Electrification of the GO Transit Rail Network

Stakeholder Workshop #4
Detailed Assessment

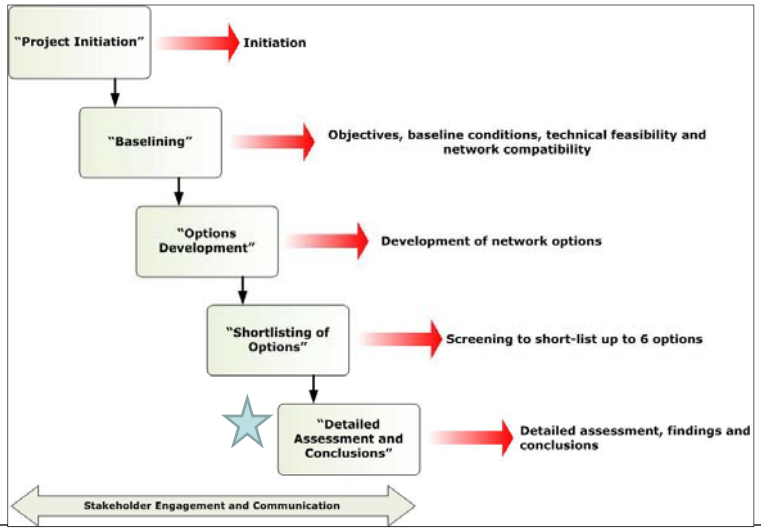
Preliminary Key Findings

December 1st 2010

PRESENTATION OVERVIEW

1. Study Overview & Where We Are
2. Recap: The Reference Case and Getting to the 6 Options
3. Description of 6 Options
4. Key Findings of Multiple Category Evaluation
5. Answers to Frequently Asked Questions
6. Next Steps

Study Overview & Where We Are



Objectives

Criteria

Screening

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Electrification Study

Study Approach and Objectives

- Study Approach
  - Objective
  - Comprehensive
  - Inclusive
  - Evidence Based
- Study Objectives
  - Technology, Capacity and Transit Service Impacts
  - Environment and Health
  - Community and Land Use
  - Economic
  - System Costs, Funding, Financing and Delivery

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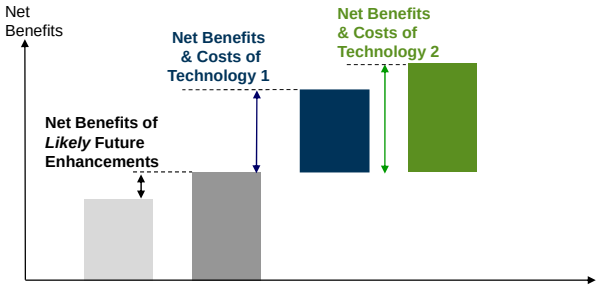
Electrification Study

Reference Case

- Basis for comparison of options
- Evaluate the incremental impacts of each technology



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Electrification Study

Reference Case – Rolling Stock

- MP40 Loco (Tier 4), 10 bi-level coaches

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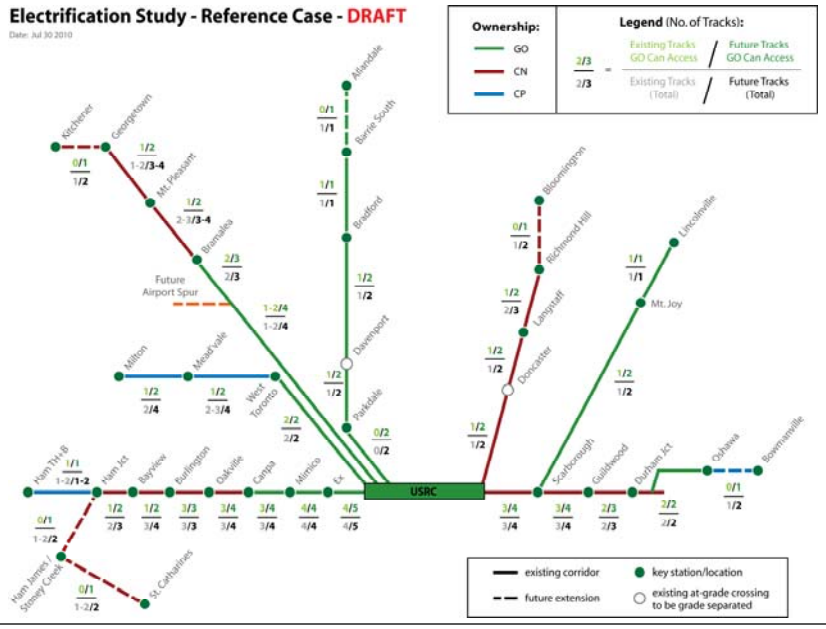
Electrification Study



