Ontario Power Authority

Exhibit D

Transmission Options

Chris Mak, M. Eng., P. Eng.

Senior Advisor, Power System Reliability

Maxlin Inc.

1.0 Ontario Power Grid

The Ontario power grid developed over the last century has resulted in an integrated transmission grid consisting of facilities at 500 kV, 230 kV and 115 kV. The 115 kV transmission network, due to its limited ability in bulk electricity transmission, is used as radial supply in southern Ontario. The Ontario power grid is interconnected with its neighbouring power grids in Quebec, Manitoba, New York, Michigan and Minnesota which, in turn, are interconnected with their neighbouring grids. Due to the interconnectedness, all power grids in North America, including Ontario, plan and operate their respective systems in accordance with the standards set by the North America Electric Reliability Council and their respective regional reliability councils. Northeast Power Coordinating Council is the regional reliability council governing the standards on its members systems consisting of entities from Ontario, Quebec, the Maritime Provinces in Canada, New York and the New England States in the U.S.

Efficient and reliable transmission of bulk electricity is enhanced by:

- A high voltage transmission grid that connects major centres in the province with the shortest transmission distance where practical, and
- Redundancy and alternative routes that provide both reliability and flexibility.

Higher transmission voltages provide better capability to transport electricity over longer distances. Meanwhile, the shorter the required transmission distance, the higher the reliability performance since shorter transmission lines have lower exposures to external elements. In addition, higher transmission voltages and shorter transmission distance both contribute to reducing transmission losses, energy dissipated as heat into the environment.

1.1 Reliability Electricity Supply

A reliable electricity supply must consider and prepare for the impact of equipment outages before they occur. Failure of the electricity delivery system can happen in fractions of a second following equipment outages. Thus, safe and reliable operation of

such a system requires that failure events be anticipated and boundaries established to ensure the system can automatically settle into a safe operating mode following a failure.

This is further complicated by the fact that electricity cannot be stored in meaningful quantities, and the supply and demand must be balanced nearly instantaneously under the real-time operating conditions when station equipment and lines can be unexpectedly removed from service due to factors such as icing, lightning strikes, tree contacts, equipment failures, etc. As well, station equipment and lines require planned outages periodically so that routine maintenance or repairs can be carried out. It is important that supply is not interrupted every time such an incident or outage occurs. Therefore, the bulk supply capability is based on the event that one of the two circuits is out of service, meaning that when each circuit is running at half its capability, the line is at capacity. Any increase in load beyond that point would exceed the capability of a single circuit and can therefore no longer supply the load reliably or meet the IESO Supply Deliverability Guidelines. In such a case if a circuit were to fail then the total load would exceed the capability of the remaining circuit and some load would have to be disconnected automatically to avoid an interruption of the entire load.

A reliable bulk transmission system delivering electricity to a major load center such as Northern York Region should meet the following performance requirements, which are included in the OPA planning considerations:

1. With all elements of the supply infrastructure in service to supply the area load, the equipment must operate within its normal limits. The voltages on the transmission and distribution lines must be within acceptable ranges.

2. With all transmission elements in service pre-contingency, the loss of a transmission element, which would also result in the loss of the connected transformers, should not result in the interruption of area load. All the remaining elements must be within their applicable ratings and the voltages on the transmission and distribution lines must be within the acceptable ranges.

This requirement is in conformance with the IESO's Supply Deliverability Guidelines, which state in part:

> *For loads between 250 MW and 500 MW: with all transmission elements in service pre-contingency, any single element contingency should not result in an interruption of supply to a load level greater than 250 MW.*

This is considered as good utility practice and adopted by utilities worldwide.

Firm capacity from local generation station(s) to supply local area load should be based on the planning principle that the largest unit in the area is assumed to be out of service.

3. A diverse bulk supply source, either in the form of local generation or alternate high voltage transmission line transporting generation into the area, is available to supply as much area load as possible in the event of the loss of the existing main bulk supply facilities.

