

2023 NPCC Québec Comprehensive Review of Resource Adequacy

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1. EXECUTIVE SUMMARY

The Québec Balancing Authority Area submits this assessment of resource adequacy to comply with the Reliability Assessment Program established by the Northeast Power Coordinating Council (NPCC). The guidelines for the review are specified in Appendix D of the NPCC Regional Reliability Reference Directory #1, “*Guidelines for Area Review of Resource Adequacy*”.

The 2023 Comprehensive Review of Resource Adequacy covers the study period from winter 2023-2024 through winter 2027-2028. Changes in assumptions about facility and system conditions, generation resources availability, load forecast and electricity sector regulations since the last Comprehensive Review and the impact of these changes on the overall reliability of the Québec electricity system are highlighted therein.

The internal demand forecast has been revised upward since the last comprehensive review mainly due to an increase in the industrial sector demand and at some extent to demand from the other consumption sectors. About 345 MW of new generation capacity have been added to the system since the filing of the last Comprehensive Review. An additional 2,148 MW of wind generation are expected to be commissioned over the assessment period.

The results of this comprehensive review show that the loss of load expectation (LOLE) for the Québec area is below the NPCC reliability criterion of not more than 0.1 day per year for all years of this assessment under the base case scenario. For the high case scenario of demand forecast, the area would need additional capacity.

1.1 Major Findings

The 2023 Comprehensive Review results show that the Québec area will meet the NPCC resource adequacy criterion that requires a loss of load expectation (LOLE) value of less than 0.1 days/year for all years of this review.

1.2 Major Assumptions and Results

Major assumptions are summarized in Table 1.1.

Table 1.1 Major Assumptions

ASSUMPTION	DESCRIPTION
Study Period	Winter periods 2023-2024 to 2027-2028.
Adequacy Criterion	NPCC Loss of Load Expectation (LOLE) requirement of not more than 0.1 days/year.
Reliability Model	GE's MARS program.
Load Growth (incl. exports)	Base Case: 0.65% per year High Case: 0.75% per year
Load Model	Hourly loads with forecast uncertainty
Generation Capacity Additions	2,148 MW of wind generation are expected to be in service by the end of 2027.
Generation Capacity Retirements	No significant unit retirements are scheduled over the period of this review
Interconnection Transmission System Constraints	Transmission system representation is shown in Appendix A, sections A3 and A7.1 of this report. NECEC and CHPE new interconnections have been added to the Transmission System.
Emergency Operating Procedures (EOP)	Assumed 4,439 MW of load relief from interruptible load, DR programs and voltage reduction.
Resource Availability	Forced Outages modeled: Based on Seasonal Equivalent Demand Forced Outage Rate (EFORd) five -year historical data (2017-2022).
Energy savings	Expected energy savings programs: Up to 184 MW by 2027-2028.

Table 1.2 **Summary of Results**

All resources in this assessment are assumed to be in service as planned. Results in Table 1.2 show that the Québec area will meet the LOLE criterion under the base case demand forecast for all years of this review.

Winter Peak	Base case scenario (days/year)	High case scenario (days/year)
2023-2024	0.066	0.125
2024-2025	0.020	0.054
2025-2026	0.034	0.096
2026-2027	0.034	0.100
2027-2028	0.025	0.102

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3. INTRODUCTION

The Northeast Power Coordinating Council (NPCC) conducts resource adequacy reviews of its member areas to ascertain whether each area will have adequate resources to meet the NPCC Resource Reliability Criterion.

Hydro-Québec (HQ) is the entity responsible for resource planning in the Québec Balancing Authority Area. HQ is also responsible for all activities regarding load forecasts and resource procurement required to supply the internal load. As such, HQ is the reporting entity for this assessment.

The purpose of this report is to present the results of the Québec Balancing Authority Area's comprehensive review of resource adequacy to the NPCC. Results of this resource adequacy review, conducted by Hydro-Québec and submitted to the NPCC, are documented in accordance with the reporting guidelines specified in Appendix D of the NPCC Regional Reliability Reference Directory #1, "*Guidelines for Area Review of Resource Adequacy*".

This report includes information of Hydro-Québec in its Distribution, Generation and Transmission activities that are required to conduct the reliability assessment of the Québec Area.

The information presented in this Comprehensive Review covers the period from November 2023 through October 2028 and is based on the Québec internal demand forecast used in the first Progress Report of the 2023-2032 Supply Plan, which was filed at the Québec Energy Board on November 1, 2023¹. Also, this information is consistent with the NERC 2023 Québec Long Term Reliability Assessment (2023 LTRA).

3.1 Reference to Most Recent NPCC Comprehensive Review

Comparisons between this review and the previous Comprehensive Review, submitted in October 2020 and approved by the NPCC Reliability Coordinating Committee (RCC) on December 1st, 2020, are included in this report.

¹ <https://www.regie-energie.qc.ca/fr/participants/audiences-en-cours/distribution>

3.2 Comparison of this Review and Previous Review

3.2.1. Demand Forecast

The demand forecast presented in this review focuses on winter annual peaks. Two demand scenarios are presented: a base case demand and a high case demand forecast. Winter peak demand forecasts for this 2023 Comprehensive Review are presented in Table 3.2.1 and Figure 3.2.1, along with the 2020 Comprehensive Review forecasts.

Demand forecast methodology is basically the same as in the previous Comprehensive Review. The Québec peak load forecast is based on normal weather conditions. For this purpose, a 52-year reference period is used to assess average temperatures (1971-2022). The same reference period is used to assess demand uncertainty resulting from weather. More details on forecast methodology are provided in Appendix A.

Load forecast includes the impact of energy savings on energy and capacity requirements. The expected energy savings of programs to be deployed and those remaining active during the five years covered by this review are estimated to be 168 MW by 2024-2025 and 184 MW in 2027-2028.