Electrification Study

Reference Case - Service Level

Time of Day	Direction	Reference Case
Peak Period	Peak	More trains per hour
Peak Period	Counter-peak	Adds Hourly Service*
Off-Peak Period	Both	Adds Hourly Service*

* Adds half-hourly on Lakeshore Line

Union Station Capacity Study Preliminary Finding:
Union Station, with track modifications, can accommodate the service levels in the Reference Case

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Electrification Study

Technology Alternatives
Rolling Stock

Hybrid Drive Loco

Dual Mode Loco

Maglev

CNG-Fuelled Loco

Electric Multiple Unit

Electric Loco

Diesel Loco

Electric Multiple Unit

Rolling Stock Technology Alternatives
Shortlist

Diesel Loco

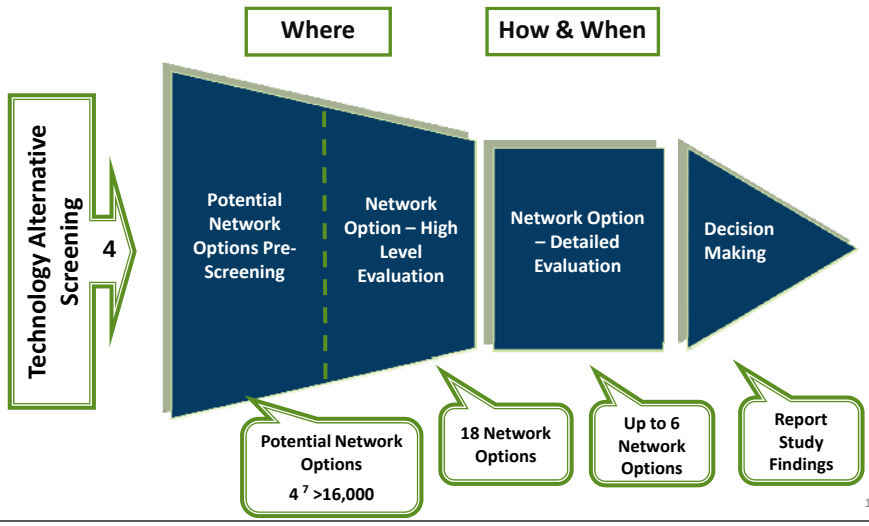
Electric Loco

Dual Mode Loco

Electric Multiple Unit

Power Supply – OPA confirms sufficient power available in the grid

Option Progression



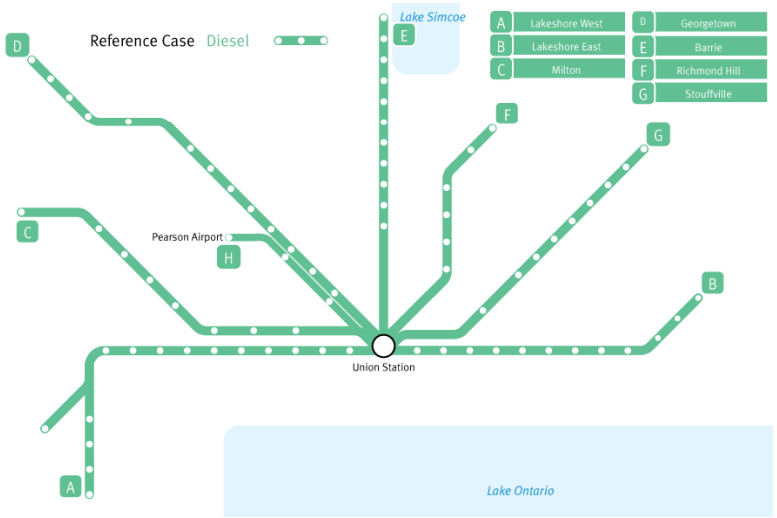
Preliminary Pre-Screening Criteria for Generating Network Options