   For a major load centre such as Northern York Region, it is important to include supply security or diversity as part of the planning considerations. This is consistent with IESO's Supply Deliverability Guidelines, which state in part:

   > *With all transmission elements in service, for any double circuit contingency that results in a supply interruption of between 250 MW and 500 MW, all load should be restored by switching operations within a typical period of 30 minutes.*

1.2 230 kV Transmission in York Region

Bulk electricity transmission supplying the York Region consists of 230 kV transmission lines from four major 500/230 kV stations located in northern greater Toronto area: Claireville TS, Richview TS, Cherrywood TS and the newly built Parkway TS. These 230 kV transmission lines transport bulk electricity to nearby load areas in York Region where a number of 230/44/28 kV transformer stations step down the voltages to

distribution levels at 44 kV or 28 kV. From there local distribution companies deliver electricity to their customers via distribution feeders ranging in length of about 20-25 km depending on the distribution voltages.

Since the transmission infrastructure supplying the York Region is based entirely on 230 kV voltage class, the optimum choice of voltage class for new transmission lines is 230 kV. This will optimize efficiency and effectiveness in integrating the existing 230 kV transmission facilities with the new ones. Using other voltage classes such as 500 kV or 115 kV would require additional 500/230 kV or 230/115 kV transformation facilities which have significant cost increase for the 500 kV, and higher transmission losses and lower reliability performance for the 115 kV.

1.3 Existing Transmission Corridors into Northern York Region

There are three existing transmission corridors, two from the south and one from the north into Northern York Region.

The first corridor runs north from Parkway TS to Buttonville TS to Armitage TS in Newmarket. The Parkway-Buttonville section, about 3 km in length, consists of a two-circuit 230 kV line supplying Buttonville TS. The Buttonville-Armitage section, about 22 km in length consists of a single-circuit 115 kV line with the northern portion being used as a 44 kV feeder supplying Whitchurch-Stouffville. The southern portion is being used as a 28 kV feeder to supply Markham. This corridor about 22 km in length is wide enough for consolidation by dismantling and replacing the existing 115 kV line with a 230 kV two-circuit line from Buttonville TS to Newmarket.

The second corridor, which currently provides electricity supply to Armitage TS, runs north from Claireville TS to Marsh Junction (36 km) and a line tap (8 km) from Holland Junction to Armitage TS in Newmarket for a total length of about 44 km.

The third corridor consists of a 115 kV line running east from Essa TS to supply the 115 kV transformer station Barrie TS 11 km away. The line continues in the southeast direction toward Holland Junction in King Township. The section between Barrie TS to

Holland Junction is about 36 km and is currently used as a 44 kV feeder from Barrie TS as a backup supply for Southern Bradford. The corridor continues in the southeast direction consisting of 8.5 km of the 230 kV line tap to Armitage TS. The total length of this corridor is about 55 km.

1.4 Cost Considerations in Building Transmission Lines into Northern York Region

One of the bulk supply options is to increase the transmission capability to supply Northern York Region by adding new transmission facilities. Any transmission project would have to be coupled with transformation and distribution facilities since a transmission line by itself does not alleviate the transformation or distribution bottlenecks.

This can be achieved by:

- building a new transmission line on an existing right-of-way,
- building a new transmission line on a new right-of-way,
- upgrading of an existing line by replacing the conductors and towers if required,
- re-building an existing 230 kV 2-cct line into a four-circuit line,

The cost of transmission line increases as the transmission distance increases. The cost of 230 kV underground cables is about 5 times that of an overhead 230 kV 2-cct line. Building new lines on new right-of-ways can result in significant cost increases for right-of-way acquisition (in tens of million).

With respect to consolidating and re-building on existing right-of-ways, it is important to note that converting a 2-cct 230 kV line that is currently in operation for load supply into a 4-cct 230 kV line will be also very costly. This is because in addition to the high cost of a 4-cct line compared to a 2-cct 230 kV line, there will be significant costs incurred during the construction stage since temporary by-pass line sections will have to be

constructed to maintain existing load supply. The temporary by-passes will be dismantled after the new line is placed in service. This would apply to the Claireville-Holland Junction -Armitage corridor.

