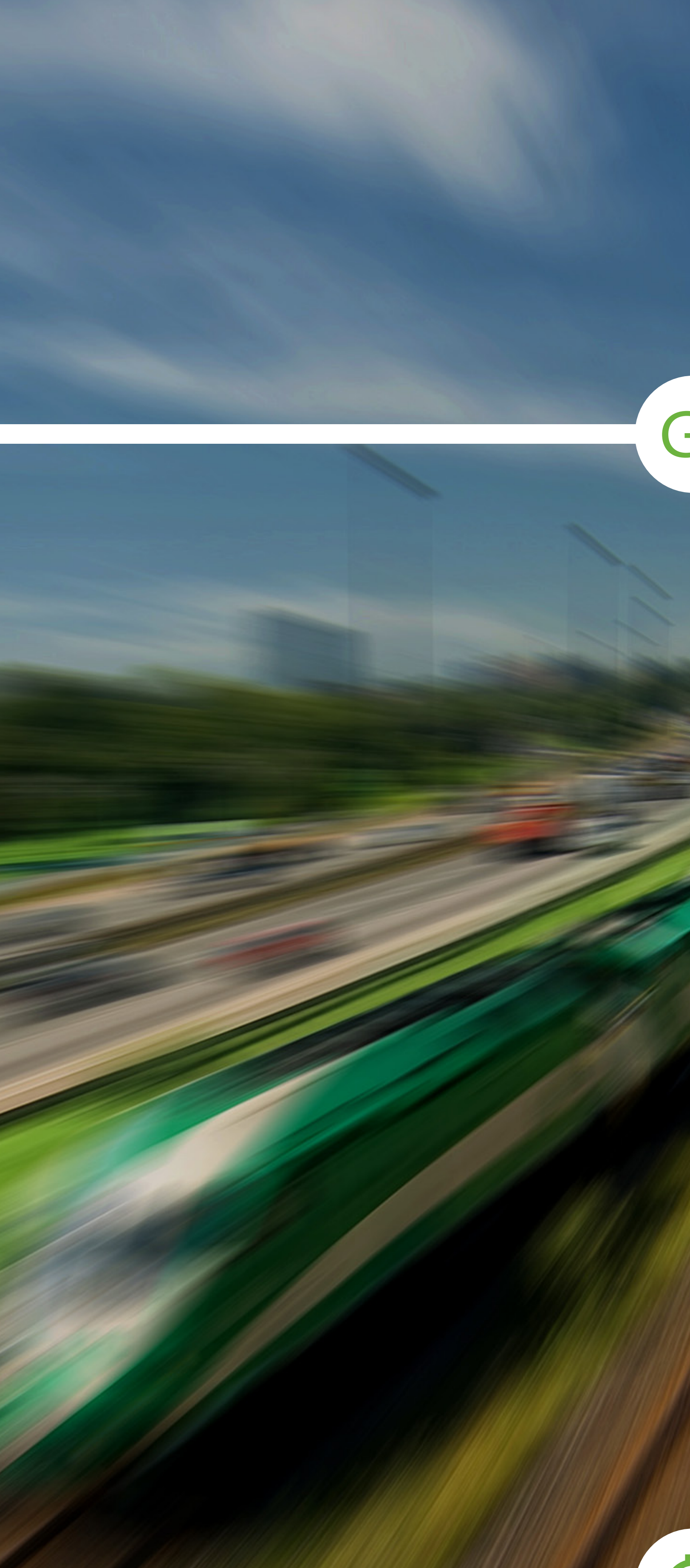

GO Electrification Study

Final Report

December 2010

METROLINX
An agency of the Government of Ontario

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GO ELECTRIFICATION STUDY

Final Report

December 2010

Prepared for:

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FINAL REPORT

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EXECUTIVE SUMMARY

CONTEXT

Metrolinx, through its GO Transit operating division, operates a comprehensive transportation system of bus and commuter rail lines in the Greater Toronto and Hamilton Area (GTHA). The system includes the GO Transit rail network, which is an essential part of Metrolinx's service to the area commuters. GO Transit currently provides commuter rail service on seven corridors in the GTHA, using conventional diesel locomotives and non-powered bi-level coaches in push-pull configuration.

In late 2008, Metrolinx published a Regional Transportation Plan – The Big Move – a multimodal vision for regional transportation to strengthen the economic, social and environmental sustainability of the GTHA. The Big Move sets out a fast, frequent and expanded regional rapid transit network as a key element of the plan. The plan includes establishing Express Rail and Regional Rail services at frequencies and speeds that could potentially be enhanced by system electrification.

GO 2020 is GO Transit's strategic plan, which sets out a strategy for meeting the GTHA's interregional transportation needs as identified in The Big Move. GO 2020 envisions more frequent peak period and two-way all day rail service, which could potentially be provided by an electrified system.

ELECTRIFICATION STUDY

In January 2010, Metrolinx initiated a study of the electrification of the entire GO Transit rail system as a future alternative to diesel trains now in service. The overriding purpose of the Electrification Study is to provide Metrolinx's Board of Directors with the information needed to decide how GO Transit trains will be powered in the future – using electricity, enhanced diesel technology or other means.

STUDY SCOPE AND METHODOLOGY

The study was guided by the Electrification Study Terms of Reference, which were developed with advice from a multi-stakeholder Community Advisory Committee and approved by the Metrolinx Board. It considered the entire GO Transit rail network – all seven corridors – as well as the future Airport Rail Link (ARL) between Union Station and Pearson International Airport.

The study used expanded and enhanced GO Transit rail network from the network of today as a basis of comparison. This "Reference Case" assumed that additional tracks and some of GO's proposed line extensions (to St. Catharines, Kitchener, Allandale, Bloomington Road, and Bowmanville) will be constructed in the coming years, resulting in increased service and train volumes.

The Reference Case also assumed that Tier 4 Diesel MP40 rolling stock will be in operation as GO Transit has committed to convert to Tier 4 emission standards. In 2015, Tier 4 emissions compliancy will be mandated for all new and remanufactured locomotives in the United States. This is therefore the rolling stock against which other technologies were compared in the study.

The study methodology included:

- Development of the **operating plan** for the Reference Case;
- A **comprehensive rolling stock technology assessment**, which examined the technologies – electric, diesel and alternative fuel sources – that could be used to provide future GO Transit and ARL service;
- Consideration of **power supply and distribution options** – overhead wires, third-rail, and others – to deliver electricity to a potential future electrified rail service;

- Identification and **evaluation of network options** for electrifying part or all of the GO Transit rail network and ARL;
- **Detailed assessment** of a "short list" of network options; and
- Development of **findings and conclusions**.

The study also included a comprehensive stakeholder engagement and communications program to reach out to and consult with stakeholders throughout the one-year study process.

ROLLING STOCK TECHNOLOGY ASSESSMENT

Rolling stock technologies examined as part of the comprehensive assessment generally fell into four broad categories:

- **Diesel**: including Diesel Locomotives and Diesel Multiple Units;
- **Electric**: including Electric Locomotives and Electric Multiple Units;
- **Dual-Mode**: hybrid technologies that include both an on-board diesel engine, as well as capability to operate in electric propulsion mode when in electrified territory; and
- **Alternative Rolling Stock Technologies and Fuels**: including Alternative Locomotive Fuels, Hybrid Drive Trains, Hydrogen Fuel Cell Trains, Maglev, and other New System Concepts.

As a result of the rolling stock technology assessment, which looked at technical, commercial and compatibility criteria, four technologies were selected for more detailed study: Diesel Locomotives with bi-level coaches; Electric Locomotives with bi-level coaches; Electric Multiple Units with bi-level coaches; and Dual-Mode Locomotives with bi-level coaches.

For the Airport Rail Link service, single-level, self-propelled diesel-powered railcars known as diesel multiple units (DMU) in two-car trains were compared to single-level electric multiple units (EMU) in two-car trains.

POWER SUPPLY AND DISTRIBUTION OPTIONS

Power supply and distribution technologies reviewed as part of the study included three main types:

- **Overhead Catenary**: trains are powered by overhead wires;
- **Third-Rail**: trains are powered via electrical infrastructure placed on the ground alongside or in between railway tracks (e.g. Toronto Transit Commission subway);
- **Alternative System Technologies**: trains are powered using hydrogen fuel cell technology or from batteries that store energy.

The conclusion of the assessment, which looked at technical, commercial and compatibility criteria, is that the power supply option most appropriate for the GO Transit rail network and ARL is the use of an overhead catenary system. An autotransformer-fed system operating at 2x25 kV AC electrification voltage and commercial frequency of 60 Hz was selected and used for the development of the study's conceptual design and cost estimates.

EVALUATION OF NETWORK OPTIONS

The Electrification Study looked at where on the GO Transit rail network the four technologies that emerged from the rolling stock assessment – Diesel Locomotives, Electric Locomotives, Electric Multiple Units, and Dual-Mode Locomotives – could be used in the future. It was assumed that Diesel Multiple Units would be converted to Electric Multiple Units on the ARL if the Georgetown corridor is electrified.

From over 16,000 possible network options, the study team concluded that 18 options merited further study. These options ranged from electrifying one line (Georgetown or Lakeshore) to electrifying all corridors to some extent, using either Electric Locomotives or Electric Multiple Units, possibly supplemented with Dual-Mode Locomotives. These 18 network options were evaluated at a high level to see how they compare in terms of transportation efficiency, environmental and cost considerations.

Based on the results of the high level evaluation, it was concluded that electric locomotives would be the technology taken forward for detailed assessment against the Reference Case Tier 4 diesel locomotives, and that six options would be carried forward for more detailed assessment in the final phase of the study:

- Option 1 – Electrification of the Air Rail Link (ARL) and Georgetown;
- Option 2 – Partial electrification of Lakeshore (from Bowmanville to Hamilton James);
- Option 3 – Partial electrification of Lakeshore and electrification of ARL and Georgetown;
- Option 11 – Partial electrification of Lakeshore and electrification of ARL, Georgetown and Milton;
- Option 15 – Partial Electrification of Lakeshore and electrification of ARL, Georgetown, Milton and Barrie; and
- Option 18 – Electrification of the entire network.

The electrification of the Lakeshore line would extend from Bowmanville in the east to Hamilton James in the west and excludes Hamilton TH&B and St. Catharines due to the high cost of tunnel and bridge modifications and the limited number of trains from/to St. Catharines.

For the Airport Rail Link service, single-level Tier 4 diesel multiple units (DMU) in two-car consists would be compared to single-level, electric multiple units (EMU).

INFRASTRUCTURE AND ROLLING STOCK ELEMENTS

The following list summarizes the infrastructure and rolling stock elements of electrification:

- Power supply
  - Traction power substations and connection to grid
  - Switching stations / autotransformer Stations
  - Overhead catenary system
- Bridge replacement and reworking
- Grounding within 250m of the nearest rail, as required, for:
  - Structures, buildings, station platforms, fencing, pipelines, above-ground fuel tanks and other utilities

- Modifications to the track to ensure compatibility with electrification, including track bonding and grounding to limit induced voltages and maintain safety
- Modifications to the signal system to immunize against the effects of electromagnetic interference
- Control centre - additional equipment
- Rolling stock procurement

DETAILED ASSESSMENT: KEY FINDINGS AND CONCLUSIONS

Each of the six "short-listed" options was compared and contrasted against the Reference Case and each other. Drawing on the Electrification Study Terms of Reference, the study team identified 6 key evaluation categories to compare and contrast the "short-listed" network options. These evaluation categories and related considerations included:

- **Environment and Health**: Considerations – greenhouse gas emissions; regional and local air quality; electromagnetic fields; noise and vibration.
- **User Benefits/Quality of Life**: Considerations – journey time savings; reliability
- **Social and Community**: Considerations – impacts on residents and users of community, institutional and recreation facilities.
- **Economic:** Considerations - cost-effectiveness; employment effects; land use and property values.
- **Financial**: Considerations – capital and operating cost; revenues.
- **Deliverability**: Considerations – constructability, acceptability.

Based on the multiple category evaluation, key findings and conclusions of the Electrification Study include:

ENVIRONMENT AND HEALTH

- Electric trains do not emit Greenhouse Gases (GHG) from the locomotives, but rather at the source of electricity generation. Trains propelled by electricity emit less GHG than diesel trains. By electrifying larger sections of the GO Transit rail network, greater GHG reductions can be achieved. Electrifying the entire network would deliver a 94% reduction in GO Transit's future GHG emissions, although this reduction would only be a small fraction (0.32%) of the overall region's emissions.
- Electric trains do not emit Critical Air Contaminants (CAC) from the locomotives, but rather at the source of electricity generation. The more the network is electrified, the more people benefit from the improved air quality. However, analysis of the concentrations of air contaminants such as particulate matter ($PM_{2.5}$), NO_x and SO_x with Tier 4 Diesel locomotives shows that the impact of the Reference Case service levels would already be well below the stringent World Health Organization standards. As more corridors are electrified, the local air quality improves, but the health benefit associated with electrification is likely to be marginal.
- There are also regional and local air quality improvements due to electrification, but as GO Transit has already committed to operating diesel locomotives which are compliant with Tier 4 emission standards in the medium term horizon, the incremental impact of electrification, in the context of health, is relatively modest.

- There are numerous and inconclusive epidemiological studies on electromagnetic fields (EMF) from overhead power lines and OCS; there is no consistent relationship between electromagnetic fields and health issues.
- There is a slight reduction in noise and vibration due to electric locomotives being slightly quieter than diesel. However, the differences in noise levels between diesel and electric locomotive trains would not generally be perceivable due to the noise levels of the coaches which are common to both train sets.

USER BENEFITS/QUALITY OF LIFE

- Due to faster acceleration and deceleration, journey time savings can be achieved with electric locomotives as compared to diesel locomotives.
- Depending on the option, the average time saving per passenger trip from electrification would be between 2.4 and 2.8 minutes.
- The greatest journey time benefits are realized from electrifying Lakeshore (due to most ridership) followed by Georgetown. The least benefits would result from electrifying Richmond Hill (due to line speeds and track curvature that restrict potential transit time savings).
- Electric locomotive trains are typically more reliable than diesel locomotive trains, but overall the reliability benefits to passengers are not significant given that failures due to engine breakdowns are relatively infrequent.

SOCIAL AND COMMUNITY

- The Georgetown Corridor has the most people living closest to the corridor and its electrification may provide the greatest impacts and benefits - although the benefits are modest.
- Overhead catenaries, substations and autotransformer stations are likely to result in negative visual impacts.
- The need for grounding within 250m of the nearest rail, as required, for structures, buildings, station platforms, fencing, pipelines, above-ground fuel tanks and other utilities, may negatively interfere with and impact adjacent properties.

ECONOMIC

- Journey time savings translate to benefits to users and improve the economic competitiveness of the region.
- Electrifying the GO Transit Rail network is expected to generate employment during construction and in operation which in turn increases the economic output of the region.
- Due to faster journey times and slightly improved air quality, noise and vibration, property prices along the electrified rail corridor could benefit from a slight increase in value, although some properties immediately overlooking the overhead catenary system may result in a decrease in value, depending on site-specific conditions.

FINANCIAL

Capital Costs

- Electrification of any option would involve a significant capital investment, with incremental capital cost estimates ranging from about $900 million for the electrification of the Georgetown line only (Option 1) to over $4 billion for the electrification of the entire network.
- Electrification of Lakeshore and Georgetown together is notably lower than the sum of the individual parts because when both are electrified, there are cost synergies.

Operating and Maintenance Costs

- The cost of energy provided by diesel fuel is greater than the cost of energy derived from an electrical system, and cost of diesel fuel is expected to increase at a greater rate than electricity.
- There are significant uncertainties over cost of electricity and diesel in the future.
- Electric Locomotives are less expensive to maintain than diesel locomotives. Annual operating and maintenance cost savings are estimated at about $7 million for the electrification of the Georgetown Corridor only (Option 1) and $53 million for the electrification of the entire network (option 18), 2021 values with real inflation.

Revenue

- Faster acceleration and deceleration of electric trains reduce journey times which attract additional riders and generate increased farebox revenue.

DELIVERABILITY

Ownership

- Electrification would be easier to implement on GO Transit owned corridors as these are expected to require fewer negotiations.
- Electrification of freight corridors would need to be negotiated with CN and CP.

Bridge Replacements

- Eleven bridge replacements would be required to electrify the entire network. Of these, three are needed on the Georgetown corridor and four are needed for Lakeshore.

Reference Case

- There is a need to consider the phasing and coordination of the reference case infrastructure required to deliver the increased service with the electrification work.

OVERALL CONCLUSION

There are transportation and economic benefits to electrification. There are also small environmental, social and community benefits. Health benefits are expected to be marginal. Electrification of any option would involve a significant capital investment, but would result in some operations and maintenance cost savings.

Of the options considered, electrifying the Lakeshore corridor between Bowmanville and Hamilton James (Option 2) is the most cost effective option in delivering these benefits, while the inclusion of the

Georgetown (Option 3) and Milton corridors (Option 11) delivers higher levels of benefits without significantly reducing the cost effectiveness of implementing those options.

The transportation Benefit Cost Ratio (BCR) takes into account the monetized benefits and costs over the project life cycle, and depends on a number of key assumptions. A wide range of sensitivity tests were conducted on these assumptions, including infrastructure capital costs, rolling stock capital costs, operating and maintenance costs, energy cost inflation, and ridership/demand forecasts.

The results of the sensitivity analysis indicated that the BCR of each option was:

- relatively sensitive to the infrastructure capital costs, incremental O&M cost savings and energy cost inflation assumptions;
- moderately sensitive to ridership/demand forecasts; and
- relatively insensitive to incremental rolling stock capital costs.

The sensitivity tests also indicated that while each option's BCR could vary widely depending on the various assumptions, the relative performance of each option still held:

- Option 2 (Lakeshore) consistently emerged as the best performing option, with a BCR likely to be above 1:1 and possibly significantly higher;
- Option 3 (Lakeshore and Georgetown) and Option 11 (Lakeshore, Georgetown and Milton) remained very similar in BCR terms relative to one another, with a fair chance of delivering a BCR higher than 1:1;
- Options 1 and 18 did not yield a BCR greater than one under the current evaluation framework and the range of sensitivities tested.

From an implementation perspective, there are advantages to integrating the electrification work with the Reference Case service level increases. If the electrification infrastructure work is implemented prior to the service level increases, there could be savings in construction schedule and cost. Moreover, the subsequent increase in service levels would ensure that the benefits of electrification accrue to the largest possible number of riders.

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1. INTRODUCTION

The purpose of this report is to detail the Electrification Study methodology, evaluation, findings and conclusions.

This report:

- Describes the **planning context** for the Electrification Study.
- Provides a comprehensive overview of the **study methodology**, including:
  - study principles,
  - study stages,
  - progression of options, and
  - multiple category evaluation.
- Provides a comprehensive description of the ongoing **stakeholder engagement and communications**, including:
  - strategy and methodology,
  - highlights, and
  - stakeholder feedback.
- Describes the **study conclusions at key milestones**, including:
  - baselining/ Reference Case development,
  - operating plan development,
  - rolling stock technology assessment,
  - power supply technology assessment,
  - conceptual design of electrification system, and
  - pre-screening and high level evaluation.
- Describes the **six options** which underwent **detailed assessment or multiple evaluation**.
- Describes the **key findings and conclusions** from the multiple category evaluation of the six options.

2. PLANNING CONTEXT

The Electrification Study took place within the context of a number of planning initiatives such as Places to Grow, The Big Move, and GO 2020. These are described below in sections 2.1 to 2.3.

Electrification is being considered for the commuter transit provided on the GO Transit rail lines. In developing the evaluation framework that guided the GO Electrification Study, the planning and strategic documents noted above were considered. Specifically, the documented visions, goals and objectives guided the formation of the study objectives[1], which were used in assessing the appropriateness of electrification for one or more of the seven GO Transit lines servicing the Greater Golden Horseshoe area. The planning documents were also the foundation for developing the Reference Case for the study, which is described in Section 4 of this report.

2.1. Places to Grow

In 2005 the Government of Ontario passed the Places to Grow Act. The Places to Grow Act helps the Ontario government strategically plan for growth. It gives the government the authority to designate any geographic region of the province as a growth plan area and develop growth plans. Growth plans identify where and how development should occur within a region and help guide government investments.

In June 2006 the growth plan for the Greater Golden Horseshoe was released. The Greater Golden Horseshoe is one of the most important regions in Canada and is among the fastest growing areas in North America. The region extends from Niagara Falls to Peterborough. Currently home to over eight million people, the region is expected to have another 3.7 million people and 1.8 million more jobs by 2031.

This 25-year growth plan will guide urban development in the Greater Golden Horseshoe and provides a framework for the government to coordinate planning and decision-making for long-term growth and infrastructure development. The plan recognizes that while growth can be good for our economy, urban sprawl has an adverse effect on the economy, our health, the environment and quality of life. A key element of the plan is the recognition that more people must spend more time commuting to work resulting in more vehicles contributing to gridlock, delays in the movement of goods and elevated pollution levels.

The Places to Grow plan envisions further intensification of built-up areas, with a focus on urban growth centres, intensification corridors, major transit station areas, brownfield sites and grey fields. The plan recognizes that concentrating new development in these areas will provide a focus for transit and infrastructure investments which in turn will support future growth. The plan places the highest priority on public transit for transportation infrastructure planning and major transportation investments. The plan also establishes criteria to guide decisions on transit planning and investment.

