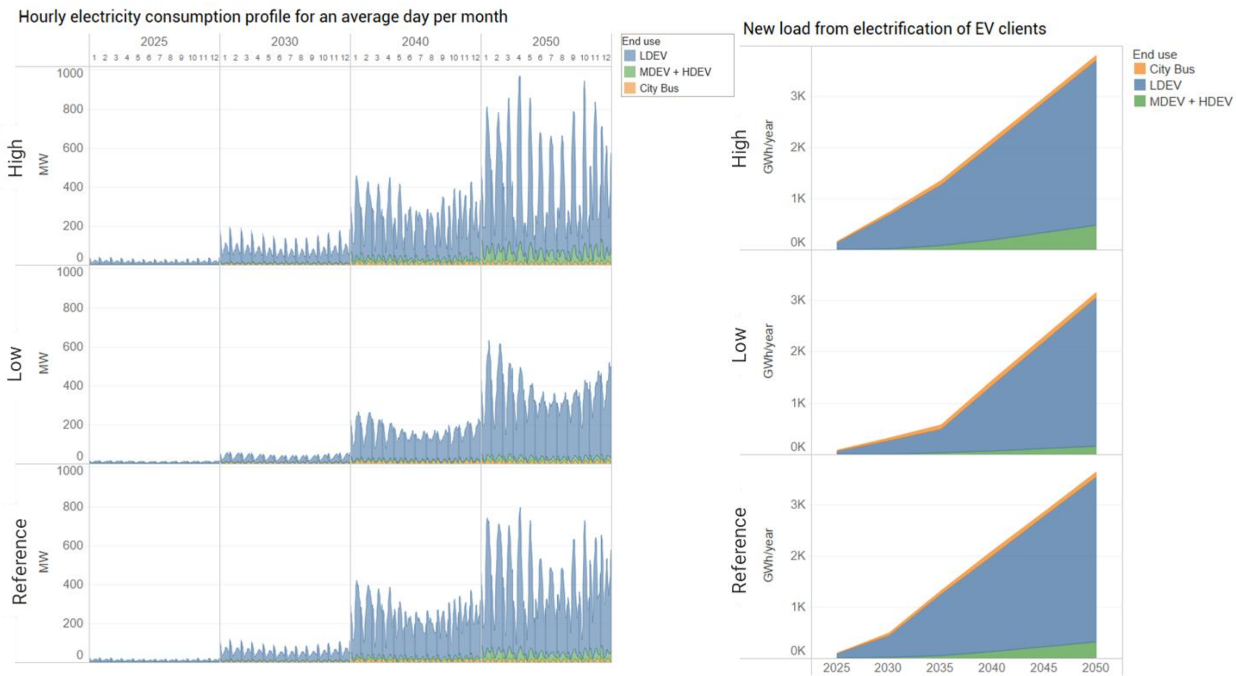
METRIC	HIGH SENSITIVITY	LOW SENSITIVITY	INFORMED BY
% of New Electric LDV Sales	2026 – 30% 2030 – 90% 2035 – 100%	2026 – 16% 2035 – 40% 2050 – 90%	High: Combination of City of Ottawa Energy Evolution[32] & Federal Targets Low: Sustainability Solutions Group's Pathway Study on Transportation in Ottawa[33]

[32] City of Ottawa Energy Evolution.
[33] Sustainability Solutions Group Pathway Study on Transportation in Ottawa, 2019.

METRIC	HIGH SENSITIVITY	LOW SENSITIVITY	INFORMED BY
Charger Types	Residential L1 or L2 - 85% Public L2 – 12% Public DCFC – 3%	Residential L1 or L2 – 80% Public L2 – 17% Public DCFC – 3%	Dunsky[30], JD Power[31], Black & Veatch analysis
Rate Incentive Adoption	90%	50%	High: BC Hydro TOU Rate Application High-End Sensitivity[28] Low: BC Hydro TOU Rate Application Low-End Sensitivity[28]
MDV/HDV Load as a Percentage of total LDV load	2050 – 15% (increases incrementally up to 15% by 2050)	2050 – 5% (increases incrementally up to 5% by 2050)	Black & Veatch & HOL analysis

As illustrated in Figure 34, adoption rates of both LDV and MDV/HDV significantly influence the rate at which EV load grows. From 2030-2040, the High Scenario outpaces the Reference Scenario because EVs have already reached 90% of new vehicle sales by 2030. The opposite can be seen in the Low Sensitivity, as EVs do not reach 40% of new sales until 2035 and have still not fully displaced ICE vehicles by 2050. Separate from the quantity of load, the transportation load profile changes drastically in the High and Low case due to the levels of rate incentive adoption. When compared to the Reference Scenario with 75% adoption, the High sensitivity (with 90% adoption) EV load shifted more towards midday hours when load is generally lower, potentially aiding in HOL load management. Conversely, the EV load in the Low sensitivity displays much less severe peaks than the other two shown because, with only 50% rate incentive adoption, fewer people are prioritizing charging at certain times of low demand during the day.

Figure 34. High & Low Sensitivity Transportation Electrification



Residential, Commercial, and Federal Electrification

In the building sectors for the High and Low Sensitivities, electrification rates, decarbonization timing, and efficiency of heating were all altered to reflect the more and less aggressive projection, respectively. Efficiencies were improved in the High Sensitivity to reflect a societal acceptance of electrification and the associated innovation to be expected with such a shift. The opposite logic was applied to the Low Sensitivity. Table 8 provides an overview of the residential and commercial electrification assumptions used in the high and low sensitivities.

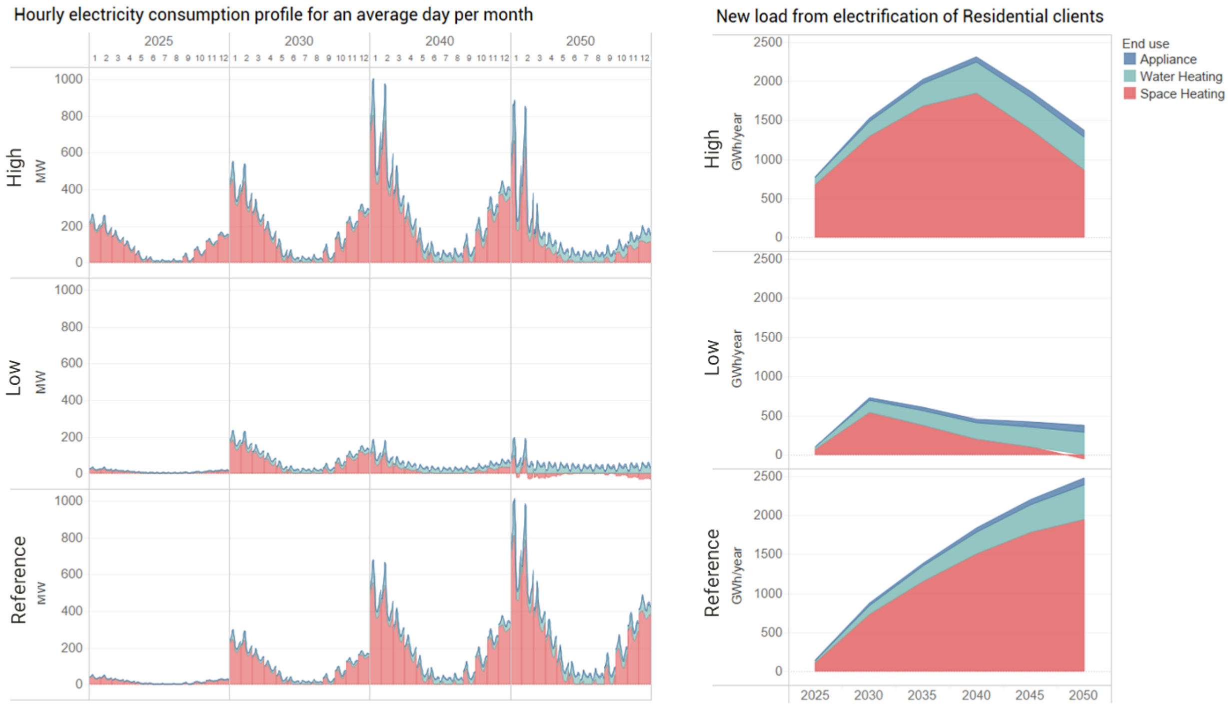
Table 8. Residential & Commercial Segment Electrification Assumptions: High & Low Sensitivities

METRIC	HIGH SENSITIVITY	LOW SENSITIVITY	INFORMED BY
Space Heating Electrification Target (Achieved by 2050)	85% electric heating	40% electric heating	High: Enbridge Pathways Study, Electrification Scenario[24] Low: Enbridge Pathways Study, Diversified Scenario[24]
Heat Pump Space Heating COP	Residential – 3.96 Commercial – 3.67	Residential – 3.24 Commercial – 3.00	• Weighted average electric heating efficiencies • Enbridge Pathways Study[24] • National Energy Code of Canada for Buildings
Extreme Temperature (-10°C) Space Heating COP	Residential Space Heating – 1.43 Commercial Space Heating – 1.43	Residential Space Heating – 1.76 Commercial Space Heating – 1.76	Black & Veatch & HOL analysis leveraging combination of datasets above

As expected, heating demand in the High Sensitivity and Reference Scenario shares more similarities when compared to the Low Sensitivity. However, the difference in the decarbonization curve between these two scenarios should be noted. The High Sensitivity assumes a more aggressive decarbonization curve compared to the more moderate curve assumed in the Reference Scenario. In the High Sensitivity, decarbonization is assumed to be nearly complete by 2040, compared to 2050 in the Reference Scenario. Further, residential heat pump adoption is assumed to be higher in the High Sensitivity compared to the Reference Scenario, resulting in overall more efficient heating loads in the later years in the horizon as adoption is increased. This is reflected in an observed decline in total electrification in the High Sensitivity post-2040 through the end of the horizon.

