Toronto Integrated Regional Resource Plan Addendum: Richview x Manby 230 kV Circuit Upgrades

Appendices

November 2021

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Powering Tomorrow.

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Appendix A: Incremental Cost Effective Achievable CDM Potential Methodology

To understand incremental CDM potential in the Toronto IRRP Addendum study area, data and assumptions were leveraged from the first integrated electricity and natural gas achievable potential study (APS) in Ontario[1], which was completed by the IESO and OEB in 2019. The main objective of the APS was to identify and quantify energy savings potential (electricity and natural gas), GHG emission reductions and associated costs from demand side resources for the period from 2019-2038. The study is used to inform future energy efficiency policy and/or frameworks, program delivery as well as long-term resource planning.

The 2019 APS determined that both electricity and natural gas have significant cost-effective energy efficiency potential in the near and longer term. Depending on the type and level of customer incentives provided, provincial summer peak demand savings potential ranges from 2,000 to 3,000 MW and provincial energy savings potential ranges from 18 to 24 TWh by the end of the forecast period in 2038.

Modeling undertaken for this study also produced considerable data that can be used to understand energy efficiency opportunities at a more local level. Specifically, the 2019 APS results are broken out by:

- IESO transmission zone - see map available on the IESO's website[2]
- Customer segment - e.g., single family dwellings, multi-unit residential buildings, large commercial office, restaurant, school, warehouse, etc.
- End use – e.g., lighting, space heating, space cooling, plug load, etc.
- Measure – e.g., high bay LED lighting, air source heat pumps, building recommissioning

To calculate CDM potential for the Addendum Study, forecasted annual demand savings assumptions were taken from the outputs of the maximum achievable potential scenario of the APS for applicable stations in the City of Toronto and applied to the reference forecast developed for this addendum. The maximum achievable potential scenario captures potential from all CDM measures that are cost effective from the provincial system perspective – i.e., they produce benefits from avoided energy and system capacity costs that are greater than the incremental costs of the measures.

As noted in Section 5.1. of the main report, savings that are expected to come through committed CDM programs, including the provincial 2021-2024 framework that were not

[1] 2019 Conservation Achievable Potential Study, https://www.ieso.ca/2019-conservation-achievable-potential-study

[2] IESO Zonal Map, https://www.ieso.ca/localContent/zonal.map/index.html

accounted for when the 2019 APS was developed, have been removed from the forecasted CDM potential.

Achievable potential in the APS also considers both technical considerations affecting energy efficiency potential such as the number of customers with low-efficiency equipment or operations that can technically be upgraded, and market considerations such as customer responses to payback periods under different incentive rates. The energy efficiency potential estimates resulting from this analysis provide insight into the magnitude of energy efficiency savings that would be beneficial to the provincial electricity grid and can likely be achieved given customer behavior.

Appendix B: Forecast Methodology

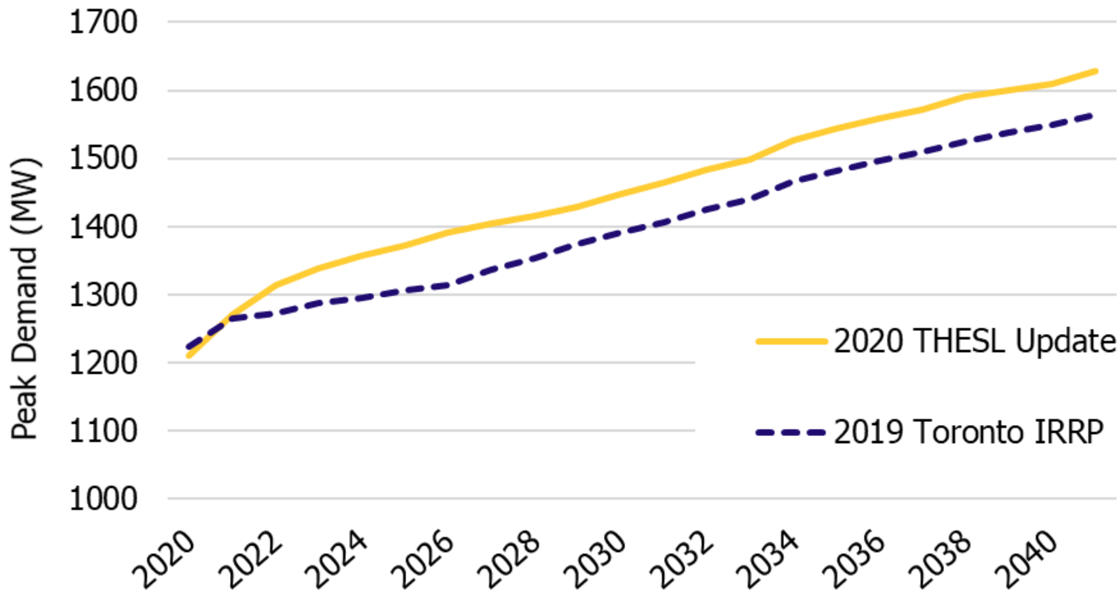
B.1 Toronto Hydro Demand Forecast Methodology

As part of the process to produce the IRRP Update regarding Richview x Manby transmission lines, Toronto Hydro-Electric System Limited revisited and updated its forecasts for the area under study. These lines serve eight stations and, at times, a ninth station, all within Toronto. Therefore, the forecasts for each of these nine stations was provided and based upon the peak demand and known data as of the summer of 2020. This forecast was developed using the same assumptions and methods used in the development of the forecast for the Toronto Integrated Regional Resource Plan of 2019.

The current forecast reflects an increase in peak demand for the same time periods as compared to the previous forecast. Please see Figure 1 below for a year by year comparison of the two forecasts for the corridor demand. Overall, the new forecast reflects a 1.2% increase over the previous forecast for the stations serving Toronto Hydro.

Plans to deal with growing demand has led to a new station going into service in the area, Copeland TS in the downtown core, and an existing station to be expanded, Runnymede TS, which serves the Eglinton cross-town LRT. A station expansion to Horner TS will go into service in 2022. Growth in these areas continues to be strong. Other changes to the forecast are related to the transfer of load between stations to optimize the use of the new capacity.

Figure 1 | 2020 Update RxK Stations



B.2 Demand Profile Forecast Methodology

A load duration forecast consists of a series of year long hourly profiles ("8760 profile", based on the number of hours in a year), which have been scaled to the appropriate annual peak demand. These profiles are studied to determine the feasibility of using non-wires alternatives to address needs in the region, and to determine which type of non-wires alternatives may be best suited to meet the needs.

Hourly load forecasting was conducted on a station-level, using a multiple linear regression with approximately five years' worth of historical hourly load data. Firstly, a density-based clustering algorithm was used for filtering the historical data for outliers (including fluctuations possibly caused by load transfers, outages, or infrastructure changes).

Subsequent to the removal of outliers, the historical hourly data was combined with select predictor variables to perform a multiple linear regression and model the station's hourly load profile. For the Richview South area, the following predictor variables were used:

- Calendar factors (such as holidays and days of the week)
- Weather factors (including temperature, dew point, wind speed, cloud cover, and fraction of dark; both weekday and weekend heating, cooling, and dead band splines were modelled)
- Demographic factors (population data[3])
- Economic factors (employment data[4])

Model diagnostics (training mean absolute error, testing mean absolute error) were used to gauge the effectiveness of the selected predictor variables and to avoid an over-fitted model. While future values for calendar, demographic, and economic variables were incorporated in a relatively straightforward manner, the unreliability of long-term weather forecasts necessitated a different approach for predicting the impact of future weather.