Forecasts also include the load shaving resulting from the residential dual energy program, a rate option for residential customers equipped with a dual energy space heating system (electric/fuel oil, other). When the outside temperature falls below a given level, the space heating system automatically runs on the other source. The impact of this program on peak load demand is about 380 MW for the 2023-24 winter period.

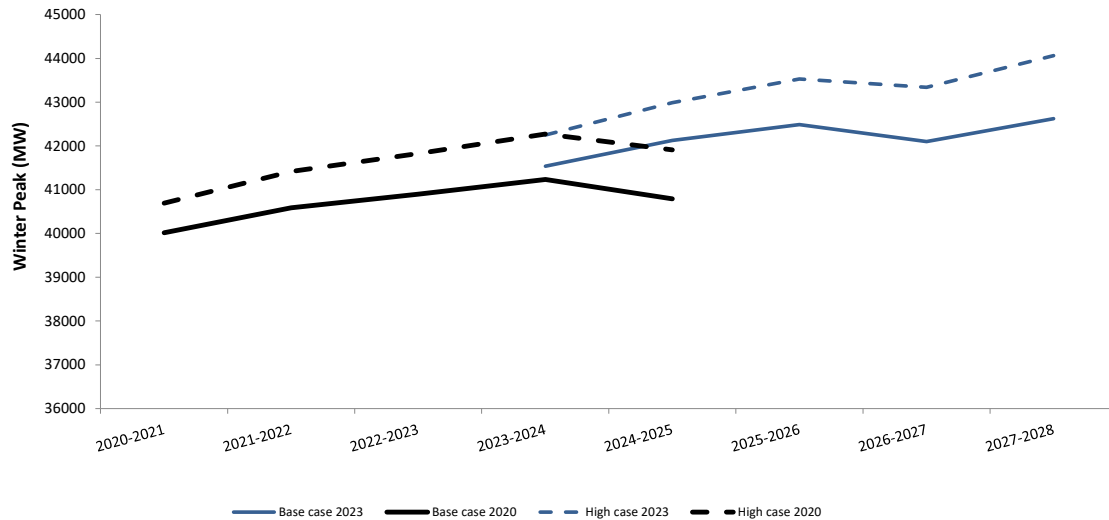
The average annual growth rate over the entire period of this review is approximately 0.65 percent in the base case scenario. Under the high demand forecast scenario, peak load demand is expected to increase, on average, by 1.0 percent.

Table 3.2.1 Comparison of Demand Forecasts (MW)

Winter Peak	Base case Scenario			High case Scenario		
	2023 Comprehensive Review	2020 Comprehensive Review	Difference	2023 Comprehensive Review	2020 Comprehensive Review	Difference
2023-2024	41,539	41,233	306	42,250	42,270	-21
2024-2025	42,125	40,788 ¹	1,337	42,985	41,910 ¹	1,075
2025-2026	42,488			43,525		
2026-2027	42,100			43,337		
2027-2028	42,622			44,063		
5-year Average Growth Rate	0.64%	0.75%		1.06%	1.0%	

¹: Does not include exports on NEISO FCM market.

Figure 3.2.1 Comparison of Demand Forecasts



As shown in Table 3.2.1, the demand forecasts for the two next winters of this review in the base case scenario are +306 and +1,131 MW higher compared to the demand forecasts presented in the 2020 Comprehensive review for the same years. This difference in forecast is mainly explained by a higher demand in the industrial sector demand and at some extent to demand from the other consumption sectors. In 2025, the effective shift in the load forecast is 405 MW when adjusting for exports on the NE FCM market in this review.

3.2.2. Planned Resources

Most of resources in the Québec area are hydro power generation owned and operated by Hydro-Québec. Hydro-Québec also operates one thermal generation station (for peaking purposes only).

Remaining resources are owned and operated by Independent Power Producers (IPPs) and are under long term power purchase agreements with Hydro-Québec. The purchased energy and capacity are from wind, small hydro (run of river plants) and biomass generation. A small amount of solar energy owned by Hydro-Québec is in service with marginal contribution at winter peak period.

New Resource Additions

Since the last comprehensive review, one hydro generating unit (La Romaine-4) has been commissioned in 2022, adding 260 MW of capacity to the system power. Another 85 MW of capacity including biomass (61 MW) and wind (24 MW) were added to the system.

A total of 2,148 MW of wind power generation are expected to be commissioned during the assessment period. A 204 MW from Apuiat project is expected to be in service by 2024-2025 winter period. Additional 400 MW from Des neiges project (Phase 1) is expected to be in service for the 2025-2026 winter period. Another 1,144 MW from the 2021 call for tenders is expected to be in service by December 2026. Finally, a 400 MW from Des neiges project (Phase 2) will be in service in 2027-2028 winter period.

Also, 600 MW of firm import capacity from Ontario will be added to the resources. A new agreement between Hydro-Québec and the IESO will be signed in 2024. For this purpose, the governments of Québec and Ontario have already signed a Memorandum of Understanding (MOU). This agreement will allow Hydro-Québec to import 600 MW of firm capacity during the winter periods from 2025 to 2031 except for the winter 2027 and to export 600 MW of firm capacity to Ontario during summer peak period.

Most of other resources are Demand Response (DR) programs that are intended to reduce significantly the load forecast at winter peak period.

Summary of Available Resources

Table 3.2.2-2 and Fig 3.2.2 show the available resources in the Québec area. It also includes a comparison with the planned resources from the previous Comprehensive Review.

Table 3.2.2-1 Comparison of Available Resources 2020 vs 2017 Review (MW)

Winter Peak	2023 Comprehensive Review	2020 Comprehensive Review	Difference
2023-2024	46,691	46,588	103
2024-2025	48,098	46,804	1,294
2025-2026	48,335	-	-
2026-2027	48,179	-	-
2027-2028	49,008	-	-

The difference between the two reviews is +103 MW for the 2023-2024 and +1,294 MW for the 2024-2025 winter peak period respectively. The main factors explaining these differences are:

- A mix of additional DR capacity (+468 MW) and unavailable capacity for the next winter (-365 MW) explain the difference between the two assessments for the 2023-2024 winter period.
- + 204 MW of wind generation for 2024-2025 with 36% of contribution at winter peak period.
- + 218 MW of additional available capacity including improvements in unit ratings.
- + 515 MW of additional DR programs.
- + 600 MW of firm imports from Ontario in the new agreement that will be signed between Hydro-Québec and the IESO and will be effective in November 2024.
- - 115 MW of available capacity (biomass, small hydro and other).