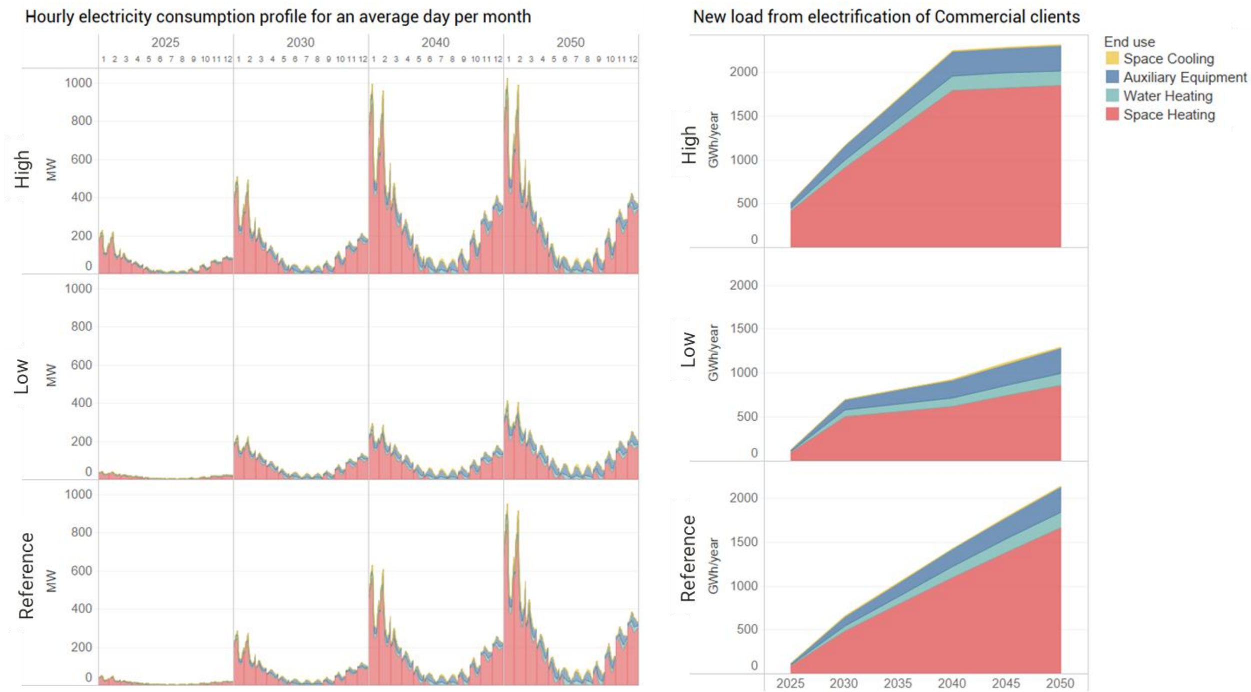
As an example, the Reference Scenario reaches over 1,000 MW of residential heating electrification in January on one day; during that same day, the High Scenario reaches 880 MW and the Low Scenario only 188 MW. This trend is more clearly shown in Figure 35. This trend is especially true for the period between 2040 and 2050 after full decarbonization is reached in the High Sensitivity. In the Low Sensitivity, space heating shows negative values at the end of the horizon as existing electric resistance space heating is converted to higher-efficiency heat pumps or low carbon gas.

Figure 35. High & Low Sensitivity Residential Electrification



The same trends observed in residential electrification are true for commercial electrification. As demonstrated in Figure 36, the High Sensitivity load increases driven by near-complete decarbonization by 2040 ramps up significantly towards 2040 compared to the Reference Scenario. After 2040, commercial, residential, and federal building electrification in the Reference Scenario catches up and then eventually outpaces the High Sensitivity.

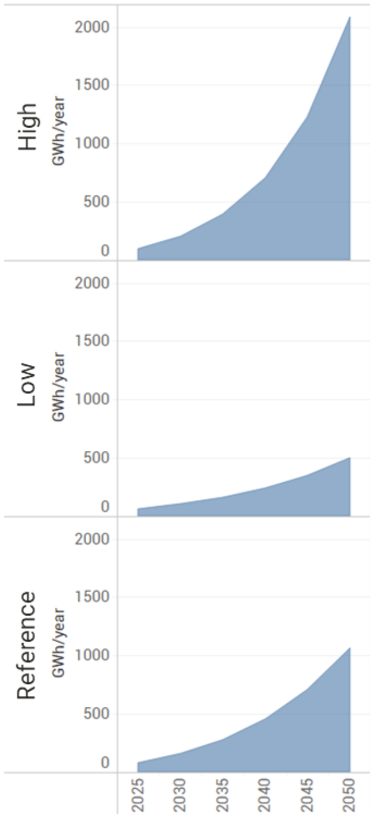
Figure 36. High & Low Sensitivity Commercial Electrification



Distributed PV Generation

The High & Low Sensitivities utilized the Aggressive Scenario and Conservative Scenario, respectively, from the City of Ottawa's Pathways Study on Solar Power (reflected in Figure 9).[26] The different growth rates across projections lead to significant differences in PV generation on HOL's grid. By 2050 PV in the High sensitivity generates 2,089 GWh per year, nearly twice as much as the Reference Scenario while the Low sensitivity generates 501 GWh – less than half the Reference Scenario. The resulting PV generation projection of each sensitivity is shown in Figure 37.

Figure 37. High & Low Sensitivity Annual Projected PV Generation



2.3 RESULTS SUMMARY & COMPARISON

Black & Veatch modeled system-level results for HOL's grid by compiling baseload and new electrification load across all customer segments for each of the three primary scenarios. This section summarizes key results for these scenarios and provides insights on the drivers of load growth and peak shifts throughout the study horizon. In all scenarios and sensitivities, load growth and peak demand are expected to increase dramatically. Projected building and heating electrification across all sectors paired with a shift from internal combustion engine vehicles (ICE) to EVs adds expected but considerable load increases to the HOL distribution system.

Impact on Peak Load and Peak Timing

All scenarios project significant peak load growth for HOL's grid (see Figure 38 and Figure 39). The Reference Scenario peak demand grows at a CAGR of 4.7% from 1,348 MW in 2022 to 4,947 MW in 2050. Policy-Guided Scenario peak demand grows at an annual rate of 5.2% to reach 5,573 MW in 2050 while Dual-Fuel Scenario peak grows at a slower CAGR of 3.1% per year, reaching 3,135 MW in 2050. This type of dramatic growth associated with the decarbonization of Ottawa's economy is an expected departure from the observed trend in the past decade-plus on HOL's system of flat or declining peak load (1,518 MW in 2010 and 1,308 MW in 2014.) This expectation is driven from the relatively aggressive decarbonization assumptions and existing initiatives supporting those assumptions for Canada to meet its aggressive emissions and net-zero targets in the mid-to-long term.

Figure 38. Scenario Peak By Year

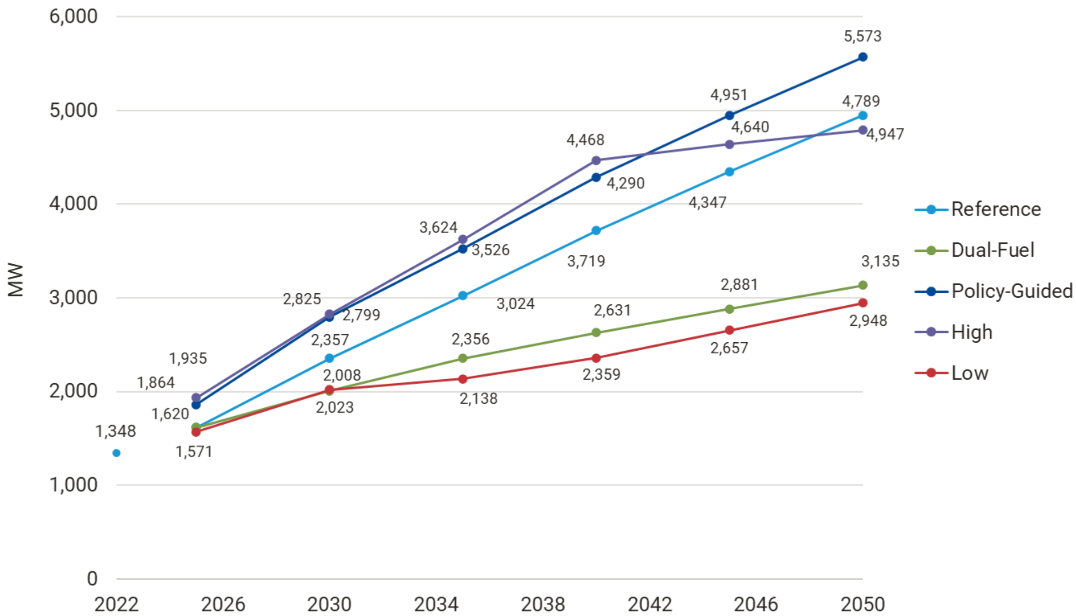


Figure 39. Scenario & Sensitivity Peak Timing Projections

Scenario	2022	2025	2030	2035	2040	2045	2050
Reference	17:00	15:00	18:00	18:00	18:00	18:00	18:00
	July 20	July 16	Jan 20	Jan 20	Jan 20	Jan 20	Jan 20
Dual-Fuel	17:00	15:00	18:00	18:00	18:00	18:00	13:00
	July 20	July 16	Jan 23	Jan 22	Jan 23	Jan 23	Mar 1
Policy-Guided	17:00	18:00	18:00	18:00	18:00	18:00	18:00
	July 20	Jan 21	Jan 20	Jan 20	Jan 20	Jan 20	Jan 20

Note: yellow indicates summer peak; blue indicates winter peak

In the Reference and Dual-Fuel Scenarios, HOL's system remains summer-peaking through 2025 (seen in yellow cells in Figure 39), as it is today. In all scenarios, the system-level peak shifts to winter by 2030 with the Policy-Guided Scenario becoming winter-peaking by 2025, as expected given that this scenario was modeled with the most aggressive decarbonization curve. Conversely, the delay in the switch to winter-peaking in the Reference and Dual-Fuel Scenarios is driven by the applied decarbonization curve which projects a tempered rate of decarbonization in the near term before decarbonization technologies such as heat pumps and electric vehicles reach widespread adoption in the mid-term.

The shift to winter peak timing is largely driven by space heating. This effect is especially pronounced in the Reference and Policy-Guided Scenarios, where higher electrification rates in buildings lead to spikes in space heating when temperatures are low and impact heating efficiency. Compounding this effect is the prevalence of electric resistance heating in the Policy-Guided Scenario, which has lower efficiency than heat pumps. The Dual-Fuel Scenario is much less exposed to these lower efficiencies due to high penetration of dual-fuel heat pump systems which switch to gas when efficiencies drop below a certain threshold.