Each future date was first modelled using historical weather data from the equivalent day of year throughout the past 10 years. Additionally, to fully assess the impact of different weather sequences against the other non-weather variables, the historical weather for each of the 10 previous years was shifted both ahead and behind up to seven days, resulting in 15 daily variations. This approach ultimately led to 150 possible hourly load forecasts for each future year being forecast. For example:

- 10 years of historical weather data ×15 weather sequence shifts =150 weather scenarios for each year being forecast

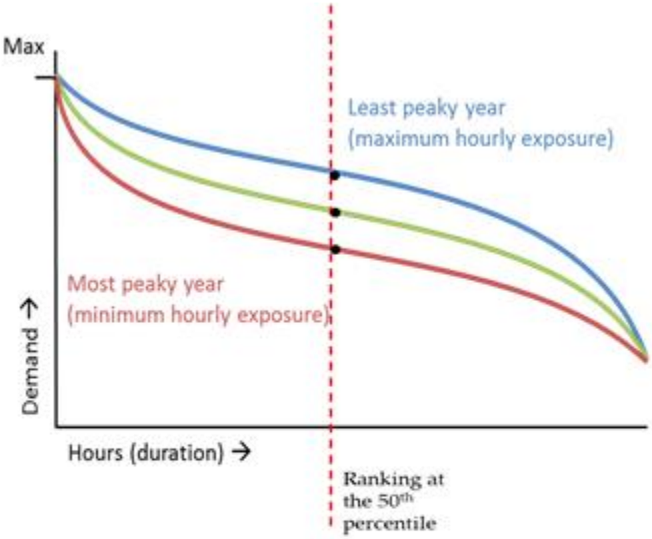
[3] Sourced from the Ministry of Finance and Statistics Canada

[4] Sourced from the Centre for Spatial Economics, IHS Markit Ltd., and the Conference Board of Canada

- E.g., June 2nd 2025 was forecasted assuming the historical weather from every May 26th to June 9th that occurred between 2011 and 2020.

Subsequently, the list of 150 forecasts were ranked in ascending order based on their median values. Load duration curves which illustrate this ranking can be seen in Figure 2.

Figure 2 | Example of Ranking Load Duration Curves Created from Hourly Load Profiles



The forecast in the 3rd percentile was chosen as the "Extreme Peak" (extreme profile, red curve) and the forecast in the 50th percentile was chosen was the "Median Peak" (median profile, green curve).

The yearly forecasts were scaled to their respective maximums from the peak demand forecast, and added together to form a single multi-year forecast.

B.2.1 Characteristic of Need in Richview South Area

For the purpose of this IRRP, need characterization was done for all Richview South loads[5] as they are supplied by the Richview x Manby circuits.

The historical hourly data for all stations was combined and one linear regression model was used. Once the 150 normalized forecasts were created, they were scaled to the demand forecast. The load duration forecast provided information regarding the amount by which the load is expected to exceed the limit of the circuits as well as the amount of time spent over the limit, or the total event hours. Table B.2.1 shows the annual energy requirements based on this information.

[5] Including Dufferin TS and Southern Mississauga/Oakville load

Table 1 | Characteristic of Need in Richview South Area

	2025	2030	2040
Annual Energy Need (MWh)	1,700	4,300	15,400
Capacity Need (MW)	200	290	470

Appendix C: Technical Needs Assessment Report to support the Addendum to 2019 Toronto Integrated Regional

C.1. Introduction

Based on the outcome of the Integrated Regional Resource Plan ("IRRP") for the Toronto region in 2015, the need for additional capacity on the 230 kV transmission lines that supply Manby Transformer Station ("TS") from Richview TS was identified. The need was driven by growth in downtown Toronto, southern Etobicoke, the City of Mississauga and the Town of Oakville.

The 2019 Toronto IRRP identified the need for additional electricity transfer capacity on the Richview TS to Manby TS path. The recommendation was that Hydro One rebuild the existing 115 kV idle line between Richview TS and Manby TS and uprate it to a 230 kV double-circuit line. The new line would connect at Richview TS and Manby TS by sharing the existing terminations for the 230 kV circuits R2K and R15K on the same corridor (the "Richview x Manby reinforcement"). This recommendation was reinforced in the 2020 Toronto Regional Infrastructure Plan (RIP) led by Hydro One.

As part of its ongoing planning efforts, the Technical Work Group continues to monitor developments in the region, even after plan completion, to identify signposts of change that should be considered in terms of their impact on the plan recommendations. In the case of the 2019 Toronto IRRP and RIP, there have been a number of changes including: potential COVID-19 impacts on the area's demand, as well as additional information on the energy efficiency (EE) potential in the Toronto area. This additional information on EE potential in the region has enabled the IESO to identify EE as a feasible near-term alternative that could defer the need for the Richview x Manby reinforcement and should be considered further.

As a result of the changes described above, and their potential impact on the Toronto IRRP recommendations, the IESO has further recommended that an Addendum be initiated so as to explore these changes with the technical working group. This planning study aims to support the Addendum to the 2019 Toronto IRRP.

C.1.1 Purpose

The purpose of this planning study report is to document the results of power system analysis used to determine the performance of the existing transmission system in the Richview TS x Manby TS x Cooksville TS area (the "Richview South" system). The results of this planning study will be used to re-confirm the need and timing for reinforcements to the Richview South system. This report will not be analyzing options that will increase the load meeting capability of the area. Analyzing options (and looking at sensitivities surrounding Dufferin on Manby supply) is left to the final Addendum report.

– End of Section –

C.2. Scenarios and Assumptions

C.2.1 Credible Scenarios Assessed

The following scenario was selected for analysis to establish the performance of the existing system based on recognized planning standards and criteria as referenced in Section 1.

Table 2: Description of Credible Scenarios

Year	Scenario Description
2021	• 230 kV Claireville TS bus operated split • 230 kV Richview TS bus operated split • Dufferin TS on normal (Leaside sector) supply • Copeland TS on normal (Manby West sector) supply

C.2.2 Facility Ratings Assumptions

Facility rating assumptions for monitored circuit sections are summarized below:

Table 3: Summary of Facility Ratings

Circuit	From	To	Summer Ratings (Amps)		
			Cont	LTE	STE
R1K	Richview TS	Manby TS	1160	1530	1940
R2K	Richview TS	Manby TS	1160	1530	1940
R2K	Manby TS	Vansco JCT	1060	1400	1900
R2K	Vansco JCT	Horner TS	1080	1080	3960
R2K	Manby TS	Manby TS	1350	1800	2170
R13K	Richview TS	Manby TS	1160	1530	1940
R13K	Manby TS	Manby TS	1350	1800	2170
R13K	Manby TS	Vansco JCT	1060	1400	1900
R13K	Vansco JCT	Horner TS	1080	1080	3960
R15K	Richview TS	Manby TS	1160	1530	1940
R24C	Richview TS	Applewood JCT	1690	2260	2930
R24C	Applewood JCT	Cooksville TS	1290	1700	2090
K21C	Manby TS	Applewood JCT	1350	1800	2170
K21C	Manby TS	Applewood JCT	1350	1800	2170
K21C	Applewood JCT	Cooksville TS	1558	1558	5998
K21C	Cooksville TS	Cooksville TS	1290	1700	2090
K23C	Manby TS	Applewood JCT	1690	2120	2660
K23C	Applewood JCT	Cooksville TS	1290	1700	2090
K23C	Applewood JCT	Applewood JCT	1350	1800	2170

C.2.3 System Assumptions

C.2.3.1 System Load by Zone

The load forecast is based a combination of the 2021 Summer Master Base case load assumption, modified as follows:

- Updated Toronto IRRP load forecast provided by Toronto Hydro Electric Systems Limited (THESL),
- 2021 GTA West IRRP Load forecast,
- Direct connect transmission customer(s)' loading is consistent with the latest 2021 Summer Master Base Case,
- New direct connect transmission customer(s)' loading based on Hydro One's

most updated forecast.