[1] The Electrification Study objectives are detailed in the document entitled "High Level Decision Making Framework", refer to section 3.3. This document may be found in Appendix 1 of this report.

For further information on the Places to Grow Plan, refer to Section 2.1 of the Baseline Report, found in Appendix 3.

2.2. The Big Move

Metrolinx was created by the Government of Ontario to develop and integrate a multi-modal transportation plan for the Greater Toronto and Hamilton Area (Toronto, Hamilton, Durham, Halton, Peel and York).

Metrolinx has developed a Regional Transportation Plan (RTP) called "The Big Move", which will guide future transportation development in the GTHA. The Metrolinx RTP includes the construction of over 1,200 kilometres of rapid transit — more than triples what exists now. This will provide 80 per cent of residents in the region with access to rapid transit within two kilometres of their homes. This will facilitate the reduction in average commute times and transit riders will have access to jobs that were previously difficult to reach by transit.

The Big Move identifies new transportation initiatives that amount to two billion dollars annually over the next 25 years — the largest public transit expansion in half a century. Over its life span, this investment will not only help create thousands of new green and well-paid jobs, but also will save billions of dollars in time, energy and other efficiencies.

Transportation related emissions account for about one-third of greenhouse gases emitted in Ontario. The Big Move will provide travel alternatives which will reduce emissions leading to a healthier environment. Each year traffic congestion costs $6 billon through delays and lost productivity. An improved transit system will enhance our competitiveness, provide direct employment and contribute $70 billion in business revenue.

The vision and goals for the Regional Transportation Plan (RTP) are described in section 2.2 of the Baseline Report found in Appendix 3.

2.3. GO 2020

GO Transit is the Greater Toronto and Hamilton Area's interregional public transportation service. Each weekday GO Transit carries over 200,000 passengers on 180 train trips and 2000 bus trips. The trains operate on seven train lines and service almost 60 stations. GO Transit carries approximately 55 million people annually.

GO 2020 is GO Transit's strategic plan which commits to meeting the region's interregional transportation needs, consistent with the Growth Plan for the Greater Golden Horseshoe and Metrolinx's RTP. Together, GO 2020 and Metrolinx 's RTP provide the basis for GO Transit's 10-year capital program, three-year operating plan, and annual business plans and budgets.

GO Transit's vision is to be the preferred choice for interregional travel in the Greater Golden Horseshoe,[2] with a comprehensive network, frequent service, adequate seating capacity, competitive travel times, and service reliability.

For further information on the GO 2020 Plan, refer to section 2.3 of the Baseline Report, found in Appendix 3.

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[2] GO 2020, 2008; p. 11

3. METHODOLOGY OVERVIEW

3.1. Study Principles

GO Transit currently uses diesel-electric locomotives in push-pull operations with bi-level passenger coach and cab cars. The objective of this study was to assess future technology options, to review their viability in various corridor environments as well as at the network level, and to develop a detailed analysis of the information gathered, so as to assist Metrolinx in determining if there is a case for electrification of the GO Transit network, either in whole or in part.

In a society where there is a growing realization that financial resources are finite, investment decisions are increasingly dependent on the return that investment is likely to make. The justification of a multi-billion dollar investment will require the consideration of its ability to achieve strategic objectives, a full understanding of its impacts, and that the chosen solution offers the best return or value for money.

The decision on whether to meet future service requirements by using conventional and future diesel powered trains or by utilizing trains powered by electricity or alternate means is highly complex and requires a great deal of consideration of impacts across a wide range of disciplines. Some of these impacts can be quantified or valued in monetary terms, while others will be more qualitative or subjective.

The study considered and evaluated technology and network options in a traceable, defensible and transparent manner through the application of a decision-making framework in which alternatives are differentiated through multi-attribute criteria. The study team comprised various expert advisors to provide input on the relevant potential impacts associated with electrification, covering the breadth and depth of issues to ensure that the information underpinning the evaluation is robust.

The Electrification Study was guided by four key principles that were developed by Metrolinx and its Community Advisory Committee:

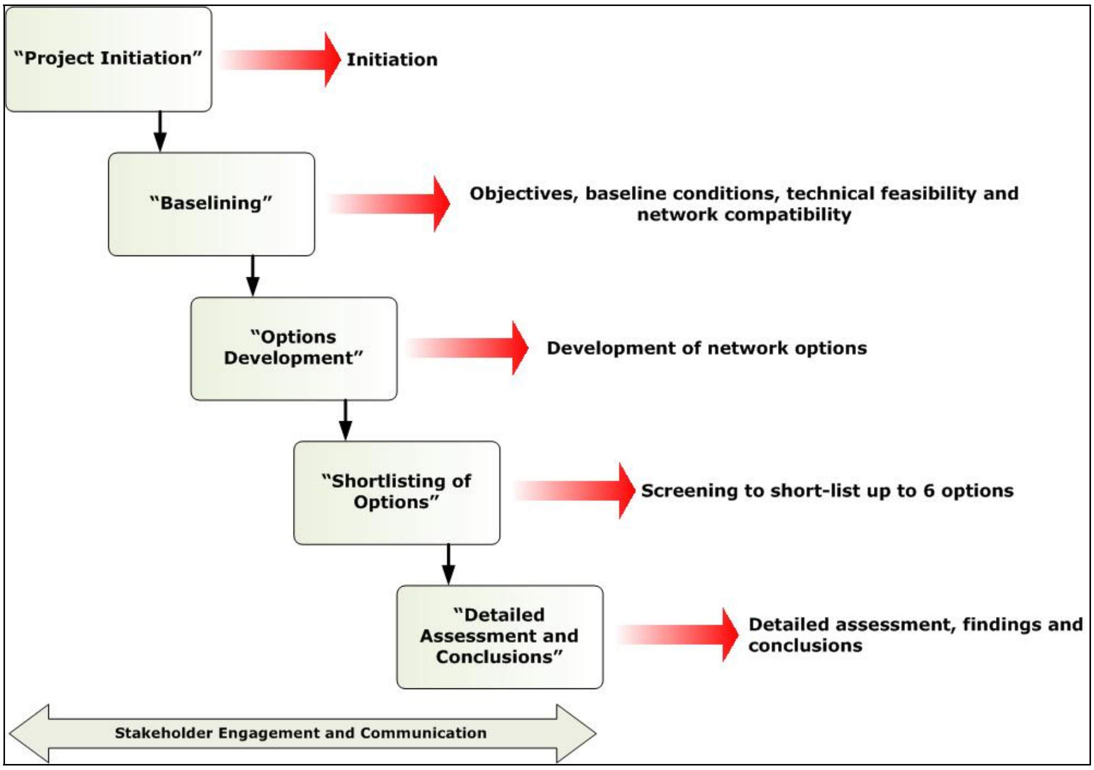
- Objective: The study (and associated stakeholder engagement and communications program) will be conducted through a transparent, step-by-step process, so that results are traceable and readily understood.
- Comprehensive: The study will look at a full range of potential technologies electric, diesel and others to power GO Transit trains in the future. The economic, social, environmental, operational and health benefits and impacts of the various technologies will be investigated.
- Inclusive: The study team will strive to engage a broad spectrum of stakeholders throughout the process.
- Evidence-Based: The study team will provide stakeholders with robust and credible information on technology options based on the most up-to-date research and methods to enable informed participation.

3.2. Study Stages

The Electrification Study followed a comprehensive five phase process to provide Metrolinx's Board of Directors with the information needed to decide on how GO Transit trains will be powered in the future. The five phases are:

- Project Initiation;
- Baselining;
- Options Development;
- Shortlisting of Options; and
- Detailed Assessment and Conclusions.

Figure 1: Stages of the Electrification Study



Stage 1 - Project Initiation

The Project Initiation stage of the study included establishing the study scope and methodology in consultation with Metrolinx; it also included the mobilization of the Electrification Study consultancy team.

A deliverable of the Project Initiation stage was the High Level Decision Making Framework (DMF) which summarizes the overall Study evaluation approach. This is found in Appendix 1 of this report.

Stage 2 - Baselining

The Baselining stage set the strategic context for the study and established the foundation which underpins the evaluation of electrification. In particular, it considered:

- the strategic goals and objectives of Metrolinx as set out in the Big Move, or Regional Transportation Plan (RTP) published in 2008;
- the Electrification Study objectives and the opportunities to which electrification of the GO Transit network can help Metrolinx deliver those strategic goals;
- the current and future transportation environment, in particular the rolling stock, network and service frequencies of the GO Transit network and passenger demand in the study horizon (the Reference Case); and
- values and insight from stakeholders and the communities, and their feedback.

The direct output of the Baselining stage of the study is the Baseline Report which incorporates the Reference Case Workbook (found in Appendix 3 of this report).

Stage 3 - Options Development

The Options Development stage of the study essentially tackled the following elements:

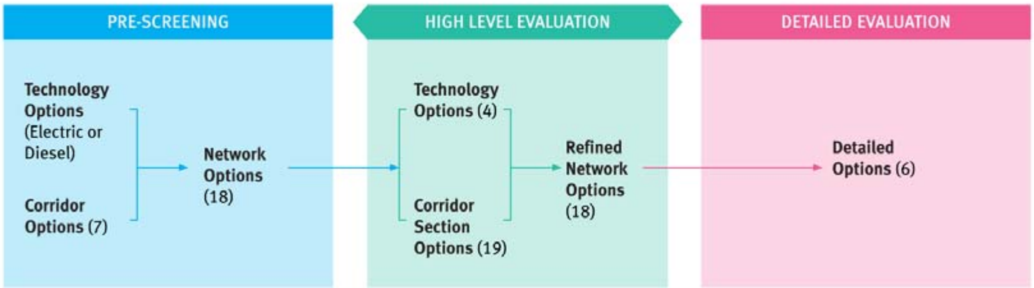
- Undertaking a review of potential rolling stock options and taking forward a shortlist of technologies for further consideration by screening out alternatives which did not fit GO's requirements or were viewed as unproven and risky;
- Undertaking a review of potential electricity power supply system options most appropriate for the GO Transit network - then used as the basis of costing the electrification;
- Consulting with the public and stakeholders on the possibilities and receiving feedback;
- Considering the long list of potential combinations of technologies and corridors, and identifying the criteria upon which the pre-screening of network options is undertaken; and
- Undertaking the pre-screening exercise to remove those network options that did not meet the agreed criteria, and retaining 18 network options for high level evaluation.

The Rolling Stock Technology Assessment Report (Appendix 4) considered all rolling stock technologies and recommended four technologies for further evaluation. Considerations to the power supply options most appropriate for the GO Transit network are found in the Electrification Systems Technology Assessment Report (Appendix 6).

Stage 4 - Shortlisting of Options

Following the development of 18 network options and the potential technologies that could be adopted, these network and technology options were evaluated at a high level as illustrated in Figure 2.

Figure 2: Evaluation of Options



The process for creating the shortlist of options included:

- Collecting rolling stock technology specifications and corridor information covering relevant costs, journey time improvements, population and environmental impacts to produce a matrix of data;
- Undertaking a high level **technology evaluation** to determine the optimal electric train technology, as compared to the Reference Case, to be implemented on the GO Transit network, and considering screening out technologies which are less cost-effective in delivering transportation and environmental benefits;
- Undertaking a high level **corridor section evaluation** to determine the optimal corridors for electrification, and an order of priority in electrifying corridor sections; and
- Informed by the corridor section evaluation, identifying which of the 18 network options are most cost-effective in delivering transportation and environmental benefits. A total of six refined network options, using the optimal technology and with partial electrification where appropriate, were taken forward for detailed evaluation and comparison with the Reference Case.

Consultation with the public and stakeholders and receiving feedback continued in this phase.

Stage 5 - Detailed Evaluation and Conclusions

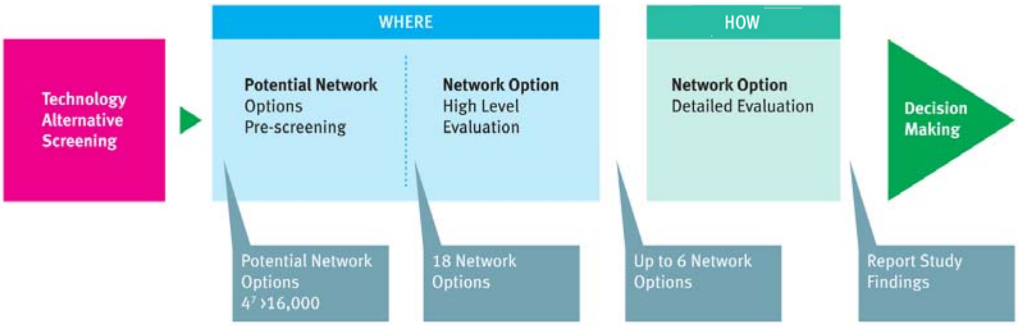
The final stage of the study focused on the detailed evaluation of electrification options as compared to the option of using Tier 4 diesel locomotives (the Reference Case). This included:

- Developing the detailed Multiple Category Evaluation (MCE) framework used to evaluate options (found in Appendix 8-J);
- Undertaking a detailed risk assessment on issues which may affect the case for electrification (Appendix 8-J);
- Undertaking the detailed MCE on the six shortlisted network options, including sensitivity and scenario testing which may affect decision making (found in Appendix 9);
- Considering wider constraints and opportunities and implications on other Metrolinx studies on the Electrification Study and vice versa; and
- Determining key phasing and implementation considerations, discussed in Section 12 and Appendix 10 of this report.

3.3. Progression of Options

The process for progression of options is summarized in the following diagram, Figure 3. As the study evolved, options which were most likely to deliver the benefits associated with electrification in the most cost effective manner were examined in the detailed evaluation stage.

Figure 3: Progression of Long List to Short List of Options



3.4. Multiple Category Evaluation Framework

The multiple category evaluation (MCE) framework for evaluating the merits of electrifying the GO Transit network is consistent with Metrolinx's other evaluation frameworks. Naturally, there are particular elements which reflect the unique nature of the Electrification Study. The evaluation framework sought to cover all the relevant impacts of electrification.

The impacts were captured under the following categories:

- Environmental and Health;
- User Benefits/Quality of Life;
- Social and Community;
- Economic;
- Financial; and
- Deliverability.

Table 1 sets out the sub-categories that were considered at the detailed evaluation stage under the MCE categories. Further information on the development of the evaluation framework is set out in the High Level Decision Making Framework (Appendix 1). Section 11 of this report summarizes the findings and conclusions of the multiple category evaluation; details are found in Appendix 9.

Table 1: Multiple Category Evaluation and Sub Categories Considered

Multiple Category	Sub Category
Environmental and Health	Greenhouse Gas Emissions and Climate Change
	Regional Air Quality
	Local Air Quality and associated Health Impacts
	Other Health Impacts
	Noise and Vibration
	Aquatic Ecosystems
	Effect on Parks / Public Open Space
User Benefits/Quality of Life	Transportation Efficiency (Users)
	Transportation Efficiency (Non-Users)
	Transit Network/ System Access
	Reliability
	Comfort and Expandability
Social and Community	Land Use Integration
	Local Impacts
Economic	Cost-Effectiveness
	Land Use and Property Value
	Property Effects
	Wider Economic Benefits During Construction
	Wider Economic Benefits During Operations
	Taxes
Financial	Total Capital Cost
	Total Operating Cost
	Total Revenues
Delivery	Constructability
	Acceptability

4. STAKEHOLDER ENGAGEMENT AND COMMUNICATIONS

4.1. Introduction

Determining how GO Transit Trains will be powered in the future is an important decision – one that requires an examination of benefits and costs of the various technology options, as well as consideration of community values and priorities. Metrolinx recognized the importance of engaging stakeholders as part of the Electrification Study process. Prior to the commencement of the Electrification Study, Metrolinx formed a multidisciplinary, geographically diverse Community Advisory Committee (CAC) that assisted in the preparation of the study Terms of Reference. These Terms of Reference called for the development of a comprehensive "proactive stakeholder engagement and communication plan" as well as implementation of a stakeholder engagement process that would "consider, document and consolidate feedback by impacted GO Transit stakeholders."

4.2. Stakeholder Engagement Strategy

Building on the direction in the study Terms of Reference, the study team worked with Metrolinx staff to develop a comprehensive Stakeholder Engagement and Communications Plan for the Electrification Study. This plan outlined how Metrolinx and the study team would reach out to and engage GTHA stakeholders during the development of the study in order to:

- Educate stakeholders about the study process and electrification options, such that they can provide informed feedback during the study; and
- Facilitate input from stakeholders throughout the study process, in order to inform decision-making and study conclusions.

The stakeholder plan was specifically developed to address the key principles – objective, comprehensive, inclusive and evidence based – that were established for the study by Metrolinx, in consultation with the CAC. The plan was also designed to ensure that GTHA stakeholders are provided with the opportunity to contribute focused feedback on key outputs identified by Metrolinx and the CAC for the study.

4.3. Guiding Principles for Stakeholder Engagement

The Stakeholder Engagement and Communications Plan included a set of principles – based on those developed by Metrolinx and the CAC – to guide engagement activities throughout the Electrification Study process:

- **Objectivity**: The study (and associated engagement and communications program) will be conducted through a transparent, step-by-step process, such that study outcomes are traceable and readily understood by stakeholders.
- **Comprehensiveness**: Multiple opportunities for stakeholder participation – including face-to-face meetings and web-based consultation – will be provided during the study, backed by a multi-faced communications program, designed to generate broad awareness of the study and electrification issues and options.

- **Inclusiveness:** The study will strive to engage a broad spectrum of stakeholders – reflecting the ethno-culturally diverse and complex stakeholder environment in the Greater Toronto and Hamilton area – throughout the study process.
- **Evidence-Based**: The study team will provide stakeholders with robust and credible information on electrification options – based on the most up-to-date research and methods – to enable informed participation in the study process.
- **Traceability**: The results of the stakeholder engagement program will be clearly documented and the impact of participant input on decision-making will be demonstrated.

4.4. Overview of Engagement Methodology

The Stakeholder Engagement and Communications Plan included a variety of face-to-face and web-based approaches to reach out to and engage community and industry groups, GO Transit rail users, and the general public in the Electrification Study, as summarized in Table 2.

Table 2: Stakeholder Outreach and Engagement Methods

Stakeholder Group	Outreach & Engagement Methods
Former Community Advisory Committee	Update Meetings
Non-Government Stakeholders from across GHTA: environment/health, community, land use, social planning, transportation, commuter groups, business, economic, development, academic	Workshop Series
Rail System Users	Meetings with GO's Customer Service Advisory Committee (CSAC) – made up of rail system users
General Public	Web-based Consultation, Media Briefings
Government Agencies – Municipal, Provincial, Federal	Meetings and Briefings
Technical – including Rail (CN/CP/VIA) and Electrical (e.g., OPA, Hydro One)	Technical Working Meetings

To view a copy of the full Stakeholder Engagement and Communications plan, please refer to Appendix 2B.

4.5. Stakeholder Engagement Highlights to Date

The following sections outline the key engagement and communications activities that were conducted throughout the completion of the Electrification Study.

Non-Government Stakeholder List and Study Database

At the start of the Electrification Study, a list of approximately 100 non-government organization contacts was created, representing the broad geographic scope of the study and the diverse study topic areas. Those identified on this list were invited to participate at the Electrification Study Stakeholder Workshops and have received regular email updates from the study team[3].

The study team also created and maintained a database of interested individuals, stakeholders, agencies, businesses and organizations that it used for communication purposes. The stakeholder database currently contains approximately 500 contacts, including:

- Members of the former Community Advisory Committee (CAC);
- The list of Non-Governmental Organizations invited to participate at the Electrification Study Workshops;
- Municipal Planning and Transportation Officials, and Transit Service Providers;
- Provincial and Federal Agencies with a potential interest in the study;
- Technical (rail and electrical organizations);
- GTHA residents and contacts who request to be added to the study contact list through the project website; and
- Municipal, Provincial and Federal politicians with constituencies in the study area.

Electrification Study Website

In early April 2010, Metrolinx and the study team activated the enhanced Electrification Study website, with a more user friendly interface where stakeholders could obtain up-to-date project information, electrification fact sheets and case studies, background reports, previous electrification studies, and learn how to participate in the Electrification Study process. Integrated into this website was the opportunity for stakeholders to communicate with the study team via a dedicated study email address, and to provide comments on key project reports. Website visitors were invited to comment on several foundational study reports, including the High Level Decision-Making Framework, Rolling Stock Technology Assessment, Baseline Report, Power Supply and Distribution Systems Technology Assessment, Network Options Report and the Progress Report.

The study website can be accessed through the home page of both the Metrolinx and GO Transit websites.

[3] Workshop invitation lists are available in Appendix 2C.

Stakeholder Workshop # 1

The first non-government stakeholder workshop for the Electrification Study took place on Wednesday, March 31, 2010. The workshop introduced representatives from non-governmental organizations to the study and obtained early feedback on the study approach and objectives. In addition, the workshop provided the study team with an opportunity to interact with organizations from across the GTHA, enabling increased understanding of stakeholder values and goals related to the Electrification Study. In total, twenty-five representatives of non-governmental organizations attended the first workshop. A full report on Workshop #1 is included in Appendix 2C.