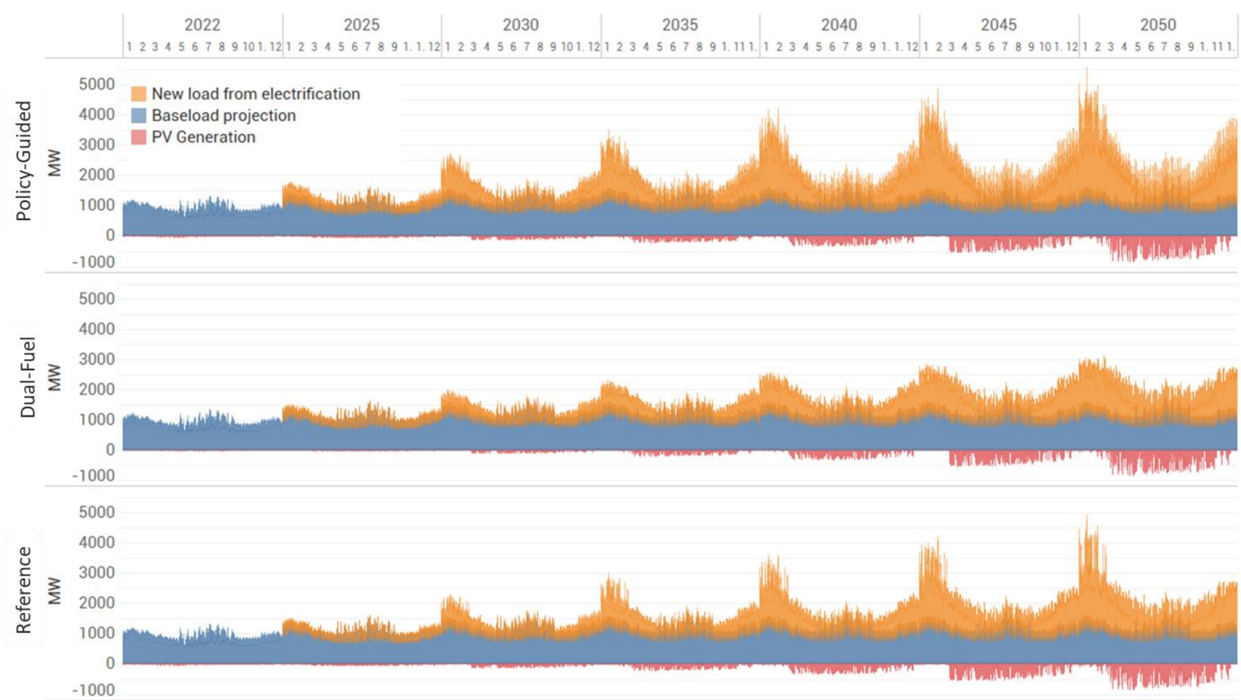
Peak demand in the Reference and Dual-Fuel Scenarios is also tempered by EV Charging incentives, which displace EV charging load from peak demand hours to low demand hours. These rate incentives are effective at lessening peak demand because they drive shifts in projected charging load away from the early evening when residents return from work, plug in their EV, turn the heat on, and begin cooking dinner.

Impact on Annual Electricity Consumption

Across the study horizon, new electrification load is the primary driver of load growth. Baseload consumption grows 10% between 2025 and 2050 while new electrification load grows over 2,000% in the same period in the Reference Scenario. In the summer months, EVs become the dominant source of new load for all scenarios as space heating and water heating become the dominant source of new load in the winter months.

The Policy-Guided Scenario projects the highest annual consumption of the three primary scenarios, 9% higher than the Reference Scenario and 10% higher than the Dual-Fuel Scenario in 2025. This trend continues and the gap widens through 2050, where it is 14% and 20% higher than the Reference and Dual-Fuel Scenarios respectively (see Figure 40). This higher annual load is driven by the full electrification of buildings across all customer segments in the Policy-Guided Scenario, while the other two scenarios maintain differing proportions of gas in the energy mix. While the Reference and Dual-Fuel Scenarios show similar annual consumption, the penetration of dual-fuel heating systems causes significantly different peak demand.

Figure 40. System-Level Annual Load Profile by Scenario



A detailed assessment of the implications of a decarbonization-driven electrification future on the HOL distribution system is outlined in the following section, specifically considering planning and systems upgrades for the HOL distribution system under a future in which the Reference Scenario is realized.

3.0 Decarbonization Load Impacts to HOL's Distribution System

3.1 METHODOLOGY & ASSUMPTIONS

Once the load was projected (approach and key findings by scenario in Section 2.0), a mitigation strategy to manage this increase in load was developed in two steps:

(1) an overload analysis to determine which substations are overloaded; and

(2) proposed strategies to manage the overload conditions at specific substations.

The methods for these tasks are described below.

Overload Analysis

The projected Reference Scenario load allocated to the existing 92 substations within HOL's service territory, as described in Section 2.1 Methodology and Assumptions, was utilized to assess if an overload condition was projected at each substation. HOL provided the characteristics for each of the 92 substations that was used as input into this analysis.[34] These inputs are included in Appendix A.

An initial screening was performed to evaluate if a substation needed to be included in the comprehensive overload analysis. Of the 92 existing HOL substations, 35 were excluded from the overload analysis if they met either of the following criteria. As such, only 57 substations are evaluated for overload[35]. Substations were not included for one of the following two reasons:

- If the substation is already planned for a voltage upgrade, or
- If the substation is planned to be decommissioned

Many of these planned voltage upgrades and decommissions are due to the load growth expected on HOL's existing 4kV system. Forecasts from HOL, further supported by this study, indicate the 4kV system will not be able to support expected load growth. As a result, the 4kV system is being upgraded to supported future load growth.

An overload condition is defined as when the allocated load from the Reference Scenario exceeds the station planning rating for each substation on an hourly basis. HOL provided the station planning ratings

[34] For the purposes of this analysis, Black & Veatch considered Bridlewood MS as two substations, one rated at 28kV and one at 8kV. If combined, the total substations is 92.
[35] Due to Bridlewood MS being modeled as 2 different substations with different characteristics, the overall results may vary resulting in 93 total substations being evaluated.

for each substation to be used in this analysis. Due to the effects of temperature on transformer capacity, separate planning ratings for summer and winter were used.[36]

The overload analysis compared the hourly projected load against the existing winter or summer planning rating depending on the month of the applied load. If the projected load exceeds the planning rating for the time of year the load occurs, the amount of overload was determined and an overload condition for that season is noted. If there is an overload for either winter or summer, then it is considered to be overloaded for that year.

The analysis was done for the years 2035 and 2050. These two years were selected as 2035 would indicate a lower, but more certain load case in the short term, where the 2050 load case would indicate a higher, but more uncertain load case in the long run. These two cases are used to set lower and upper bounds for needed investments to address the new load profiles on the distribution system.

Management of Overload Conditions

Once the overload conditions were established, two approaches were utilized to address the overload condition at each substation: evaluation of the potential to transfer the load from the overloaded substation to connected substations in the same grouping within the same distribution system and/or evaluation of the options for capital improvements to accommodate decarbonization load projections.

Potential to Transfer Load

HOL substations were organized in groupings that represent the potential capability of transferring load from one substation to another within the same grouping. This provides HOL flexibility in handling unusually high loads in times of peak stress or managing load when substations are unavailable for maintenance.[37] Given the new decarbonization projected load, these groupings could be utilized to distribute the load from the overloaded substation to connected substations in the same grouping. By doing so, this approach would allow HOL to avoid system modifications to address the overloaded condition and thus potentially avoid capital expenditure.

To evaluate whether the load that exceeds the planning ratings for equipment at each substation could be transferred, the amount of load above the planning rating (summer or winter, as appropriate given the time of year of the load) was compared to the available capacity in the connected substations within the same grouping. If there was available capacity in the connected substations based on their load at that same hour and their planning rating, then the potential to transfer the load was flagged. An illustrative example is shown in Figure 41. If not, it is not considered to be able to transfer the load. This is illustrated in Figure 42.

[36] The winter planning rating was applied from November through March, and the summer planning rating was applied from April through October.
[37] These groupings are shown in Appendix A.

Figure 41. Potential to Transfer Overload Illustrative Example

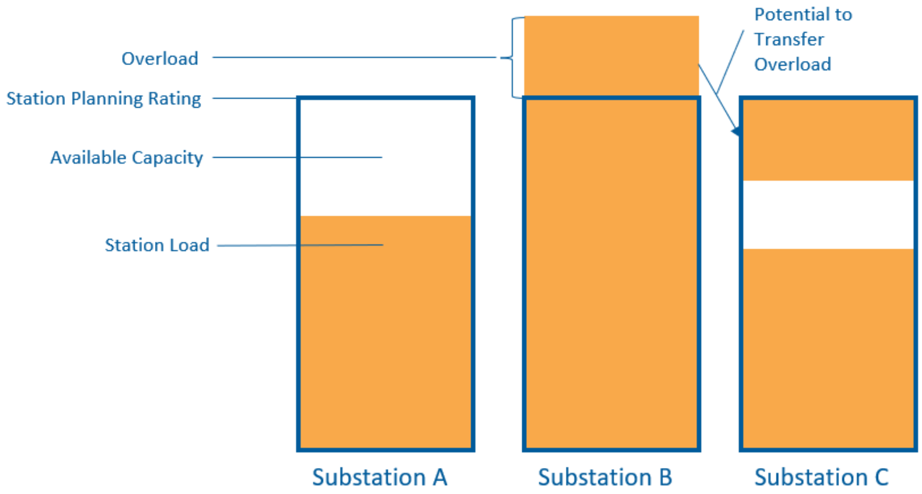
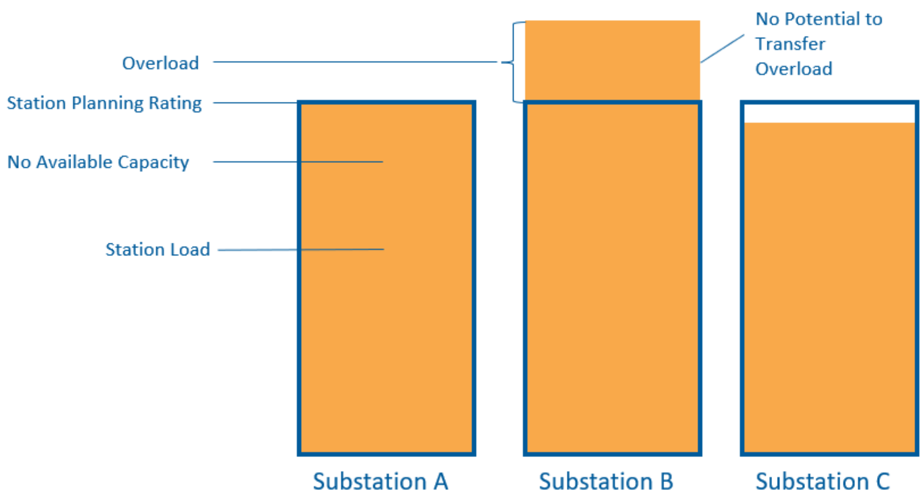


Figure 42. No Potential to Transfer Overload Illustrative Example



It should be noted that this evaluation only determines the potential to transfer the load as it evaluates the load against the substation planning ratings, but does not include the following considerations that would be required to do fully determine if a transfer is possible:

- Available feeder circuit capacity
- Available feeder tie circuit capacity
- Protection and coordination settings

A detailed system connected feasibility study and other distribution model studies are required to fully determine if a transfer can actually be performed. Because this evaluation only includes the potential to transfer the overload, this analysis was used to set upper and lower bounds on capital investment required to address the overload. Upgrades required for substations that cannot transfer the overload sets the minimum amount of capital investment needed to address the overload. The upper bound assumes that no substations can transfer the load and modifications are needed for all substations to handle the overload.