Similar high cost will incur in consolidating and re-building the existing 115 kV line that is currently supplying a 115 kV transformer station. In addition to the bypasses, there will be additional costs in either replacing the existing 115 kV transformer station with a 230 kV station, or adding 230/115 kV transformation facilities. These additional costs are estimated to be in the $10 million to $20 million range. This would apply to the Essa-Barrie-Armitage corridor.

For illustration purposes, typical unit costs for transmission facilities are shown below. It must be emphasized that these typical unit costs are only useful for screening, ranking and evaluating the cost differentials between the transmission options. This is because they are largely dictated by the transmission lengths and foreseeable additional costs such as the requirements of additional 500/230 or 230/115 kV transformation facilities, FACTS devices, temporary bypasses, right-of-way acquisition costs, etc. The implementation costs of these options can be very quite different from estimates derived from these unit costs since the former required detailed engineering and design work. However, recognizing the characteristics of the options that have been considered, there is a high degree of confidence that the cost differentials or the cost ranking of these options would not change.

Representative Unit Costs for Transmission Facilities

(Suitable only for use in high level comparison of the transmission options, ROW costs, engineering and design, contingencies not included, +/- 40% accuracy)

115 kV 2-circuit line = $0.9 M to $1.2 M/km

230 kV 2-circuit line = $1.2 M to $1.6 M/km

230 kV 2-circuit cable = $6 M/km

500 kV 2-circuit line = $1.8M to $2.5 M/km

230 kV AC/DC multi-circuit line = $1.6 M to $2 M/km

Re-conductor with high ampacity conductor = $0.7 M to $0.9 M/km

Two 230/115 kV transformers = $9 M

Two AC/DC converter stations (160 MW each) = $100 M

Flexible AC Transmission System = $20 M

500/230 kV Transformer Station = $110 M

1.5 Transmission Options Considered

Nineteen transmission options including those that were proposed by the working group were evaluated. Proposals from the working group include new right-of-ways, upgrading existing line and using HVDC/FACT transmission technologies. The following table provides a summary comparison of these transmission options with their preliminary cost estimates. Figure 1 and 2 provide a geographic view of the routes of these transmission options.

#	**Transmission Option**	**Major Facilities**	**Option Source**	**New ROW**	**Cost Estimate**	**Estimate Source**
1	230 kV Line from Buttonville to Armitage	22 km of overhead line	OPA	No	$50 M	OPA
2	230 kV lines from Buttonville to Gormley	10 km of overhead line	OPA	No	$23 M	OPA
3	115 kV lines from Buttonvilee to Armitage	22 km of overhead line	OPA	No	$50 M	OPA
4	230 kV line from Parkway to Armitage	25 km of overhead lines	Markham A1	No	$60 M	H1
5	Existing Corridor – O/H and Underground Parkway to Armitage	25 km of overhead and Underground lines	Markham A2	No	$130 M	H1
6	Existing Corrdior - AC/DC Parkway to Armitage	25 km of AC/DC multi-cct overhead lines and AC/DC converter stations	Markham A3	No	$150 M	OPA