Metrolinx Planning and Transportation Leaders Forum

The Electrification Study team was invited to provide an introduction to the study to the Metrolinx Planning and Transportation Leaders Forum on April 15th, 2010. The meeting provided an opportunity for the study team to answer questions and obtain feedback from municipal planning and transportation leaders across the GTHA on the study objectives, process and approach.

GO Transit Customer Service Advisory Committee Meeting

On May 3, 2010, the Electrification Study team was invited to attend the GO Transit Customer Service Advisory Committee quarterly meeting to discuss the study progress and the stakeholder engagement and communications strategy. The results of the meeting reaffirmed the study team's engagement approach and highlighted the anticipated interest from the broader stakeholder community once a short list of the options is developed in the Fall of 2010.

Update Meeting (Georgetown Corridor)

On May 27th, 2010, the Electrification Study team hosted an Update Meeting for communities located along the Georgetown South Corridor. The meeting provided participants with an opportunity to review the work completed to date and ask questions and provide comments to the Electrification Study Team. An estimated 100 individuals attended the Update Meeting, with 84 participants opting to sign in prior to the meeting. The meeting offered the study team an opportunity to hear the specific concerns of the communities along Georgetown South Corridor and obtain preliminary feedback on the proposed rolling stock and network options. A full report on the Update Meeting is included in Appendix 2D.

Municipal Transit Leaders Briefing

In order to gain input from municipal transit operators across the GTHA, the Electrification Study team organized a Transit Leaders Briefing on June 15th, 2010. The meeting, held via conference call, introduced participants to the Electrification Study and provided an opportunity for the participants to ask questions and provide comments related to municipal transit operations. To review the highlights of the briefing please refer to Appendix 2E.

Government Agency Consultations

In addition to the municipal meetings described above, study team members met with Provincial government agencies – including the Ontario Ministry of Transportation, Ontario Power Authority and Hydro One - to discuss the study process and related considerations.

Stakeholder Workshop # 2

The second non-government stakeholder workshop was held on June 15th, 2010 and engaged eleven representatives from non-governmental organizations. The workshop presented and invited feedback on the rolling stock technology and network options developed for the GO Transit network. In addition, participants engaged in an interactive discussion about the proposed approach for the further assessment of options. A full report on Workshop #2 is included in Appendix 2F.

Community Advisory Committee Update Meeting

On July 7th, 2010, the Electrification Study team met with members of the former CAC to obtain feedback on the study team's progress. The results of the meeting reaffirmed the study teams approach and highlighted the importance of calculating the community, land use, and environmental impacts of the various rolling stock technology and network options. A full report on the meeting is included in Appendix 2G.

Stakeholder Workshop #3

The third non-government stakeholder workshop for the Electrification Study took place on Wednesday, September 22nd, 2010. The workshop provided stakeholders with an opportunity to provide feedback on the high level evaluation used to identify a 'short-list' of six network options for the potential electrification of the GO Transit network. In addition, it provided non-governmental organizations with an opportunity discuss the various study outputs posted to the Electrification Study website and provide feedback on the work completed to date. In total, eighteen representatives of non-governmental organizations attended the third workshop. A full report on Workshop #3 is included in Appendix 2H.

Media Briefing

To facilitate an understanding of Electrification Study progress, on September 28, 2010 the study team and Metrolinx staff organized a one-hour update session for various media representatives. The session provided the media with an opportunity to learn more about the work completed by the study team in an effort to help them understand how the GO Transit rail network could be powered in the future. During the briefing participants were given the opportunity to ask Metrolinx staff questions pertaining to the ongoing progress of the Electrification Study.

Community Advisory Committee Update Meeting

On November 24th, 2010, the Electrification Study team met with members of the former CAC to update the group of the study team's progress and present key preliminary findings and the results of the detailed assessment of the network options. The meeting highlighted the diverse factors that will need to be considered during the decision making process following the completion of the Electrification Study. To view the Community Advisory Committee meeting notes on please refer to Appendix 2I.

Stakeholder Workshop #4

The fourth and final non-government stakeholder workshop for the Electrification Study took place on Wednesday, December 1st, 2010. The workshop presented key preliminary findings and the results of the detailed assessment of network options. The workshop also provided stakeholders with an opportunity to provide input into the preliminary findings through asking questions and providing comments to the Electrification Study team. In total, nineteen representatives of non-governmental organizations attended the forth workshop. A full report on Workshop #4 is included in Appendix 2J.

Media Briefing

On December 15, 2010, Metrolinx staff hosted a one-hour media briefing for representatives who attended the previous session in November. The purpose of the briefing was to present the key preliminary findings and the results of the detailed assessment. The session provided participants with an update on the progress of the Electrification Study. Further, it provided media the opportunity to discuss the Electrification Study process with Metrolinx staff during the final stages of the study.

Technical Working Sessions

In order to understand the broad factors required to electrify the GO Transit network, the study team met with a number of train operators and service providers. The results of these technical working sessions, which included meetings with Canadian National Railway (CN), Canadian Pacific Railway (CP), Hydro One, The Ontario Power Authority (OPA) and the Greater Toronto Airport Authority (GTAA), highlighted the level of complexity required to electrify the GO Transit network.

In addition, the study team has met with representatives of Agence Métropolitaine de Transport (AMT), who are currently undertaking a similar Electrification Study, to discuss their experience and the study team's progress. The meeting affirmed the study team's approach and provided an opportunity to dialogue with AMT on lessons learned and best practices for electrification.

4.6. Highlights of Stakeholder Feedback

Throughout the year long Electrification Study, several key issues emerged as areas of interest and concern for stakeholders. A more complete listing of issues/comments, along with study team responses, is provided in Appendix 2K of this report. In summary, the major issues identified to date and the corresponding study team response (italicised) are listed below:

- Many stakeholders emphasized the need to **integrate the Airport Rail Link (ARL) into the Electrification Study** and stressed the importance of considering electrification in implementing the ARL. Further, several stakeholders suggested that the ARL should be a starting point for electrification.

  In July, 2010, Metrolinx was asked by the Ontario government to build, own, and operate the ARL. The ARL was included in the Terms of Reference of the Electrification Study and has been fully integrated in the Electrification Study. The ARL, which will be situated in the Georgetown Corridor, has been included in the study team's assessment of the technology and network options.

- Further **details on when Metrolinx's Board of Directors will make decisions and act upon the findings and conclusions** of the Electrification Study are requested.

  The Electrification Study will be completed by late December 2010. It is anticipated that the Metrolinx Board will consider the study findings and conclusions at the Board meeting in February 2011.

- Some members of the public have expressed concern about the potential to bias the study findings in favour of Tier 4 technology. The study team should **include the costs of converting existing locomotives to Tier 4 technology** as part of comparing costs during the study.

  The study team considered the increased costs of Tier 4 locomotives and did not assume the fleet is in place. This cost was used for comparing diesel and electric operations in an objective manner.

- There are **several ongoing studies currently underway that will have an impact on the electrification of the GO Transit rail network**. Specifically, the Union Station Capacity Study and Union 2031 Demand/Opportunity Study need to be incorporated into the study findings and addressed in the Electrification Study. A number of stakeholders have recognized that Union Station is a key factor in where and how electrification can be implemented.

  The study team has met with the consultants engaged in these studies and have made every effort to integrate the findings and conclusions of the ongoing Metrolinx studies (e.g. Union Station Capacity Study, Union 2031 Demand/ Opportunity Study) that are available into the Electrification Study.

- **Electrify the Georgetown South Corridor on a priority basis.** A number of communities surrounding the Georgetown South Corridor have expressed significant concerns about the environmental, air quality, noise, and community impacts of existing operations and planned service expansion within their communities.

  The Electrification Study is an objective and comprehensive assessment of the electrification technology and network options available to GO Transit. The study's findings and conclusions will be used by the Metrolinx Board to make a recommendation(s) to the Province of Ontario.

- The study team should **ensure the Reference Case is an accurate operating/service plan for the medium term in the GTHA.** A number of stakeholders highlighted that the service levels outlined in the Electrification Study are lower than those outlined in 'GO 2020' and 'The Big Move' and expressed concerns that the Reference Case does not accurately depict the operating environment in the medium term.

  The Reference Case is consistent with GO 2020 which bridges the service levels forecasted in The Big Move. All corridors evolve differently, however demand is consistently higher for the Lakeshore line.

- **Do not overstate the costs for electrifying the GO Transit network.** Several initiatives are currently underway are ensuring new rail infrastructure is compatible with electrified rail operations. The study team should ensure they do a thorough assessment of the cost for electrifying the GO Transit network to ensure it is not inflated.

  The study examined the additional costs of providing an electrified railway to meet the service requirements of the Reference Case.

- **Human and environmental health, quality of life, and social impacts** need to be reviewed and given priority when screening the technology and network options. Many stakeholders emphasized the particular importance of understanding the impacts of greenhouse gas emissions, local air quality, and noise on communities surrounding GO Transit rail lines.

  Human and environmental health, quality of life, and other community impacts were important components of the detailed assessment of the available technology and network options for GO Transit. For the purposes of the study, credible and recognized guidelines for environmental and human health standards (such as those outlined by the World Health Organization and Ontario Ministry of the Environment) were used to understand human, environmental, and community impacts of the various technology and network options.

5. BASELINING/REFERENCE CASE DEVELOPMENT

As described in the previous methodology overview, baselining/ Reference Case development was a critical stage of the study wherein a comprehensive description of existing conditions was developed, including:

- The GO Transit network of seven rail corridors;
- The infrastructure (tracks, stations, platforms, parking lots, signal systems, bridges, crossings, culverts and grade separations) that supports GO's rail operations;
- The current service levels provided by GO Transit to its rail passengers for each of the seven rail corridors; and
- The rolling stock – locomotives and coaches – now used to provide GO Transit rail service in the GTHA.

This information is found in Appendix 3, Baseline Report.

In addition, the Reference Case was developed in consultation with Metrolinx staff. The purpose of developing the Reference Case was to provide a basis for comparison and to ensure that the incremental benefits and costs of electrification were captured. This is described below.

5.1. Reference Case for the Electrification Study

The Reference Case presents a point in time which was established for the purposes of comparison without burdening Electrification with the proposed development and service plans that are planned regardless of the technology.

The Reference Case was developed to provide a consistent basis and assumptions for comparing future technology and network options as part of the Electrification Study. It represents a reasonable scenario for future GO Transit rail service which incorporates existing attributes and approved/planned enhancements of GO's rail network, rolling stock, rail infrastructure and service levels consistent with the GO2020 service vision. The Reference Case was prepared specifically for this study and includes a high level service concept (not a plan), which is one possible outcome, subject to detailed feasibility, passenger demand and capital/operating funding. The following outlines the key assumptions made in developing the Reference Case, which is described below in terms of rolling stock, infrastructure, and service levels. For more detailed information about the Reference Case, refer to Section 4 of the Baseline Report, found in Appendix 3.

Assumptions

This study has made a number of assumptions about the GO Transit rail network, service level and available infrastructure to enable a consistent and identifiable approach to be taken when comparing alternative technologies.

The key assumptions for the Reference Case are as follows:

- Union Station will have the capacity to receive the inbound and outbound services in the Reference Case.
- Each train will have 10 bi-level coaches, with seating capacity for 1540 passengers and this will be the same for each corridor.
- Train length will not be changed during normal daily operation.
- The operations of CN/CP/ONR and Via Rail are assumed to have no impact on the proposed schedule.
- The whole GO Transit rail network will be considered for Electrification.

Reference Case Rolling Stock

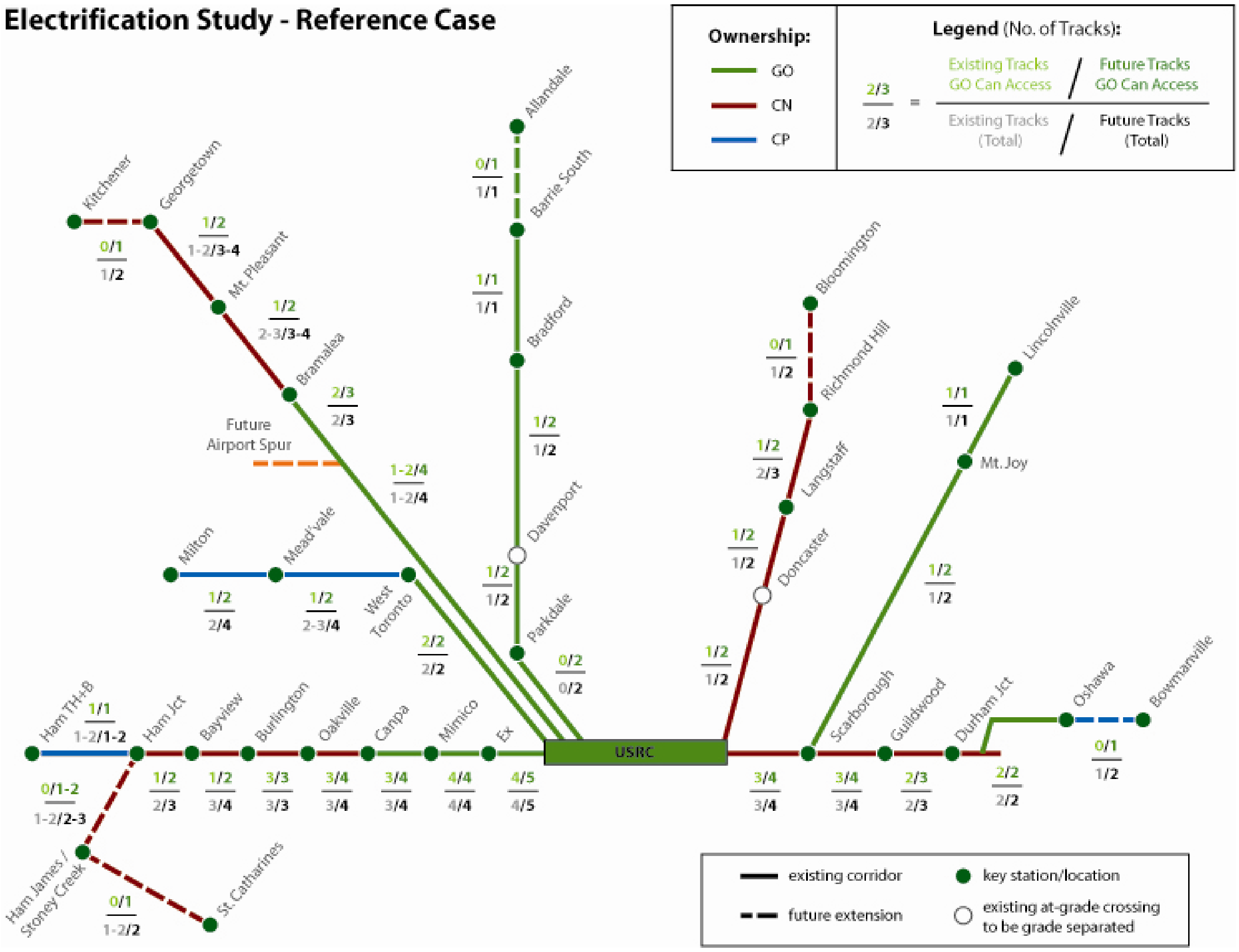
As part of the GO Electrification Study, the Reference Case assumed that Tier 4 Diesel MP40 rolling stock will be in operation. GO Transit has committed to convert to Tier 4 emission standards. In 2015, Tier 4 emissions compliancy will be mandated for all new and remanufactured locomotives in the United States. This is therefore the rolling stock against which other technologies are assessed in the study.

For the Airport Rail Link service, single-level, self-propelled diesel-powered railcars known as diesel multiple units (DMU) in two-car trains will be compared to single-level electric multiple units (EMU).

Reference Case Infrastructure

The infrastructure including additional track and corridor extensions included in the Reference Case is shown in Figure 4.

Figure 4: Reference Case Schematic Network Showing Ownership, Number of Tracks and Location of Facilities



Note: Schematic is illustrative and strictly for the purposes of the Electrification Study comparative analysis

The additional stations and corridor extensions included in the Reference Case are shown in Figure 5.

Figure 5: Reference Case Network Schematic Showing Stations and Corridor Extensions

Note: Schematic is illustrative and strictly for the purposes of the Electrification Study comparative analysis

Reference Case Service Levels

The Reference Case refers to a future concept that was prepared to provide an effective base, which can be used to assess the benefits of alternate modes of propulsion. Further analysis of the operating plan is required to refine systemic requirements. Final implementation may vary as feasibility is confirmed, demand warrants, and operating/capital funding is provided in the medium term horizon.

The Reference Case is only an indication of the increase in service over the next decade to be used to inform the assessment of options within this study. It assumes 629 train trips per day, an almost 250% increase over the current 180 train trips per day.

The following details are taken from the description of the Reference Case service concept as supplied by Metrolinx.

Table 3: Reference Case Service Levels

Corridor	Number of trains arriving at Union Station in the 3-hour AM peak		Number of trains arriving at Union Station every weekday	
	Current	Reference Case	Current	Reference Case
Lakeshore West	13	20	63	104
Lakeshore East	12	17	63	98
Milton	7	14	14	62
Georgetown	6	14	13	61
Air Rail Link (ARL)	0	12	0	140
Barrie	4	10	8	53
Richmond Hill	4	9	9	52
Stouffville	5	12	10	59
Total	**51**	**108**	**180**	**629**

6. ROLLING STOCK TECHNOLOGY ASSESSMENT

The rolling stock technology assessment entailed identifying a broad range of existing and future potential rolling stock technologies that could be used to provide future GO Transit rail services. Rolling stock technologies considered include:

- Diesel Locomotives
- Diesel Multiple Units (DMU)
- Electric Locomotives
- Electric Multiple Units (EMU)
- Dual-Mode Locomotives
- Dual-Mode Multiple Units
- Alternative Rolling Stock Technologies and Enhancements, including
  - Alternative Locomotive Fuels
  - Hybrid Drive Trains
  - Hydrogen Fuel Cell Drive Trains
  - Maglev
  - New System Concepts

In addition to describing and comparing the technical attributes of these technologies, the rolling stock technology assessment involved the use of four screening criteria to identify a "short list" of technologies for further assessment. The criteria used in the assessment include:

- Is the technology proven?
- Is the technology commercially viable?
- Is the technology compatible with the Reference Case infrastructure?
- Is the technology compatible with the Reference Case service levels?

After examination of the candidate rolling stock technologies, it was concluded that a number of technology alternatives should be eliminated from further consideration based on the application of the four screening criteria.

Further, it was recommended that the following technologies be carried forward for more detailed assessment and analysis as part of the Electrification Study:

- Diesel Locomotives – Bi-Level coaches
- Electric Locomotives – Bi-Level coaches
- Electric Multiple Units – Bi-Level coaches
- Dual-Mode Locomotives – Bi-Level coaches

These rolling stock technologies are illustrated in Figures 6 to 9, respectively.

Figure 6: GO Diesel Locomotive-Hauled Train (MP40PH-3C) to be converted to Tier 4

Figure 7: Example of an Electric Locomotive

Figure 8: Example of an Electric Multiple Unit train

Figure 9: Example of a Dual Mode Locomotive

7. OPERATING PLAN FOR THE ELECTRIFICATION STUDY

An assessment of the short-listed rolling stock technologies was carried out at the Reference Case traffic level. As part of this assessment, it was necessary to develop the GO Transit operating scenario for the Reference Case in order to develop an estimate of the number of train sets required, peak load, and energy requirements to operate the projected service.

The trains consisted of 10 bi-level cars hauled by 1 electric or dual-mode locomotive (or 12 bi-level EMUs – for an equivalent seating capacity) on all corridors, except the Airport Rail Link, where 2-car single-level electric multiple unit trains were modeled. The operating scenario was developed specifically for this study and was based on numerous assumptions (such as the location of overnight train storage etc.) which are subject to further planning and analysis. The operating scenario, peak load and energy requirements are the key inputs in sizing and spacing of the electric substations.

The analysis showed that a total of 92 train sets are needed to operate the GO Reference Case service and four train sets are needed for the ARL service (excluding spares/standby). The weekday diesel requirement for GO Transit train operation with the diesel locomotive and ARL trains with DMU is estimated at 58,320 imperial gallons of diesel fuel (including hotel power and 10% allowance for train idling).

An operations analysis was carried out to estimate the journey time savings in the train operation with the different technology options. The journey time savings arise principally from the difference in the hauling capacity of the different technologies. Train operation with a Tier-4 compliant MP40 diesel-electric locomotive or equivalent is the base against which the journey times with the alternate technologies are compared. A key assumption is no change in the maximum allowable speeds of GO Transit trains, which are constrained by the Reference Case track configuration.

EMUs have significantly higher pulling capacity compared to diesel-electric locomotives throughout the full operating range of GO Transit trains and hence offer the highest savings in journey time. With EMUs, the savings are approximately 8 to 18 minutes for most of the corridors. The electric locomotive has a somewhat higher pulling capacity than the diesel-electric locomotive in the mid to upper speed range but an inferior pulling capacity in the lower speed range and therefore offers fewer savings in journey time than the EMU. With the electric locomotives, the estimated savings are approximately 3 to 8 minutes for most of the corridors. Note that on the Richmond Hill and Stouffville corridors line speeds and track curvatures restrict potential transit time savings. Refer to Table 4 for a more detailed comparison by corridor.