Capital Improvements to Accommodate Overload

The second approach to manage the new projected load in the Reference Scenario involved modifications to the existing distribution system, accomplished via either a wires only solution (i.e., traditional substation upgrades) or a non-wires solution. Examples of potential non-wires solutions (NWS) include solar, BESS, combustion turbines (CTs), RECIPS, fuel cells, and micronuclear. From these options, only BESS and RECIPs were considered. Solar was not included due to the large amount of land per MW required. Moreover, solar is least effective in winter when the new system peak occurs. CTs and fuel cells are not as effective in this use case due to significant dynamic and part load operation compared to RECIPs. Micronuclear was not considered due to technology maturity, cost, and schedule/licensing issues.

As a result of this NWS screening, the following technologies were evaluated for each of the overloaded substations:

- Wires Only Solutions – Consideration of only traditional wires solutions to addressed substation overload conditions. Wires only solutions include upgrades to existing substations and/or the addition of new substations.
- BESS – Evaluation of the role of BESS as an NWS to address substation overloads over the study horizon. If the substation had enough capacity during non-overload hours to sufficiently charge a BESS to discharge during an overload condition, the substation was determined to be eligible for a BESS. If there was not sufficient power available to charge a BESS prior to the overload, a BESS was not proposed, and the wires only was applied.
- RECIPs – Evaluation of the role of RECIPs as an NWS to address substation overloads. Each overloaded substation was evaluated to determine the required size and directional cost of the RECIP required.

The evaluation of each of these technologies only considers the required capacity to address the overload. No technical feasibility analysis was performed as part of the study. Items that were not considered but are recommended for future analysis include but are not limited to the following:

- Available footprint to upgrade existing transformers, add new transformers, add BESS or reciprocating engines to an existing substation.
- Available land to add new substations in the required service area.
- Ability of circuits outside of the substation to carry the additional load.
- Ability to provide sufficient natural gas to the reciprocating engines.

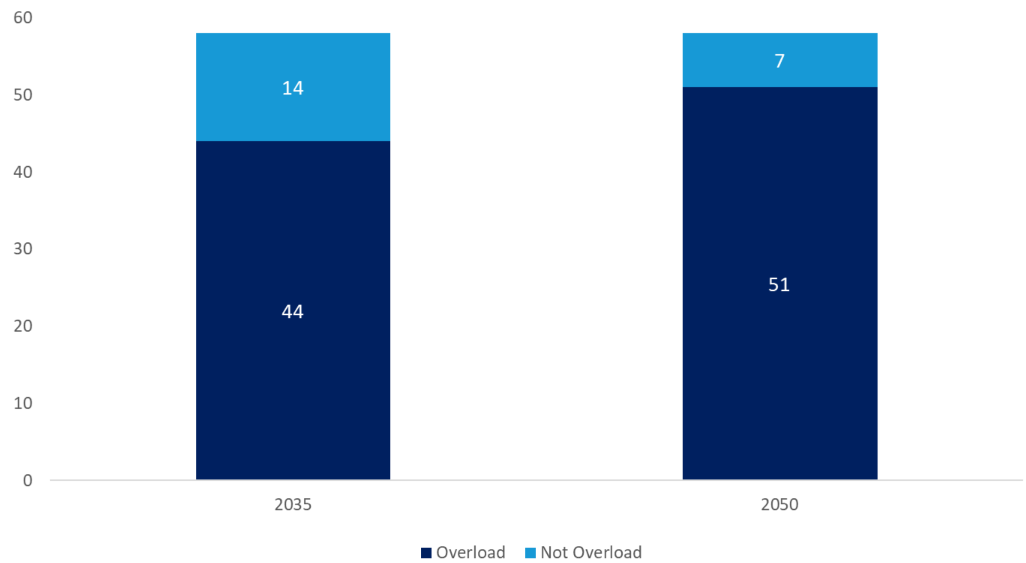
3.2 SUBSTATION OVERLOAD RESULTS & SOLUTIONS SCENARIOS

The results of the overload analysis are presented in two sections. The first section outlines the substation overloads that were identified and the second discusses the different wires and non-wires solutions assessed in this analysis to address substation overload. The second section provides a deep dive into the comparison of the two primary solution scenarios and compares the ROM cost of addressing the overload conditions to ensure future HOL system reliability.

Substation Overload Results

As discussed in Section 3.1, 35 of the 92 substations were excluded from this overload analysis. Of the remaining 58 substations, 44 of them are forecasted to experience an overload condition between 2025 and 2035, compared to 51 experiencing an overload condition between now and 2050.[38] Overloads were determined consistent with the methodology described in Section 3.1 Methodology and Assumptions. Figure 43 shows the cumulative number of overloaded substations of the 58 assessed substations, in 2035 and 2050 using the Reference Scenario load profiles. As shown in Figure 43, 44 of the 58 substations face their first overload condition by 2035, assuming Reference Scenario load profiles are realized this early in the study horizon. An additional 7 of the 58 substations reach overload conditions in 2040 or later. The remaining 7 substations do not reach overload conditions.

Figure 43. Cumulative Substation Condition in 2035 & 2050



Though peak demand increases the most dramatically later in the study horizon, early horizon substation overload (overloads between now and 2035) are also very impactful, driving necessary investment of substation upgrades in the short-term. More simply, even in the near-term with tempered pace of electrification, HOL should expect that if projections actualize, significant investment will be required in the short- to mid-term to meet projected short-to mid-term load growth.

Though a number of overload conditions occur early in the study horizon, 13 substations may be able to leverage substation transfers to transfer load from the overloaded substation to other connected

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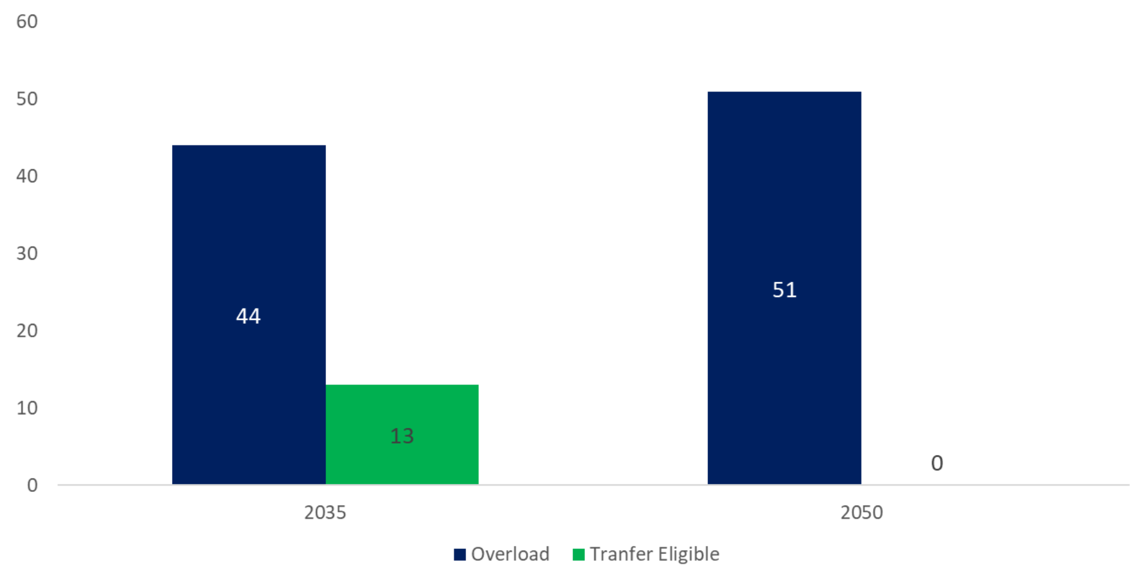
[38] 58 Substations are evaluated due to Bridlewood MS being split into two separate substations for the analysis resulting in 93 total substations (35 excluded + 58 included).

substations. As an example, the Bayshore DS substation is projected to reach overload condition as early as 2025. However, this analysis determined there is available capacity in the connected substations to potentially transfer load. While a system impact study was outside of the scope of this assessment, load transfers during periods of overload conditions should be studied in greater detail to inform short-term investment strategies. Figure 44 shows the number of substations both facing overload and eligible for connected substation transfer. As an example. In 2025, of the 21 overload substations, 8 have enough available capacity at the connected substations that substation upgrades may not necessarily be required to prevent an outage.

Figure 44. Cumulative Substation Overloads with Transfer Eligibility in 2035 & 2050



Solutions Scenario Assessment and Findings

Investment Model Methodology

As part of the overload assessment, two NWS technology assessments were developed to measure the relative cost of non-wires solutions compared to traditional wires upgrades. As part of this assessment, an Excel-based directional ROM investment plan was developed to calculate non-wires solution capital expenses, operating expenses, and fuel requirements. Further, the investment plan compares the solutions scenario NPVs assuming transferable load (the low case) and assuming no transferable load (the high case).