C.2.4 Study Area Assumptions

C.2.4.1 Study Area Load by Station Bus

The load forecast used for the Manby East sector, Manby West sector (with Copeland TS), Manby Dual Element Spot Network (DESNs), and Horner TS is consistent with the updated Toronto IRRP load forecast. The forecast used for Cooksville TS, Lorne Park TS, and Oakville TS is consistent with the 2021 GTA West IRRP. The direct connect transmission customer(s)' loading is consistent with the latest 2021 Summer Master Base Case. New direct connect transmission customer(s)' loading based on the most updated forecast from Hydro One is also included. The total load of all of these stations is referred to as "Richview South loads". All forecasts represent summer extreme weather peak demand.

Table 4 shows the 2021 Richview South load forecast which was used in this study. For reference, the load forecast for 2030 and 2040 is also provided to show the expected change in demand in the area.

Table 4: Study Area Load (MW)

Station(s)	Year		
	2021	2030	2040
Cooksville TS	104	136	145
Horner TS	138	217	255
Lorne Park TS	80	88	94
Manby East (115 kV TSs)	347	382	419
Manby West (115 kV TSs)	455	483	546
Manby TS DESNs	190	153	170
Oakville TS	140	137	139
Existing transmission customer(s)	15	15	15
New transmission customer(s)	-	7	20
Total	**1,469**	**1,618**	**1,803**

A 0.9 power factor was used for conservatism and to ensure consistency with assumptions used in the 2019 Toronto IRRP planning studies for steady state thermal and voltage assessments. Low-tension shunt capacitor banks were placed in-service as necessary to control transmission voltages to desired levels.

C.2.5 Credible Planning Events

C.2.5.1 Steady State Planning Events Studied

The following summarizes the critical single and double contingencies studied, consistent with NERC and NPCC planning events. In addition, this report studied the most limiting contingency of the existing system as identified by the Richview to Manby Reinforcement SIA (2018-637); namely the R24C + K23C double contingency following an R15K outage. This extra contingency will be compared to the studied contingencies below to determine the load meeting capability (LMC) of the system.

The studied N-1 contingencies are:

- R1K
- R2K
- R13K
- R15K
- R24C

The studied N-2 contingencies are:

- R1K + R2K
- R13K + R15K

C.2.6 Planning Criteria

The study applied planning criteria in accordance with planning events and performance as detailed by:

- North American Electric Reliability Corporation ("NERC") TPL-001 "Transmission System Planning Performance Requirements" ("TPL-001"),
- Northeast Power Coordinating Council ("NPCC") Regional Reliability Reference Directory #1 "Design and Operation of the Bulk Power System ("Directory #1"), and
- IESO Ontario Resource and Transmission Assessment Criteria ("ORTAC").

– End of Section –

C.3. Study Results – Existing System

Under normal system configuration, without any 230 kV circuit upgrades, the existing system is insufficient to meet the Richview South loads from summer of 2021 and beyond. The limiting contingency is the loss of R15K, which leads to R2K exceeding its LTE rating, with all elements initially in service. The LMC of the system is 1,469 MW, in line with the 2021 demand forecast.

Please note that the following legend was used to identify circuit loadings that exceed the applicable emergency ratings.

- A red highlight indicates loading is above the applicable thermal rating as follows:
  - Continuous ratings when all elements are in-service;
  - LTE ratings for pre-contingency conditions when one element is initially out of service;
  - LTE ratings for post-contingency conditions when one element is lost with no prior outages;
  - STE ratings for post-contingency conditions when there are prior outages or more than one element is lost.
- An orange highlight indicates overloading of a rating which the contingency will not be assessed against (i.e. exceeding LTE rating after losing two or more transmission elements). This does not violate performance criteria and is provided for information.
- A yellow highlight indicates loading of the applicable rating is over 70% but below 100% of the emergency rating.

C.3.1 Pre-contingency: N-0

C.3.1.1 Thermal Assessment

With all elements initially in-service in the Richview South study area, no violations to pre-contingency thermal ratings are observed.

Table 5: Circuit Thermal Assessment – All Elements In-service

Circuit	From	To	Summer Cont. Rating (Amps)	2021 (Amps)
R1K	Richview TS	Manby TS	1160	662
R2K	Richview TS	Manby TS	1160	908
R2K	Manby TS	Vansco JCT	1060	181
R2K	Vansco JCT	Horner TS	1080	184
R2K	Manby TS	Manby TS	1350	728
R13K	Richview TS	Manby TS	1160	672
R13K	Manby TS	Manby TS	1350	517
R13K	Manby TS	Vansco JCT	1060	155
R13K	Vansco JCT	Horner TS	1080	160
R15K	Richview TS	Manby TS	1160	913
R24C	Richview TS	Applewood JCT	1690	423
R24C	Applewood JCT	Cooksville TS	1290	423
K21C	Manby TS	Applewood JCT	1350	123
K21C	Manby TS	Applewood JCT	1350	123
K21C	Applewood JCT	Cooksville TS	1558	258
K23C	Manby TS	Applewood JCT	1290	249
K23C	Applewood JCT	Cooksville TS	1290	250

C.3.1.2 Steady State Voltage Assessment

With all elements initially in-service in the Richview South study area, no violations to pre-contingency voltage magnitude criteria are observed.

Table 6: Voltage Assessment – All Elements In-service

	2021 (kV)
Cooksville TS	239.9
Manby East	240.5
Manby West	240.4
Richview TS (AH1 bus)	241.1
Richview TS (AH2 bus)	240.5

C.3.2 Post-contingency: N-1

As per ORTAC, circuit sections are required to be loaded below their long term emergency (LTE) ratings after the loss of a single transmission element. Load flow analysis has identified that the loss of R15K would result in thermal violations exceeding the LTE under 2021 forecast load conditions. Study results outlining the impact of single contingencies on monitored circuits in the Richview South corridor are reported below.

C.3.2.1 Thermal Assessment

Under 2021 forecast load conditions following an R15K contingency, post-contingency loading of R2K shows a violation of ORTAC standards (loading exceeds LTE ratings). This is shown in Table 7 below. This violates thermal loading criteria and is identified as a reliability need.