Figure 3.2.2 Comparison between 2020 and 2017 Available Resources

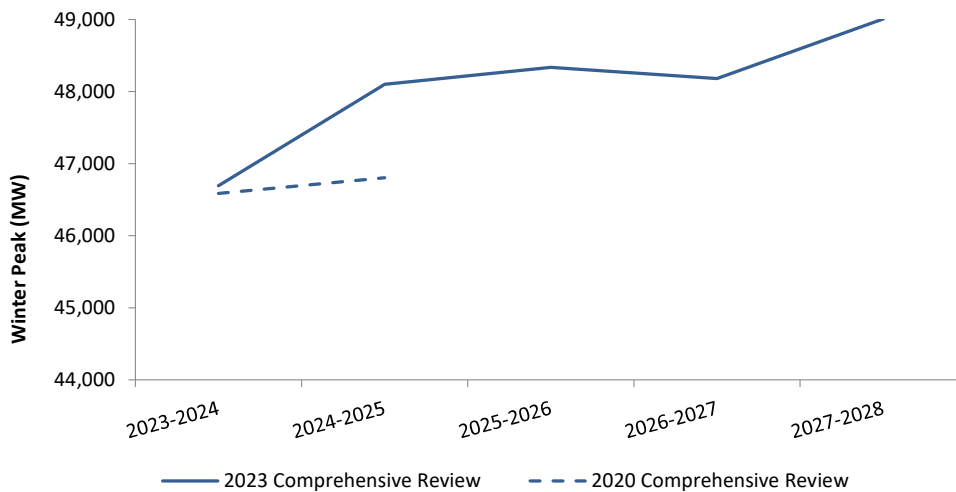


Table 3.2.2-2 below summarizes the installed wind capacity and capacity contribution at winter peak period for all years of the present review. By 2023-2024, installed capacity is estimated at 3,820 MW.

Table 3.2.2-2 Installed Wind Capacity and Capacity Credit at Peak Time Period (MW)

Winter Peak	Wind Installed Capacity (MW)	Capacity Value at peak ¹ (MW)
2023-2024	3,820	1,375
2024-2025	4,024	1,449
2025-2026	4,024	1,449
2026-2027	5,458	1,747
2027-2028	5,758	1,843

¹: The estimated capacity credit value at peak time varies between 32% and 36%.

Unavailable, mothballed and Retired Resources

In this review, about 300 MW of hydro generation capacity is planned to be unavailable during the next winter 2023-2024 due to retirement of one hydro generation unit. Trans-Canada thermal plant (507 MW) is still mothballed over the period of this assessment. Finally, there is no significant unit retirement scheduled during this review.

4. RESOURCE ADEQUACY CRITERION

4.1 Statement of Resource Adequacy Criterion

In the Québec Balancing Authority Area, the NPCC resource adequacy criterion from Directory #1– Design and Operation of the Bulk Power System is used to assess resource adequacy. This criterion reads as follows:

“The probability (or risk) of disconnecting firm load due to resource deficiencies shall be, on average, not more than one day in ten years as determined by studies conducted for each Resource Planning and Planning Coordinator Area. Compliance with this criterion shall be evaluated probabilistically, such that the loss of load expectation (LOLE) of disconnecting firm load due to resource deficiencies shall be, on average, no more than 0.1 day per year. This evaluation shall make due allowance for demand uncertainty, scheduled outages and deratings, forced outages and deratings, assistance over interconnections with neighboring Planning Coordinator Areas, transmission transfer capabilities, and capacity and/or load relief from available operating procedures”.

4.2 Statement of How the Criterion is Applied

The reliability criterion is used to assess the adequacy of available resources to reliably supply the Québec area’s electricity needs. Also, it is used to establish the Québec Area Reference Reserve Margin.

Consideration can be given to Québec’s interconnections with New Brunswick, Ontario, New York and New England and the resultant potential for capacity purchases which can be assumed. More details on this issue are provided in section 5.1.

Generating unit scheduled and forced outages have been assessed by considering actual historical outage data for the 2017-2022 period.

Before any load disconnection will occur, a series of emergency operating procedures (EOPs) will be invoked. In order to properly represent the system operation, EOPs are modeled considering their constraints, dispatching order and the amount of load relief or capacity increase. Table 4.2 summarizes the assumptions regarding the load relief from EOPs used for this study.

Table 4.2 Emergency Operating Procedures

STEP	PROCEDURE	EFFECT	IMPACT VALUE IN MW
1	Interruptible Load & DR Programs	Load Relief	4,189
2	Emergency Purchases	Increase Capacity	Varies ¹
3	Voltage Reduction	Load Relief	250
4	30-Minute Reserve Reduction	Allow Operating Reserve to decrease	500
5	10-Minute Reserve Reduction	Allow Operating Reserve to decrease	750
6	Customer Disconnection	Load Relief	As needed

¹: Winter purchases vary from 1,100 MW to 1,700 MW over the period of this assessment. See section 5.1 for more details.

4.3 Resource Requirements to Meet Criterion

For the purposes of this study, the adequacy of the area's existing and planned resources is assessed through the calculation of the annual LOLE and compared with the 0.1 days/year criterion established by the NPCC in its Directory #1. The resulting Reserve Margin is therefore set as the Québec Area Reference Reserve Margin. Simulation results show that the Reference Reserve Margins vary between 11.8 percent and 14.2 percent over the period of this review.