Table 4: Journey Time Savings

Journey Time Savings Over Reference Case (min)				
Route	Train Type	Service	Electric Loco-Hauled Cars	EMU Train
			Electric Loco + 10 Bi-level Cars	6 Bi-level Powered Cars + 6 Bi-level Unpowered Cars
LW: Hamilton – Union	Local	Inbound	7	17
	Local	Outbound	6	16
LE: Bowmanville – Union	Local	Inbound	6	16
	Local	Outbound	8	18
MT: Milton – Union	Local	Inbound	3	9
	Local	Outbound	4	9
GT: Kitchener – Union	Local	Inbound	7	14
	Local	Outbound	11	18
BA: Allandale – Union	Local	Inbound	4	12
	Local	Outbound	6	14
RH: Bloomington – Union	Local	Inbound	0	4
	Local	Outbound	1	5
ST: Lincolnville - Union	Local	Inbound	1	6
	Local	Outbound	3	8

The dual-mode locomotive in the diesel mode is technically very similar to an MP40 locomotive and consequently offers no journey time savings, while the dual-mode locomotive in the electric mode offers more savings due to its slightly superior pulling effort compared to a MP40 unit (but not as much as an electric locomotive). With the dual-mode locomotive in the electric mode, the savings are approximately 2 to 6 minutes for most of the corridors.

For details on the journey time savings of each rolling stock technology, please refer to Appendix 5 of this report.

8. POWER SUPPLY TECHNOLOGY ASSESSMENT

The power supply technology assessment entailed identifying a broad range of existing and future potential electrification system technologies that could be used to provide power to the future GO Transit rail services. The electrification system technologies considered included the following candidates:

- DC electrification systems,
- AC electrification systems at commercial frequency,
- AC electrification systems at non-commercial frequency,
- Combination of AC and DC electrification systems, and
- Alternative system technologies and enhancements, including:
- Wayside energy storage, and
- Wayside hydrogen fuel cell power generation.

In addition to describing and comparing the technical attributes of these technologies, the electrification system technology assessment involved the use of five screening criteria to identify a "short list" of technologies for further assessment. The criteria used in the assessment include:

- Is the technology proven?
- Is the technology technically viable?
- Is the technology commercially viable?
- Is the technology compatible with the Reference Case infrastructure?
- Is the technology compatible with the Reference Case service levels?

Following examination of the candidate electrification system technologies, a number of technology alternatives were eliminated from further consideration based on the application of the screening criteria. Further, it was determined that the following technologies satisfied the evaluation criteria to the highest degree, and therefore should be carried forward for more detailed assessment and analysis as part of the Electrification Study:

- Direct-fed system operating at 1x25 kV ac electrification voltage and commercial frequency of 60 Hz;
- Autotransformer-fed system operating at 2x25 kV ac electrification voltage and commercial frequency of 60 Hz; and
- Direct-fed system operating at 1x50 kV ac electrification voltage and commercial frequency of 60 Hz.

During further evaluation it also became apparent that several bridges along the route have limited vertical clearance. Since the 1x50 kV electrification system requires higher vertical clearance above the rail than the 2x25 kV system, more bridges would have to be modified should the 50 kV system be implemented. This would be uneconomical due to requirements for frequent track lowering or bridge raising.

Also, advantages of the 2x25 kv autotransformer-fed system over the 1x25 kv direct-fed system include greater substation spacing.

Therefore, the technology selected and recommended for development of conceptual design and cost estimate of the GO Transit system electrification is:

- Autotransformer-fed system operating at 2x25 kV ac electrification voltage and commercial frequency of 60 Hz

The advantage of the 2x25 kV autotransformer-fed system is that it achieves substation "reach" comparable to the 50 kV system with the need to provide clearances only for 25 kV voltage. The system is being used extensively overseas and in the United States the system is used by Amtrak on the Northend Electrification system from New Haven, CT to Boston, MA, a distance of 156 miles. The autotransformer system is a standard system used for the type and size of commuter networks like the GO Transit network. Other examples of commuter railroads in the United States being powered by the same system in revenue service include:

- New Haven Line from Pelham, NY to New Haven, CT operating at 2x12.5 kV, 60 Hz, and owned by Metro- North Railroad (MNR)
- Morris & Essex Line from Kearny Junction in Kearny, NJ (just outside New York, NY) to Dover, NJ and Gladstone, NJ operating at 2x25 kV, 60 Hz, and owned by New Jersey Transit (NJT)
- Commuter line network in Philadelphia and its suburbs operating at unique 24 kV/12 kV, 25 Hz, and owned by Southeastern Pennsylvania Transportation Authority (SEPTA)

Figure 10: Typical 2x25 kV System Autotransformer Station

The 2x25 kV autotransformer-fed system is also being employed in the design for electrification of the California High Speed Rail project linking San Francisco, Sacramento, Los Angeles and San Diego.

In Canada, the Agence Métropolitaine de Transport (AMT) uses direct-fed 1x25 kV, 60 Hz system for electrification of their Deux Montagnes commuter line. However, the 2x25 kV, 60 Hz autotransformer system is being considered in AMT's Electrification Study.

The chosen technology is fully compatible with the technology used by Agence Métropolitaine de Transport (AMT) for electrification of their Deux Montagnes commuter line in suburban Montreal. In the event that the entire Toronto-Montreal route is electrified in the future, VIA, freight and/or high speed trains would be able to operate along the corridor without conflicts.

9. CONCEPTUAL DESIGN OF THE ELECTRIFICATION SYSTEM

A comprehensive computer-aided train operation simulation and electrical system load-flow modeling was performed for the operating schedule included in the Reference Case. The trains consisted of 10 bi-level cars hauled by electric locomotives on all corridors, except the Airport Rail Link, where 2-car single-level electric multiple unit trains were modeled. The results of the modeling studies provided the performance of the rolling stock and the traction electrification system for evaluation of the conceptual design suitability and adequacy. Further, they predicted power demands at each substation and system energy consumption for estimates of the electrification system operating costs.

Based on the train simulation system modeling studies, the conceptual design of the system was developed. Assuming full electrification of all the seven corridors and the Airport Rail link, the system can be supplied with power using seven (7) traction power substations, 17 autotransformer stations, and four (4) switching stations.

Figure 11: Typical 2x25 kV System Substation

The substations are shown in the following Table 5:

Table 5: Location of Traction Power Substations

GO System Line	Metrolinx Substations	Hydro One Substations	Voltage (kV)	Note
Lakeshore West Line	Mimico	Horner	230	Traction power substation would be near Hydro One substation.
	Burlington West	Cumberland	230	Traction power substation would be near Hydro One substation.
Lakeshore East Line	Scarborough	Warden	230	The substation would also supply Richmond Hill and Stouffville lines. Approximately 1.5 mile of transmission line or cable would be required.
	Oshawa	Thornton	230	Approximately one mile of 230 kV transmission line or cable would be required.
Georgetown Line	Dixie Road	Bramalea	230	Approximately ¾ mile of 230 kV transmission line or cable would be required.
	Guelph	Campbell	230	Approximately 1.5 miles of transmission line or cable would be required.
Barrie Line	Newmarket	Armitage	230	Substation would supply the entire Barrie line. Approximately two spans of transmission line would be required.

Hydro One confirmed sufficient thermal capacity of the supply circuits at all sites. The power supply at Armitage substation is currently limited and should improve by 2011 when the peaking York Energy Center generating plant comes on line.

In order to provide the substation transformers with sufficient power and to maintain high reliability of supply, the transformers would be connected to the 230 kV high voltage transmission network of the local power utility Hydro One. In order to limit provision of costly high voltage transmission lines or cables, the traction power substations would be located as close as possible to Hydro One substations.

For redundancy purposes, each Metrolinx substation would include two equally rated traction power transformers. Power from the transformers to the power distribution system and eventually the trains would be delivered via wayside switchgear arrangements required for control and protection of the overhead contact system (OCS).

The total annual system-wide energy consumption is estimated at 284 million kWh. For details related to the conceptual design of the electrification system, refer to Appendix 7.

The following pricing for electricity costs was used in the cost estimates:

- Power demand charge: $5.41/kW for maximum 1-hour demand at each transformer
- Energy consumption charge: $0.0855/kWh

Together, these two charges provided the estimated average annual cost of electricity at 10.8 cents/kWh (or 0.108 $/kWh) for the entire network.

In view of the single phase nature of the loads, harmonics, and fluctuation, it is normal for the utility companies involved with electrification to assess the impact of the loads on a case by case basis. This would be done by an Impact Assessment and/or Connection Assessment.

It should be noted that 25 kV single phase ac traction load and its supply from power utility transmission system is a very much common practice. Over 50,000 miles or 80,000 km of railroad are electrified worldwide using this system. Amtrak's Northend electrification (157 miles from New Haven, CT to Boston, MA) is electrified at 25 kV ac with primary supply being obtained at 115 kV from the three utility companies in the area - Connecticut Light and Power, Narragansett Electric (now National Grid) and Boston Edison (now NStar). Unbalance & harmonic content at all the sites were found to be within the acceptable limits of the utility companies. California High Speed Rail also proposes to use this system with power to be obtained from Pacific Gas & Electric Co. and from Anaheim Public Utilities.

Figure 12: Typical Two-Track 2x25 kV OCS and Feeder System with Side Pole Construction

Figure 13: Typical Multi-Track 2x25 kV OCS and Feeder System with Portal Construction

10. PRE-SCREENING AND HIGH LEVEL EVALUATION

As described in Section 3, the study process entailed looking at the myriad of possible combinations of corridor and rolling stock technology options and pre-screening these to develop a "long list" of network options for high level evaluation. The results of this process are set out below.

10.1. Pre-Screening

Over 16,000 (or 4^7) network options were identified, based on:

- The 4 alternative technologies – four "short listed" rolling stock technologies were considered including electric locomotives, electric multiple units, dual-mode locomotives and diesel locomotives (the existing "reference case" technology) and
- The 7 corridor alternatives – the potential use of a "short listed" rolling stock technology on any specific GO Transit line.

Pre-screening criteria were applied to substantially reduce the 16,000+ potential network options for further evaluation. These criteria were:

- The three "short listed" technologies that require electrification – electric locomotives, electric multiple units, dual-mode locomotives – were considered to be a single "family" of technologies;
- The Lakeshore East and Lakeshore West corridors to operate the same type of rolling stock technology; and
- Investment in electrification should be focused on the corridors – Georgetown, Lakeshore East and Lakeshore West – that have the highest demand/service and are likely to deliver the most benefits.

Once the pre-screening criteria were applied, a "long list" of 18 network options was identified for further evaluation. These include network options that range from electrifying one line to electrifying all corridors to some extent, using either electric locomotives or EMUs, potentially supplemented with dual-mode locomotives.

10.2. High Level Evaluation

The primary objective of the high level evaluation was to screen the "long list" of network options down to a manageable "short list" of 6, ensuring that there is a transparent and logical rationale for taking forward these options and focusing the detailed evaluation on options which most merit examination.

The high level evaluation enabled the determination of the appropriate way forward on a number of key issues including:

- The Preferred Technology;
- The Optimal Service Sections for Each Corridor;
- The Use of Dual-Mode Locomotive Trains; and,
- The Shortlist of 6 options.

This section of the report covers the conclusions under each of these in turn, focusing on the high level evaluation of environmental, transportation, economic (cost efficiency) and implementation aspects of the MCE (Multiple Category Evaluation).

The Preferred Technology

The shortlisted technology options considered as part of the high level evaluation included:

- Diesel Locomotives (as current but converted to Tier 4 emission standards, as assumed in the Reference Case);
- Electric Locomotives;
- Electric Multiple Units (EMUs); and,
- Dual-Mode Locomotives – these were considered on services which would operate through partially electrified sections of the corridor on the assumption that passengers would prefer not to interchange to reach their final destination if that was beyond the electrified part of the corridor.

It is assumed that in each case the trains would operate the service level under the Reference Case and will have the same passenger carrying capacity. This means that all locomotive options would have 10 passenger cars plus a locomotive and in the EMU option there would be 12 passenger cars, of which half would have propulsion equipment. The need for this level of propulsion equipment significantly increased the costs of this technology.

Based on the findings of the high level evaluation, the Electric Locomotive trains were concluded as the "Preferred Technology" for the detailed evaluation stages of this Electrification Study. Compared to the Diesel Locomotive trains, they deliver passenger time savings and environmental benefits and were more cost effective in doing so than other technologies. (EMUs cost around 40% more in capital costs, while over the 30-year life cycle they were around 2.5 times more expensive, meaning a significantly larger capital and operating budget would be required.)

In the case of the ARL, it is assumed that the initial deployment of DMUs will be replaced by EMUs if the Georgetown line is electrified either in part or in full.

This conclusion on preferred technology for the detailed evaluation stages of the project does not preclude EMUs being deployed in the future on services which justify further expenditure to enhance the service, make better use of infrastructure enhancements and/or provide greater operational flexibility.

The Optimal Sections of Each Corridor

In the high level evaluation, the 7 GO Transit lines were divided into a total of 19 service section options for the purpose of examining the merits of partial electrification against full electrification. This was undertaken because it may not be worthwhile to electrify an entire corridor, especially if there are few trains that operate along long stretches of a line.

Having analysed the corridor and rolling stock characteristics and produced life cycle costs and benefits, it was concluded that, in general, it is more cost effective (in terms of delivering transportation and environmental benefits) to electrify the entire route rather than sections of route.

The exception to this is the Lakeshore West corridor. In this case, the optimal end point is Hamilton James, as Hamilton TH+B and St. Catharines do not strengthen the case for electrifying the full route, due to due to the limited number of trains destined there and the cost of modifications to the Hunter St. tunnel and adjacent bridges on the CP tracks.

The Use of Dual-Mode Locomotive Trains

Given that it is preferable to electrify the entire corridor in all circumstances with the exception of the Lakeshore West corridor beyond Hamilton James, there is an option to run either Diesel Locomotive or Dual Mode locomotive trains for services to Hamilton TH+B and St. Catharines.

Dual-Modes do not provide significant benefits over Diesel Locomotives because they are costly to purchase and do not deliver significant O&M savings in the case of St. Catharines. As the Dual-Mode trains remain a less proven technology and only a small fleet would be required to operate these services, the incremental rolling stock cost may well be significantly higher than assumed in the evaluation as manufacturers would need to design and construct a small fleet of Dual-Mode Locomotives which makes them impractical.

It was therefore concluded that Diesel Locomotive trains would be retained on services that operate through partially electrified sections on the Lakeshore West line if it is not fully electrified. However, Dual-Mode Locomotive Trains may provide flexibility when looking at a phased implementation.

The Shortlist of Options

Based on the findings from the evaluation of service sections and using the preferred technology of the Electric Locomotive train, it was possible to identify the priority in which the sections could be electrified if the maximum benefits were to be delivered first. It was concluded that after the Lakeshore and Georgetown corridors, Milton and Barrie were the other strongest performing corridors in terms of delivering transportation and environmental benefits most cost-effectively.

The 6 network options taken forward for detailed evaluation and comparison against the Reference Case include the electrification of:

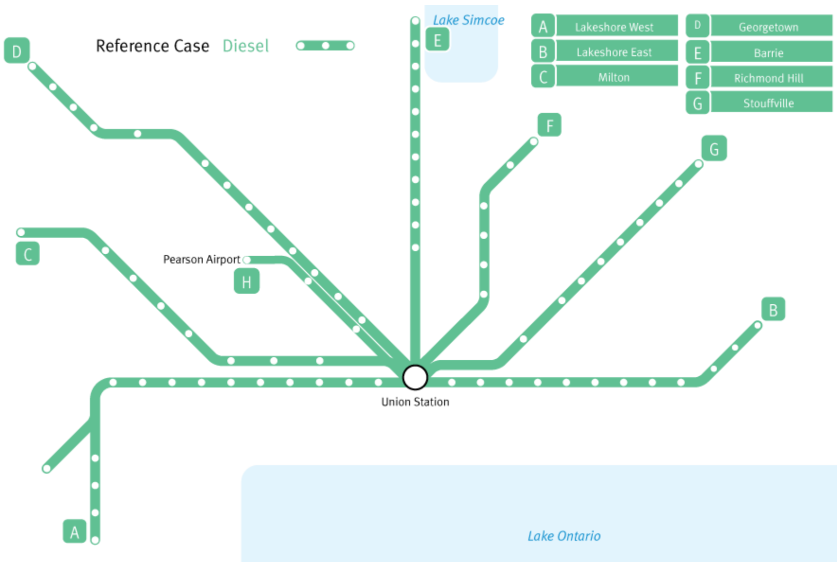
- The Georgetown line (including the ARL) from Union to Kitchener (Option 1);
- The Lakeshore East and West lines from Bowmanville to Hamilton James (Option 2);
- The Georgetown and Lakeshore lines together (Option 3);
- The Georgetown and Lakeshore lines plus the Milton line from Union to Milton (Option 11);
- The Georgetown and Lakeshore lines plus the Milton line and the Barrie line from Union to Allandale (Option 15); and
- The entire GO Transit network (Option 18).

The short-listed options are described further in Section 10 of this report.

11. THE SIX SHORT-LISTED OPTIONS

This Section describes the six short-listed options in detail. Note the Reference Case is defined in Section 5 and illustrated below.

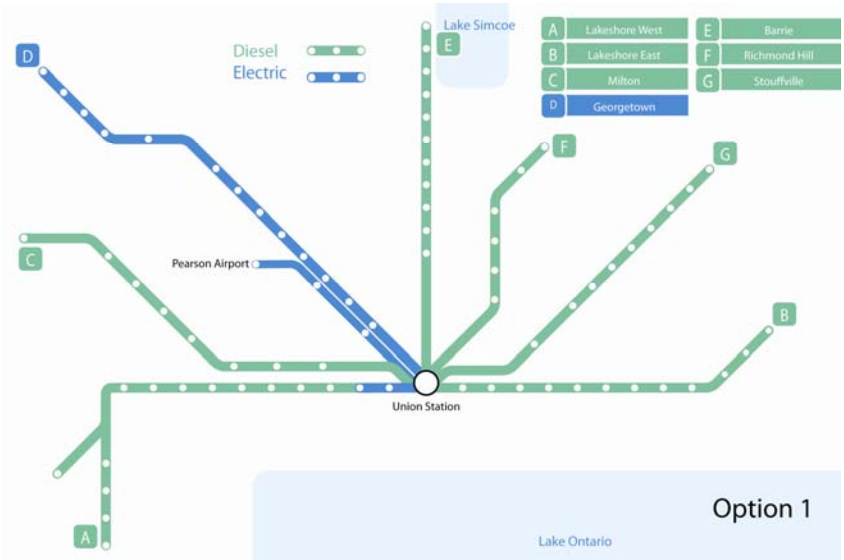
Figure 14: Reference Case



11.1. Option 1 – Georgetown Corridor

As illustrated in Figure 15, this option includes the electrification of the Georgetown corridor on the Metrolinx network and includes the Airport Rail Link (ARL). All other corridors on the Metrolinx network would be upgraded to the Reference Case and would run Tier 4 Diesel locomotives.

Figure 15: Option 1 - Georgetown from Union to Kitchener (including the ARL)



Electrification of the Georgetown corridor would include the following features:

- Provision of overhead catenary to electrify the route originating in Union Station and terminating at the Kitchener GO Transit station. The electrified revenue service route length is approximately 100.5 kilometres. The total electrified length is 114.7 km including the distance to get to the Willowbrook maintenance facility.
- Electric locomotives pulling 10 bi-level cars with weekday peak service between Kitchener and Union Station. Off-peak service, weekend and holiday service would operate between Mt. Pleasant GO Transit Station in Brampton and Union Station only.
- Electric Multiple Units (EMUs) in two car train consists operating at 15 minute headways 17.5 hours per day (approx 05:00 am to 01:00 am) for the ARL.`
- Midday and overnight storage would be at Willowbrook, Georgetown and Kitchener with maintenance at Willowbrook.
- Nightly storage as well as all maintenance at Willowbrook yard.
- Provision of appropriate clearance for the OCS at all overhead structures.

- Electrifying the Georgetown corridor includes Union Station and will also require:
  - the grounding of structures, buildings, station platforms, fencing, pipelines, above-ground fuel tanks and other utilities within 250m of the nearest rail, as required;
  - modifications to the track to ensure compatibility with electrification, including track bonding and grounding to limit induced voltages and maintain safety;
  - modifications to the signal system to immunize against the effects of electromagnetic interference; and
  - the provision of additional equipment in the current control center to operate the electrification system.

Table 6: Key Statistics for Option 1- Georgetown Corridor

Item	Option 1			
GO Network Length	316.2	mi.	508.9	km
Electrified Length	71.3	mi.	114.7	km
Traction Power Substation			3	
Switching Stations			2	
Autotransformer Stations			3	
Bridges Rebuilt			3	
Bridges Reworked			8	
Total Bridges			11	
Locomotives				
Electric			17	
Diesel			91	
Electric Multiple Units (ARL)			12	

11.2. Option 2 – Lakeshore East Corridor

As illustrated in Figure 16, this option includes electrification of the Lakeshore corridor, east from Bowmanville and west to Hamilton James. The Hamilton TH&B and St. Catharines corridors on the Lakeshore West Line would not be electrified and service on these corridors would be provided by Tier 4 diesel locomotives. Service on all other corridors would also be provided by Tier 4 diesel Locomotives as per the Reference Case.