1. Electric Locomotive, Multiple Unit, and Dual Mode Loco are considered the same family of technologies
2. Lakeshore East and West to operate the same technology
3. Highest service/demand corridors

High Level Evaluation of Electrification Options

- Findings:
  - Electric Locomotive pulling 10 coaches most cost effective electric train to use for the comparison to the diesel option
  - Most value for money from electrifying entire corridor (except LW Ham) as final state
  - ARL: single level DMU conversion to single level EMU
  - 6 network options taken forward to compare with diesel option

Reference Case



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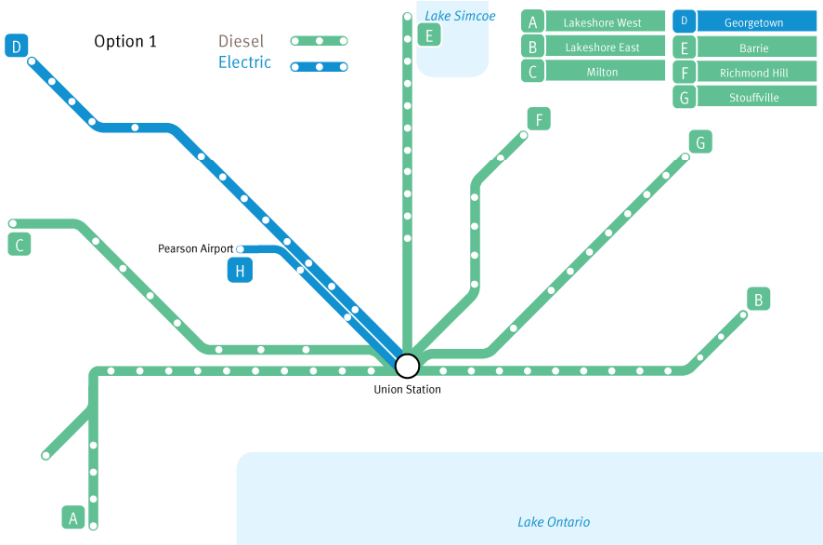
Electrification Study

Georgetown & ARL



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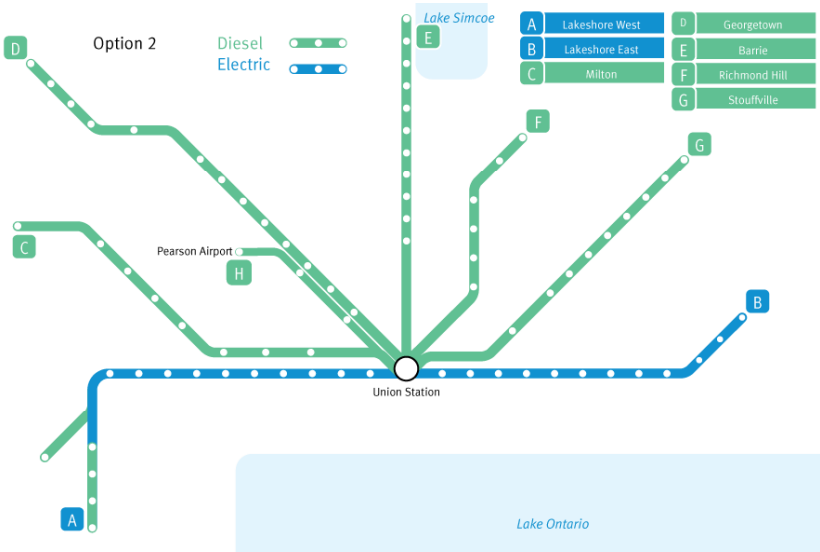
Electrification Study

Georgetown & ARL - Key Stats

Item	Option 1
GO Network Length	316.2 mi. 508.9 km
Electrified Length	64.6 mi. 104.0 km
Traction Power Substation	2
Switching Stations	2
Autotransformer Stations	3
Bridges Replaced	0
Bridges Reworked	8
Total Bridges	8
Locomotives	
Electric	17
Diesel	91

Plus 12 EMU's on the ARL

Lakeshore



Lakeshore - Key Stats

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 Replaced	4
Bridges Reworked	17
Total Bridges	21
Locomotives	
Electric	34
Diesel	74