4.4 Comparison of Québec and NPCC Criteria

The Québec Balancing Authority Area reliability criterion for this review is the same as the NPCC criterion, as defined in Section 4.1.

4.5 Resource Adequacy Studies Done Since the 2020 Review

The Québec Area provides all data and reliability studies required by NERC and NPCC.

Specifically, the Area provides data and narratives for NERC's summer, winter and long-term Reliability Assessments on an annual basis. These documents cover the entire assessment area and incorporate demand, resources and transmission data for the next season or with a 10-year outlook in the case of the long-term assessment. The data provided is sourced from Hydro-Québec in its Distribution, Generation and transmission activities. Similarly, the Québec Area provides data and narratives for NPCC's annual summer and winter Reliability Assessment as well as long range Adequacy Overview, Tie-benefit Study and ProbA assessment.

Additionally, other reliability studies are developed by entities in the Area, as necessary. For example, HQ conducts a resource adequacy study to evaluate the reserve margin level included in its triennial procurement plan and in the annual plan update. The procurement plan has a 10-year outlook. The reserve margin level presented in the plan is established in compliance with the NPCC reliability criterion. Other data and attestations

are also requested by the Regulator for the regulated activities, La Régie de l'énergie, three times a year to demonstrate short-term resource adequacy.

5. RESOURCE ADEQUACY ASSESSMENT

5.1 Reliability Assessment Based on the Base Case Scenario

Table 5.1.1 shows the LOLE evaluations for the base case demand forecast. According to these results, the Québec area will have adequate resources to meet the NPCC criterion for the entire period of this review. This was achieved with the inclusion of 1,600 MW of winter capacity purchases.

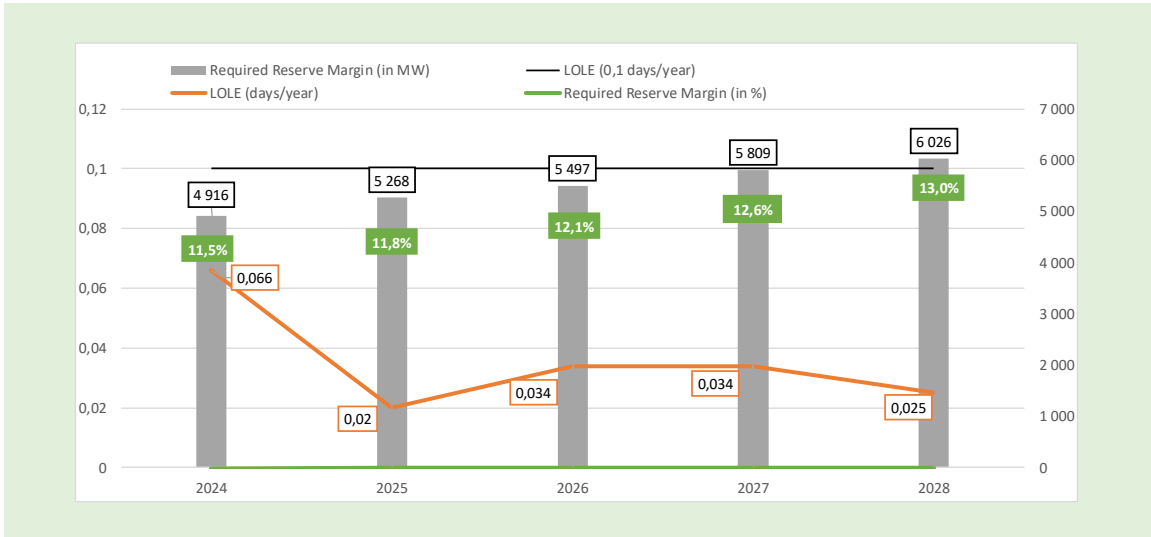
Each year, Hydro-Québec will purchase the required amount of capacity on the markets to meet its requirements. This capacity could either be supplied by resources within the area or by imports. To secure the appropriate access to capacity located in neighboring areas, Hydro-Québec has designated the Massena-Châteauguay (1,000 MW) and the Dennison-Langlois (100 MW) interconnections to meet its resource requirements during winter peak period. The Québec area limits its planned capacity purchases to capacity accessible from summer peaking neighbouring areas having an organized capacity market structure. Also, as part of the new electricity agreement that will be signed in 2024 between Hydro-Québec and the IESO, Hydro-Québec will import 600 MW of firm capacity from Ontario each winter period (from November to April). The new agreement will end by 2030-2031 winter period and is not applicable for the 2027 winter months.

Table 5.1.1 shows both planned and reference reserve margins for each winter until 2027-2028. Reserve margins are expressed in MW or as a percentage of the annual peak load. The planned reserve margin is the difference between planned resources and the forecasted annual peak load. The required reserve margin in MW is the capacity needed to meet the NPCC resource adequacy criterion. The required reserve margins are calculated by removing/adding unconstrained capacity (such as import capacity) from/to the system until the 0.1 days/year LOLE criteria is obtained.

Table 5.1.1 Planned Resources to meet criteria under Base Case Demand Forecast

Winter Peak	Planned Resources (MW)	Annual peak load (MW)	Planned Reserve		LOLE (Days/year)	Reference Reserve		LOLE (Days/year)
			MW	(%)		MW	(%)	
2023-2024	46,691	41,539	5,151	12.4%	0.066	4,791	11.5%	0.100
2024-2025	48,098	42,125	5,973	14.2%	0.020	4,968	11.8%	0.100
2025-2026	48,335	42,488	5,847	13.8%	0.034	5,147	12.1%	0.100
2026-2027	48,179	42,100	6,079	14.4%	0.034	5,324	12.6%	0.100
2027-2028	49,008	42,622	6,386	15.0%	0.025	5,541	13.0%	0.100

Figure 5.1 Summary of Results



5.2 High Case Demand Forecast

For the winter peak period 2023-2024, the high case scenario is approximately 710 MW higher than the base case load forecast and the difference reaches about 1,441 MW for the winter period 2027-2028. On average, over the forecast period, the Québec load is expected to increase by about 1.0 percent annually under the high case demand forecast.