This assessment does not take a position on behind-the-meter or utility scale assets. HOL can and should explore partnership opportunities with local organizations and solar, BESS, or RECIP owners to evaluate joint ownership models to reduce HOL total costs. While this assessment does contemplate the amount of NWS generation needed, deployment and alternative ownership strategies should be carefully considered and evaluated.

Wires and non-wires solution (BESS and RECIPs) capital costs were assumed to be incurred the year before required at the substation. Operating expenses were assumed on an ongoing annual basis from the point of investment. For the purposes of this assessment summary operating expenses were assumed, including annual substation OPEX, BESS OPEX, RECIP engine OPEX, BESS energy losses, and natural gas fuel costs.[39] The following financial assumptions were used as provided by HOL:

- Capital inflation rate: 5.3%
- Service inflation rate: 2.4%
- Discount Rate: 6.21%
- Borrowing costs: 6.5%
- NPV calculated on a 2026 CAD basis

Solution scenarios were evaluated in two separate horizons. The first is through 2035 and the second is from 2024 through 2050. When the 2035 NPV is provided, cash flow ends in 2035 to determine the short-to-mid-term NPV. In the 2050 horizon, cash flows end in 2050 for the long-term horizon NPV. All inputs are in 2024 CAD and cashflow NPV results are real values.

Costs were assessed and compared in two study horizons:

1. System-wide investments by 2035: This assessment evaluated the required capital infrastructure needed to address substation overload conditions between now and 2035. 2035 provides a lower but more certain decarbonization load projection.
2. System-wide investments by 2050: This assessment evaluated the required capital infrastructure needed to address substation overload conditions between now and 2050. Since Reference Scenario load continues to increase over the study horizon, substations overload and thereby capital investment is dramatically higher in this study horizon. 2050 provides a higher but less certain decarbonization load projection.

NWS Technology Assessment Summary Results

BESS were identified as a potential NWS to be considered given the technology's general power system flexibility, reliability services, and ability to potentially provide short-term deferment. For the purposes of this analysis, chemical BESS such as lithium-ion were assumed given that they are the most widely available and cost-effective technology on the market today. However, specific technology and chemistries are likely to evolve as technologies continue to advance and federal incentives promote the deployment of the BESS solutions. One limitation of the BESS when considering the Reference Scenario, specifically, is that BESS is typically most cost-effective in small to moderate overload conditions, which is generally not the case in the substation overloads identified.[40]

Substations with available capacity to charge the BESS were determined as feasible for a BESS. Aside from considerations of charging capacity, the general feasibility of the BESS including available land, specific

[39] Substation capital costs and operating expenses reflect proprietary HOL data. BESS and RECIP capital costs and operations expenses leverage Black & Veatch proprietary data and National Renewable Energy Laboratory (NREL) data. Natural gas cost forecasts are from Black & Veatch models in the Ottawa, Canada service territory.
[40] This analysis assumed a standard lithium-ion 4-hour BESS for cost assumptions. Additional BESS sizes and types should be considered in HOL's future required feasibility studies.

BESS types, etc. are not considered, as this phase of work is intended to provide a screen of BESS eligible substations. A detailed feasibility study should be completed to further evaluate the role of BESS technology at the eligible substations. BESS sizing was estimated based on the expected capacity needed to satisfy the highest overload hour at each eligible substation.

As a future phase of this study, a detailed feasibility study and due diligence of the BESS eligible substations should be considered. Given the pre-feasibility study phases of this assessment, the results of this scenario should not be interpreted as the optimal BESS strategy, but as a screen criterion of the substations in which BESS could be considered. Because of the magnitude of the overload conditions, the size of the BESS required at many of the substations is likely not feasible but highly informative to understand the limitation of this technology as a feasible solution during times of potentially extreme overload conditions.

The results of the BESS-eligible substations were used as an input into the cost optimized scenario (results which are summarized later in this section). In the 2035 horizon, four of the 44 substations did not have available capacity to charge the BESS and were therefore not considered eligible for BESS. Those four substations (Lisgar TL, Marchwood MS, Orleans TS, and Stafford Road DS) assumed the same wires upgrades considered in the wires only solution scenario. In the 2050 horizon, 21 of the 51 overloaded substations do not have the availability capacity to charge the BESS and therefore were not considered eligible for BESS.

RECIP engines are a common NWS as they provide numerous grid benefits and a reliable power supply during system overloads or grid interruptions. RECIPs offer comparatively low installed costs compared to other NWS and offer additional capabilities such as black start, peaking, and emergency power applications (typically greater than 98% availability) and can operate using low carbon fuels such as biogas, renewable natural gas, and hydrogen.[41]

Unlike BESS, RECIPs do not require available capacity to charge, so that step in the analysis was not required and therefore the estimated RECIP size and directional cost was evaluated for each of the 44 overloaded substations in 2035 and all 51 overloaded substations in 2050. The results of this level of analysis are intended to provide a screen of the required RECIP sizes and associated costs to serve the required load at each substation. However, like in the BESS technology assessment, a detailed feasibility study should be completed to further evaluate the role of RECIPs at the eligible substations. RECIP sizing was estimated based on the expected size needed to satisfy the highest overload hour and duration at each substation. All overloaded substations were evaluated.

As a future phase of this study, a detailed feasibility study and due diligence of the RECIP eligible substations should be considered. Given the pre-feasibility study phase of this assessment, the results of this scenario should not be interpreted as the optimal RECIP strategy, but as a screen criterion of the substations in which RECIPs could be considered. A future feasibility study should consider environmental

[41] This study assumed the use of natural gas powered RECIPs, but low carbon fuels should be considered in future feasibility studies.

considerations of RECIPs such as emissions and noise limitations, as well as fuel-availability, and environmental permitting.

Solution Scenario Results

Traditional Wires Only

As part of the wires only solution scenario it was assumed that only traditional wires upgrades would be available to ensure overloaded substations have the available capacity to meet the overload condition. Table 9 shows the wires upgrades considered for this analysis.

Table 9. Evaluated Substation Wires Upgrades

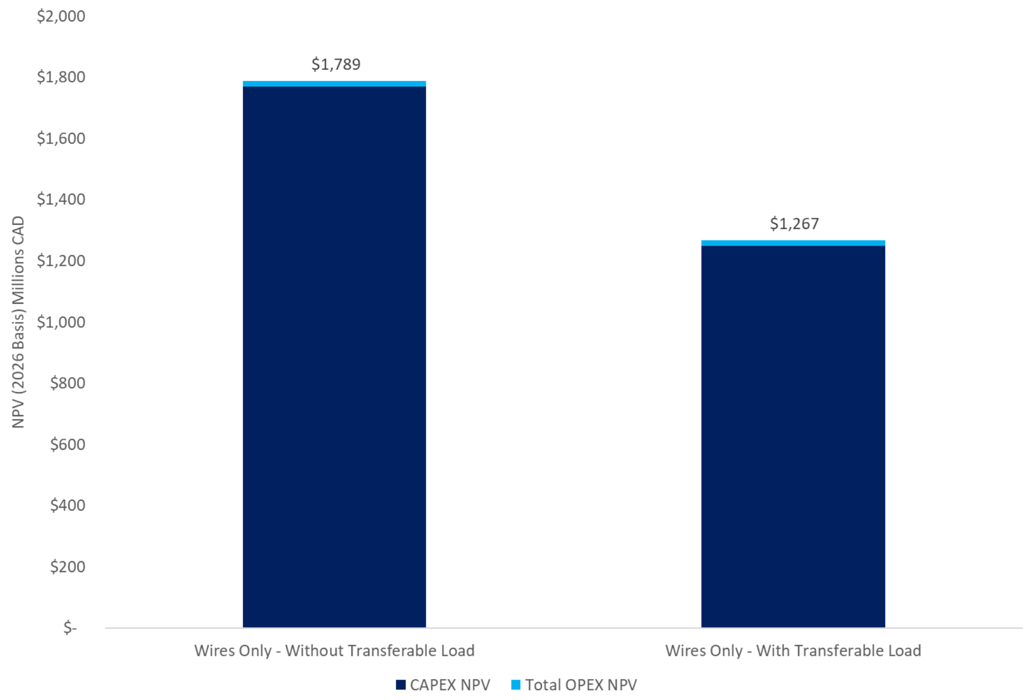
LOW SIDE VOLTAGE (KV)	NUMBER OF EXISTING TRANS-FORMERS	TYPE OF UPGRADE	NEW CAPACITY (MVA)	NEW SUMMER PLANNING RATING (MVA)	NEW WINTER PLANNING RATING (MVA)	COMMENTS
44	N/A	Add new substation (2 transformers)	2*100	120	130	Includes switchgear
44	2	Upgrade existing transformer(s), add one new transformer	3*100	240	260	Includes switchgear
44	2	Upgrade existing transformer(s)	2*100	120	130	
27.6	N/A	Add new substation (2 transformers)	2*100	120	130	Includes switchgear
27.6	4	Upgrade existing transformer(s)	4*100	360	390	
27.6	2	Upgrade existing transformer(s), add one new transformer	3*100	240	260	Includes switchgear
27.6	2	Upgrade existing transformer(s)	2*100	120	130	
27.6	1	Upgrade existing transformer(s), add one new transformer	2*100	120	130	Includes switchgear

27.6	1	Upgrade existing transformer(s)	1*100	100	100	If it continues to be a single transformer station, it cannot load to the LTR and will be restricted load to design rating.
13.2	N/A	Add new substation (2 transformers)	2*100	120	130	Includes switchgear
13.2	3	Upgrade existing transformer(s)	3*100	240	260	
13.2	2	Upgrade existing transformer(s), add one new transformer	3*100	240	260	Includes switchgear
13.2	2	Upgrade existing transformer(s)	2*100	120	130	

In the 2035 period, 44 substations reached overload conditions and required wires upgrades. Of the 44 substations, 13 could satisfy overload conditions through upgrades to the existing transformer(s) and nine require both upgrade of the existing transformer and the addition of a new transformer. 50% (22 substations specifically) are projected to require the addition of a new 27.6kV substation, the most capital intensive of the upgrades required.[42] Alternatively, if transferable load is considered, 13 of the 44 substations could potentially avoid costly substation upgrades. The estimated savings is shown in Figure 45, the wires only solutions scenario cash flow NPV drops by nearly $522 million CAD when assuming connective substations can absorb excess substation load to prevent and overload condition.