Table 7: Circuit Thermal Assessment – Post-contingency N-1 (2021 Forecast Load)

Circuit	From	To	Ratings (Amps)		Loss of R15K		
			LTE	STE	Amps	LTE	STE
R2K	Richview TS	Manby TS	1530	1940	1544	101%	80%
R2K	Manby TS	Vansco JCT	1400	1900	172	12%	9%
R2K	Vansco JCT	Horner TS	1080	3960	175	16%	4%
R2K	Manby TS	Manby TS	1800	2170	1372	76%	63%

C.3.2.2 Steady State Voltage Assessment

No violations to post-contingency voltage criteria were found during the single-circuit contingency analysis.

C.3.3 Post-contingency: N-2

C.3.3.1 Thermal Assessment

As per ORTAC, circuit sections are required to respect short term emergency (STE) ratings after the loss of two transmission elements (e.g., adjacent circuits on a common tower). Loading must respect LTE ratings within the time afforded by the STE ratings, in this case, 15 minutes.

The 2021 forecast load condition was assessed to confirm that the N-1 condition is still more limiting than the N-2 condition as control actions are permissible following the N-2 contingencies.

Following the loss of R13K and R15K, all circuit loadings are found to be within LTE ratings, except for R2K, which exceeds its LTE rating but not its STE rating. Similarly, following the loss of R1K and R2K, all circuit loadings are found to be within LTE ratings, except for R15K, which exceeds its LTE rating but not its STE rating. This is demonstrated in Table 8. The immediate post-contingency thermal loading criteria are met. Control actions to reduce loading to within LTE ratings are explored further in the next section.

Table 8: Circuit Thermal Assessment – Post-contingency N-2 (2021 Forecast Load)

Circuit	From	To	Ratings (Amps)		Loss of R1K + R2K			Loss of R13K + R15K		
			LTE	STE	Amps	LTE	STE	Amps	LTE	STE
R1K	Richview TS	Manby TS	1530	1940	N/A	N/A	N/A	1215	79%	63%
R2K	Richview TS	Manby TS	1530	1940	N/A	N/A	N/A	1751	114%	90%
R2K	Manby TS	Vansco JCT	1400	1900	N/A	N/A	N/A	347	25%	18%
R2K	Vansco JCT	Horner TS	1080	3960	N/A	N/A	N/A	356	33%	9%
R2K	Manby TS	Manby TS	1800	2170	N/A	N/A	N/A	1404	78%	65%
R13K	Richview TS	Manby TS	1530	1940	1355	89%	70%	N/A	N/A	N/A
R13K	Manby TS	Manby TS	1800	2170	1013	56%	47%	N/A	N/A	N/A
R13K	Manby TS	Vansco JCT	1400	1900	348	25%	18%	N/A	N/A	N/A
R13K	Vansco JCT	Horner TS	1080	3960	357	33%	9%	N/A	N/A	N/A
R15K	Richview TS	Manby TS	1530	1940	1628	106%	84%	N/A	N/A	N/A

C.3.3.2 Thermal Assessment (Reducing loading to below LTE)

Under the assumed study conditions, N-2 contingencies reported above result in post-contingency loading that exceeds LTE ratings. As per ORTAC Section 4.7.2, the loading on these sections must be reduced to respect their LTE rating, within the time afforded by the STE ratings, in this case, 15 minutes. This section reports on the ability of possible control actions to reduce post-contingency loading to within LTE ratings.

It is found that none of the double-circuit contingencies studied (R1K + R2K and R13K + R15K) would result in the remaining Richview to Manby circuits to exceed their STE ratings under the load assumptions considered.

Furthermore, it is found that curtailing up to 150 MW of load at John TS and Strachan TS, would be sufficient to respect LTE ratings.

The more restrictive contingency assessed was the loss of R13K+R15K, and therefore only results for this contingency are reported in Table 9 below. It was found that curtailment of up to 150 MW of load is sufficient to reduce post-contingency loading to within LTE, and therefore respects ORTAC requirements.

Table 9: Circuit Thermal Assessment – Post-contingency – 150 MW of Load Curtailment – N-2 (2021 Forecast Load)

Circuit	From	To	Ratings (Amps)		Loss of R13K + R15K		
			LTE	STE	Amps	LTE	STE
R2K	Richview TS	Manby TS	1530	1940	1503	98%	77%
R2K	Manby TS	Vansco JCT	1400	1900	342	24%	18%
R2K	Vansco JCT	Horner TS	1080	3960	350	32%	9%
R2K	Manby TS	Manby TS	1800	2170	1166	65%	54%

C.3.3.3 Steady State Voltage Assessment

No violations to post-contingency voltage criteria were found during the double-circuit contingency analysis.

C.3.4 Pre-contingency: N-1-0

This scenario was studied as the R15K outage followed by loss of R24C and K23C was identified as the most limiting by the Richview to Manby Reinforcement SIA (2018-637). This contingency and outage combination will be compared to the studied contingencies above to determine the LMC of the system.

C.3.4.1 Thermal Assessment

As per ORTAC, circuit sections are required to respect LTE ratings after the loss of one transmission element. Thermal violations at R2K are observed (exceeds LTE rating) when R15K is initially experiencing an outage. In order to mitigate this, John TS and Copeland TS (2021 peak demand of 315 MW) are transferred over to Leaside supply. Note that this control action is dependent on available capacity on the Leaside sector.

Table 10: Circuit Thermal Assessment – R15K outage – John TS and Copeland TS transferred to Leaside sector supply

Circuit	From	To	Summer LTE Rating (Amps)	2021 (Amps)
R1K	Richview TS	Manby TS	1530	646
R2K	Richview TS	Manby TS	1530	1108
R2K	Manby TS	Vansco JCT	1400	182
R2K	Vansco JCT	Horner TS	1080	186
R2K	Manby TS	Manby TS	1800	926
R13K	Richview TS	Manby TS	1530	656
R13K	Manby TS	Manby TS	1800	504
R13K	Manby TS	Vansco JCT	1400	153
R13K	Vansco JCT	Horner TS	1080	157
R15K	Richview TS	Manby TS	1530	N/A
R24C	Richview TS	Applewood JCT	2260	398
R24C	Applewood JCT	Cooksville TS	1700	398
K21C	Manby TS	Applewood JCT	1800	174
K21C	Manby TS	Applewood JCT	1800	173
K21C	Applewood JCT	Cooksville TS	1558	360
K23C	Manby TS	Applewood JCT	2120	203
K23C	Applewood JCT	Cooksville TS	1700	203

C.3.5 Post-contingency: N-1-2

C.3.5.1 Thermal Assessment

As per ORTAC, circuit sections are required to respect STE ratings after the loss of two transmission elements (e.g., adjacent circuits on a common tower). Loading must respect LTE ratings within the time afforded by the STE ratings, in this case, 15 minutes.

Following the loss of R24C and K23C, with R15K initially on outage, all circuit loadings are found to be within LTE ratings, except for R2K, which exceeds its LTE rating but not its STE rating. This is demonstrated in Table 11. The immediate post-contingency thermal loading criteria are met. Control actions to reduce loading to within LTE ratings are explored further in the next section.