Figure 16: Option 2 - Lakeshore East & West from Bowmanville to Hamilton James

Electrification of the Lakeshore corridor would include the following features:

- Provision of overhead catenary and traction power supply substations to electrify the route originating in the east at Bowmanville, through Union Station and terminating at Hamilton James. The electrified revenue service route length for the Lakeshore East portion of the route is approximately 69 kilometres and the Lakeshore West portion is approximately 63 kilometres.
- Electric locomotives pulling 10 bi-level cars with weekday peak service between Union station and Bowmanville and Union Station and Hamilton James. Off peak service would operate east and west over the same routes.
- Midday and overnight layovers would occur at a variety of locations depending on the closest location to the trip termination. These include Hamilton TH&B, Don Yard, Bathurst Yard, Stoney Creek, Willowbrook and the East Maintenance Facility. Maintenance of the Lakeshore West trains would take place at Willowbrook and the Lakeshore East trains at the new East Maintenance Facility.
- Provision of appropriate clearance for the OCS at all overhead structures.

- Electrifying the Lakeshore corridor includes the Union Station Rail Corridor and will also require:
  - the grounding of structures, buildings, station platforms, fencing, pipelines, above-ground fuel tanks and other utilities within 250m of the nearest rail, as required;
  - modifications to the track to ensure compatibility with electrification, including track bonding and grounding to limit induced voltages and maintain safety;
  - modifications to the signal system to immunize against the effects of electromagnetic interference; and
  - the provision of additional equipment in the current control center to operate the electrification system.

Table 7: Key Statistics for Option 2- Lakeshore Corridor

Item	Option 2			
GO Network Length	316.2	mi.	508.9	km
Electrified Length	82.3	mi.	132.4	km
Traction Power Substation			4	
Switching Stations			3	
Autotransformer Stations			1	
Bridges Rebuilt			4	
Bridges Reworked			19	
Total Bridges			23	
Locomotives				
Electric			34	
Diesel			74	
Diesel Multiple Units (ARL)			12	

11.3. Option 3 – Georgetown and Lakeshore Corridors

As illustrated in Figure 17, this option includes electrification of the Georgetown Corridor and Lakeshore Corridor from Bowmanville to Hamilton James. The Hamilton TH&B and St. Catharines corridors on the Lakeshore West Line would not be electrified and service on these corridors would be provided by Tier 4 diesel locomotives. Service on all other corridors would also be provided by Tier 4 diesel Locomotives as per the Reference Case.

Figure 17: Option 3 - Georgetown and Lakeshore

Electrification of these 2 corridors would include the following features:

- Provision of overhead catenary to electrify the Georgetown route originating in Union Station and terminating at the Kitchener GO Transit station. The electrified revenue service route length is approximately 100.5 kilometres.
- Provision of overhead catenary and traction power supply substations to electrify the Lakeshore East route originating in the east at Bowmanville, through Union Station and terminating at Lakeshore West Hamilton James station. The electrified revenue service route length for the Lakeshore East portion of the route is approximately 69 kilometres and the Lakeshore West portion is approximately 63 kilometres.
- Electric Multiple Units (EMUs) in two car train consists operating at 15 minute headways for the ARL service
- Electric locomotives pulling 10 bi-level cars with weekday peak service between Kitchener and Union Station. Off-peak service, weekend and holiday service would operate between Mt. Pleasant GO Transit Station in Brampton and Union Station only.
- Electric locomotives pulling 10 bi-level cars with weekday peak service between Union station and Bowmanville and Union Station and Hamilton James. Off peak service would operate east and west over the same routes.
- For the Georgetown Corridor, midday and overnight storage would be at Willowbrook and Kitchener with maintenance at Willowbrook for the ARL and Georgetown corridors.

- For the Lakeshore Corridor, midday and overnight layovers would occur at a variety of locations depending on the closest location to the trip termination for the Lakeshore East and West corridors. These include Hamilton TH&B, Don Yard, Bathurst Yard, Stoney Creek, Willowbrook and the East Maintenance Facility. Maintenance of the Lakeshore West trains would occur at Willowbrook and the Lakeshore East trains at the new East Maintenance Facility.
- Provision of appropriate clearance for the OCS at all overhead structures.
- Electrifying the Georgetown and Lakeshore corridors includes the Union Station Rail Corridor and will also require:
  - o the grounding of structures, buildings, station platforms, fencing, pipelines, above-ground fuel tanks and other utilities within 250m of the nearest rail, as required;
  - o modifications to the track to ensure compatibility with electrification, including track bonding and grounding to limit induced voltages and maintain safety;
  - o modifications to the signal system to immunize against the effects of electromagnetic interference; and
  - o the provision of additional equipment in the current control center to operate the electrification system.

Table 8: Key Statistics for Option 3- Georgetown and Lakeshore

Item	Option 3			
GO Network Length	316.2	mi.	508.9	km
Electrified Length	145.7	mi.	234.5	km
Traction Power Substation			6	
Switching Stations			4	
Autotransformer Stations			4	
Bridges Rebuilt			4	
Bridges Reworked			24	
Total Bridges			28	
Locomotives				
Electric			50	
Diesel			57	
Electric Multiple Units (ARL)			12	

11.4. Option 11 – Georgetown, Lakeshore and Milton Corridors

As illustrated in Figure 18, this option includes electrification of the Georgetown, Lakeshore East and West Corridors from Bowmanville to Hamilton James and Milton corridors. The Hamilton TH& B and St. Catharines corridors on the Lakeshore West Line would not be electrified and service on these corridors would be provided by Tier 4 diesel locomotives. Service on all other corridors would also be provided by Tier 4 diesel Locomotives as per the Reference Case.

Figure 18: Option 11 – Georgetown, Lakeshore and Milton

Electrification of these 4 corridors would include the following features:

- Provision of overhead catenary to electrify the Georgetown route originating in Union Station and terminating at the Kitchener GO Transit Station. The electrified revenue service route length is approximately 100.5 kilometres.
- Provision of overhead catenary and traction power supply substations to electrify the Lakeshore East route originating in the east at Bowmanville, through Union Station and terminating at Lakeshore West Hamilton James station. The electrified revenue service route length for the Lakeshore East portion of the route is approximately 69 kilometres and the Lakeshore West portion is approximately 63 kilometres.
- Provision of overhead catenary and traction power supply substations to electrify the Milton corridor originating at Union Station and terminating at Milton Station. The electrified revenue service length for the Milton corridor is approximately 50.2 kilometres.
- Electric Multiple Units (EMUs) in two car train consists operating at 15 minute headways for the ARL service

- Electric locomotives pulling 10 bi-level cars with weekday peak service between Kitchener and Union Station. Off-peak service, weekend and holiday service would operate between Mt. Pleasant GO Transit Station in Brampton and Union Station only.
- Electric locomotives pulling 10 bi-level cars with weekday peak service between Union Station and Bowmanville and Union Station and Hamilton James. Off peak service would operate east and west over the same routes.
- Electric locomotives pulling 10 bi-level cars with weekday peak service between Union Station and Milton Station and off-peak, holiday and weekend service operating between Union Station and Meadowvale Station.
- For the Georgetown Corridor, midday and overnight storage would be at Willowbrook and Kitchener with maintenance at Willowbrook for the ARL and Georgetown corridors.
- For the Lakeshore Corridor, midday and overnight layovers would occur at a variety of locations depending on the closest location to the trip termination for the Lakeshore East and West Corridors. These include Hamilton TH&B, Don Yard, Bathurst Yard, Stoney Creek, Willowbrook and the East Maintenance Facility. Maintenance of the Lakeshore West trains would occur at Willowbrook and the Lakeshore East trains at the new East Maintenance Facility.
- For the Milton Corridor, midday and overnight layovers would occur at Union and Milton Stations. Maintenance would be at Willowbrook.
- Provision of appropriate clearance for the OCS at all overhead structures.
- Electrifying the Georgetown, Lakeshore and Milton corridors includes the Union Station Rail Corridor and will also require:
    - the grounding of structures, buildings, station platforms, fencing, pipelines, above-ground fuel tanks and other utilities within 250m of the nearest rail, as required;
    - modifications to the track to ensure compatibility with electrification, including track bonding and grounding to limit induced voltages and maintain safety;
    - modifications to the signal system to immunize against the effects of electromagnetic interference; and
    - the provision of additional equipment in the current control center to operate the electrification system.

Table 9: Key Statistics for Option 11 - Georgetown, Lakeshore and Milton

Item	Option 11			
GO Network Length	316.2	mi.	508.9	km
Electrified Length	172.1	mi.	277.0	km
Traction Power Substation			6	
Switching Stations			4	
Autotransformer Stations			7	
Bridges Rebuilt			4	
Bridges Reworked			24	
Total Bridges			28	
Locomotives				
Electric			63	
Diesel			45	
Electric Multiple Units (ARL)			12	

11.5. Option 15 – Georgetown, Lakeshore, Milton and Barrie Corridors

As illustrated in Figure 19, this option includes electrification of the Georgetown, Lakeshore East and West Corridors from Bowmanville to Hamilton James and the Milton and Barrie corridors. The Hamilton TH& B and St. Catharines corridors on the Lakeshore West Line would not be electrified and service on these corridors would be provided by Tier 4 diesel locomotives. Service on all other corridors would also be provided by Tier 4 diesel Locomotives as per the Reference Case.

Figure 19: Option15 – Georgetown, Lakeshore, Milton and Barrie

Electrification of these 5 corridors would include the following features:

- Provision of overhead catenary to electrify the Georgetown route originating in Union Station and terminating at the Kitchener GO Transit station. The electrified revenue service route length is approximately 100.5 kilometres.
- Provision of overhead catenary and traction power supply substations to electrify the Lakeshore East route originating in the east at Bowmanville, through Union Station and terminating at Lakeshore West Hamilton James station. The electrified revenue service route length for the Lakeshore East portion of the route is approximately 69 kilometres and the Lakeshore West portion is approximately 63 kilometres.
- Provision of overhead catenary and traction power supply substations to electrify the Milton corridor originating at Union Station and terminating at Milton Station. The electrified revenue service length for the Milton corridor is approximately 50.2 kilometres.
- Provision of overhead catenary and traction power supply substations to electrify the Barrie corridor originating at Union Station and terminating at Allendale Station. The electrified revenue service length for the Barrie corridor is approximately 101.3 kilometres.
- Electric Multiple Units (EMUs) in two car train consists operating at 15 minute headways for the ARL service
- Electric locomotives pulling 10 bi-level cars with weekday peak service between Kitchener and Union Station. Off-peak service, weekend and holiday service would operate between Mt. Pleasant Go Transit Station in Brampton and Union Station only.
- Electric locomotives pulling 10 bi-level cars with a weekday peak service between Union Station and Bowmanville and Union Station and Hamilton James. Off peak services would operate east and west over the same routes.
- Electric locomotives pulling 10 bi-level cars with a weekday peak service between Union Station and Milton Station and off-peak, holiday and weekend service operating between Union Station and Meadowvale Station.
- Electric locomotives pulling 10 bi-level cars with a weekday peak service originating at Union Station and terminating at Allendale Station. Off-peak, weekend and holiday service would operate between Union Station and Bradford.
- For the Georgetown Corridor, midday and overnight storage would be at Willowbrook and Kitchener with maintenance at Willowbrook for the ARL and Georgetown corridors.
- For the Lakeshore Corridor, midday and overnight layovers would occur at a variety of locations depending on the closest location to the trip termination for the Lakeshore East and West Corridors. These include Hamilton TH&B, Don Yard, Bathurst Yard, Stoney Creek, Willowbrook and the East Maintenance Facility. Maintenance of the Lakeshore West trains would occur at Willowbrook and the Lakeshore East trains at the new East Facility.
- For the Milton Corridor, midday and overnight layovers would occur at Union and Milton Stations. Maintenance would be at Willowbrook.

- For the Barrie Corridor, midday and overnight layovers would occur at Allendale, Bradford and Union Station with maintenance occurring at both the Willowbrook and new East Maintenance Facility.
- Provision of appropriate clearance for the OCS at all overhead structures.
- Electrifying the Georgetown, Lakeshore, Milton and Barrie corridors includes the Union Station Rail Corridor and will also require:
  - the grounding of structures, buildings, station platforms, fencing, pipelines, above-ground fuel tanks and other utilities within 250m of the nearest rail, as required;
  - modifications to the track to ensure compatibility with electrification, including track bonding and grounding to limit induced voltages and maintain safety;
  - modifications to the signal system to immunize against the effects of electromagnetic interference; and
  - the provision of additional equipment in the current control center to operate the electrification system.

Table 10: Key Statistics for Option 15 – Georgetown, Lakeshore, Milton and Barrie Corridors

Item	Option 15			
GO Network Length	316.2	mi.	508.9	km
Electrified Length	232.1	mi.	373.5	km
Traction Power Substation			7	
Switching Stations			4	
Autotransformer Stations			10	
Bridges Rebuilt			4	
Bridges Reworked			30	
Total Bridges			34	
Locomotives				
Electric			76	
Diesel			32	
Electric Multiple Units (ARL)			12	

11.6. Option 18 – Entire Network

As illustrated in Figure 20, this option includes electrification of all corridors including full electrification to Hamilton TH&B as well as St. Catharines.

Figure 20: Option 18 - The entire GO Transit network

Electrification of the entire GO Transit network would include the following features:

- Provision of overhead catenary to electrify the Georgetown route originating in Union Station and terminating at the Kitchener GO Transit Station. The electrified revenue service route length is approximately 100.5 kilometres.
- Provision of overhead catenary and traction power supply substations to electrify the Lakeshore East route originating in the east at Bowmanville, through Union Station and terminating at Lakeshore West St. Catharines Station and including Hamilton TH&B and Hamilton James. The electrified revenue service route length for the Lakeshore East portion of the route is approximately 69 kilometres and the Lakeshore West portion is approximately 74.5 kilometres.
- Provision of overhead catenary and traction power supply substations to electrify the Milton corridor originating at Union Station and terminating at Milton Station. The electrified revenue service length for the Milton corridor is approximately 50.2 kilometres.
- Provision of overhead catenary and traction power supply substations to electrify the Barrie corridor originating at Union Station and terminating at Allendale Station. The electrified revenue service length for the Barrie corridor is approximately 101.3 kilometres.

- Provision of overhead catenary and traction power supply substations to electrify the Richmond Hill corridor originating at Union Station and terminating at Bloomington Station. The electrified revenue service length of the Richmond Hill corridor is approximately 46.1 kilometres.
- Provision of overhead catenary and traction power supply substations to electrify the Stouffville corridor originating at Union Station and terminating at Lincolnville Station. The electrified revenue service length of the Stouffville corridor is approximately 49.3 kilometres.
- Electric Multiple Units (EMUs) in two car train consists operating at 15 minute headways for the ARL service
- Electric locomotives pulling 10 bi-level cars with weekday peak service between Kitchener and Union Station. Off-peak service, weekend and holiday service would operate between Mt. Pleasant Go Transit Station in Brampton and Union Station only.
- Electric locomotives pulling 10 bi-level cars with weekday peak service between Union Station and Bowmanville and Union Station and Hamilton James. Off peak service would operate east and west over the same routes.
- Electric locomotives pulling 10 bi-level cars with weekday peak service between Union Station and Milton Station and off-peak, holiday and weekend service operating between Union Station and Meadowvale Station.
- Electric locomotives pulling 10 bi-level cars with weekday peak service originating at Union Station and terminating at Allendale Station for the Barrie corridor. Off-peak, weekend and holiday service would operate between Union Station and Bradford.
- Electric locomotives pulling 10 bi-level cars with weekday peak service originating at Union Station and terminating at Bloomington Station for weekday peak service on the Richmond Hill corridor. Off-peak, weekend and holiday service would operate between Union Station and Richmond Hill.
- Electric locomotives pulling 10 bi-level cars with weekday peak service originating at Union Station and terminating at Lincolnville Station for Stouffville corridor. Off-peak, weekend and holiday service would operate between Union Station and Mount Joy Station.
- For the Georgetown Corridor, midday and overnight storage would be at Willowbrook and Kitchener with maintenance at Willowbrook for the ARL and Georgetown corridors.
- For the Lakeshore Corridor, midday and overnight layovers would occur at a variety of locations depending on the closest location to the trip termination for the Lakeshore East and West Corridors. These include Hamilton TH&B, Don Yard, Bathurst Yard, Stoney Creek, Willowbrook and the East Maintenance Facility. Maintenance of the Lakeshore West trains would occur at Willowbrook and the Lakeshore East trains at the new East Facility.
- For the Milton corridor, midday and overnight layovers would occur at Union and Milton Stations. Maintenance would be at Willowbrook.

- For the Barrie corridor, midday and overnight layovers would occur at Allendale, Bradford and Union Station with maintenance occurring at both the Willowbrook and new East Facility.
- For the Richmond Hill corridor, midday and overnight layovers would occur at the Bethesda, and Don Yards as well as Union Station. Maintenance would occur at both Willowbrook and the new East Facility.
- For the Stouffville corridor, midday and overnight layovers would occur at the Lincolnville and Union Stations. Maintenance would occur at both Willowbrook and the new East Facility.
- Provision of appropriate clearance for the OCS at all overhead structures.
- Electrifying the entire GO Transit rail network includes the Union Station Rail Corridor and will also require:
    - the grounding of structures, buildings, station platforms, fencing, pipelines, above-ground fuel tanks and other utilities within 250m of the nearest rail, as required;
    - modifications to the track to ensure compatibility with electrification, including track bonding and grounding to limit induced voltages and maintain safety;
    - modifications to the signal system to immunize against the effects of electromagnetic interference; and
    - the provision of additional equipment in the current control center to operate the electrification system.

Table 11: Key Statistics for Option 18 – Entire Network

Item	Option 18			
GO Network Length	316.2	mi.	508.9	km
Electrified Length	316.2	mi.	508.9	km
Traction Power Substation			7	
Switching Stations			4	
Autotransformer Stations			17	
Bridges Rebuilt*			11	
Bridges Reworked			41	
Total Bridges			52	
Locomotives				
Electric			107	
Diesel			0	
Electric Multiple Units (ARL)			12	
** Includes the Hunter Street Tunnel*				

12. MULTIPLE CATEGORY EVALUATION – FINDINGS & CONCLUSIONS

Based on the findings of the high level evaluation, it was concluded that Electric Locomotive trains would be the technology to be taken forward to the detailed evaluation stage of this Electrification Study. In the case of the Airport Rail Link, it is assumed that the initial deployment of Diesel Multiple Units (DMUs) will be converted to by Electric Multiple Units (EMUs) if the Georgetown line is electrified either in part or in full.

This section presents a detailed analysis on the "short list" of 6 network options informed by the high level evaluation of sections of the network.

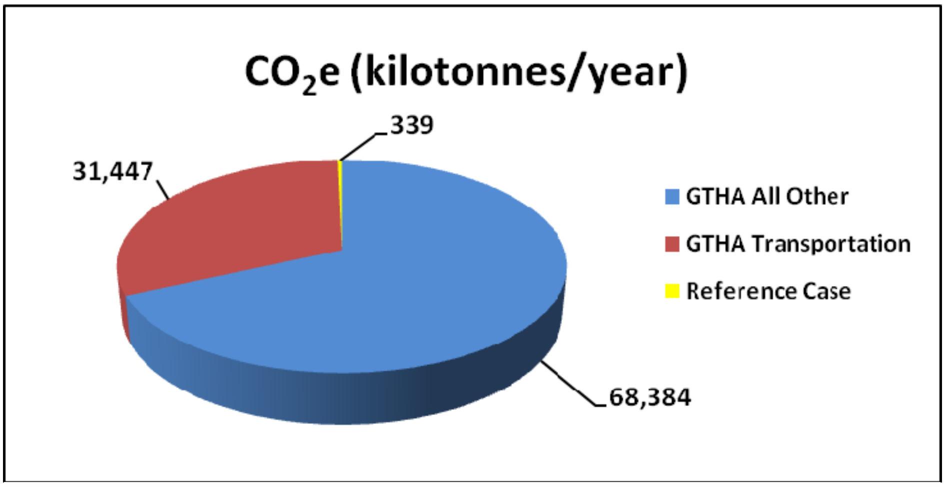
These six network options are evaluated using the Multiple Category Evaluation (MCE) methodology, systematically comparing the impacts on costs, users, environment, economy and community, and illustrating the trade-offs among the often conflicting criteria. A detailed evaluation of each subcategory from the MCE was carried out and the assessment of the options relative to the Reference Case is presented in the MCE Summary Table, Table 17 at the end of this section.

The detailed MCE Findings and Conclusions are found in Appendix 9 of this report.

12.1. Environment and Health

Trains propelled by electricity emit less Greenhouse Gases (GHG) and Critical Air Contaminant (CAC) than the emission standards of the Tier 4 diesel-electric locomotive. However, as shown in Figure 21, GO Transit Rail's contribution to GHG is very small compared to the overall emissions from transportation in Ontario.