[42] Future system impact analyses could determine if fewer, but larger, new substations could address overload conditions rather than replacing every overloaded substation. For example, a new 100MVA station could support overloads from multiple other substations.

Figure 45. Wires Only Solutions Scenario Cashflow NPV (2035 Horizon): Comparison of Transferable & Non-Transferable Load

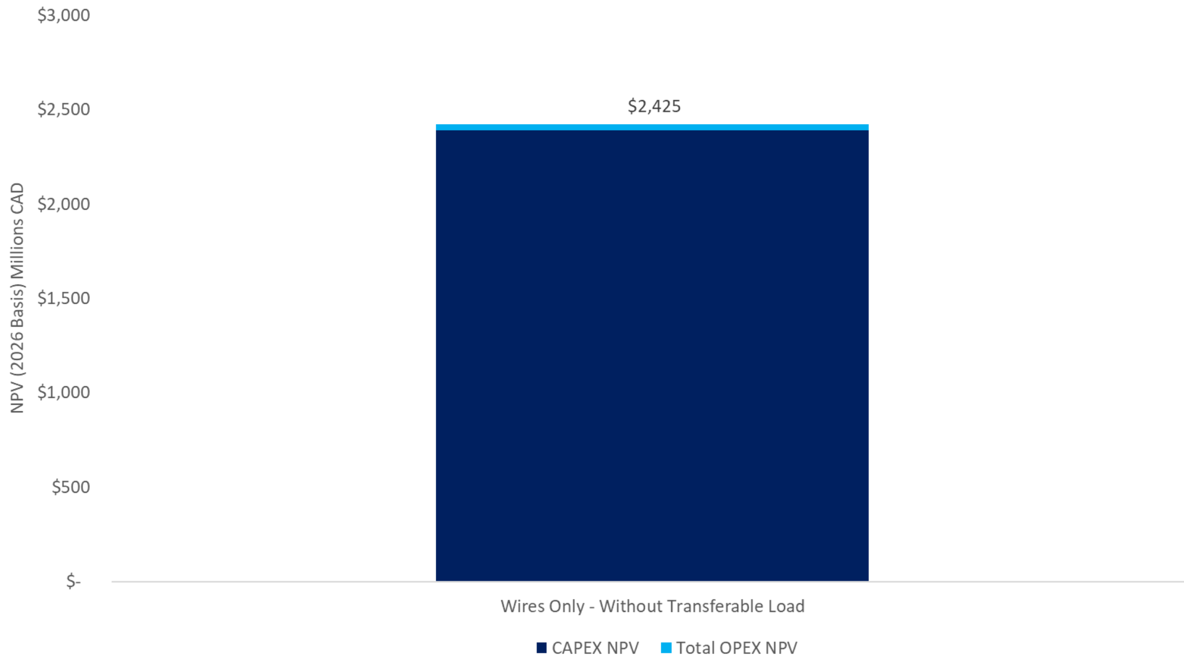


Given the projected increase in load the Reference Scenario and therefore CAPEX required in both scenarios, the required investment is considerable. Without transferable load, $1.77 billion CAD in wires investment is required, paired with an expected $18.5 million CAD in OPEX (in existing and incremental OPEX) to support new wires investment. Conversely, if considering transferable load CAPEX NPV reaches $1.25 billion CAD with $18 million CAD in supporting OPEX NPV in the 2035 horizon.

If HOL were to consider longer-term investment to meet 2050 load an additional $620 million CAD in CAPEX would be required, paired with an increase in OPEX of $16.3 million CAD (total CAPEX and OPEX as shown in Figure 46).[43] Transfers were not eligible during the long-term 2050 horizon study, given the lack of available capacity of connected substations, driven by the much larger increases in projected load later in the study horizon. The number of overloaded substations increased from 44 in the 2035 horizon to 51 in the 2050 horizon (assuming no transferable load).

[43] The comparison between 2035 and 2050 compares the NPV assuming no transferable load. If we compare the 2035 cashflow NPV with transferable load to the non-transferable load cashflow 2050 NPV, the increase is $1.14 billion CAD.

Figure 46. Wires Only Solutions Scenario Cashflow NPV (2050 Horizon)



Cost Optimized Solutions Scenario

The cost optimized solution scenario evaluates the lowest cost solution at each substation over the 2035 and 2050 periods. The lowest cost solution was identified by the lowest cashflow NPV (CAPEX NPV and OPEX NPV) over either the 2035 or 2050 horizon. It is important to note that the cost optimized solutions only contemplate the cost of distribution wires upgrades and not the associated upstream transmission or generation costs.[44] As a result, each substation within this solution scenario that realizes an overload condition is identified as addressing an overload with either a wires only solution, a BESS, or a RECIP. Table 10 shows the results of the cost optimization technology solution in the 2035 horizon for all 44 overloaded substations. BESS was the lowest cost solution at 2 substations, traditional wires was the lowest cost solution in 21 substations, and in the remaining 21 substation RECIPs were the cost optimized solution.

Table 10. Cost Optimized Substation Solutions: 2035 Horizon

SUBSTATION NAME	COST OPTIMIZED SOLUTION
HAWTHORNE TS	BESS
TERRY FOX MTS	BESS
BARRHAVEN DS	RECIP
BAYSHORE DS	RECIP
BEACONHILL MS	RECIP

SUBSTATION NAME	COST OPTIMIZED SOLUTION
BLACKBURN MS	RECIP
BORDEN FARM DS	RECIP
BRIDLEWOOD MS 8kV	RECIP
CASSELMAN MS	RECIP
CENTREPOINTE DS	RECIP

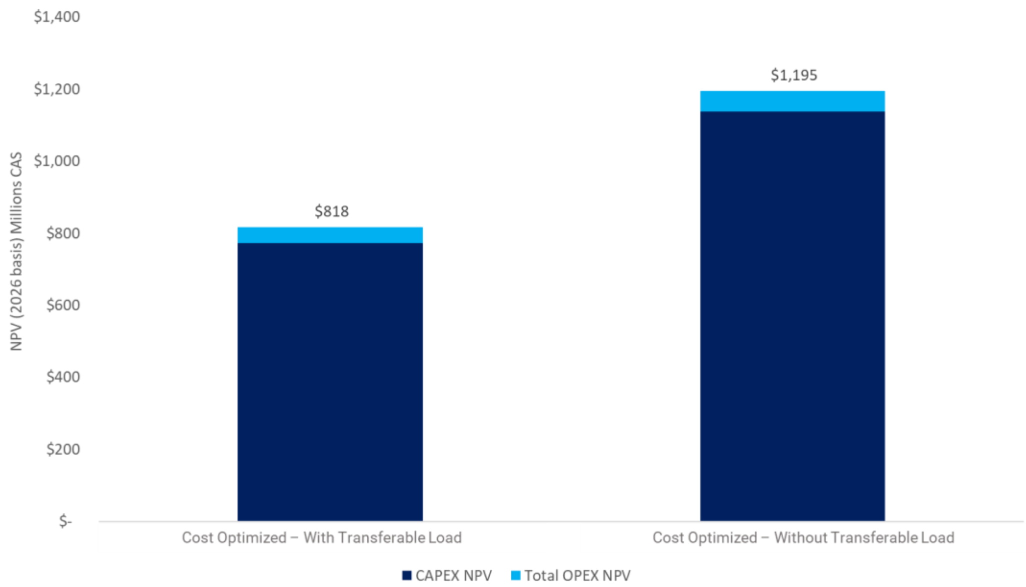
[44] Further, the timing and feasibility of the implementation was not included in this study. Black & Veatch provides detailed recommended next steps, which include a future feasibility study, in Section 4.

SUBSTATION NAME	COST OPTIMIZED SOLUTION
EPWORTH DS	RECIP
JOCKVALE DS	RECIP
LONGFIELDS DS	RECIP
MOULTON MS	RECIP
PARKWOOD HILLS DS	RECIP
Q.C.H. DS	RECIP
RICHMOND NORTH DS	RECIP
BEAVERBROOK MS	RECIP
BECKWITH DS	RECIP
MANORDALE DS	RECIP
SOUTH MARCH DS	RECIP
STARTOP MS	RECIP
WOODROFFE DS	RECIP
BRIDLEWOOD MS 28kV	Wires Upgrade
CARLING TM	Wires Upgrade
Cyrville MTS	Wires Upgrade
Ellwood MTS	Wires Upgrade

SUBSTATION NAME	COST OPTIMIZED SOLUTION
FALLOWFIELD MTS	Wires Upgrade
HINCHEY TH	Wires Upgrade
JANET KING DS 28kV	Wires Upgrade
KANATA MTS	Wires Upgrade
KING EDWARD TK	Wires Upgrade
LEITRIM MS	Wires Upgrade
LIMEBANK MS	Wires Upgrade
LINCOLN HEIGHTS TD	Wires Upgrade
LISGAR TL	Wires Upgrade
MARCHWOOD MS	Wires Upgrade
NEPEAN TS	Wires Upgrade
OVERBROOK TO	Wires Upgrade
RIDEAU HEIGHTS DS	Wires Upgrade
RIVERDALE TR	Wires Upgrade
SOUTH MARCH TS	Wires Upgrade
ORLEANS TS	Wires Upgrade
STAFFORD ROAD DS	Wires Upgrade

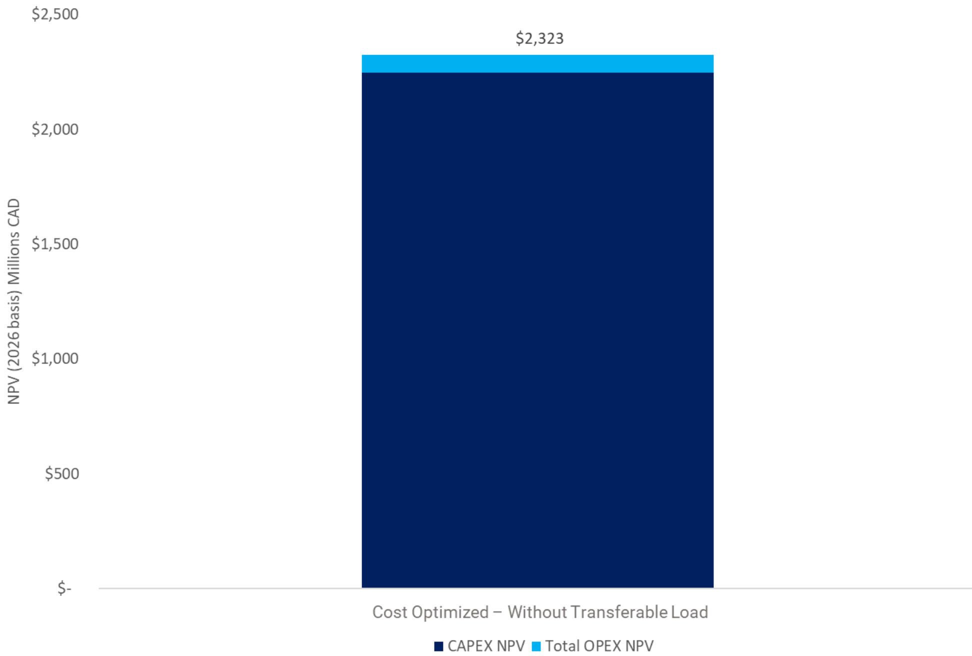
As expected, the cost optimized solution scenario has a lower scenario NPV compared to the wires only solution scenario, whether considering substation load transfer or not. If considering potential substation load transfers through 2035, the solution scenario cash flow NPV reaches nearly $818 million CAD. Conservatively, if not considering substation load transfers cashflow NPV through 2035, this increases to $1.2 billion CAD. The 2035 cashflow NPV for both transferable and non-transferable load are shown in Figure 47.