Table 11: Circuit Thermal Assessment – R15K Outage – R24C and K23C contingency – John TS and Copeland TS on Leaside sector supply

Circuit	From	To	Ratings (Amps)		Loss of R24C + K23C		
			LTE	STE	Amps	LTE	STE
R2K	Richview TS	Manby TS	1530	1940	1679	110%	87%
R2K	Manby TS	Vansco JCT	1400	1900	148	11%	8%
R2K	Vansco JCT	Horner TS	1080	3960	149	14%	4%
R2K	Manby TS	Manby TS	1800	2170	1533	85%	71%

C.3.5.2 Thermal Assessment (Reducing loading to below LTE)

Under the assumed study conditions, N-2 contingencies reported above result in post-contingency loading that exceeds LTE ratings. As per ORTAC Section 4.7.2, the loading on these sections must be reduced to respect their LTE rating, within the time afforded by the STE ratings, in this case, 15 minutes. This section reports on the ability of possible control actions to reduce post-contingency loading to within LTE ratings.

It is found that the R24C + K23C contingency would not result in the remaining Richview South circuits to exceed their STE ratings under the load assumptions considered. However, it was found that R2K would exceed its LTE rating following the contingency.

In order to mitigate this, up to 75 MW of load at Strachan TS would need to be curtailed/rejected to respect LTE ratings of R2K. The results of the above control action are shown in Table 12 below.

Table 12: Circuit Thermal Assessment– R15K Outage – R24C and K23C contingency – John TS and Copeland TS on Leaside sector supply – 75 MW of load curtailment/rejection at Strachan TS

Circuit	From	To	Ratings (Amps)		Loss of R24C + K23C		
			LTE	STE	Amps	LTE	STE
R2K	Richview TS	Manby TS	1530	1940	1496	98%	77%
R2K	Manby TS	Vansco JCT	1400	1900	154	11%	8%
R2K	Vansco JCT	Horner TS	1080	3960	157	15%	4%
R2K	Manby TS	Manby TS	1800	2170	1342	75%	62%

C.3.5.3 Steady State Voltage Assessment

No violations to post-contingency voltage criteria were found during the double-circuit contingency analysis.

– End of Section –

C.4. Conclusion

Based on the results above, under the updated demand forecast, it is found that an N-1 contingency in the Richview x Manby corridor (loss of R15K) will lead to loading of R2K above its LTE rating during 2021 summer peak conditions. This is a violation of ORTAC. Therefore, the LMC of the system is 1,469 MW. The N-1-2 outage and contingency combination studied in Section C.3.5 was determined to be less limiting than the N-1 contingency, as the N-1-2 event allows for pre and post contingency control actions. These control actions used in Section C.3.5 have shown to be able to respect the circuits' LTE ratings. Based on the forecast in Table 4, this violation is expected to persist and worsen as demand in the area is forecasted to increase.

It is recommended that the main body of the addendum to the 2019 Toronto IRRP fully address the need on the Richview x Manby circuits, such that the recommended solution(s) are able to accommodate both current and expected future loadings in line with the applicable reliability standards.

– End of Section –

Appendix D: Richview TS x Manby TS 230 kV Circuit Upgrade Capability Study

D.1. Introduction

D.1.1 Purpose

The purpose of this planning study report is to document the results of power system analysis used to determine the performance of the transmission system in the Richview TS x Manby TS x Cooksville TS area (the "Richview South" system) following the "Phase 1" upgrades as reported in the SIA Report for the Richview TS to Manby TS Transmission Reinforcement Project (CAA ID: 2018-637) (the "SIA Report"). The results of this planning study will be used to evaluate the capability of the Phase 1 upgrades to meet the demands of the 2019 Toronto IRRP addendum forecast. It is highly recommended that the reader familiarize themselves with the aforementioned SIA Report before continuing with this report.

– End of Section –

D.2. Scenarios and Assumptions

D.2.1 Brief Description of Phase 1 Upgrades

According to the SIA Report, Phase 1 of the RxK upgrades involves the following:

- The existing idle 115 kV line between Richview TS and Manby TS will be rebuilt into two new 230 kV circuits, which are then bundled into one super-circuit. The new 230 kV super-circuit will take the breaker positions of the existing circuit R15K at both ends and be designated as circuit R15K.
- The existing circuit R15K will be re-connected at both ends, taking the breaker positions of the existing circuit R1K and renamed R1K.
- The existing R1K and R2K circuits will be bundled as one new super-circuit R2K, taking the breaker positions of the existing R2K at both ends.
- The Horner TS tap point on the existing R13K circuit will be moved onto the new circuit R15K.
- The existing last section of K21C of 9 meters connected to Cooksville TS will be upgraded. The long-term thermal rating of the new line section will be at least 2000 Amps.

D.2.2 Credible Scenarios Assessed

The following scenarios were selected for analysis to establish the performance of the existing system based on recognized planning standards and criteria as referenced in Section D.1.

Dufferin TS is normally supplied from the Leaside sector. In the event of a contingency in the Leaside sector, Dufferin TS may be transferred to Manby East, as required. This post-contingency condition is represented by Scenario 2.

Table 13: Description of Credible Scenarios

<table>
<tr><th>Scenario Number</th><th>Year</th><th>Scenario Description</th><th>Scenario Specific Characteristics</th></tr>
<tr><td>1</td><td rowspan="2">2040</td><td rowspan="2">• 230 kV Claireville TS bus operated split
• 230 kV Richview TS bus operated split
• System reconfigured according to Phase 1 description as found in CAA ID 2018-637
• Copeland TS on Manby supply</td><td>• Dufferin TS on normal (Leaside sector) supply</td></tr>
<tr><td>2</td><td>• Dufferin TS on emergency (Manby East sector) supply[6]</td></tr>
</table>

[6] This assumes that there is already at least an N-1 outage scenario on the Leaside sector

D.2.3 Facility Ratings Assumptions

Facility rating assumptions for monitored circuit sections are summarized below:

Table 14: Summary of Facility Ratings

Circuit	From	To	Summer Ratings (Amps)		
			Cont	LTE	STE
R1K	Richview TS	Manby TS	1160	1530	1940
R2K	Richview TS	Manby TS	2320	3060	3880
R2K	Manby TS	Vansco JCT	1060	1400	1900
R2K	Vansco JCT	Horner TS	1080	1080	3960
R13K	Richview TS	Manby TS	1160	1530	1940
R15K	Richview TS	Manby TS	2320	3060	3880
R15K	Manby TS	Vansco JCT	1060	1400	1900
R15K	Vansco JCT	Horner TS	1080	1080	3960
R24C	Richview TS	Applewood JCT	1690	2260	2930
R24C	Applewood JCT	Cooksville TS	1290	1700	2090
K21C	Manby TS	Applewood JCT	1350	1800	2170
K21C	Manby TS	Applewood JCT	1350	1800	2170
K21C	Applewood JCT	Cooksville TS	1558	2000	5998
K21C	Cooksville TS	Cooksville TS	1290	1700	2090
K23C	Manby TS	Applewood JCT	1690	2120	2660
K23C	Applewood JCT	Cooksville TS	1290	1700	2090

D.2.4 System Assumptions

D.2.4.1 System Load by Zone

The load forecast is based a combination of the 2021 Summer Master Base case load assumption, modified as follows:

- Toronto IRRP addendum load forecast provided by Toronto Hydro Electric Systems Limited (THESL),
- 2021 GTA West IRRP Load forecast,
- Direct connect transmission customer(s)' loading is consistent with the latest 2021 Summer Master Base Case.
- New direct connect transmission customer(s)' loading based on the most updated forecast Hydro One has.