Figure 21: Current Annual GHG Emissions in GTHA



By electrifying larger sections of the GO Transit Rail network, greater GHG reductions can be achieved – electrifying the entire network would deliver a 94% reduction of GO Transit Rail's future contribution to GHG emissions, although this reduction would only be a small fraction (0.32%) of the overall region's emissions. Nevertheless, all options with the exception of Option 1 (the electrification of the Georgetown line) meet or exceed the Big Move's Regional Transportation Plan strategic target of reducing GHG emissions per passenger by 25%.

Electric trains do not emit CAC from the locomotives, but rather at the source of electricity generation. The impacts of CAC on the local community and adjacent sensitive receptors were considered, and the more the network is electrified, the more people benefit from improved air quality. However, analysis of the concentrations of air contaminants such as particulate matter ($PM_{2.5}$), NO_x and SO_x with Tier 4 Diesel locomotives shows that the impact of the Reference Case service levels would already be well below the stringent World Health Organization standards. As more corridors are electrified, the local air quality improves, but the health benefit associated with electrification is likely to be relatively small.

The study also investigated the potential impact of electromagnetic fields (EMF) from overhead power lines and OCS. There are numerous and inconclusive epidemiological studies on this topic and there is no consistent relationship between electromagnetic fields and health issues.

While operating an electrified system has increased safety risks for trespassers and workers (i.e. risks such as arching from metal structures), this can be mitigated by the appropriate signage, protection and education as demonstrated in systems around the world.

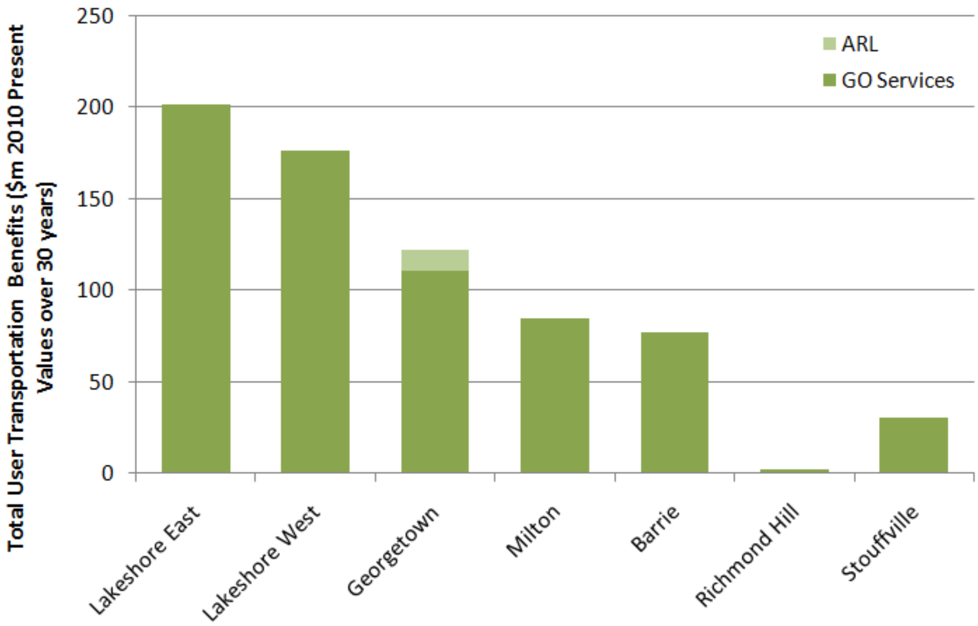
There is a slight reduction in noise and vibration due to electric locomotives being slightly quieter. However, the differences in noise levels between diesel and electric locomotive trains would not generally be perceivable because the noise levels due to the coaches are common to both train sets.

The assessment of each option under the Environmental and Health considerations is presented in the MCE summary table, Table 17 at the end of this section.

12.2. User Benefits/Quality of Life

Electric locomotives produce journey time savings because of higher performance characteristics meaning that they accelerate and decelerate more rapidly. For example, the time savings using an electric locomotive train from Hamilton to Union station would save passengers 7 minutes. The more corridors electrified, the greater the time saving benefits, with Option 18 delivering almost $700m in 2010 present values in user benefits over the evaluation period. Figure 22 breaks down the user journey time savings by corridor.

Figure 22: Total User Journey Time Savings by Corridor ($m 2010 Present Values)



Almost half of the total journey time benefits can be delivered through the electrification of the Lakeshore East and West corridors (Option 2), as it has the highest ridership. As illustrated in Figure 23, the average journey time savings per passengers on electrified corridors are between 2 to 3 minutes, modestly increasing the overall transportation efficiency of the GO Transit Rail network. It should also be noted that time savings offered by electric locomotives do not offer the more significant change in journey time improvements offered by EMUs.

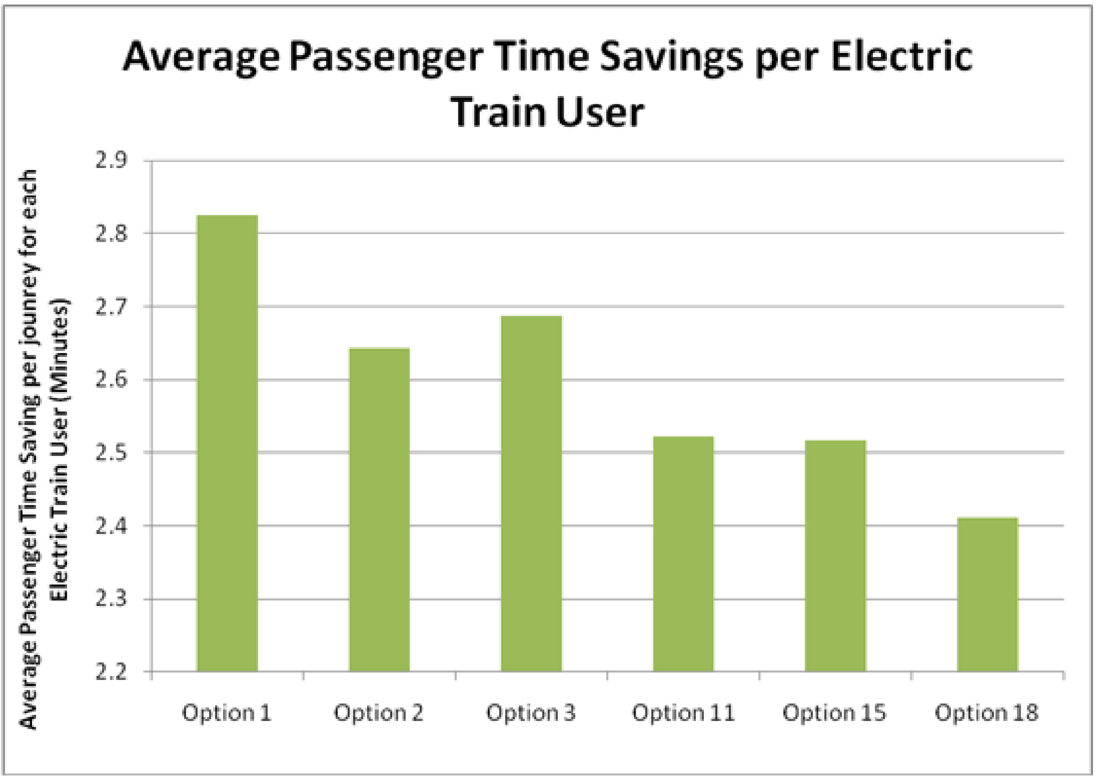
The journey time savings are expected to result in an increase in GO's ridership by around 4%, or more than 10,000 additional GO Transit Rail journeys per day by 2031. As illustrated in Figure 23, the faster electric trains will encourage modal shift from car to GO Transit Rail – a fully electrified network is expected to remove 1.6 million auto trips per annum by 2031, thereby slightly increasing the overall transit mode share of the region. The reduced vehicle kilometres travelled would result in highway decongestion for non-users and a reduction in vehicle operating costs and collision costs.

Initially, the reliability of services is likely to be lower when new electric trains are introduced. As initial technical issues are resolved, electric locomotive trains are typically more reliable than diesel locomotive trains in the longer term, but overall the reliability benefits to passengers are not significant given that failures due to locomotives are relatively infrequent.

Electrification does not add any new stations or increase the service levels / capacity above the Reference Case and therefore it does not materially change the access to the transit system or enhance comfort/capacity to passengers.

The assessment of each option under the User Benefits/ Quality of Life considerations is presented in the MCE summary table, Table 17 at the end of this section.

Figure 23: Average Journey Time Savings per Passenger



12.3. Social and Community

From the social community perspective, all six options will have residents, and users of community, institutional and recreation features within the zones of influence experiencing some negative social community impacts due to visual impacts of the Overhead Contact System (OCS), substations and autotransformers. These impacts can be particularly adverse in sections of each corridor, although there are ways to partially mitigate these impacts. In addition, the construction impacts – primarily dust and noise – will also have a negative impact on the social community.

The need for grounding within 250m of the nearest rail, as required, for structures, buildings, station platforms, fencing, pipelines, above-ground fuel tanks and other utilities, may negatively interfere with and impact adjacent properties.

The assessment of each option under the Social and Community considerations is presented in the MCE summary table, Table 17 at the end of this section.

12.4. Economic

The Reference Case presents a point in time which was established for the purposes of comparison without burdening Electrification with the proposed development and service plans that are planned regardless of the technology. The major factors in the economic analysis include the life cycle (30 year) costs of changing the technology. This includes the incremental difference between the capital costs of the Tier 4 diesel versus the electric locomotive. The life-cycle cost benefit analysis undertaken has suggested that as more corridors are electrified, more transportation benefits can be delivered. The results are presented in Table 12.

Table 12: Detailed 30 Year Life-Cycle Transportation Appraisal of Electric Locomotive Trains (All Figures in $m Discounted at 5% p.a. to 2010 Present Values)

Electric Locomotives: Transportation Appraisal Impacts (All figures in $m and Discounted at 5% p.a. to 2010 Present Values)	**Option 1** **Georgetown + ARL**	**Option 2** **Lakeshore:** Hamilton James to Bowmanville	**Option 3** **Option 1+2**	**Option 11** **Option 3 plus Milton**	**Option 15** **Option 11 plus Barrie**	**Option 18** **Full Network**
Infrastructure Capital Costs	521	764	1,089	1,251	1,584	2,369
Rolling Stock Capital Costs	62	91	139	212	310	543
Operations & Maintenance Costs	-88	-337	-424	-506	-595	-697
Incremental Revenues	-23	-50	-73	-86	-96	-109
TOTAL PRESENT VALUE COSTS	**473**	**467**	**731**	**871**	**1,204**	**2,106**
Journey Time Saving Benefits	145	409	554	657	752	845
Reliability Benefits	1	3	4	5	6	7
Auto Cost Savings	24	105	129	154	181	206
TOTAL PRESENT VALUE BENEFITS	**169**	**518**	**687**	**816**	**939**	**1,058**
Net Present Value (NPV)	**-303**	**50**	**-44**	**-55**	**-265**	**-1,048**
BENEFIT COST RATIO (BCR)	**0.36**	**1.11**	**0.94**	**0.94**	**0.78**	**0.50**

In terms of cost effectiveness, Option 2 (Lakeshore) provides the highest value for money in terms of delivering transportation benefits with a Benefit Cost Ratio (BCR) of 1.1:1, followed by Option 3 (Lakeshore, Georgetown) and Option 11 (Lakeshore, Georgetown, Milton), both at 0.9:1. For every dollar invested, there is approximately a dollar in benefits in return over the life-cycle. These options perform better primarily because they are the most intensively used corridors – more passengers benefit from time savings, while a high level of service also gives significant operating and maintenance cost savings.

The remaining options (1, 15 and 18) offer notably lower value for money in delivering transportation benefits. Option 1 (Georgetown) performs poorly with a BCR of 0.4:1 because electrifying the Georgetown line alone does not have the critical mass in transportation benefits to offset the initial capital expenditure of electrifying large sections of the Union Station Rail Corridor. To electrify the Airport Rail Link alone would have a lower BCR because it would incur most of the infrastructure costs but have limited journey time savings compared to Option 1 in its entirety. Options 15 and 18 involve electrifying corridors that are not as intensively used; they also require the premature replacement of existing diesel locomotives, meaning that they are not as cost effective.

In terms of delivering GHG reductions, Option 2 is the most cost effective, followed by Option 3 and 11, and the same order holds when the cost per new rider is considered. As there are limited health benefits associated with CAC reductions, a cost effectiveness measure for each CAC chemical has not been employed in the evaluation, although the relative performance of each option is unlikely to be different to the order based on the cost effectiveness of GHG reductions.

Electrifying the GO Transit Rail network is expected to generate economic benefits during construction (due to construction employment) and in operation (due to faster commutes, less congestion), which in turn increase the economic output of the region. Option 2 also delivers the most long term economic benefits per capital invested.

Due to faster journey times and slightly improved air quality, noise and vibration, property prices along the electrified rail corridor could benefit from a slight increase in value, although some properties immediately overlooking the OCS may result in a decrease in value, depending on site-specific conditions.

The assessment of each option under the Economic considerations is presented in the MCE summary table, Table 17 at the end of this section.

12.5. Financial

The incremental capital cost of electrifying the entire GO Transit Rail network is approximately $4.0 billion in 2010 prices (excluding inflation). This includes the infrastructure capital costs (primarily comprising of site enabling works and power system works), shown in Table 13 and rolling stock costs, shown in Table 14. These high level costs were estimated in advance of any detailed design work and in order to capture the variability in potential cost at this early stage of the project, the infrastructure capital cost components include a contingency range of 35-55% depending on the level of risk considered. It should be noted that the capital cost estimate captures only the additional requirements to operate electric trains over and above the Reference Case. It does not include other infrastructure and rolling stock requirements to meet the Reference Case level of service. Total incremental capital cost estimates (infrastructure and rolling stock) are shown in Table 15.

This incremental capital cost is partially off-set by the operating and maintenance cost savings of the electric locomotive. Electric trains provide additional revenues due to an increased demand from transit time savings, and as a result all options reduce the net annual operating costs (and therefore subsidy). Electrifying the entire network would result in almost $79m savings per annum by 2031 in real 2010 prices (see Table14), although a significant proportion of these cost savings would only materialize on the assumption that the price of diesel increases at twice the rate of electricity.

Table 13: Total Incremental Infrastructure Capital Costs by Option ($m 2010 prices)

Option	Infrastructure Capital Cost Estimate ($ million in 2010 prices)								Total Infrastructure Capital Cost Estimate Range		
	Catenary System	Power Supply System	Maintenance & Layover Facilities, vehicles	Overhead structures rework	Infrastructure rework costs	Sitework & special conditions	Professional services	Sub-Total cost	Total (35 % Contingency)		Total (55 % Contingency)
OPTION 1 - Georgetown	$158	$71	$54	$16	$46	$135	$37	$517	$699	to	$802
OPTION 2 - Lakeshore	$264	$119	$72	$25	$46	$182	$48	$755	$1,019	to	$1,170
OPTION 3 - Georgetown & Lakeshore	$365	$165	$88	$27	$57	$287	$71	$1,060	$1,431	to	$1,643
OPTION 11 - Georgetown, Lakeshore, Milton	$415	$187	$95	$27	$70	$335	$82	$1,210	$1,633	to	$1,875
OPTION 15 - Georgetown, Lakeshore, Milton & Barrie	$508	$229	$109	$29	$98	$437	$107	$1,517	$2,047	to	$2,351
OPTION 18 - Georgetown	$615	$277	$136	$312	$126	$576	$193	$2,236	$3,019	to	$3,466

Table 14: Total Incremental Rolling Stock Capital Costs by Option ($m 2010 prices)

Option	Incremental Rolling Stock Capital Costs ($m 2010 prices)
Option 1 - Georgetown	84
Option 2 – Lakeshore	123
Option 3 – Georgetown & Lakeshore	188
Option 11 – Georgetown, Lakeshore & Milton	288
Option 15 - Georgetown, Lakeshore, Milton & Barrie	421
Option 18 – Entire Network	736

Table 15: Total Capital Cost Estimate Range (Infrastructure and Rolling Stock)

Option	Total Capital Cost Estimate Range (Infrastructure and Rolling Stock) ($m 2010 prices)		
OPTION 1 - Georgetown	$783	to	$886
OPTION 2 - Lakeshore	$1,142	to	$1,293
OPTION 3 - Georgetown & Lakeshore	$1,619	to	$1,831
OPTION 11 - Georgetown, Lakeshore, Milton	$1,921	to	$2,163
OPTION 15 - Georgetown, Lakeshore, Milton & Barrie	$2,468	to	$2,772
OPTION 18 - Georgetown	$3,755	to	$4,202

Table 16: Annual Operating and Maintenance Cost Savings by Option ($m 2010 prices)

Option	Annual Operating and Maintenance Costs Savings ($m 2010 prices)	Annual Operating and Maintenance Cost Savings in 2021 with real inflation	Annual Operating and Maintenance Cost Savings in 2031 with real inflation
Option 1 - Georgetown	-3	-7	-10
Option 2 – Lakeshore	-15	-26	-38
Option 3 – Georgetown & Lakeshore	-18	-33	-48
Option 11 – Georgetown, Lakeshore & Milton	-21	-39	-57
Option 15 - Georgetown, Lakeshore, Milton & Barrie	-25	-45	-67
Option 18 – Entire Network	-29	-53	-79

The assessment of each option under the Financial considerations is presented in the MCE summary table, Table 17 at the end of this section.

12.6. Deliverability

The electrification of an operational railway network will pose construction challenges in order to reduce the impact to transit users, other passenger and freight service operators and the local community. It is anticipated that the construction works would not require closures to the railways during the day, while freight services running overnight may use diverted routes where possible to minimize disruption. However, some disruption must be expected.

All options involve the electrification of sections of track not currently owned by GO, which means that further investigations on the acceptance of CN and CP should be established. The construction techniques themselves are not especially challenging and all options are buildable, although the reconstruction of the tunnel approaching Hamilton TH+B could present engineering and disruption issues for Option 18.

The assessment of each option under the Deliverability considerations is presented in the MCE summary table, Table 17 at the end of this section.

12.7. Risk and Uncertainties

The risks associated with electrification were considered extensively and in most cases these have been factored into the costing or other parts of the assessment. The key risks would be that other operators such as CN and CP may set exacting requirements for electrifying corridors owned by them which make electrification no longer justified. This affects all options to a certain extent, and detailed discussions with CN and CP would be required if the project was to be taken forward to the next stage of design and development.

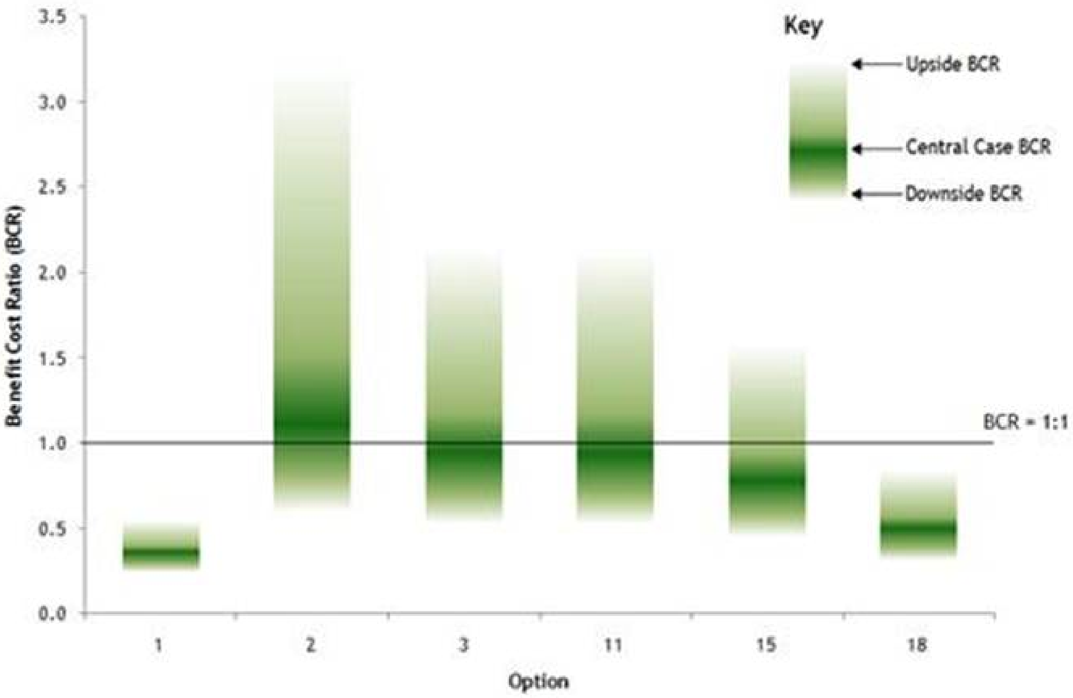
The transportation Benefit Cost Ratio (BCR) takes into account the monetized impacts over the project life cycle, and this depends on a number of key assumptions, including the deliverability of the Reference Case. A wide range of sensitivity tests were conducted, including sensitivity to assumptions regarding infrastructure capital costs, rolling stock capital costs, operating and maintenance costs, energy cost inflation, and ridership/demand forecasts. Scenarios tested include alternative service levels and optimized numbers of rolling stock.