Plus 12 DMU's on the ARL

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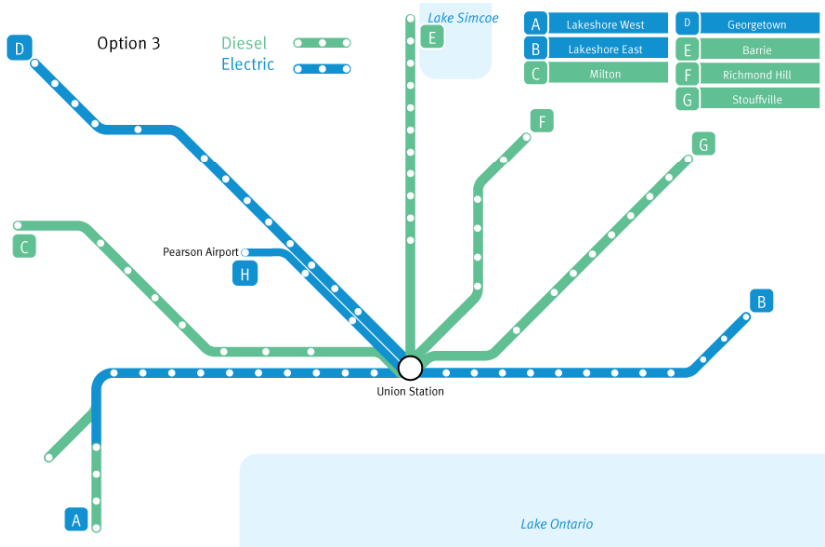
Electrification Study

Georgetown & Lakeshore



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Electrification Study

Georgetown & Lakeshore - Key Stats

Item	Option 3
GO Network Length	316.2 mi. 508.9 km
Electrified Length	147.7 mi. 237.7 km
Traction Power Substation	6
Switching Stations	4
Autotransformer Stations	4
Bridges Replaced	4
Bridges Reworked	25
Total Bridges	29
Locomotives	
Electric	50
Diesel	57

Plus 12 EMU's on the ARL

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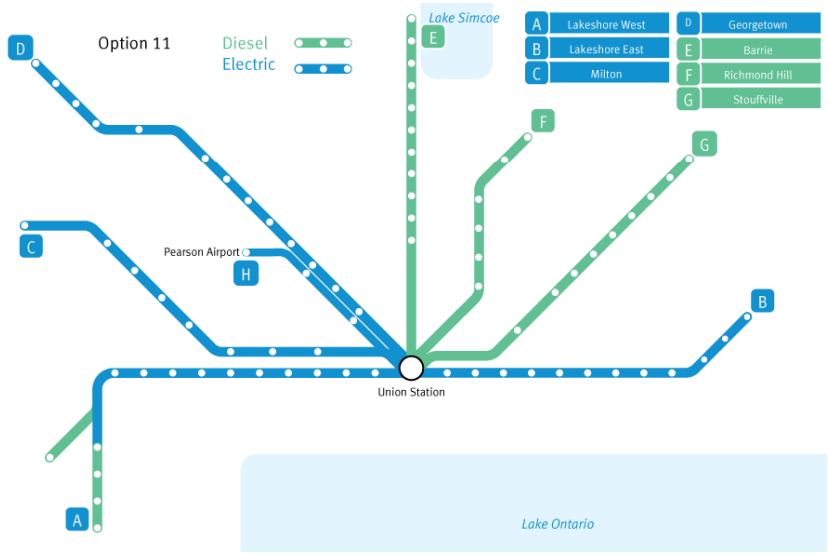
Electrification Study

Georgetown, Lakeshore & Milton



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Electrification Study

Georgetown, Lakeshore & Milton Key Stats

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 Replaced	4
Bridges Reworked	25
Total Bridges	29
Locomotives	
Electric	63
Diesel	45