D.2.5 Study Area Assumptions

D.2.5.1 Study Area Load by Station Bus

The load forecast used for the Manby East sector, Manby West sector (with Copeland TS), Manby Dual Element Spot Network (DESNs), Horner TS, and Dufferin TS is consistent with the updated Toronto IRRP load forecast. The forecast used for Cooksville TS, Lorne Park TS, and Oakville TS is consistent with the 2021 GTA West IRRP. The direct connect transmission customer(s)' loading is consistent with the latest 2021 Summer Master Base Case. New direct connect transmission customer(s)' loading based on the most updated forecast Hydro One has is also included. The total load of all of these stations is referred to as "Richview South loads". All forecasts represent summer extreme weather peak demand.

Table 15 shows the 2021 Richview South load forecast which was used in this study. For reference, the load forecast for 2030 and 2040 is also provided to show the expected change in demand in the area.

Table 15: Study Area Load (MW)

Station(s)	Year		
	2021	2030	2040
Cooksville TS	104	136	145
Horner TS	138	217	255
Lorne Park TS	80	88	94
Manby East (115 kV TSs)	347	382	419
Manby West (115 kV TSs)	455	483	546
Manby TS DESNs	190	153	170
Oakville TS	140	137	139
Existing transmission customer(s)	15	15	15
New transmission customer(s)	-	7	20
Dufferin TS	126	147	163

A 0.9 power factor was used for conservatism and to ensure consistency with assumptions used in the 2019 Toronto IRRP planning studies for steady state thermal and voltage assessments. Low-voltage shunt capacitor banks were placed in-service as necessary to control transmission voltages to desired levels.

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D.2.6 Credible Planning Events

D.2.6.1 Steady State Planning Events Studied

The following summarizes the critical single and double contingencies studied, consistent with NERC and NPCC planning events. In addition, this report studied the most limiting contingency after the Phase 1 upgrades as identified by the SIA Report; namely the R1K + R13K double contingency following a K21C outage. This additional contingency will be studied in addition to those below to determine whether the proposed Phase 1 upgrade can supply the system to the end of the forecast (i.e. 2040).

The studied N-1 contingencies are:

- R1K
- R2K
- R13K
- R15K
- R24C

The studied N-2 contingencies are:

- R1K + R13K

D.2.7 Planning Criteria

The study applied planning criteria in accordance with planning events and performance as detailed by:

- North American Electric Reliability Corporation ("NERC") TPL-001 "Transmission System Planning Performance Requirements" ("TPL-001"),
- Northeast Power Coordinating Council ("NPCC") Regional Reliability Reference Directory #1 "Design and Operation of the Bulk Power System ("Directory #1"), and
- IESO Ontario Resource and Transmission Assessment Criteria ("ORTAC").

– End of Section –

D.3. Study Results – Phase 1

In summary, with the Phase 1 upgrades, the system can sufficiently supply the Richview South loads up to the end of the study period (i.e. 2040). The load meeting capability of the system will be above the load forecast seen in 2040. The following section outlines the findings which support the preceding statement.

Note that applying the above outage and contingency combination in Section D.2.6.1 on Scenario 2 technically constitutes an N-1-1-2 outage + contingency combination since Scenario 2 is assuming that there is at least an N-1 outage on the Leaside sector in order to warrant Dufferin TS being transferred to Manby East. N-1-1-2 means that there is an outage at the Leaside, an outage at the Manby sector then followed by a double contingency. This N-1-1-2 scenario is beyond any applicable planning criteria.

Please note that the following legend was used to identify circuit loadings that exceed the applicable emergency ratings.

- A red highlight indicates loading is above the applicable thermal rating as follows:
  - Continuous ratings when all elements are in-service;
  - LTE ratings for one element is out of service;
  - STE ratings for two or more elements out of service.
- An orange highlight indicates overloading of a rating which the contingency will not be assessed against (i.e. exceeding LTE rating after losing two or more transmission elements). This does not violate performance criteria and is provided for information.
- A yellow highlight indicates loading of the applicable rating is over 90% but below 100% of the emergency rating.

D.3.1 Pre-contingency: N-0

D.3.1.1 Thermal Assessment

With all elements initially in-service in the Richview South study area, no violations to pre-contingency thermal ratings were observed.

Table 16: Circuit Thermal Assessment – All Elements In-service

Circuit	From	To	Summer Cont. Rating (Amps)	Scenario 1 (Amps)	Scenario 2 (Amps)
R1K	Richview TS	Manby TS	1160	706	887
R2K	Richview TS	Manby TS	2320	1315	1402
R2K	Manby TS	Vansco JCT	1060	363	366
R2K	Vansco JCT	Horner TS	1080	377	380
R13K	Richview TS	Manby TS	1160	707	889
R15K	Richview TS	Manby TS	2320	1325	1412
R15K	Manby TS	Vansco JCT	1060	292	294
R15K	Vansco JCT	Horner TS	1080	306	308
R24C	Richview TS	Applewood JCT	1690	470	478
R24C	Applewood JCT	Cooksville TS	1290	471	478
K21C	Manby TS	Applewood JCT	1350	169	260
K21C	Manby TS	Applewood JCT	1350	168	259
K21C	Applewood JCT	Cooksville TS	1558	319	503
K21C	Cooksville TS	Cooksville TS	1290	319	503
K23C	Manby TS	Applewood JCT	1690	298	156
K23C	Applewood JCT	Cooksville TS	1290	271	136

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D.3.1.2 Steady State Voltage Assessment

With all elements initially in-service in the Richview South study area, no violations to pre-contingency voltage magnitude criteria are observed.

Table 17: Voltage Assessment – All Elements In-service

	2040 (kV)	
	Scenario 1	**Scenario 2**
Cooksville TS	236.5	234.8
Manby East	237.2	234.5
Manby West	237.1	235.6
Richview TS (AH1 bus)	238.1	237.9
Richview TS (AH2 bus)	238.1	236.7

D.3.2 Post-contingency: N-1

As per ORTAC, circuit sections are required to be loaded below their Long Term Emergency (LTE) ratings after the loss of a single transmission element. Load flow analysis shows no violations following the loss of a single element. Study results outlining the impact of single contingencies on monitored circuits in the Richview South corridor are reported below.

D.3.2.1 Thermal Assessment

In both scenarios, none of the N-1 contingencies result in any circuit loadings exceeding their LTE ratings. The worst case N-1 contingency is Scenario 2 following an R13K contingency.

Under Scenario 2 load conditions, following an R13K contingency, post-contingency loading of R1K reaches 98% of its LTE rating. This is shown in Table 18 below. This is not a violation of thermal loading criteria.

Table 18: Circuit Thermal Assessment – Post-contingency N-1 (Scenario 2)

Circuit	From	To	Ratings (Amps)		Loss of R13K		
			LTE	STE	Amps	LTE	STE
R1K	Richview TS	Manby TS	1530	1940	1505	98%	78%

D.3.2.2 Steady State Voltage Assessment

No violations to post-contingency voltage criteria were found during the single-circuit contingency analysis.