7	Existing Corridor - Claireville to Armitage	44 km of overhead lines next to existing Claireville-Armitage line	Markham C1	No	$157 M	H1
8	Existing Corridor - Claireville to Armitage with FACTS	Reconductor 44 km of lines with high ampacity conductors (assuming no tower replacement) and install FACTS	Markham C2	No	$60 M	OPA
9	404 Corridor - Parkway to Armitage	27 km of overhead line	Markham B1	Yes	$125 M	H1
10	400 Corridor - Claireville to Armitage	49 km of overhead line	Markham D1	Yes	$166 M	H1
11	427 Corrdior - Claireville to Armitage	46 km of overhead line	Markham E1	Yes	$157 M	H1
12	115 kV Corridor - Essa to Armitage	55 km of overhead lines. 230 kV facilities at Essa TS and Barrie TS	Markham F1	No	$161 M	H1
13	Corridor Go Transit - Essa to Armitage	62 km of overhead lines. 230 kV facilities at Essa TS	Markham G1	Yes	$224	H1
14	New Corridor - Essa to Armitage	55 km of overhead lines. New 500/230 kV station	Markham H1	Yes	$198 M	OPA
15	Claireveille to Kleinberg to Armitage	48 km of overhead lines	Markham I1	Yes	$150 M	H1
16	Corridor - Cherrywood to Armitage	37 km of overhead lines	Markham J1	Yes	$142 M	H1
17	Claireville to Minden Load Relief	Oveheard lines from: • Peterborough to Lindsay • Cherrywood to Whitby • Dobbin to Gatineau ROW	Markham K1	Yes	> 250 M	OPA
18	Long Term GTA Bypass	Multi-stages, 500/230 Lines and a new 500/230 kV station	Markham L1	Yes	> 500 M	OPA
19	Highway 9 New TS to Armitage and existing 115 kV Buttonville Line	• New 500/230 kV TS • 27 km of 230 kV overhead line to Armitage Short term relief: Refurbishing existing Buttonville line • 230/115 kV Auto • 115/44 kV 20 MVA transformer	Robert Jones' Option 11	Yes	200 M	OPA