Plus 12 EMU's on the ARL

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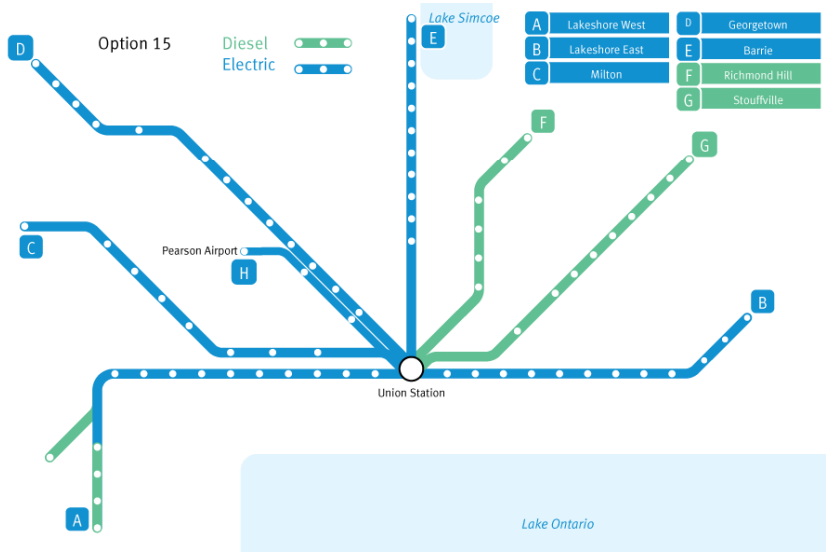
Electrification Study

Georgetown, Lakeshore, Milton & Barrie



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Electrification Study

Georgetown, Lakeshore, Milton & Barrie Key Stats

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 Replaced			4
Bridges Reworked			31
Total Bridges			35
Locomotives			
Electric			76
Diesel			32

Plus 12 EMU's on the ARL

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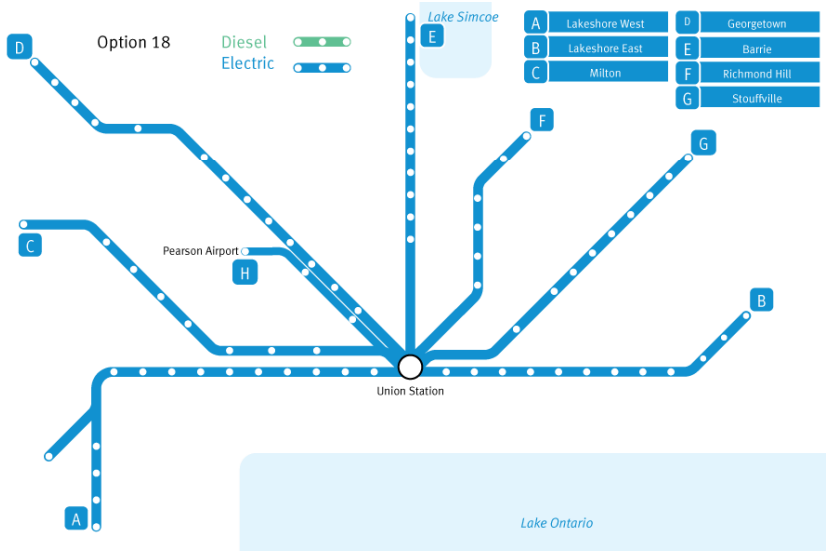
Electrification Study

Entire Network



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Electrification Study

Entire Network - Key Stats

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 Replaced	12
Bridges Reworked	39
Total Bridges	51
Locomotives	
Electric	107
Diesel	0

Plus 12 EMU's on the ARL

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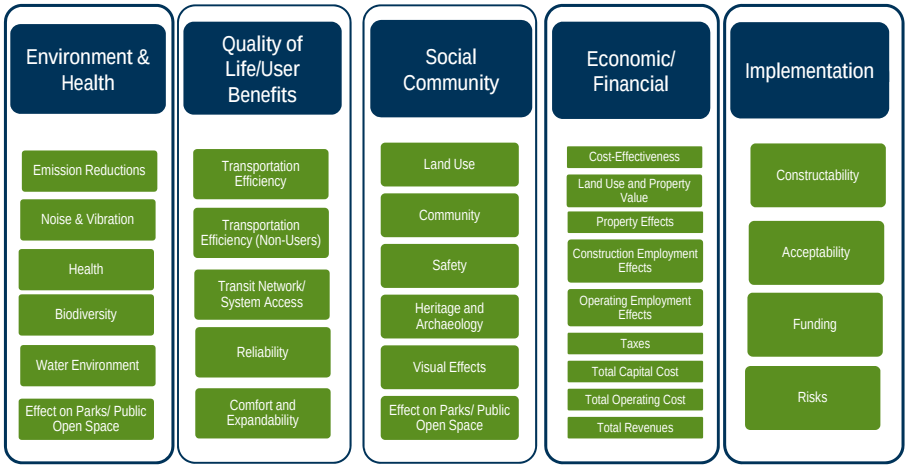
Electrification Study