D.3.3 Post-contingency: N-2

D.3.3.1 Thermal Assessment

As per ORTAC, circuit sections are required to respect short term emergency (STE) ratings after the loss of two transmission elements (e.g., adjacent circuits on a common tower). Circuit loading must be reduced to respect LTE ratings within the time afforded by the STE ratings, in this case, 15 minutes.

Under Scenario 1, none of the circuits exceed their LTE or STE ratings following the loss of R1K and R13K.

Under Scenario 2, following the loss of R1K and R13K, circuits K21C and K23C exceed their LTE ratings but not their STE ratings. This is demonstrated in Table 19. The immediate post-contingency thermal loading criteria are met. Control actions to reduce loading to within LTE ratings are explored further in the next section.

Table 19: Circuit Thermal Assessment – Post-contingency N-2 (Scenario 2)

Circuit	From	To	Ratings (Amps)		Loss of R1K + R13K		
			LTE	STE	Amps	LTE	STE
K21C	Manby TS	Applewood JCT	1800	2170	897	50%	41%
K21C	Manby TS	Applewood JCT	1800	2170	892	50%	41%
K21C	Applewood JCT	Cooksville TS	2000	5998	1769	88%	29%
K21C	Cooksville TS	Cooksville TS	1700	2090	1769	104%	85%
K23C	Manby TS	Applewood JCT	2120	2660	1968	93%	74%
K23C	Applewood JCT	Cooksville TS	1700	2090	1995	117%	95%

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D.3.3.2 Thermal Assessment (Reducing loading to below LTE)

Under the assumed study conditions, it is found that the loss of R1K and R13K would not result in the remaining Richview to Manby circuits to exceed their STE ratings under the load assumptions considered. However, under Scenario 2, the LTE ratings of K23C are exceeded.

As per ORTAC Section 4.7.2, the loading on these sections must be reduced to respect their LTE rating, within the time afforded by the STE ratings, in this case, 15 minutes. This section reports on the ability of possible control actions to reduce post-contingency loading to within LTE ratings.

This can be addressed by either transferring Dufferin TS back to Leaside sector supply[7] or curtailing up to 50 MW of load at Runnymede TS, Fairbank TS, Wiltshire TS, and Dufferin TS following the R1K + R13K contingency. This is shown in Table 20 below.

Table 20: Circuit Thermal Assessment – R1K + R13K Post-contingency – 50 MW of Load Curtailment – Scenario 2

Circuit	From	To	Ratings (Amps)		Loss of R1K + R13K		
			LTE	STE	Amps	LTE	STE
K21C	Manby TS	Applewood JCT	1800	2170	729	41%	34%
K21C	Manby TS	Applewood JCT	1800	2170	725	40%	33%
K21C	Applewood JCT	Cooksville TS	2000	5998	1432	72%	24%
K21C	Cooksville TS	Cooksville TS	1700	2090	1432	84%	69%
K23C	Manby TS	Applewood JCT	2120	2660	1530	72%	58%
K23C	Applewood JCT	Cooksville TS	1700	2090	1557	92%	74%

D.3.3.3 Steady State Voltage Assessment

No violations to post-contingency voltage criteria were found during the double-circuit contingency analysis.

[7] Load curtailment may be preferable here since Dufferin TS is initially on Manby East supply under the premise of an emergency scenario.

D.3.4 Pre-contingency: N-1-0

These scenarios were studied as the K21C outage followed by loss of R1K and R13K and was identified as the most limiting by the SIA Report. Note that applying the above outage and contingency combination on Scenario 2 technically constitutes an N-1-1-2 outage + contingency combination since Scenario 2 is assuming that there is at least an N-1 outage on the Leaside sector in order to warrant Dufferin TS being transferred to Manby East. This N-1-1-2 scenario is beyond any applicable planning criteria.

D.3.4.1 Thermal Assessment

As per ORTAC, circuit sections are required to respect LTE ratings after the loss of one transmission element. No thermal violations are observed when K21C is initially experiencing an outage.

Table 21: Circuit Thermal Assessment – K21C outage – N-1-0 Pre-contingency

Circuit	From	To	Summer Cont. Rating (Amps)	Scenario 1 (Amps)	Scenario 2 (Amps)
R1K	Richview TS	Manby TS	1160	774	964
R2K	Richview TS	Manby TS	2320	1152	1155
R2K	Manby TS	Vansco JCT	1060	359	360
R2K	Vansco JCT	Horner TS	1080	373	374
R13K	Richview TS	Manby TS	1160	775	965
R15K	Richview TS	Manby TS	2320	1160	1163
R15K	Manby TS	Vansco JCT	1060	289	289
R15K	Vansco JCT	Horner TS	1080	303	304
R24C	Richview TS	Applewood JCT	1690	584	655
R24C	Applewood JCT	Cooksville TS	1290	584	656
K21C	Manby TS	Applewood JCT	1350	N/A	N/A
K21C	Manby TS	Applewood JCT	1350	N/A	N/A
K21C	Applewood JCT	Cooksville TS	1558	N/A	N/A
K21C	Cooksville TS	Cooksville TS	1290	N/A	N/A
K23C	Manby TS	Applewood JCT	1690	523	453
K23C	Applewood JCT	Cooksville TS	1290	468	398

D.3.5 Post-contingency: N-1-2

D.3.5.1 Thermal Assessment

As per ORTAC, circuit sections are required to respect STE ratings after the loss of two transmission elements (e.g., adjacent circuits on a common tower). Circuit loadings must be reduced to respect LTE ratings within the time afforded by the STE ratings, in this case, 15 minutes.

Under Scenario 1, circuit R24C exceeds its STE rating following an R1K + R13K contingency during a K21C outage. Similarly, under Scenario 2, both K23C and R24C exceed their STE ratings following an R1K + R13K contingency during an R21C outage.

Table 22: Circuit Thermal Assessment – K21C Outage – R1K and R13K contingency

Circuit	From	To	Ratings (Amps)		Scenario 1		Scenario 2	
			LTE	STE	LTE	STE	LTE	STE
R24C	Richview TS	Applewood JCT	2260	2930	98%	76%	145%	112%
R24C	Applewood JCT	Cooksville TS	1700	2090	130%	106%	193%	157%
K23C	Manby TS	Applewood JCT	2120	2660	56%	45%	96%	77%
K23C	Applewood JCT	Cooksville TS	1700	2090	72%	59%	123%	100%

D.3.5.2 Thermal Assessment (Reducing loading to below LTE)

Under the assumed study conditions, N-1-2 contingencies reported above result in post-contingency loading that exceeds STE ratings. As per ORTAC Section 4.7.2, the loading on these sections must be reduced to respect their LTE rating, within the time afforded by the STE ratings, in this case, 15 minutes. This section reports on the ability of possible control actions to prevent loading beyond STE ratings and reduce post-contingency loading to below LTE ratings.

To minimize the use of load rejection/curtailment in both scenarios, it is recommended that Wiltshire TS (and therefore Dufferin TS) be transferred to Leaside sector supply when K21C is on outage. This can prevent loading of both R24C and K23C beyond their STE ratings following the above N-1-2 outage and contingency combination. This results in loading on K23C being reduced to below its LTE ratings. However, loading on R24C is still above its LTE ratings. This can be seen in Table 23 below. Note that this control action is dependent on available capacity on the Leaside sector.