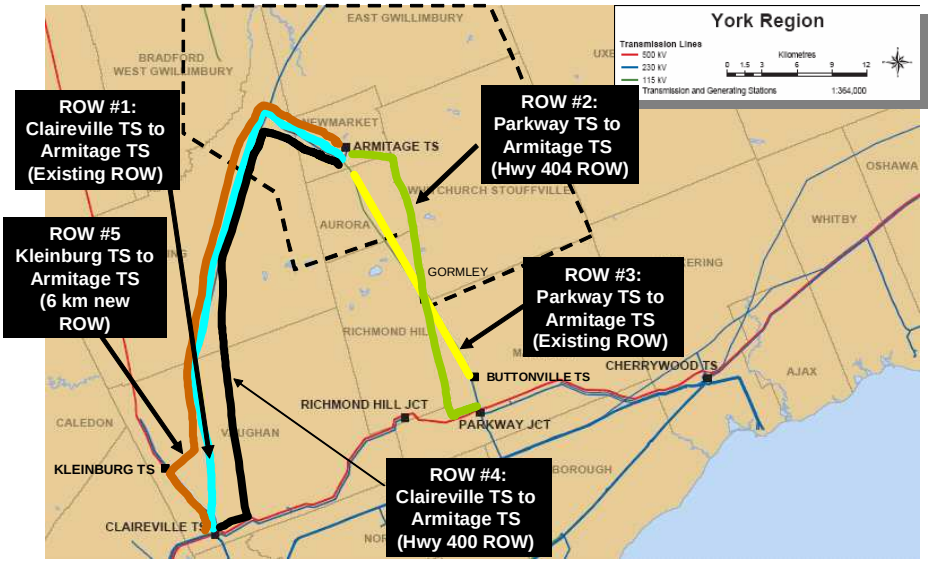

Fig. 1 Alternative Transmission Routes

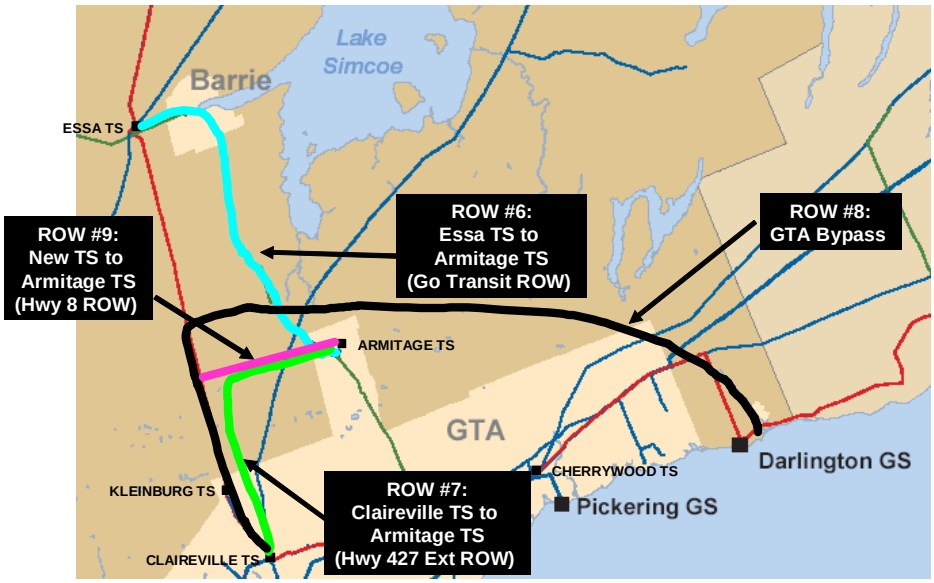

Fig. 2 Alternative Transmission Routes

Option 1 Buttonville TS to Armitage TS

The original proposal from Hydro One Networks was to upgrade the existing double-circuit 230 kV line from Parkway TS to Buttonville TS and replace the existing 115 kV line from Buttonville TS to Armitage TS with a double-circuit 230 kV line. This 115 kV line is currently used as 44 kV and 28 k distribution feeders supplying Whitchurch-Stouffville and Markham respectively. Hydro One's proposal has the potential benefits of supplying Power Stream service area loads in Southern York Region.

The OPA was able to modify this transmission option to fit into one of the OPA's possible integrated solutions to meet the Northern York Region near term and longer term needs.

The OPA proposed transmission option involves building a new line from Buttonville TS to Armitage TS without upgrading the line section from Parkway TS to Buttonville TS since it has sufficient capability to meet the identified needs in northern York Region.

This proposal to replace the existing 115 kV line running from Buttonville TS to Armitage TS with a double-circuit 230 kV line provides Northern York Region with a diversity of supply by connecting a significant portion of the area load to a second source from the transmission grid. It also provides Northern York Region with long term load meeting capability and flexibility to Southern York Region if needed.

The estimated capital cost of this transmission option, assuming overhead line construction, is $50 million. A partial underground assuming about 14 km would increase the capital cost estimate from $50 million to $112 million.

Option 2 Buttonville TS to Gormley

As a variation to the Buttonville TS to Armitage TS transmission option, OPA has also considered the Buttonville TS to Gormley option, which basically has the same characteristics except with a much shorter transmission distance of 10 km. The transmission would end in or near Gormley where a 230/44 kV transformer station can be

built to supply Northern York Region. This option has been reviewed and accepted by the three LDCs, but as a less preferred distribution option since it would involve longer feeder runs and additional distribution costs estimated to be around $7 million to $9 million range compared to the Buttonville-Armitage option.

The estimated capital cost of this transmission option assuming overhead construction is $23 million. Assuming 5 km would be underground, the capital cost estimate would increase to $44 million. If the entire line consists of underground cable, the capital cost estimate would rise to $67 million.

Option 3 Buttonville TS to Armitage TS (115 kV)

This option assumes installation of a 2-cct 115 kV line on the existing right-of-way between Buttonville TS and Armitage TS. Due to the additional 230/115 kV transformation facilities required at Buttonville TS, the estimated cost of this option is the same as Option 1 which assumes the use of a 2-cct 230 kV line. The reliability performance of Option 3 is lower and the transmission losses are higher than Option 1. In addition, this option has limited capacity and can only accommodate one transformer station.

Option 4 Parkway TS to Armitage TS (230 kV Overhead line)

This option was originally proposed by Hydro One Networks which included upgrading the line section from Parkway TS to Buttonville TS. The cost estimate is $60 M for all overhead construction.

Option 5 Parkway TS to Armitage TS (230 kV partial overhead and underground)

This option was also considered by Hydro One Networks with partially overhead and partially underground line. Including line upgrade from Parkway TS to Buttonville TS the cost estimate is $130 M.