Multiple Category Evaluation



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Electrification Study

Environment and Health

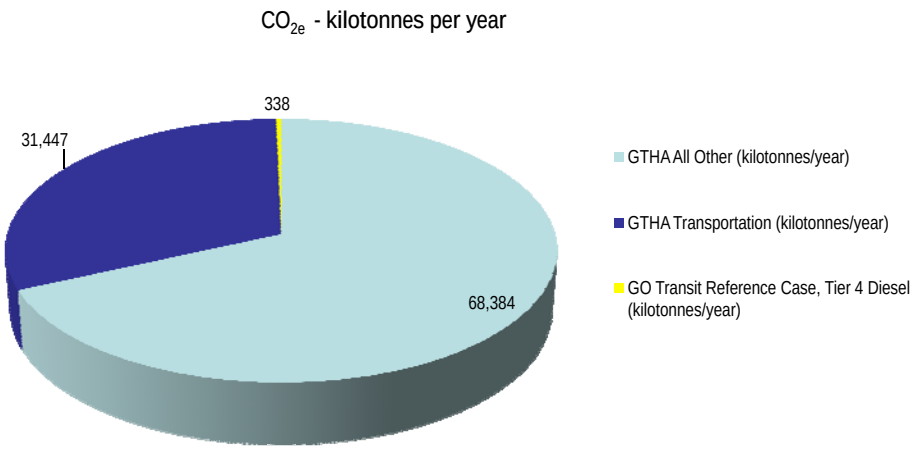
- Greenhouse Gases (GHG)
- Air Quality
  - Regional Air Quality
  - Local Air Quality
- Electromagnetic Fields
- Noise and Vibration

Environment and Health

Green House Gas (GHG) Emissions

- Diesel powered locomotives emit GHG emissions
- Electric Locomotives will also generate GHG emissions from power source
  - Ontario's electricity generation mix by 2025:
    7% thermal, 93% nuclear/renewable [OPA, 2005]

Green House Gas Emissions in the GTHA



Green House Gas Emissions Comparison

GTHA Total Emissions (tonnes/year) (based on 2007)	99,830,245

Option	Emissions from GO Trains (tonnes/year)	(% of GTHA Total)
Reference Case (Tier 4; no electrification)	339,423	0.34%
Georgetown	289,508	0.29%
Lakeshore	199,660	0.20%
Georgetown & Lakeshore	150,744	0.15%
Georgetown, Lakeshore & Milton	120,795	0.12%
Georgetown, Lakeshore, Milton & Barrie	74,873	0.08%
Entire Network	18,968	0.02%

Green House Gas Emissions Reductions from Reference Case due to Increased Ridership

Option	Auto Trips Removed (AM Peak Period)	Auto Trips Removed (Annual)	GHG Reduction (tonnes per year)	GHG Reduction (%)
Georgetown	400	320,000	1,700	0.002%
Lakeshore	900	710,000	5,400	0.005%
Georgetown & Lakeshore	1,300	1,030,000	7,100	0.007%
Georgetown, Lakeshore & Milton	1,600	1,260,000	8,400	0.008%
Georgetown, Lakeshore, Milton & Barrie	1,800	1,420,000	9,800	0.010%
Entire Network	2,000	1,580,000	11,100	0.011%

Environment and Health

Green House Gas (GHG) Emissions

- FINDING: The reference case contributes approx:
  - 339,000 CO_{2E} emissions per year, or
  - 0.34% of the total GHG emissions in the GTHA
- FINDING: Fully electrified system contributes approx:
  - 19,000 CO_{2E} emissions per year, or
  - 0.02% of the total GHG emissions in the GTHA
- FINDING: Fully electrified system reduces the total CO_{2E} emissions in the GTHA by approx:
  - 320,000 per year, or
  - 0.32%

Environment and Health

Regional Air Quality

- The most relevant pollutants with respect to regional smog are:
  - oxides of nitrogen (NO_x)
  - sulphur dioxide (SO_x)
  - fine particulate matter ($PM_{2.5}$)
  - hydrocarbons