Table 23: Circuit Thermal Assessment – K21C Outage – R1K and R13K contingency – Wiltshire TS and Dufferin TS on Leaside supply

Circuit	From	To	Ratings (Amps)		Scenarios 1 and 2		
			LTE	STE	Amps	LTE	STE
R24C	Richview TS	Applewood JCT	2260	2930	1936	86%	66%
R24C	Applewood JCT	Cooksville TS	1700	2090	1937	114%	93%
K23C	Manby TS	Applewood JCT	2120	2660	957	45%	36%
K23C	Applewood JCT	Cooksville TS	1700	2090	996	59%	48%

In order to further reduce loading on R24C to below its LTE rating, up to 100 MW of load will have to be curtailed from Runnymede TS and Fairbank TS. The result of this load curtailment can be seen in Table 24 below.

Table 24: Circuit Thermal Assessment – K21C Outage – R1K and R13K contingency – Wiltshire TS and Dufferin TS on Leaside supply – 100 MW of load curtailment at Runnymede TS and Fairbank TS

Circuit	From	To	Ratings (Amps)		Scenarios 1 and 2		
			LTE	STE	Amps	LTE	STE
R24C	Richview TS	Applewood JCT	2260	2930	1651	73%	56%
R24C	Applewood JCT	Cooksville TS	1700	2090	1651	97%	79%
K23C	Manby TS	Applewood JCT	2120	2660	933	44%	35%
K23C	Applewood JCT	Cooksville TS	1700	2090	948	56%	45%

Alternatively, if there is no capacity available on the Leaside sector to supply both Wiltshire TS and Dufferin TS, then up to 350 MW of load rejection will need to be armed on the Manby East sector under Scenario 2, and up to 200 MW of load rejection will need to be armed on the Manby East sector under Scenario 1. The results are shown in Table 25 below. Since more than two transmission elements are lost, load rejection limits under ORTAC (i.e. up to 150 MW for two elements out of service) no longer apply.

Table 25: Circuit Thermal Assessment – K21C Outage – R1K and R13K contingency – 350 MW of load rejection at Manby East for Scenario 2 OR 200 MW of load rejection at Manby East for Scenario 1

Circuit	From	To	Ratings (Amps)		Scenarios 1 and 2		
			LTE	STE	Amps	LTE	STE
R24C	Richview TS	Applewood JCT	2260	2930	1667	74%	57%
R24C	Applewood JCT	Cooksville TS	1700	2090	1667	98%	80%
K23C	Manby TS	Applewood JCT	2120	2660	1081	51%	41%
K23C	Applewood JCT	Cooksville TS	1700	2090	1088	64%	52%

D.3.5.3 Steady State Voltage Assessment

No violations to post-contingency voltage criteria were found during the double-circuit contingency analysis.

– End of Section –

D.4. Conclusion

Based on the results above, under the updated demand forecast, it is found that the most limiting contingency (i.e. K21C outage followed by R1K + R13K contingency) will not result in any violations of planning criteria. Load rejection up to 350 MW may be required under certain scenarios (i.e. when three elements are out of service on the Richview South area) which is still acceptable under applicable planning criteria. Therefore, it is expected that Phase 1 of the proposed Richview x Manby reinforcement can meet the demand as forecasted in the Toronto IRRP addendum up to the end of the study period in 2040.

– End of Section –

Appendix E: Economic Analysis

E.1 Economic Assumptions

The following is a list of the assumptions made in the economic analysis:

- The NPV of the cash flows is expressed in 2021 CAD.
- The USD/CAD exchange rate was assumed to be 0.75 for the study period.
- Natural gas prices were assumed to be an average of $3.4/MMBtu throughout the study period
- The NPV analysis was conducted using a 4% real social discount rate. Sensitivities at 2% and 8% were performed. An annual inflation rate of 2% is assumed.
- The life of the station upgrades was assumed to be 45 years; the life of the line was assumed to be 70 years; and the life of the SCGT generation[8] and storage assets were assumed to be 30 years and 10 years respectively. The life of the storage asset was based 3600 cycles, which is assumed to be used to serve the local need first, and then global energy and ancillary services for the rest of the year. Cost of asset replacement were included where necessary to ensure the same NPV study period.
- Development timelines for transmission was assumed to be 7 years; development timelines for generation and storage were assumed to be 3 years.
- The estimated overnight cost of capital for an SCGT is assumed to be approximately $2000/kW (2021 CAD) depending on the unit size, based on escalating values from a previous study independently conducted for the IESO.[9]
- Total energy storage system costs are composed of capacity and energy costs (i.e., energy storage devices are constrained by their energy reservoir). The estimated overnight cost of capital assumed is about $900-$1800/kW (2021 CAD) depending on the storage capacity to energy requirement, based on escalating Ontario-specific values from a previous study independently conducted for a collection of entities including the IESO.
- Sizing of the storage solution was based on meeting the peak capacity and peak energy requirements for the local reliability need, such that the reservoir size is capable of using existing gas resources to sufficiently charge to meet the hours of unserved energy.

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[8] Resources that have cost and operating characteristics equivalent to a Simple Cycle Gas Turbine (SCGT); any other mention of SCGT in the report is meant in this context

[9] Generally speaking, the most cost-effective transmission-connected options for meeting local needs in Toronto are resources with performance and costs on par with simple cycle gas turbines (SCGT) or combined cycle gas turbines (CCGT) generators depending on the relative size of the capacity versus energy requirements. New natural gas-fired generation was considered in the economic analysis for illustrative purposes to represent the cost of new generation.

- System capacity value was $128k/MW-yr (2021 CAD) based on an estimate for the Cost of the Marginal New Resource (Net CONE), a new SCGT in southwestern Ontario, with a sensitivity of +/- 25% assessed.
- Production costs were determined based on energy requirements to serve the local reliability need, assuming fixed operating and maintenance costs of $43/kW-yr for gas-fired resources and $11/kW-yr for storage, and variable operating and maintenance costs of $6/MWh and a heat rate of 9 MMBtu/MWh for gas-fired resources.
- Carbon pricing assumptions are based on the proposed Federal carbon price increase, from $50/t in 2022 to $170/t by 2030, and applied to a facility's production.
- The assessment was performed from an electricity consumer perspective and included all costs incurred by project developers, which were assumed to be passed on to consumers.

E.2 Summary of Results

The table below shows the expected NPV cost of each option studied.

Table 26 | Cost of options studied

Option Description	Total NPV cost ($2021 millions)
RxK Upgrade in 2025	$23
Incremental CDM programs plus DR starting from 2025 to 2030, RxK Upgrade in 2031 (Dufferin on Leaside supply)	$28
Incremental CDM programs plus DR starting from 2025 to 2030, RxK Upgrade in 2031 (Dufferin on Manby supply)	$86
Incremental CDM programs plus storage starting in 2025 to 2030, RxK Upgrade in 2031 (Dufferin on Leaside supply)	$84
Incremental CDM programs plus SCGT starting in 2025 to 2030, RxK Upgrade in 2031 (Dufferin on either supply)	$307
FACTS device from 2025 to 2030, RxK Upgrade in 2031 (Dufferin on Leaside supply)	$30
FACTS device from 2025 to 2027, RxK Upgrade in 2028 (Dufferin on Manby supply)	$32

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