Figure 47. Cost Optimized Solution Scenario Cashflow NPV (2035 Horizon): Comparison of Transferable & Non-Transferable Load



When considering the most cost optimal solutions in the 2050 horizon, BESS was not the lowest cost option at any substation. Seven substations required no upgrades (Bells Corner DS, Janet King DS 8kV, Munster DS, Richmond South MTS, Slater TS, New 44, and Piperville). Of the 51 overloaded stations, RECIPs provided the lower cost solution in six (Bridlewood MS 8kV, Richmond North DS, Beaverbrook MS, Beckwith DS, South March DS, Woodroffe DS), and the remaining 45, wires only solutions provided the lowest cost upgrade. As expected even in the cost optimization solution scenario the 2050 cash flow NPV increased dramatically from the 2035 horizon, with the 2050 NPV exceeding $2.3 billion CAD as shown in Figure 48.

Figure 48. Cost Optimized Solution Scenario Cashflow NPV (2050 Horizon)



Solutions Scenario Comparison

The solutions scenarios present an opportunity for HOL to evaluate as it considers future feasibility studies to address substation overloads driven from Reference Scenario decarbonization load projections. Reviewing the required upgrades in the short- to mid-term 2035 horizon separately from the long-term 2050 horizon will allow HOL to make agile substation investments while future electrification driven load becomes realized.

The results of this analysis are intended to inform short and mid-term investment strategies for HOL as it evaluates both wires and non-wires solutions to address Reference Scenario decarbonization load projections. This section provides an analysis as to how each of the solution scenarios should be considered and evaluated, relative to each other, as HOL considers next steps in its system-wide upgrades.

If considering system-wide costs only, one scenario presents the most straight forward and optimal approach: the cost optimized scenario. As shown in Table 11 and Table 12, this scenario yields a lower solution cash flow and defers up to $594 million CAD in total cashflow NPV compared to the wires only solutions scenario. Table 11 and Table 12 display the projected deferred cost in the cost optimized solution scenario through both the 2035 and 2050 study horizon. Estimate deferred costs is represented as the total cash flow NPV difference between each solution scenario and the wires only solution scenario.

Table 11. Solutions Scenario Cashflow NPV Comparison (CAD) Assuming No Transfers

	WIRES ONLY	COST-OPTIMIZED
2035 NPV	1.78 billion	1.19 billion
2035 Deferred NPV	N/A	594 million
2050 NPV	2.43 billion	2.32 billion

	WIRES ONLY	COST-OPTIMIZED
2050 Deferred NPV	N/A	102 million

Table 12. Solutions Scenario Cashflow NPV Comparison (CAD) Assuming Transfers[45]

	WIRES ONLY	COST-OPTIMIZED
2035 NPV	1.27 billion	818 million
2035 Deferred NPV	N/A	449 million

To evaluate the solution scenarios, as well as the non-wires solutions developed in each scenario, five key measures were identified and evaluated. Each measure was scored on a scale of one to ten, with one being the least desirable and ten being the most desirable. The total score was calculated as the sum of all measure scores Black & Veatch applied quantitative cost metrics from its directional investment modeling results and a mix of qualitative and quantitative expertise to inform a high-level assessment of safety, reliability, resiliency, and environmental considerations. The intent of this scoring matrix is to review and evaluate the two primary solution scenarios against each other, outside of just cost considerations. The measures are defined as follows:

- Solutions Scenario Cost: Represented as the total net present value (NPV) of system-wide capital expenses (CAPEX) and operating expenses (OPEX). Rough order of magnitude (ROM) directional pricing estimates were developed for each solution scenario. The two solutions scenario NPVs were compared against one another, and the lowest cost solution was evaluated as the most desirable.
- Safety: Evaluated as how safe the proposed solutions is and potential risk it could pose to the surrounding area.
- Reliability: Evaluated as to how much power and for how long an overload could be mitigated by the evaluated solutions. Scenario solutions leveraging dispatch limited solutions were measured as less favorable.
- Resiliency: Evaluated as the total capacity of the wires or NWS assets, as well as vulnerabilities to external pressures, such as grid outages or fuel limitations.
- Environmental: Evaluated considering greenhouse gas (GHG) considerations, noise, and land use considerations.

Both solution scenarios were evaluated through both the mid-term and long-term lens. As an example, via the mid-term lens, solution scenarios and NWS were sized to meet substation load requirements through 2035. This mid-term lens is appropriate to evaluate the investments that HOL should consider in

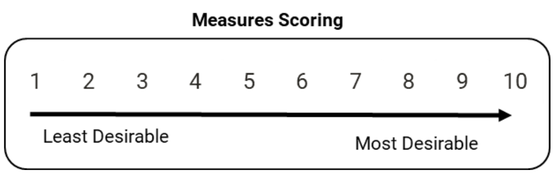
[45] There was not enough transfer capacity in the 2050 year, so 2050 values are the same as shown in the 2050 year in Table 10.

the short-term to maintain reliability through the mid-term. Alternatively, the long-term lens (substation upgrades to meet reliability through 2050), presents larger and most costly substation upgrades. The solutions scenario heatmap was applied to the 2035 findings to inform shorter-term investment strategies.

According to the results of this analysis and known uncertainties and risks, the two solutions scenarios were compared according to the above 5 factors, and then a composite score was calculated. As description of the comparison is provided the narrative following this comparison in Figure 49.

Figure 49. Solution Scenario Comparison Matrix[46]

	WIRES ONLY	COST OPTIMIZED
Measures		
Cost	5	9
Safety	10	7
Reliability	10	9
Resiliency	5	8
Environmental	5	5
Total Score (Sum)		
Overall Score	35	38



Measure 1: Cost

Cost was scored and compared based on the relative cash flow NPV of each solution scenario. The wires only solutions scenario is considered the baseline, thus reflecting a score of 5. The cost optimized solution was rated as a 9, consistent with its name. As part of future studies, it is reasonable to assume that both solution scenario costs could decline.

[46] Individual measures were scored on a scale of one to ten. The overall score is the sum of all scores.

Measure 2: Safety

For the purposes of this measure the relative safety of each solution scenario is considered. Of important note is the recognition that not all of these solutions and technologies are 100% safe, but some have objectively more risks than others. Though safety considerations must be considered even in the wires only scenario, comparatively this solution scenario was measured as the safest. Albeit a safe technology, BESS leveraged in the 2035 cost optimized scenario reduced the score to a six given the low but existing concerns of fires and considerations of safety setbacks for this technology.

Measure 3: Reliability

The wires only solution scenario was considered the most reliable for the purposes of this analysis, given that wires upgrades are assumed to always be oversized to handle the required amount of load on the system. BESS use lowered the cost optimized scenario score, purely because of the limitation to the length of period that a BESS can provide backup support and the required availability capacity to charge. RECIPs are highly reliable but require access to natural gas fuels.

Measure 4: Resiliency

Reliance on fuels outside of grid electricity were measured as more desirable than the solutions scenarios relying on 100% of grid electricity. The mix of RECIPs, BESS, and wires in the cost optimized scenario makes this scenario highly favorable from the resiliency perspective, secondary only to the RECIPs only scenario.

Measure 5: Environmental

Unique to Canada, and Ottawa specifically, is the amount of zero-carbon energy generation powering the grid. However, during times of peak demand, gas-fired generation is utilized to address incremental demand. Because of this, the wires only scenario is rated equally to the cost optimized scenario given the BESS will likely be charged from the grid and the RECIPs will likely run on natural gas. HOL should carefully consider the use of carbon-intensive fuels (such as natural gas) in a non-wires solution. While natural gas fired RECIPs will certainly address substation overload challenges and are a highly commercial and reliable technology, the use of low carbon fuels (such as hydrogen and RNG) should be considered in future as hydrogen and RNG costs continues to decline. This would provide HOL with both a reliable and low carbon system.

4.0 Next Steps and Future Studies

This study has evaluated the potential for increases in system load in the HOL distribution system based on various decarbonization and end use electrification scenarios. Additionally, impacts to the system were assessed and potential methods to mitigate those impacts were developed. It has been demonstrated that the electrification of energy end use cases such as transportation and heating will result in a significant increase in system load and is projected to require significant expenditures to address. This analysis provides a thorough examination of potential adjustments needed between now and 2050 for the HOL system to effectively address future decarbonization-driven load impacts. Though this study provides robust and comprehensive analysis into the possibility of the impact of decarbonization initiatives in the HOL service territory, additional considerations, studies, and analyses should be considered. The analysis performed in this study should be leveraged and built upon to further assess and finalize mitigation strategies to optimize capital investment. The following actions are recommended for consideration as next steps by HOL.