The sensitivity and scenario tests concluded that while there is potentially a wide range of BCRs depending on various assumptions, overall, the relative performance of each option still holds. Option 2 (Lakeshore) consistently emerges as the best performing option while Option 3 (Lakeshore and Georgetown) and Option 11 (Lakeshore, Georgetown and Milton) remain very similar in BCR terms relative to one another. Having considered the range of likely uncertainties, Option 1 (Georgetown) and Option 18 (Entire Network) are unlikely to deliver a BCR greater than 1:1, and the justification of pursuing those options in the timeframe of this Study would have to be supported by other non-monetized benefits.

Figure 24 summarizes the range of BCRs given the plausible outcomes of the factors affecting the assessment. It shows that when all the upsides and downsides are considered together as defined above, the potential range of BCRs can be quite significant.

As a proxy for the likelihood of the BCR being in a particular range, the darker green shades represent the zone where there is a higher confidence level of the BCR being in the range. It shows that Option 2 overall is likely to have a BCR above 1:1 with the possibility of being significantly higher, while Options 3 and 11 both perform similarly and have a fair chance of delivering a BCR higher than 1:1. Options 1 and 18 are not expected to yield a BCR greater than unity under the current evaluation framework with the range of scenarios tested.

Figure 24: Sensitivity and Scenario Tests – Range of BCRs



SUMMARY OF KEY MULTIPLE CATEGORY EVALUATION FINDINGS AND CONCLUSIONS

ENVIRONMENT AND HEALTH

- Electric trains do not emit Greenhouse Gases (GHG) from the locomotives, but rather at the source of electricity generation. Trains propelled by electricity emit less GHG than diesel trains. By electrifying larger sections of the GO Transit rail network, greater GHG reductions can be achieved. Electrifying the entire network would deliver a 94% reduction in GO Transit's future GHG emissions, although this reduction would only be a small fraction (0.32%) of the overall region's emissions.
- Electric trains do not emit Critical Air Contaminants (CAC) from the locomotives, but rather at the source of electricity generation. The more the network is electrified, the more people benefit from the improved air quality. However, analysis of the concentrations of air contaminants such as particulate matter ($PM_{2.5}$), NO_x and SO_x with Tier 4 Diesel locomotives shows that the impact of the Reference Case service levels would already be well below the stringent World Health Organization standards. As more corridors are electrified, the local air quality improves, but the health benefit associated with electrification is likely to be marginal.
- There are also regional and local air quality improvements due to electrification, but as GO Transit has already committed to operating diesel locomotives which are compliant with Tier 4 emission standards in the medium term horizon, the incremental impact of electrification, in the context of health, is relatively modest.
- There are numerous and inconclusive epidemiological studies on electromagnetic fields (EMF) from overhead power lines and OCS; there is no consistent relationship between electromagnetic fields and health issues.
- There is a slight reduction in noise and vibration due to electric locomotives being slightly quieter than diesel. However, the differences in noise levels between diesel and electric locomotive trains would not generally be perceivable due to the noise levels of the coaches which are common to both train sets.

USER BENEFITS/QUALITY OF LIFE

- Due to faster acceleration and deceleration, journey time savings can be achieved with electric locomotives as compared to diesel locomotives.
- Depending on the option, the average time saving per passenger trip from electrification would be between 2.4 and 2.8 minutes.
- The greatest journey time benefits are realized from electrifying Lakeshore (due to most ridership) followed by Georgetown. The least benefits would result from electrifying Richmond Hill (due to line speeds and track curvature that restrict potential transit time savings).
- Electric locomotive trains are typically more reliable than diesel locomotive trains, but overall the reliability benefits to passengers are not significant given that failures due to engine breakdowns are relatively infrequent.

SOCIAL AND COMMUNITY

- The Georgetown Corridor has the most people living closest to the corridor and its electrification may provide the greatest impacts and benefits - although the benefits are modest.
- Overhead catenaries, substations and autotransformer stations are likely to result in negative visual impacts.
- The need for grounding within 250m of the nearest rail, as required, for structures, buildings, station platforms, fencing, pipelines, above-ground fuel tanks and other utilities, may negatively interfere with and impact adjacent properties.

ECONOMIC

- Journey time savings translate to benefits to users and improve the economic competitiveness of the region.
- Electrifying the GO Transit Rail network is expected to generate employment during construction and in operation which in turn increases the economic output of the region.
- Due to faster journey times and slightly improved air quality, noise and vibration, property prices along the electrified rail corridor could benefit from a slight increase in value, although some properties immediately overlooking the overhead catenary system may result in a decrease in value, depending on site-specific conditions.

FINANCIAL

Capital Costs

- Electrification of any option would involve a significant capital investment, with incremental capital cost estimates ranging from about $900 million for the electrification of the Georgetown line only (Option 1) to over $4 billion for the electrification of the entire network.
- Electrification of Lakeshore and Georgetown together is notably lower than the sum of the individual parts because when both are electrified, there are cost synergies.

Operating and Maintenance Costs

- The cost of energy provided by diesel fuel is greater than the cost of energy derived from an electrical system, and cost of diesel fuel is expected to increase at a greater rate than electricity.
- There are significant uncertainties over cost of electricity and diesel in the future.
- Electric Locomotives are less expensive to maintain than diesel locomotives. Annual operating and maintenance cost savings are estimated at about $7 million for the electrification of the Georgetown Corridor only (Option 1) and $53 million for the electrification of the entire network (option 18), 2021 values with real inflation.

Revenue

- Faster acceleration and deceleration of electric trains reduce journey times which attract additional riders and generate increased farebox revenue.

DELIVERABILITY

Ownership

- Electrification would be easier to implement on GO Transit owned corridors as these are expected to require fewer negotiations.
- Electrification of freight corridors would need to be negotiated with CN and CP.

Bridge Replacements

- Eleven bridge replacements would be required to electrify the entire network. Of these, three are needed on the Georgetown corridor and four are needed for Lakeshore.

Reference Case

- There is a need to consider the phasing and coordination of the reference case infrastructure required to deliver the increased service with the electrification work.

OVERALL CONCLUSION

There are transportation and economic benefits to electrification. There are also small environmental, social and community benefits. Health benefits are expected to be marginal. Electrification of any option would involve a significant capital investment, but would result in some operations and maintenance cost savings.

Of the options considered, electrifying the Lakeshore corridor between Bowmanville and Hamilton James (Option 2) is the most cost effective option in delivering these benefits, while the inclusion of the Georgetown (Option 3) and Milton corridors (Option 11) delivers higher levels of benefits without significantly reducing the cost effectiveness of implementing those options.

The transportation Benefit Cost Ratio (BCR) takes into account the monetized benefits and costs over the project life cycle, and depends on a number of key assumptions. A wide range of sensitivity tests were conducted on these assumptions, including infrastructure capital costs, rolling stock capital costs, operating and maintenance costs, energy cost inflation, and ridership/demand forecasts.

The results of the sensitivity analysis indicated that the BCR of each option was:

- relatively sensitive to the infrastructure capital costs, incremental O&M cost savings and energy cost inflation assumptions;
- moderately sensitive to ridership/demand forecasts; and
- relatively insensitive to incremental rolling stock capital costs.

The sensitivity tests also indicated that while each option's BCR could vary widely depending on the various assumptions, the relative performance of each option still held:

- Option 2 (Lakeshore) consistently emerged as the best performing option, with a BCR likely to be above 1:1 and possibly significantly higher;
- Option 3 (Lakeshore and Georgetown) and Option 11 (Lakeshore, Georgetown and Milton) remained very similar in BCR terms relative to one another, with a fair chance of delivering a BCR higher than 1:1;
- Options 1 and 18 did not yield a BCR greater than one under the current evaluation framework and the range of sensitivities tested.

Table 17: Multiple Category Evaluation Summary Table

Impact Scale						
Strong Positive	Moderate Positive	Slight Positive	Neutral/No Impact	Slight Negative	Moderate Negative	Strong Negative

Category	Sub-Category	Measure	Option 1 Georgetown	Option 2 Lakeshore (excl.TH+B/St Cat)	Option 3 Lakeshore* + Georgetown	Option 11 Lakeshore*, Georgetown, Milton	Option 15 Lakeshore*, Georgetown, Milton, Barrie	Option 18 All Corridors (incl. TH+B and St Cat)
Environmental and Health	Greenhouse Gas and Climate Change	Regional Greenhouse Gases Reductions - Qualitative assessment based on the overall impact on climate change	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive
		Percentage reduction in GO Transit Rail's total GHG contributions (note: excludes modal shift emission reductions)	15%	40%	55%	64%	78%	94%
	Regional Air Quality	Regional Air Quality - Qualitative assessment based on reduced CACs emitted by GO Transit Rail to the region	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive
	Local Air Quality	Local Air Quality - Qualitative Assessment based on the impact on reduced CAC and the population who benefit from it	Slight Positive	Slight Positive	Moderate Positive	Moderate Positive	Moderate Positive	Moderate Positive
		Value of Health Benefits - Based on reduction of GO Transit Rail's contribution to regional smog ($m per annum 2010 prices)	4	7	11	13	15	18
	Other Health	Physical Fitness - Qualitative assessment based on the number of additional transit users	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive
		Electro-Magnetic Fields (EMF) - Qualitative assessment based on guidelines by the Institute of Electrical & Electronics Engineers	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact
		Qualitative assessment based on the change in safety hazard of the railway network after mitigation measures are in place	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact
	Noise and Vibration	Noise - Qualitative assessment based on the change in noise levels and the population who benefit from it	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Slight Positive	Slight Positive
		Vibration - Qualitative assessment based on the change in vibration levels and the population who benefit from it	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Slight Positive	Slight Positive
	Terrestrial Ecosystem	Qualitative assessment based on the impacts towards the terrestrial ecosystem's natural heritage	Slight Negative	Slight Negative	Slight Negative	Slight Negative	Slight Negative	Slight Negative
	Aquatic Ecosystem	Qualitative assessment based on the impacts towards the aquatic ecosystems natural heritage	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Slight Negative
	Effect on Parks / Public Open Space	Qualitative assessment based on the likely impacts towards parks and open spaces used by the local community	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact
User Benefits / Quality of Life	Transportation Efficiency	Average Journey Time Saving of Electric Train User (mins per passenger)	2.8	2.6	2.7	2.5	2.5	2.4
		Total Journey Time Saving ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	122	334	456	541	617	692
		Journey time benefits for highway users ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	23	75	98	117	135	153
		Reduction in Auto operating costs ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	41	136	176	209	242	275
		Reduction in vehicle collisions ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	6	20	26	30	35	40
	Reliability	Passenger Reliability Benefits ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	0.8	3.1	3.9	5.0	6.1	7.2
	Transit Network/	Qualitative assessment based on the improvement of accessibility of transit	Neutral/No	Neutral/No	Neutral/No	Neutral/No	Neutral/No	Neutral/No

Category	Sub-Category	Measure	Option 1 Georgetown	Option 2 Lakeshore (excl.TH+B/St Cat)	Option 3 Lakeshore* + Georgetown	Option 11 Lakeshore*, Georgetown, Milton	Option 15 Lakeshore*, Georgetown, Milton, Barrie	Option 18 All Corridors (incl. TH+B and St Cat)
	System Access		Impact	Impact	Impact	Impact	Impact	Impact
	Comfort and Expandability	Qualitative assessment based on the change in crowding levels on the trains and GO's ability to expand capacity accordingly	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact
Social Community	Land Use Integration	Qualitative assessment based on how improved transit can help shape communities and link up key activity centres	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive
	Social and Community	Qualitative assessment based on the perceived impacts towards the local communities	Moderate Negative	Moderate Negative	Moderate Negative	Moderate Negative	Slight Negative	Moderate Negative
Economic	Cost-Effectiveness	Transportation Benefit:Cost Ratio (BCR)	0.4 :1	1.1 :1	0.9 :1	0.9 :1	0.8 :1	0.5 :1
		Cost per New Rider in 2031 ($m Capex/new daily passenger)	0.44	0.26	0.27	0.26	0.30	0.41
		Tonnes of GHG saved (from technology and modal shift) per annum per $10m capital cost	670	1,220	1,170	1,140	1,060	840
		Long Term Economic (GDP+Wages) PV Benefits per $10m capital cost	3.2	7.2	6.5	6.4	5.7	4.2
	Land Use and Property Development	Qualitative assessment based on the influence on land use and potential for development	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive
	Property / Land Take	Qualitative assessment based on the property/land required to implement the option	Slight Negative	Slight Negative	Slight Negative	Slight Negative	Slight Negative	Slight Negative
	Wider Economic Impacts During Construction	Incremental GDP and wages due to construction ($m Real 2010 prices)	270-460	310-500	470-760	570-870	680-1,060	1,210-1,850
		Number of regional jobs created due to construction (Employment-years)	2,100-3,500	2,400-3,800	3,600-5,800	4,500-6,800	5,200-8,200	9,700-14,800
	Wider Economic Impacts During Operations	Incremental GDP and wages in the long term due to improved transit times ($ per annum in 2031)	15	49	64	74	87	97
		Number of regional jobs in the long term due to improved transit times (Employment-years in 2031)	160	500	660	770	890	1,000
	Taxes	Effect/increased provincial and federal taxes in 2031 ($m per annum)	4	14	19	22	25	28
Financial	Capital Cost	Incremental Capital Cost ($m 2010 prices, i.e. excluding inflation)	790	1,160	1,660	1,980	2,570	3,950
		Incremental Capital Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	580	850	1,230	1,460	1,890	2,910
	Total Life Cycle Cost	Life Cycle Present Value Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	470	470	730	870	1,200	2,110
	Operating Cost	Incremental Operating and Maintenance Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	-90	-340	-420	-510	-590	-700
	Total Revenues	Incremental revenues of the transit network ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	23	50	73	86	96	109
	Operating Sustainability	Reduction in Operating Subsidy in 2031 ($m Real 2010 prices per annum)	-15	-49	-64	-76	-88	-103
Deliverability	Constructability	Qualitative assessment of the construction constraints, techniques and impacts to transit users	Slight Negative	Moderate Negative	Moderate Negative	Moderate Negative	Strong Negative	Strong Negative
	Acceptability	Qualitative assessment of public and stakeholder (owner and operator) acceptance of each option	Slight Negative	Moderate Negative	Moderate Negative	Moderate Negative	Strong Negative	Strong Negative

13. ELECTRIFICATION OPTIONS IMPLEMENTATION

13.1. Introduction

The implementation of the Electrification Options on the existing GO Transit network that is an operating railway presents a number of challenges. Each option has been considered with regard to the assumptions listed below and the information gathered during the Baselining exercise as presented in Appendix 3 of this report.

13.2. Key Assumptions

The following key assumptions have been made when considering the implementation of each option.

- **Reference case infrastructure**: It is assumed that the infrastructure construction work that is planned in the reference case will have been completed before any electrification construction work takes place. It is also assumed that the increases in the service levels proposed in the Reference Case will be operating whilst the electrification construction work is taking place.
- **Timing**: For each option the sequencing of each section has been carefully considered taking into account the potential disruption to the GO Transit service. It is assumed that up to 2 construction fronts would be feasible at any one time.
- **Availability of track**: In discussions with GO Transit it was agreed that the access to the track for overhead working would be restricted to non service periods of operation, and that limited access for working adjacent to the track such as foundation installation or utility diversions would be permitted where the number of tracks allows working on one track with a flagging operation controlling the other tracks.
- **Union Station:** The current refurbishment of Union Station is assumed to have been completed with sufficient room having been allowed vertically for the installation of the over head catenary system. Examination of the available drawings suggests that there is sufficient room for an overhead catenary system to be installed, but a detailed survey and design is required to confirm this assumption. It is assumed that sufficient working space and access would be allowed within Union Station trainshed during the operational periods of the GO Transit service to allow grounding work to be carried out. Installation of the electrical system would be carried out when service levels permit, or during non working hours. It is assumed that the issues relating to heritage and conservation have been discussed during the Environmental Assessment of the current refurbishment, and that there are no unforeseen restrictions.
- **ARL:** The ARL service is assumed to be fully operational to the timetable proposed and that no restrictions to the service will be allowed. Work will be carried out during non service periods, and on adjacent tracks as permitted. The design of the equipment to be installed on the elevated sections of the ARL spur to the Airport will require coordination and agreement from GTAA. It is assumed that preliminary agreement will have been obtained during the construction of the spur, and that the support details incorporated during the spur construction would be available to the design team for electrification.

- **Maintenance Facilities:** It is assumed that the proposed new maintenance facility at Whitby would be fully functional and equipped for diesel train operation, but constructed to accommodate the future provision of electrification including all grounding within the building, the necessary clearances for OCS, the provision of overhead crainage that can accommodate or be modified to accommodate the OCS within the building and the space required for the installation of the specific maintenance equipment required by the electric locomotives.

  The conversion of the maintenance facilities varies for each option and assumes that with the exception of Option 2 - Lakeshore the electric GO Transit Trains and ARL trains would be serviced at Willowbrook, and then as the electrification reaches the East yard at Whitby it would be converted and used as the service levels increase.

  The decommissioning of any layover equipment and diesel refuelling is assumed to take place only in Option 18, when the diesel service is phased out. The electric trains would be shunted in and out of the maintenance shed at Willowbrook by a converted existing diesel locomotive, and that this would be replaced by a new smaller more efficient diesel locomotive in option 18 as all the existing diesel locomotives are phased out.

- **Working Hours:** The working hours for construction are limited to non service hours, restricted flagged working on corridors where the number of tracks allows, and a limited number of planned track occupancies, specifically for activities such as the replacement or jacking of overhead structures.

- **Reference Case service levels:** The Reference Case increases the frequency of trains on each corridor to 2 way all day service which significantly reduces the available working time. It is assumed that planned track occupancy would be allowed and approved by the owners of the track and the operating companies when required to allow efficient delivery of the electrification contracts.

- **Environmental Assessments:** As part of the preliminary design for each option an Environmental Assessment will be carried out. Where the option involves more than 2 corridors, a series of submissions would be made as the project progresses. This is shown on the indicative schedule in Appendix 10.

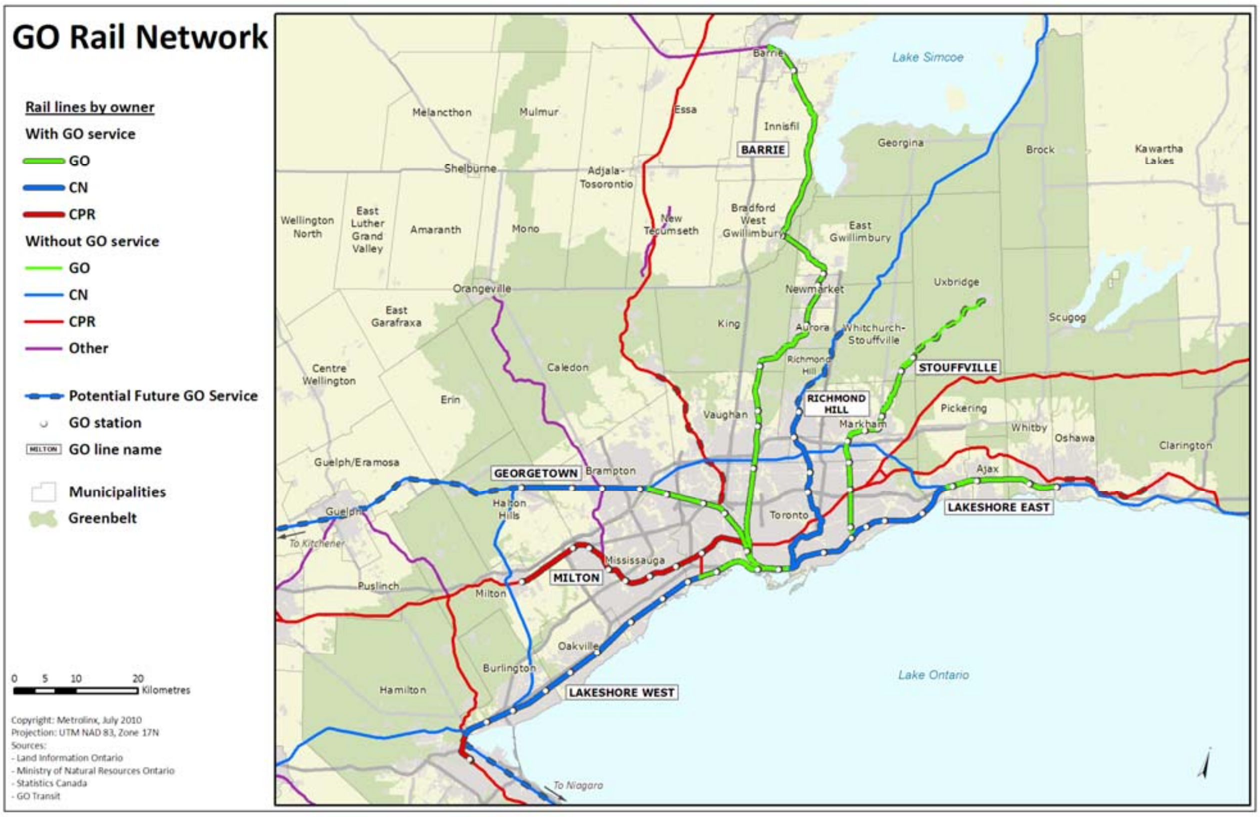
- **Stakeholder Engagement:** Stakeholder engagement will be carried out throughout the design and construction of the project.