The difference between the base case and high case is explained by a higher population growth, stronger economic activity. This is an extreme level that has an estimated ten percent probability of being exceeded.

5.2.1. LOLE Values, High Case Demand Forecast

Table 5.2.1 shows that under the high case demand forecast, LOLE results are less than the 0.1 days/year of loss of load expectation for all the winter peak periods except for winters 2024-25 and 2027-28 where the LOLE are above 0,1 days/year. Additional resources if needed could be achieved by some additional purchases from neighboring areas.

Planned resources, demand forecasts and LOLE under the high case demand forecast are presented below.

Table 5.2.1 Planned Resources and LOLE under High Case Demand Forecast

Winter Peak	Planned Resources (MW)	Annual peak load (MW)	Planned Reserve		LOLE (Days/year)
			MW	(%)	
2023-2024	46,691	42,250	4,441	10,5	0.125
2024-2025	48,098	42,985	5,112	11,9	0.054
2025-2026	48,335	43,525	4,810	11,1	0.096
2026-2027	48,179	43,337	4,842	11,2	0.100
2027-2028	49,008	44,063	4,945	11,2	0.102

5.3 Contingency Mechanisms for Managing Demand and Resource Uncertainties

Supply planning involves some uncertainty related to demand as well as resources. Resources could be limited or insufficient in relation to the required quantities.

If, in any case, the expected required reserve would fall below critical level, it would be possible to make some additional purchases from neighboring areas.

5.4 Impacts of Major Proposed Changes to Market Rules on Area Reliability

In the Québec area, there are no structured short term (daily, hourly or real time) electricity markets. Most of new supplies are contracted by HQD through long term PPAs. Neither the quantity of available capacity nor the energy dispatched is based on market ability to react to price signals. There are no expected changes to the actual electricity market structure within the period covered by this review.

6. PROPOSED RESOURCE MIX

6.1 Reliability Impacts of Capacity Mix, Demand Resource Response and Transportation or Environmental Considerations

Table 6.1 and Figure 6.1 show the expected available generation capacity mix at winter peak period for each year of this review. The information regarding existing and future resources as of September 2023 have been used for this evaluation.

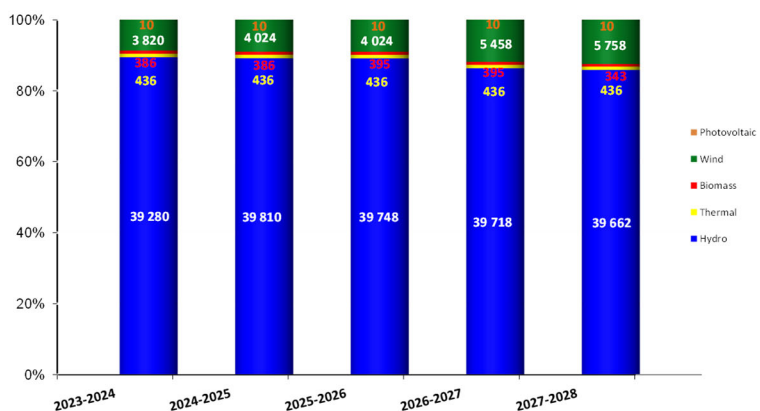
Table 6.1 Québec Available Capacity Mix by Fuel Type (MW)

Fuel Type	2023-2024	2024-2025	2025-2026	2026-2027	2027-2028
Hydro	39,280	39,810	39,748	39,718	39,662
Thermal	436	436	436	436	436
Biomass	386	386	395	395	343
Wind ¹	3,820	4,024	4,024	5,458	5,758
Photovoltaic ²	10	10	10	10	10
Total	43,933	44,667	44,613	46,017	46,210

¹: For wind, the numbers correspond to installed capacity. A 32-36 percent of nameplate capacity is expected at winter peak time.

²: PV expected value at peak time is not significant.

Figure 6.1 Québec Available Capacity Mix by Fuel Type (%)



Although actual wind installed capacity is about 3,820 MW, the area total capacity is still mainly composed of large reservoirs hydro complexes that can react quickly to adjust their

generation output and meet the sharp changes in electricity net demand. The forecasted changes to resource mix are not expected to have impacts on reliability over the period of this review.

6.2 Available Mechanisms to Mitigate Reliability Impacts of Capacity Mix, Demand Resource Response, Transportation and/or Environmental Considerations

Québec area's energy requirements are met for the most part by hydro generating stations, located on different river systems and scattered over a large territory. The major plants are backed by multiannual reservoirs (water reserves lasting more than one year).

Due to those multi-year reservoirs, a single year of low water inflow cannot adversely impact the reliability of energy supply. However, a series of few consecutive dry years may require some operating measures as the reduction of exports or imports from neighbouring areas.

To assess its energy reliability, Hydro-Québec has developed an energy criterion stating that sufficient resources should be available to go through a sequence of 2 consecutive years of low water inflows totalling 64 TWh or a sequence of 4 years totalling 98 TWh and having a 2 percent probability of occurrence. The use of operating measures and the hydro reservoirs should be managed accordingly. Reliability assessments based on this criterion are presented three times a year to the Québec Energy Board. Such documents can be found on the “Régie de l’Énergie du Québec» website²”.

Fuel supply and transportation are not an issue in the Québec area. The Trans-Canada Energy thermal plant (507 MW) is presently mothballed and not expected to return during the period of this assessment. The fossil fuel generation (Bécancour, 436 MW) is used for peaking purpose only and adequate fuel supplies are stored nearby. The storage capacity is enough to generate about 60 hours of energy at maximum power.

No other conditions that would create supply reductions are expected for the period covered by this assessment.