Option 6 Parkway TS to Armitage TS (AC/DC Line)

This option assumes the use of multi-circuit AC/DC line between Parkway TS to Buttonville TS and a bipolar DC line to Armitage TS. Two HVDC converter stations one at Parkway TS and another one at Armitage TS would be required at an estimated capital cost of $100 M. The total estimated cost including transmission line is $150 M.

High Voltage Direct Current (HVDC) transmission is a proven technology and has been utilized worldwide economically and reliably for long distance transmission such as large scale coal-by-wire, or hydro-by-wire due to economies of scale, or submarine cable transmission where ac transmission is not technically feasible, or interconnecting two ac system with different characteristics. However, application of HVDC to transmit power over such a short distance and in a relatively small quantity into a load centre well established with ac supply infrastructure would lend itself to be uneconomic. This is also impractical considering the operating and maintenance issues and the potential need of integrating dc supply into the existing ac transmission and distribution systems.

Option 7 Claireville TS to Armitage TS (New 230 kV Overhead line next to Existing line)

This option was also considered by Hydro One Networks which included building a 230 kV overhead line along the existing 230 kV line from Claireville TS to Armitage TS. The capital cost estimate for this option is $157 M.

Option 8 Claireville TS to Armitage TS (Line Upgrade and FACTS)

This option requires upgrading the 230 kV line between Claireville TS to Armitage TS to higher ampacity. To prevent voltage collapse, it was proposed that FACTS devices be

included at the receiving end. Flexible AC Transmission System (FACTS) is basically series or shunt reactive devices controlled by electronic switches called thyristors with microprocessor controllers. FACTS devices such as static Var compensators, thyristor controlled series capacitors are also proven technology and are primarily applied on bulk power system.

Application of FACTS devices is not considered suitable in this situation for two primary reasons; (a) FACTS devices are expensive and would be in the order of $20 M, and (b) reduction in the reliability performance of the existing supply from Claireville to Armitage due to the introduction of two additional series components in the transmission system.

The total cost of this option is about $50 M assuming no tower replacement is required. Preliminary information shows that it is highly likely that the existing towers would not be compatible with heavier conductors. Subject to detailed engineering and design by Hydro One, major cost increases are expected to accommodate tower replacements and the need for building temporary bypasses.

This option would not meet performance requirement #3 discussed in Section 1.1.

Option 9 Highway 404 Corridor Buttonville TS to Armitage TS

One of the alternative right-of-ways proposed by the Working Group was to run from Parkway TS to Armitage TS along Highway 404. This has the benefit over the existing right-of-way in that it minimizes routing near residential neighbourhoods. There are, however, a number of uncertainties and risks associated with using this right-of-way approach which is representative of the 400 series provincial highways.

First, routing the line to and from Highway 404 poses considerable difficulty. At the south end, building from Parkway TS to 404 could be done above ground along an existing right-of-way across the top of the Greater Toronto Area (GTA). However, this seriously limits the potential use of that right-of-way in the future since there is only space allowance for one additional line which could otherwise run across the entire GTA. In the alternative, the line could be undergrounded to 404, but this adds significant cost,

and also has the potential to interfere with overhead lines, particularly with regard to maintenance access.

Second, given the proximity of 404 to Buttonville Airport, the line would most likely have to be undergrounded in the vicinity of the airport to comply with regulations, further adding more cost to the option.

Third and the most serious issue is the use of the Highway 404 right-of-way itself. The Ministry of Transportation representative, in his presentation to the Working Group, indicated that there is no available space along the existing right-of-way to allow for a transmission corridor. Therefore, using the highway corridor would require widening it by expropriating adjacent lands, adding to the cost, uncertainty, and construction time. It is essentially the same as acquiring a new right-of-way that is not parallel to a 400-series highway. Given the risks and costs associated with this route, the need for at least partial undergrounding, and the difficulty in getting the line to and from highway 404, the OPA does not feel that it is a viable option to pursue.