- **CN / CP constraints:** The GO Transit rail network corridors are owned by GO, CN and CP, as shown in Figure 25 and all 3 companies operate train services on all of the corridors. Construction work on each corridor will require the detailed design and construction proposals to be reviewed and agreed before construction contracts are awarded. Required working arrangements will need to be coordinated to meet the requirements of GO, CN and CP and incorporated into the design and construction contracts.

  The indicative schedule assumes that these discussions take place during the preliminary design phase of each option as design proposals are being developed and before the environmental assessment is submitted.

- **Purchase of Locomotives:** Locomotive design and procurement would not start until after the Environmental Assessment has been approved and would be separate contracts for the procurement of the Electric Locomotives for GO Transit service and the retrofitting of the ARL trains.
- **Construction Sequence:** For operational requirements all tracks within the Union Station Rail Corridor either West or East will be electrified for every option. This allows for the unplanned closure of a switch or section of track in the approaches to Union Station and reduces delays to scheduled services.
- **Construction Packages:** The construction packages may be split into scope specific packages and then into specific sections, for example;
    - Enabling Works.
    - Power Systems OCS Work.
    - Supply contract for the substations.
    - Signals system upgrades across the whole electrified network in conjunction with CN.
    - Hydro One would be responsible for the connection of each substation to the grid.
    - Maintenance and storage facilities upgrades excluding the installation of the OCS.
- **Corridor Ownership:** The complexity of the ownership of each corridor is shown on 524 below. The selection of each construction section and the determination of the sequence of phasing each option considered the ownership and interaction with the train services operated on each line. Detailed proposals would be developed with the owners of each corridor during the preliminary design stage and stakeholder consultaion. The planning of the construction sequence and hours of working would take this into account.

Figure 25: GO Transit Rail Network Corridor Ownership map



- **Construction Phases**: The schematic below shows the entire GO Transit network. Each corridor has been divided into corridor sections and these are indicated e.g. LW1, LW2 etc. These corridor sections were derived from the service schedule and have been used to determine the construction phases.

Figure 26: Network schematic showing Corridor sections

- **Construction Sequence**: The construction sequence for each of the 6 options has been divided into phases and these are shown in a series of schematic diagrams for each option in Appendix 10A. An indicative implementation schedule for each option has been also provided in Appendix 10A.

The construction sequence for each option is described below.

Option 1 – Georgetown

Option 1 consists of 3 phases as shown below.

- Phase 1 – Union Station to Brampton
  - Phase 1A from Union Station to Willowbrook Maintenance Facility and the West Toronto Diamond.
  - Phase 1B construction could start at the same time as Phase 1A and progress westward from West Toronto Diamond to the airport spur and Pearson Airport. Once completed an electrified service would be implemented on the ARL.
- Phase 2 would follow completing the section between the airport spur and Brampton, allowing a scheduled service to start for trains to Bramalea.
- Phase 3 follows Phase 2 and continues electrification to Kitchener.

Option 2 – Lakeshore

Option 2 consists of 4 phases as shown below.

- Phase 1 from Union Station eastwards to the Whitby Maintenance Yard and Oshawa. Once completed the electrified service would be implemented to Oshawa.
- Phase 2 from Union Station westward to Oakville. Once completed the electrified service would be implemented to Oakville and allow a through service at Union Station where scheduling permits.
- Phase 3 follows on from Phase 2 extending the electrification to eastward Hamilton James, and allowing the electrified service to be extended to Hamilton James.
- Phase 4 extends the electrification to Bowmanville and once completed the electrified service would be available along the full extent of the electrified sections of the Lakeshore line.

Option 3 – Lakeshore and Georgetown

Option 3 consists of 7 phases as shown below.

- Phase 1 – Union Station to Brampton
  - Phase 1A from Union Station to Willowbrook Maintenance Facility and the West Toronto Diamond.
  - Phase 1B would start at the same time as Phase 1A and progress westward from West Toronto Diamond to the airport spur and Pearson Airport. Once completed an electrified service would be implemented on the ARL.
- Phase 2 would follow completing the section to Brampton, allowing a scheduled service to start for trains to Bramalea.
- Phase 3 from Union Station westward to the Whitby Maintenance Yard and Oshawa. Once completed and the electrified service would be implemented from Union Station to Oshawa.
- Phase 4 from Union Station westward to Oakville. Once completed the electrified service would be implemented to Oakville and allow a through service to Oshawa where scheduling permits.
- Phase 5 follows on from Phase 4 extending the electrification eastward to Hamilton James, and allowing the electrified service to be extended to Hamilton James.
- Phase 6 extends the electrification to Bowmanville and once completed the electrified service would be available along the full extent of the electrified sections of the Lakeshore line.
- Phase 7 from Brampton extended to Kitchener and the implementation of a full electrified service on the Georgetown line.

Option 11 – Lakeshore, Georgetown, and Milton

Option 11 consists of 10 phases.

- Phases 1 through 8 are constructed the same as Option 3.
- Phase 9 would follow on the Milton Line from West Toronto to Meadowvale permitting electrified service to Meadowvale.
- Phase 10 would follow completing the line to Milton.

Option 15 – Lakeshore, Georgetown, Milton and Barrie

Option 15 consists of 12 phases as shown below.

- Phases 1A through 10 are constructed in the same sequence as Option 11and then continues along the Barrie Line in 2 stages.
- Phase 11 to Bradford
- Phase 12 completing the line to Allendale.

Option 18 – All Corridors

Option 18 consists of 18 phases as shown below.

- Phases 1 through 12 are constructed in the same sequence as Option 15.
- Phase 13 and 14 along the Stouffville Line to Lincolnville:
- Phases 15 and 16 to Bloomington on the Richmond Hill Line;
- Phase 17 to Hamilton TH&B on the Lakeshore Line; and,
- Phase 18 to St. Catharines on the Lakeshore Line.

13.3. Implementation Schedule

The detailed indicative Implementation Schedule in Appendix 10 is indicative and has been developed based up on the assumptions and the sequencing of each option shown above, and in discussion with GO Transit. A summary indicative Implementation schedule is included below.

Longer periods have been allowed for specific sections where the complexity and service schedule indicate construction access would be limited such as the Union Station Corridor and the section that includes the tunnels and bridges outside of Hamilton.

The preliminary design stage would develop the schedule further, as and when the specific requirements of GO Transit, CN, CP, Hydro One and other stakeholders are known.

The schedule shows that a corridor is completed and the network electrified, tested and commissioned before construction work is commenced on the next corridor to reduce the risk of service interruption.

The schedule has been developed considering a series of activities that are described in Appendix 10.

13.4. Findings and Conclusions

The available time for construction is limited by the level of service and therefore if the reference case service level increase was integrated with the electrification construction work on each corridor there would be savings in construction schedule and cost.

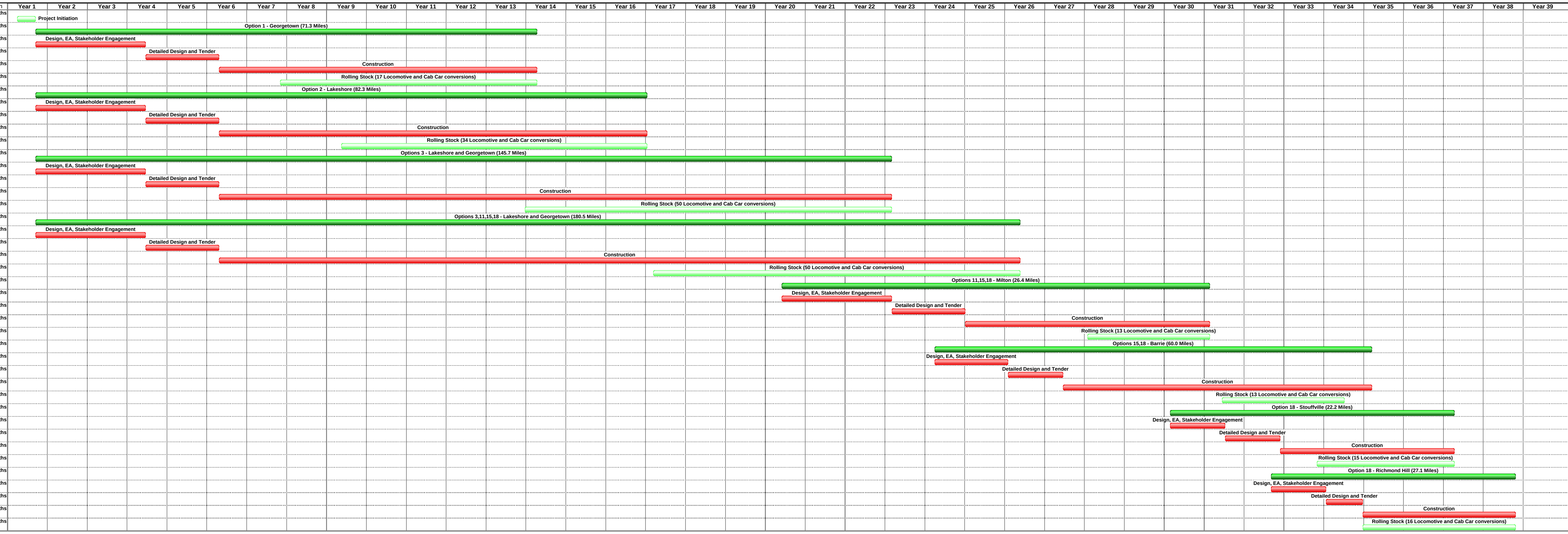
The negotiations with CN and CP will have a direct bearing on the construction sequence and schedule.

13.5. Summary Indicative Implementation Schedule

The following schedule is a summary of the detailed schedule in Appendix 10.

Electrification Study - Indicative Implementation Schedule for all Options
Final Draft

ID	Task Name	Duration
1	Project Initiation	6 months
2	Option 1 - Georgetown (71.3 Miles)	164 months
3	Design, EA, Stakeholder Engagement	36 months
6	Detailed Design and Tender	24 months
7	Construction	104 months
16	Rolling Stock (17 Locomotive and Cab Car conversions)	84 months
17	Option 2 - Lakeshore (82.3 Miles)	200 months
18	Design, EA, Stakeholder Engagement	36 months
21	Detailed Design and Tender	24 months
22	Construction	140 months
31	Rolling Stock (34 Locomotive and Cab Car conversions)	100 months
32	Options 3 - Lakeshore and Georgetown (145.7 Miles)	280 months
33	Design, EA, Stakeholder Engagement	36 months
36	Detailed Design and Tender	24 months
37	Construction	220 months
51	Rolling Stock (50 Locomotive and Cab Car conversions)	120 months
52	Options 3,11,15,18 - Lakeshore and Georgetown (180.5 Miles)	322 months
53	Design, EA, Stakeholder Engagement	36 months
56	Detailed Design and Tender	24 months
57	Construction	262 months
73	Rolling Stock (50 Locomotive and Cab Car conversions)	120 months
74	Options 11,15,18 - Milton (26.4 Miles)	140 months
75	Design, EA, Stakeholder Engagement	36 months
78	Detailed Design and Tender	24 months
79	Construction	80 months
84	Rolling Stock (13 Locomotive and Cab Car conversions)	40 months
85	Options 15,18 - Barrie (60.0 Miles)	143 months
86	Design, EA, Stakeholder Engagement	24 months
89	Detailed Design and Tender	18 months
90	Construction	101 months
96	Rolling Stock (13 Locomotive and Cab Car conversions)	40 months
97	Option 18 - Stouffville (22.2 Miles)	93 months
98	Design, EA, Stakeholder Engagement	18 months
101	Detailed Design and Tender	18 months
102	Construction	57 months
108	Rolling Stock (15 Locomotive and Cab Car conversions)	45 months
109	Option 18 - Richmond Hill (27.1 Miles)	80 months
110	Design, EA, Stakeholder Engagement	18 months
113	Detailed Design and Tender	12 months
114	Construction	50 months
119	Rolling Stock (16 Locomotive and Cab Car conversions)	50 months



Project: Schedule Option15 LK,GT,MI,
Date: Wed 12/22/10

Task | Summary

14. FUTURE CONSIDERATIONS – BEYOND THE REFERENCE CASE

In order to undertake the Electrification Study in a manner that various technology and network options could be evaluated on a consistent basis, it was necessary to make a number of assumptions associated with the GO Transit rail network, including infrastructure, services and operations as defined by the Reference Case. This reflects Metrolinx's view on improvements likely to be reasonably funded and delivered in the medium term.

Clearly, in the longer term, improvements over and above those set out in the Reference Case may be implemented. This section of the report discusses how the findings of the Electrification Study may change if different assumptions were to be made regarding further investments or decisions made in the future. These are seen as steps to be taken to reach the vision set out in the Regional Transportation Plan, *The Big Move*.

There are a number of scenarios that might potentially increase the case for electrification in the future; these have been considered under four headings:

- Level of Service: Those initiatives that can be undertaken without changes to the infrastructure through modifications to the level of service, scheduling and operational practices;
- Union Station and Network-wide Improvements: Significant reconstruction at Union Station would be able to unlock more capacity beyond the Reference Case. In addition, infrastructure enhancements can be made throughout the network through changes to track alignment, station configurations and corridor speed increases;
- Electric Multiple Units (EMUs): The electric trains operated could be Electric Multiple Units (EMUs) rather than electric locomotives; and,
- Fare Policy: Changes to the demand brought about by the manner in which population and employment distributions evolve, and the transit offer that is made to the public through fare initiatives.

Each of these scenarios that might affect the case for electrification in the future is considered in the subsequent sections.

14.1. Level of Service

The level of service assumed to operate on the network is one of the key factors in delivering benefits associated with electrification. The level of service assumed in the Reference Case has been designed by GO Transit and Metrolinx to satisfy the expected ridership demands in the future while respecting the operational constraints at Union Station.

Based on the findings of the study, the economic and environmental case for electrification would be improved on a network with a higher level of service assumed, thereby utilizing the investment in the electrification systems more intensively. This is because for the same capital investment (catenary, power supply systems, infrastructure works), there are more benefits to be gained (operating and maintenance cost savings, passengers benefiting from reduced journey times, and reduced emissions). Intrinsically, a more frequent service is more attractive to passengers.

The Big Move envisaged a level of service over and above that assumed in the Reference Case, and demand levels anticipated in that document on some or all of the corridors may exceed those forecast with the Reference Case levels of service.

Once the trains have reached their maximum length, the only way to increase capacity further is to operate a more intensive pattern of service. To operate a more intensive service through Union Station in the peak hours is not possible without changing both the infrastructure at the station and operating practices, but it is possible that either of these could be implemented within a 30-year timeframe.

Non-Stop/Local Services

The Reference Case assumes that during peak periods there will be a number of faster non-stop services. This means passengers making longer trips will have larger journey time savings when compared to a service that stops at all stations (referred to here as local service).

A mixture of non-stop and local services is an appropriate way to provide relatively fast journey times for longer-distance passengers to Union Station, whilst providing capacity for those travelling shorter distances. The use of electric trains on all-stop services, with their superior acceleration and deceleration capability, would help to reduce the operating differential between the faster and slower trains and potentially allow a greater number of services to operate. In creating additional capacity for operating extra trains – either non-stop or local - this increase in service would help to meet growing demand in a cost-effective manner.

Scheduling and Operational Practices

As part of the Reference Case, it is assumed that all trains would be of the same train length and would be able to operate on different corridors at all times of the day. Given that passenger demand on some trains, particularly the off peak and counter peak services, is not expected to reach capacity, it may be possible to operate a different length of train customized to meet demand with improved operational cost efficiencies.

This would involve trains dividing and joining during their operating day. While not a common practice in the GO system today, this is common practice in railways across the world. It does create an additional level of operational complexity and takes an additional 3-5 minutes to undertake this manoeuvre. Electric multiple units (EMUs) are best suited for running in formations of 1, 2 or 3 trains as they more easily facilitate the benefits of splitting and joining. A detailed operational study would be necessary to examine the usage of rolling stock through the GO operating day to find an optimum solution. Issues such as staff availability, capacity at stations to split and join, and layover facilities would need careful examination. The benefits of being able to tailor the length of train to the expected demand at different times of day would yield a range of valuable cost savings.

14.2. Union Station and Network-wide Improvements

Peak-Hour

Union Station is the major focal point to the GO rail network. It is also where the majority of long distance inter-city VIA services terminate. When the service levels of the Reference Case are met, Union Station is expected to be operating at or near capacity. This capacity is limited by the slow access and exit speeds of Union Station and the very long dwell times of trains. Dwell times are a function of the existing narrow platforms and access to those platforms.

Rebuilding Union Station within its current urban footprint would mean providing fewer GO Transit platforms, but ones which are much wider. This could allow dwell times to be reduced, and thereby enable a higher frequency of service. Rebuilding the platforms at Union Station will also present the opportunity to modify the trackwork at each end of the station to allow faster approach speeds. Overall there might be some reduction in operational flexibility.

One option which would allow a greater peak-hour frequency to operate through Union Station without significant infrastructure expenditure is to revise the allocation of platforms between GO Transit and the other operators using the station. Their trains are infrequent, and optimizing the platform utilization around GO Transit may bring some benefits in terms of access speeds into/out of the station, as well as providing some additional platform and track capacity.

Metrolinx has been considering alternative ways of enhancing GO rail passenger services and relieving the operational constraints at Union Station for demand that is over and beyond the Reference Case service levels. Preliminary findings highlight that the final destination of the majority of GO trips into Union Station are within walking distance of Union Station. Therefore, an alternative to reduce the demand for Union Station would involve the provision of new below grade corridor(s) that would provide congestion relief.

Electric trains are more cost-effective in tunnels or below grade corridors because the requirements for ventilation are significantly less onerous than those for diesel. Electric trains also have greater power to operate on the significant gradients that are normally associated with below grade corridors. The cost advantages suggest electrification is a more optimal solution should below grade corridors be selected to address capacity issues beyond the Reference Case.

Network-wide

It is likely that investment in other parts for the network would be necessary to allow a more intense peak-hour service to operate. Investment in additional track and signalling modifications will allow a larger number of trains to operate. An important consideration is the interaction between GO Transit and other services operated by CN, CP and Via Rail. Service enhancement plans for all the operators within the Toronto area need to be considered together to allow the delivery of a level of service appropriate to each company's needs, be it for passengers or freight interests.

Off-Peak Period

At present, the off-peak train service is limited to the Lakeshore East and Lakeshore West corridors, and the Reference Case scenario will involve a considerable expansion in the level of service to create a two-way all-day operation across the network. *The Big Move* forecasts that demand across the GO network will evolve to require a much more frequent commuter service.

Electric multiple units (EMUs), running in variable lengths, would allow for customization of the combinations of the number of units (1, 2 or 3) operating at different times of day. This is likely a more cost-effective way of addressing a more intensive off-peak service.

One benefit of electric multiple units, whether during the peak or off-peak period, is the ability to deliver journey time savings. Their higher power to weight ratio, when compared to a traditional locomotive and coaches, allows not only a higher rate of acceleration/deceleration (of great importance on a route with frequent station stops), but also the ability to operate at a higher speed for a greater proportion of the journey.

Corridor Speeds

The speed at which trains operate is determined by the line speed, the operating characteristics of the rolling stock, and by the level of congestion on the network. Journey time reductions are of benefit to passengers, and our analysis of demand patterns as a result of journey time reductions suggests that there are significant benefits to be realized. The corridor speeds are currently set at a variety of levels across the network. If these speeds were altered to allow for higher speeds, even greater benefits in journey time savings could be generated by electric locomotives or EMUs.

14.3. Electric Multiple Units (EMUs)

In the high level technology evaluation, electric locomotive trains were compared against Electric Multiple Unit (EMU) trains. The conclusion was that electric locomotives, while generating lower levels of journey time benefits, were overall more cost effective in delivering transportation and environmental benefits. This was because EMUs are more expensive to procure when compared on a whole-train basis (one electric locomotive + 10 passenger coaches compared with 12 Electric Multiple Unit carriages) and EMUs are also more costly to maintain than diesel locomotive trains (while electric locomotive trains can reduce operating and maintenance costs).

Subsequent to the detailed evaluation of the six network options with electric locomotive trains, the transportation case for EMUs was examined. From a transportation efficiency point of view, there was very little difference between the two technologies when considered on the best performing network options (Options 2, 3 and 11). However, compared to electric locomotive trains, EMUs cost around 40% more in capital costs, while over the 30-year life cycle they were around 2.5 times more expensive, meaning a significantly larger capital and operating budget would be required.

However, there are a number of ways in which, beyond the Reference Case, GO Transit could potentially optimize the infrastructure in a way that fully exploits the potential of EMUs. EMUs offer a significant change in journey time savings and a greater potential to meet the long term vision set out in *The Big Move*. As the GTHA continues to grow beyond the Reference Case, the case for EMUs would also improve, so the possibility of deploying EMUs on the GO Transit network should not be ruled out further in the future.

14.4. Transit Fares

The study assumes that transit fares increase in line with inflation over the evaluation period. If transit fares were to become lower, such as with off-peak discounts, more riders could be attracted to the system.

As set out in The Big Move, a fully integrated fare system throughout the GTHA could be used to stimulate further demand by incentivising passengers to travel at different times of the day and with greater frequency across all transit modes.