² <https://www.regie-energie.qc.ca/fr/participants/suivis-administratifs/electricite-distribution>

6.3 Reliability Impacts Related to Compliance with Provincial Requirements

As a member of the Western Climate Initiative, the province of Québec has implemented a cap-and-trade system for greenhouse gas (GHG) emission allowances, with the first compliance beginning January 1st, 2013. The carbon market is aimed at companies that emit at least 25,000 metric tons of CO₂ equivalent each year. Regulated companies are required to acquire emission units for each ton they release into the atmosphere. The government sets annual maximum GHG emission unit caps that are progressively lowered over time. As the Québec's electricity generation system is predominantly hydro (about 90 percent) and wind power generation (about 9 percent), there's no significant impact on reliability.

APPENDIX: DESCRIPTION OF RESOURCE RELIABILITY MODEL

APPENDIX

The GE MARS model is used for the purpose of this review. This model uses a sequential Monte Carlo simulation to assess the reliability of a system comprised of a number of interconnected areas containing generation and load. This Monte Carlo process simulates each targeted year repeatedly (multiple replications) to evaluate the impacts of a wide range of possible random combinations of load and generator outages. The transmission system is modeled in terms of transfer limits (constraints) on the interfaces between interconnected areas.

Chronological system operating margins are developed by combining randomly generated operating states of the generating units and inter-area transfer limits with the hourly chronological loads. The model can compute various reliability measurements, including Loss of Load Expectation (LOLE) which is selected as the principal reliability metric.

For each hour of the year, the program computes the isolated area margins based on the available capacity and demand in each area. GE MARS then uses a transportation algorithm to determine the extent to which areas with negative margin can be assisted by areas having positive (excess) margin, subject to the available transfer constraints between the areas. The program collects the statistics for computing the reliability metrics and proceeds to the next hour. After simulating all the hours in the year, the program computes the annual metrics and tests for convergence. If the simulation has not converged to an acceptable level, it proceeds to another replication of the year under study.

1. LOAD MODEL

1.1 Description and Basis of Period Load Shapes

GE MARS model employs an 8760 hours chronological subarea load model. The load model currently used relies on an actual year of historical loads. This model is then scaled up to the winter peak for the future years being analyzed.

The Québec peak load forecast is based on normal weather conditions. First, the energy-sales forecast is built on the forecast from four different consumption sectors—domestic, commercial, small and medium-size industrial and large industrial. The model types used in the forecasting process are different for each sector and are based on end-use and/or econometric models. They consider weather variables, economic-driver forecasts, demographics, energy efficiency, and different information about large industrial customers. This forecast is normalized for weather conditions based on an historical trend weather analysis.

The requirements are obtained by adding transmission and distribution losses to the sales forecasts. The monthly peak demand is then calculated by applying load factors to each end-use and/or sector sale. The sum of these monthly end-use/sector peak demands is the total monthly peak demand.

1.2 Load Forecast Uncertainty

Load Forecast Uncertainty (LFU) includes weather and load uncertainties. Weather uncertainty is due to variations in weather conditions. It is based on a 52-year temperature database (1971-2022), adjusted by 0.30°C (0.54°F) per decade starting in 1971 to account for climate change. Moreover, each year of historical climatic data is shifted up to ±9 days to gain information on conditions that occurred during either a weekend or a weekday. Such an exercise generates a set of 364 different demand scenarios. The base case scenario is the arithmetical average of the peak hour in each of these 364 scenarios. Load uncertainty is due to the uncertainty in economic and demographic variables affecting demand forecast and to residual errors from the models.

Overall uncertainty is defined as the independent combination of weather uncertainty and load uncertainty. The overall uncertainty is expressed as a percentage of standard deviation over total load.

In the MARS model, load forecast uncertainty is modeled through the load forecast multipliers. These multipliers are directly derived from the distribution of the load. For each multiplier, a probability of the load level occurring is associated. There is a set of seven probability points that allows to adequately represent the distribution of the load. The probability distribution of the load is assumed to follow a skewed distribution. The standard deviation ranges from 1,840 MW for the winter 2023-2024 to 2,019 MW for the last winter of this assessment.

1.3 Demand and Energy Projects of Interconnected Entities

The loads and resources of interconnected entities within the area that are not members of the area were not considered.

1.4 Demand-Side Management

The demand forecast presented in section 3.2.1 takes into account the impact of energy savings on sales and capacity requirements. These energy savings consist of the energy efficiency measures to be deployed and those remaining active during the five years covered by this review.

Forecasts also take into account the load shaving resulting from residential dual energy. This program is handled in the same way as energy savings: it is not included as a resource but its impact on peak demand (~ 271-380 MW) is included in demand forecasts.

Other interruptible load programs specifically designed for peak shaving and fully dispatched by the system operator are included as resources (see section 5 of the Appendix).

Table A-1.4 **Expected Energy Savings on Forecasted Winter Peak Demand (in MW)**

Winter Peak	Energy savings (MW)
2023-2024	168
2024-2025	170
2025-2026	170
2026-2027	176
2027-2028	184

2. SUPPLY-SIDE RESOURCE REPRESENTATION

The MARS model has the capability to model different types of resources used in the Québec area: hydroelectric, thermal, wind and demand management resources.

For each generation unit modeled, the installation and retirement dates and planned maintenance requirements must be specified. Other data such as maximum rating, forced outage rates, and net modification of the hourly loads depend on the unit type. The planned outages for all types of units in the MARS model can be specified by the user or automatically scheduled by the program on a weekly basis.

2.1.1. Definitions

For Hydro units with installed capacity larger than 30 MW, Dependable Capacity is calculated as the net output a unit can sustain over a specified period modified for month limitations. The period that a unit can sustain is defined as two consecutive hours per month. This definition may seem optimistic but proper use of the reservoirs usually make this capacity available daily. The Dependable Capacity varies from month to month according to projected reservoirs levels. Beauharnois (1,741 MW), Les Cèdres (104 MW) and Carillon (602 MW) generating stations are not modeled according to this definition. The specific treatment for these power stations will be discussed in section A.4.

For Hydro units with installed capacity less than 30 MW, Dependable Capacity is defined as the average power based on operational historical generation.