The capital cost estimate for this option is $125 M.

Option 10 Highway 400 Corridor - Claireville TS to Armitage TS

This option runs along the Highway 400 Corridor with 49 km of overhead line between Claireville TS to Armitage TS. Similar implications on routing transmission lines on the 400 series highways as option 9 are expected.

The capital cost estimate for this option is $166 M.

Option 11 Highway 427 Corridor - Claireville TS to Armitage TS

This option requires 46 km of overhead line along the Highway 427 Corridor from Claireville TS to Armitage TS. Similar implications on routing transmission lines on the 400 series highways as option 9 are expected.

The capital cost estimate for this option is $157 M.

Option 12 115 kV Corridor – Essa TS to Armitage TS

This option utilizes the existing 115 kV transmission corridor from Essa TS to Armitage TS. The 115 kV line currently supplying Barrie TS would have to be dismantled and replaced with a 230 kV 2-cct line from Essa TS to Barrie TS to Armitage TS of about 55 km in length. The 115 kV transformer station at Barrie TS would also have to be replaced with a 230 kV transformer station. During the construction stage, temporary 115 kV line bypasses would have to be constructed to maintain supply to the load that is currently supplied from the 115 kV transformers at Barrie TS.

The capital cost estimate for this option is $161 M.

Option 13 Corridor Go Transit – Essa TS to Armitage TS

This option follows the Go Transit corridor from Barrie to Newmarket. It requires 62 km of overhead 230 kV line, 230 kV facilities at Essa TS and acquisition of new right-of-ways.

The capital cost estimate for this option is $224 M.

Option 14 New Corridor – Essa TS to Armitage TS

This option is similar to Option 13 except routing a new 230 kV line on a new corridor from Barrie to Newmarket of 55 km in length. Including the Essa to Barrie section, this option requires 62 km of overhead 230 kV line, station facilities at Essa TS and acquisition of new right-of-ways.

The capital cost estimate for this option is $198 M.

Option 15 Claireville TS to Kleinberg TS to Armitage TS

This option involves upgrading the existing 230 kV line section from Claireville TS to Kleinberg TS. A new line will be built from Kleinberg TS north to Armitage TS on a new right-of-way.

The capital cost estimate for this option is $150 M.

Option 16 Cherrywood Ts to Armitage TS

This option involves a new 230 kV line on a new right-of-way from Cherrywood TS in a northwest direction to Armitage TS. The line length is about 37 km.

The capital cost estimate for this option is $150 M.

Option 17 Claireville to Minden Load Relief

This option involves construction of several new lines: from Peterborough to Lindsay, from Cherrywood to Whitby and from Dobbin to Gatineaou right-of-way.

The capital cost estimate for this option is expected to exceed 250 M.

Option 18 Long Term GTA Bypass

This option involves a Long Term GTA Bypass proposal in which a second 500 kV transmission corridor is to be routed due north from Darlington GS and in a northwest direction to Essa TS. It involves a multi-stage construction of 500/230 kV lines on new right-of-ways and station facilities.

The capital cost estimate for this option is expected to exceed $500 M.

Option 19 Highway 9 New TS to Armitage and Refurbish existing 115 kV Buttonville Line

This option involves a new 500/230 kV transformer station connected to the 500 kV 2-cct line from Bruce GS to Toronto. A new 230 kV 2-cct line is to be built on a new right of way along Highway 9 to Armitage TS. Prior to the completion of new 500/230 kV line and station facilities, the existing 115 kV single circuit line from Buttonville TS to Armitage TS is to be refurbished to provide temporary load relief to the supply of orthern York Region.

The capital cost estimate for this option is $200 M.

1.6 Preferred Transmission Option

The Buttonville-Gormley option has the shortest transmission distance and lowest cost. It has the least uncertainty and scored the highest overall ranking based on the evaluation factors that were discussed and considered in the Working Group. Therefore, the Buttonville-Gormley option is the preferred option if transmission into Northern York Region is required to supply continuing load growth.