- Assess Load Increases Compared to Reference Case Decarbonization Load Projections: On an ongoing annual basis, substation level and system-level load projections should be assessed and compared to load growth actuals. Changes in electrification incentives and standards should be carefully monitored to revisit and adjusted load projections as necessary. As with all load projections, this assessment should be monitored and updated to incorporate the most up-to-date assumptions and baseline consideration.
- Confirm Potential for Load Transfers: This study evaluated whether there was the *potential* to transfer loads from an overloaded substation to a connected substation in the same grouping. When available, future system connectivity and impact studies should be performed to confirm whether projected load transfers can actually occur by evaluating all other system constraints, including, but not limited to, available feeder capacity, available feeder-feeder tie capacity, and protection and coordination schemes.
- Evaluate Potential Combinations of Wires and NWS for Selected Substations: In the 2050 horizon evaluation specifically, 8 substations were overloaded to the extent that a new substation was required as well as an upgrade to the existing substation. A system connectivity study and a technology feasibility study should be completed to determine if it would be more cost effective to utilize an NWS such as a BESS or RECIP. This evaluation would determine the most cost-effective approach for handling these substations.
- Technical Feasibility: The scope of this study determined only the required capacity for wires and non-wires solutions to address the overloaded substation and did not address technical feasibility for the proposed solutions. It is recommended complete a detailed Pre-Front-End Engineering and Design Study as well as a detailed feasibility be completed to evaluate the lowest cost investment option for each site, considering substation specific constraints. Technical feasibility studies should evaluate the following at a minimum:
    - Available footprint to upgrade existing transformers, add new transformers, add BESS or RECIPs to an existing substation
    - Available land to add new substations or other NWS in the required service area
    - Ability of circuits outside of the substation to carry the additional load
    - Ability to provide sufficient natural gas to the RECIPs
    - Availability of other fuel alternatives such as hydrogen or renewable natural gas
    - Ability to permit NWS
- Determine the Capital Investment Horizon for Each Site: Because the 2050 projected Reference Scenario load was far higher than the 2035 projection, the amount of overload is higher for 2050 than 2035, which resulted in higher capital expenditure to address the overload. It is recommended to evaluate the load conditions for each site and the difference in capital investment to make a final decision on which year to base an investment decision.

5.0 References

The following public sources were reviewed or referenced to inform this study. All references are linked to the associated assumptions via a footnote in main narrative of the report.

British Columbia Utilities Commission

BC Hydro Optional Residential Time-of-Use Rate Application, 2023.

Canada Energy Regulator

Canada's Energy Future: Energy Supply and Demand Projections to 2050, 2023.

City of Ottawa

Ottawa Climate Change Master Plan, 2020.

Energy Evolution, 2024.

Growth Projections for the New Official Plan, 2019.

Leidos Canada Pathway Study on Solar Power in Ottawa, 2017.

Solutions Group Pathway Study on Transportation in Ottawa, 2019.

Enbridge

Pathways to Net-Zero Emissions in Ontario, 2022.

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Canada's Changing Climate Report, 2019.

Canada's 2030 Emissions Reduction Plan: Clean Air, Strong Economy, 2022.

Greenhouse Gas Pollution Pricing Act (S.C. 2018, C. 12, S. 186), 2019.

National Energy Code of Canada for Buildings, 2020.

Updated Projections for Canada's Public Charging Infrastructure Needs, 2022.

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Electric Vehicle Experience Home Charging Study, 2023.

MDPI

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Natural Resources Canada
Commercial/Institutional Sector – Ontario Energy Use, 2024.

Residential Sector - Ontario Energy Use, 2024.

Ontario Energy Board
Ontario Ultra-Low Overnight Rate, 2024.

Ottawa Energy Evolution
Modelling Ottawa's Greenhouse Gas Emissions to 2050, 2020.

Hydro Ottawa Station Table

The following Hydro Ottawa and Hydro One owned stations in the table below are used to supply Hydro Ottawa's customers. The stations are herein referenced by the nomenclature (Hydro Ottawa Station Name) used by Hydro Ottawa.

Hydro Ottawa Station Name	Designation	Owner	Primary/Secondary Voltage (kV)
Albion TA	HVDS	Hydro One-Hydro Ottawa	230/13.2
Albion UA	DS	Hydro Ottawa	13.2/4.16
Augusta UD	DS	Hydro Ottawa	13.2/4.16
Bantree AL	DS	Hydro Ottawa	13.2/4.16
Barrhaven DS	DS	Hydro Ottawa	44/8.32
Bayshore DS	DS	Hydro Ottawa	44/8.32
Bayswater UJ	DS	Hydro Ottawa	13.2/4.16
Beaconhill MS	DS	Hydro Ottawa	44/8.32
Beaverbrook	DS	Hydro Ottawa	44/12.43
Beckwith DS	DS	Hydro One	44/27.6
Beechwood UB	DS	Hydro Ottawa	13.2/4.16
Bells Corner DS	DS	Hydro Ottawa	44/8.32
Bilberry TS	HVDS	Hydro One-Hydro Ottawa	115/27.6
Blackburn MS	DS	Hydro Ottawa	44/8.32
Borden Farm DS	DS	Hydro Ottawa	44/8.32
Bridlewood MS 28kV	HVDS DS	Hydro Ottawa	115/27.6 44/27.6
Bridlewood MS 8kV	HVDS DS	Hydro Ottawa	115/8.32 44/8.32
Bronson SB	DS	Hydro Ottawa	13.2/4.16
Brookfield AF	DS	Hydro Ottawa	13.2/4.16
Cahill AN	DS	Hydro Ottawa	13.2/4.16
Cambrian MTS	HVDS	Hydro Ottawa	115/27.6 230/27.6
Cambridge AM	DS	Hydro Ottawa	13.2/4.16
Carling SM	DS	Hydro Ottawa	13.2/4.16
Carling TM	HVDS	Hydro One-Hydro Ottawa	115/13.2
Casselman MS	DS	Hydro Ottawa	44/8.32
Centrepointe DS	HVDS	Hydro Ottawa	115/8.32

Church AA	DS	Hydro Ottawa	13.2/4.16
Clifton UL	DS	Hydro Ottawa	13.2/4.16
Clyde UC	DS	Hydro Ottawa	13.2/4.16
Cyrville MTS	HVDS	Hydro Ottawa	115/27.6
Dagmar AC	DS	Hydro Ottawa	13.2/4.16
Eastview UT	DS	Hydro Ottawa	13.2/4.16
Edwin UV	DS	Hydro Ottawa	13.2/4.16
Ellwood MTS	HVDS	Hydro Ottawa	230/13.2
Epworth DS	HVDS	Hydro Ottawa	115/8.32
Fallowfield MS	HVDS	Hydro Ottawa	115/27.6
Fisher AK	DS	Hydro Ottawa	13.2/4.16
Florence UF	DS	Hydro Ottawa	13.2/4.16
Gladstone UX	DS	Hydro Ottawa	13.2/4.16
Hawthorne TS	HVDS	Hydro One	230/44
Henderson UN	DS	Hydro Ottawa	13.2/4.16
Hillcrest AH	DS	Hydro Ottawa	13.2/4.16
Hinchey TH	HVDS	Hydro One-Hydro Ottawa	115/13.2
Holland SH	DS	Hydro Ottawa	13.2/4.16
Janet King DS 28kV	DS	Hydro Ottawa	44/27.6
Janet King DS 8kV	DS	Hydro Ottawa	44/8.32
Jockvale DS	DS	Hydro Ottawa	44/8.32
Kanata MTS	HVDS	Hydro Ottawa	230/27.6
King Edward SK	DS	Hydro Ottawa	13.2/4.16
King Edward TK	HVDS	Hydro One-Hydro Ottawa	115/13.2
Langs AP	DS	Hydro Ottawa	13.2/4.16
Leitrim MS	DS	Hydro Ottawa	44/27.6
Limebank MS	HVDS	Hydro Ottawa	115/27.6
Lincoln Heights TD	HVDS	Hydro One-Hydro Ottawa	115/13.2
Lisgar TL	HVDS	Hydro One-Hydro Ottawa	115/13.2
Longfields DS	DS	Hydro Ottawa	44/27.6
Manordale DS	HVDS	Hydro Ottawa	115/8.32
Marchwood MS	HVDS	Hydro Ottawa	115/27.6
McCarthy AQ	DS	Hydro Ottawa	13.2/4.16
Merivale MTS	HVDS	Hydro Ottawa	115/8.32
Moulton MS	HVDS	Hydro Ottawa	115/27.6
Munster DS	DS	Hydro Ottawa	44/8.32
Nepean AB	DS	Hydro Ottawa	13.2/4.16

Nepean TS	HVDS	Hydro One	230/44
Orleans TS	HVDS	Hydro One	230/27.6 115/27.6
Overbrook SO	DS	Hydro Ottawa	13.2/4.16
Overbrook TO	HVDS	Hydro One-Hydro Ottawa	115/13.2
Parkwood Hills DS	DS	Hydro Ottawa	44/8.32
Playfair AJ	DS	Hydro Ottawa	13.2/4.16
Q.C.H. DS	DS	Hydro Ottawa	44/8.32
Queens UQ	DS	Hydro Ottawa	13.2/4.16
Richmond North DS	DS	Hydro Ottawa	44/8.32
Richmond South DS	HVDS	Hydro Ottawa	115/8.32
Rideau Heights DS	DS	Hydro Ottawa	44/8.32
Riverdale SR	DS	Hydro Ottawa	13.2/4.16
Riverdale TR	HVDS	Hydro One-Hydro Ottawa	115/13.2
Russell TB	HVDS	Hydro One-Hydro Ottawa	115/13.2
Shillington AD	DS	Hydro Ottawa	13.2/4.16
Slater SA	DS	Hydro Ottawa	13.2/4.16
Slater TS	HVDS	Hydro One-Hydro Ottawa	115/13.2
South Gloucester DS	HVDS	Hydro One	115/8.32
South March TS	HVDS	Hydro One	230/44
South March DS	DS	Hydro Ottawa	44/12.43
Stafford Road DS	DS	Hydro Ottawa	44/8.32
Startop MS	DS	Hydro Ottawa	44/8.32
Terry Fox MTS	HVDS	Hydro Ottawa	230/27.6
Uplands MTS	HVDS	Hydro Ottawa	115/27.6
Urbandale AE	DS	Hydro Ottawa	13.2/4.16
Vaughan UG	DS	Hydro Ottawa	13.2/4.16
Walkley UZ	DS	Hydro Ottawa	13.2/4.16
Woodroffe DS	DS	Hydro Ottawa	44/8.32
Woodroffe TW	HVDS	Hydro One-Hydro Ottawa	115/13.2