For thermal units, Maximum Capacity is defined as the net output a unit can sustain over a two consecutive hour period. Maximum Capacity varies from one month to another subject to ambient temperature changes.

2.1.2. Procedure for Verifying Ratings

Ratings of generating unit are revised periodically. Hydro unit ratings are based on operational historical values and are reviewed at least annually. At the time of this ratings revision, if needed, the new data on turbine efficiency measurements, the updated operating water head and the temperature of generator cooling water are considered. Unit testing are performed as needed.

Thermal Unit Ratings are reevaluated at each unit performance test.

2.2 Unavailability Factors Represented

2.2.1. Type of Unavailability Factors Represented

Planned maintenance was modeled on a unit basis. Typical monthly percentage maintenance for Hydro units is used. The percentage is applied on the total hydro capacity available (except Beauharnois and Les Cèdres units). Thermal power plants are on maintenance during summer and each plant has its own maintenance schedule.

2.2.2. Source of Unavailability Factors Represented

Equivalent Demand Forced Outage Rate (EFORd) for existing generators are based on actual seasonal outage data reflecting historical evolution over the period 2017-2022.

New generators EFORd are based on similar generators with historical data as well as on the data provided by the manufacturer and with the conjunction with averages compiled by the Canadian Electricity Association (CEA) and NERC GADS.

2.2.3. Maturity Considerations and In-Service Date Uncertainty

The reliability model accounts for maturing units. Forced outage rates of new units are higher for the first operational years.

No uncertainty is modeled over the commissioning date of the planned generating units.

2.2.4. Tabulation of Typical Unavailability Factors

The weighted average EFORd used in this evaluation are presented in Table A-2.2.4. These forced outages rates values are computed over the period 2017-2022. They represent the seasonal historical EFORd over the last five years period.

Table A-2.2.4 Québec Area Forced Outages Rates

Unit Type	Weighted Average EFORd (%)	
	2023 Comprehensive Review	2020 Comprehensive Review
Hydro	2.1	2.4
Thermal	8.5	7.5
Biomass	6.5	7.1

2.3 Purchase and Sale Representation

The capacity purchase from Newfoundland and Labrador is represented according to the contract between Hydro-Québec and CFLCo. The expected planned on-peak value is 4,765 MW for all years of this review. Other short-term purchases (UCAP) are expected to come from neighboring areas. In this review, a 600 MW of firm imports capacity is considered over the study period except for the 2026-2027 winter period. This capacity import is under a new agreement that will be signed by Hydro-Québec and Ontario IESO next year. The agreement will be effective starting from November 2024. At the moment, the Governments of Québec and Ontario have signed a Memorandum of Understanding (MOU) that will allow the signature of the agreement.

The area's sales are long term contract sales with Cornwall (Ontario) and New England including new commitments on the Forward Capacity Market and New York. Also, exports to Ontario under the new agreement between Québec and Ontario.

2.4 Retirements

No unit generation is expected to be retired over the period of this review.

3. REPRESENTATION OF INTERCONNECTED SYSTEMS

The Québec Area is a separate Interconnection from the Eastern Interconnection, into which the other NPCC Areas are interconnected. TransÉnergie, the main Transmission Owner and Operator in Québec, has interconnections with Ontario, New York, New England and the Maritimes. There are back to back DC links with New Brunswick at Madawaska and Eel River (in New Brunswick), with New England at Highgate (in New England) and with New York at Châteauguay. The Radisson – Nicolet – Sandy Pond HVDC line ties Québec with New England. Radial load can be picked up in the Maritimes by Québec at Madawaska and at Eel River and at Stanstead feeding Citizen's Utilities in New England. Moreover, in addition to the Châteauguay HVDC back to back interconnection to New York, radial generation can be connected to the New York system through Line 7040. The Variable Frequency Transformer (VFT) at Langlois substation connects into the Cedar Rapids Transmission system, down to New York State at Dennison. The Outaouais HVDC back to back converters and accompanying transmission to the Ottawa, Ontario area are now in service. Other ties between Québec and Ontario consist of radial generation and load to be switched on either system.

Appalaches-Maine Interconnection (NECEC)

This project to increase transfer capability between Québec and Maine by 1,200 MW is in the construction phase. The project will connect to the New England Clean Energy Connect project (NECEC) in Maine. The project is expected to be in service in December 2025.

Hertel-New York Interconnection (CHPE)

This project to increase transfer capability between Québec and New York by 1,250 MW is in the construction phase. It involves the construction of a ± 400 -kV DC underground transmission line about 60 km (37 miles) long from Hertel 735/315-kV substation just south of Montréal to the Canada – U.S.A. border. The project will connect to the Champlain Hudson Power Express project (CHPE) in New York State. From the international border crossing, the DC transmission line will be extended 339 miles to a substation in Astoria, NY, where the power will be converted from DC to AC. The project in Québec also includes the construction of an AC to DC converter at Hertel substation. The project is expected to be in service in May 2026.

Interconnection capacities are established by inter-Area and intra-Area studies as deemed necessary. Table A-3 below shows interconnection limits³.

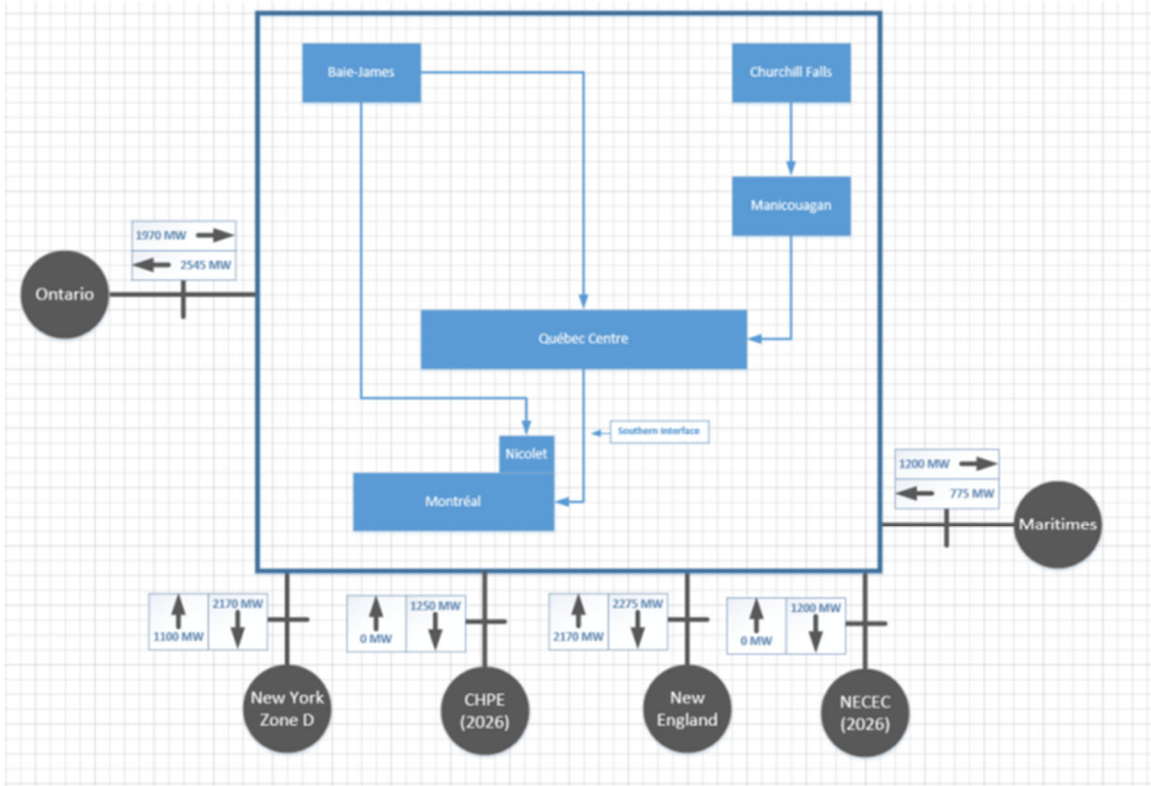
Table A-3 Québec Area Interconnections Limits

Interconnection	Flows Out of Québec (MW)	Flows Into Québec (MW)
New Brunswick	1,200	775
Ontario	2,545	1,970
New England	2,275	0
NECEC	1,200	0
New York	2,170	1,100
CHPE	1,250	0

For this review, the import capability of HVDC Sandy Pond – Nicolet interconnection has been excluded due to its unavailability during peak period. Moreover, these limits do not correspond to TTC or ATC values posted on the OASIS; they are only intended to offer a global picture of transfer capabilities to the readers of this assessment.

³ The Twin States new interconnection project announced by the DOE to come in service in 2028 was not considered in this review.

Figure A-7.2 Québec's Interconnections (2024-2028)



4. MODELING OF VARIABLE AND LIMITED ENERGY RESOURCES

For most hydro units, energy limitations are considered by using a different value of dependable capacity for each month accounting the reservoir variation effect on the net head and the generator cooling water temperature. Unlike reservoir hydro units, the run-of-river Beauharnois and Les Cèdres units are operated in parallel on the St. Laurent river. Their capability depends on water availability and varies according to seasons. Also, during ice cover formation, capacity output must be reduced. Additionally, generation is affected by navigation constraints on the St. Laurent river. Available water can be channeled through either Les Cèdres or Beauharnois. As the latter station is more efficient, priority is then given to generation at Beauharnois, leaving less water available for Les Cèdres.

Beauharnois and Les Cèdres are modeled in a separate tool designed for this specific purpose. It considers a probability distribution based on operational historical generation. This model accounts not only for water restrictions but also for maintenance and forced outages. The results are then transposed in the MARS.

All wind generation units were considered available to meet daily and monthly peak loads except when they are on planned maintenance or forced outages. The estimated contribution value of wind units at peak time varies between 32 and 36 percent of nameplate capacity.

5. MODELING OF DEMAND SIDE RESOURCES AND DEMAND RESPONSE PROGRAMS

For the resource adequacy assessment, MARS runs were modeled with the most updated demand response capacity. Forecasted demand considers the impact of energy savings and dual energy programs, as described in section 1.4 of the Appendix.

Demand response programs fully dispatched by the system operator are included as resources. The Québec area has various types of demand response resources specifically designed for peak shaving during winter operating periods. The first type of demand response resource is the interruptible load program, mainly designed for large industrial customers, with an impact of 2,556 MW during the 2023-2024 winter months. The area is also expanding its existing interruptible load program for commercial buildings which will have an impact of 568 MW in 2023-2024 and 750 MW by 2027-2028. Another similar program for residential customers will have an impact of 95 MW for winter 2023-2024 and 491 MW for winter 2027-2028.

New dynamic rate options for residential and small commercial or institutional customers will also contribute to reducing peak load during winter periods by 297 MW for winter 2023- 2024 and 445 MW for winter 2027-2028.

Moreover, data centers specialized in block-chains applications, which are part of new developments in the commercial sector, are required to reduce their demand during peak hours at Hydro-Québec's request. Their contribution as a resource is expected to be around 270 MW for all the winter periods of this assessment.

All these demand response programs are modeled as emergency operation procedures. They are modeled using EL3 unit function of GE MARS program which allows to model the specific constraints of each program.

6. MODELING OF ALL RESOURCES

Modeling of resources was as described in the above sections.

7. OTHER ASSUMPTIONS

7.1 Internal Transmission Limitations

The Hydro-Québec Transmission System has five major interfaces where operating limits are defined. In this Resource Adequacy Review, the power system has been modeled (through the MARS program) into six sub-areas.

8. RELIABILITY IMPACTS OF MARKET RULES

No reliability impacts due to market rules are anticipated in this review (see section 5.4).