Environment and Health

Regional Air Quality

- FINDING: Electrification reduces emissions
- FINDING: All options, including the Reference Case, emit a fraction of 1% of the GTHA's overall regional emissions

Pollutant	GTHA Total Emissions (tonnes/year)	Reference Case (% of GTHA Total)	Full Electrification (% of GTHA Total)
NO_x	239,291	0.2200%	0.0230%
CO	1,289,797	0.0460%	0.0011%
SO_2	218,154	0.0013%	0.0003%
HC	2,207,246	0.0030%	0.0001%
$PM_{2.5}$	1,855,235	0.0006%	0.0001%

- GTHA totals based on Ontario's 2007 total from National Pollutant Release Inventory (NPRI), produced by Environment Canada scaled by population

Environment and Health

Local Air Quality

Methodology

- Defined a study area adjacent to corridor
- Width of study area depends on:
  - GO train and ARL traffic volumes
  - Rural versus urban land-use
- Study area used to determine the potential impact on the local community
- Considered the size of population and number of sensitive locations
  - Sensitive locations - schools, hospitals, daycares, parks, etc.

Environment and Health

Local Air Quality

Methodology (continued)

- Background air quality conditions were determined by reviewing historical air pollutant monitoring from stations throughout the GTHA
  - Downtown air sampling stations
  - West Toronto Diamond air sampling station
  - Average of all air sampling stations across the GTHA
- Considered the particulate emission data for:
  - Tier 4 diesel-electric locomotive and ARL diesel multiple unit
  - Electric locomotives and ARL electric multiple unit
- Reference Case service levels established trains per hour/per day and annually

Environment and Health

Local Air Quality
Methodology (continued)

Emissions from diesel engines:

- Criteria Air Contaminants (CAC's)
- Particulate Matter (PM)
- Volatile Organic Compounds (VOC's)
- Polycyclic Aromatic Hydrocarbons (PAH's)
- Heavy metals

Environment and Health

Local Air Quality
Methodology (continued)

- CO
- NO_x
- SO_x
- PM_{10}
- $PM_{2.5}$
- Formaldehyde
- Acetaldehyde
- 1,3-Butadiene
- Benzene
- Acrolein
- B[a]p
- Metals

GO/ MOE Consultation

Focus

- NO_x
- SO_x
- $PM_{2.5}$

SO_x (SO_2) contributions from GO + ARL found to be very small upon consideration of ultra-low sulphur diesel

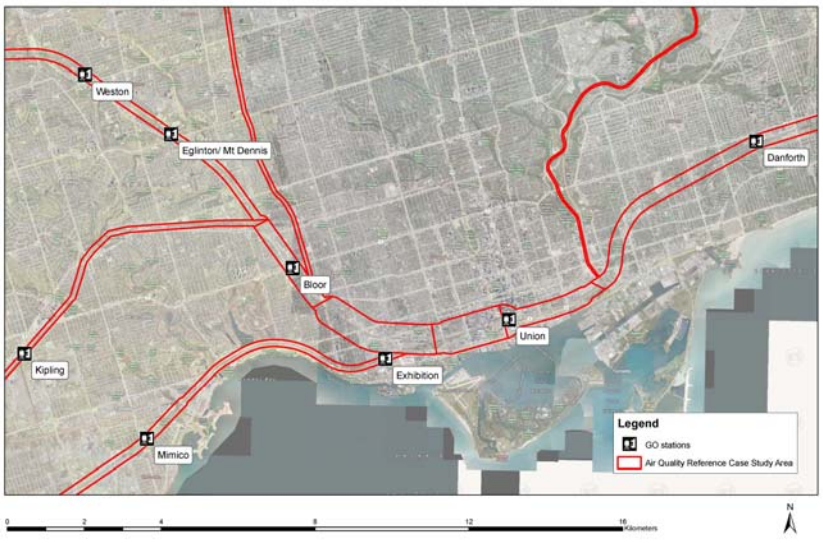
Environment and Health

Local Air Quality

Methodology (continued)

- Computer dispersion modelling used to determine the contribution from diesel trains in the Reference Case
- For each option, looked at the change due to electrification
- These emissions plotted as a function of distance from the corridor
- Compared these emissions to the background
- These emissions are considered measurable if greater than 10% of background

Air Quality Study Area (Reference Case)



Environment and Health

Health – Guidelines to Assess Air Quality Impact:

- World Health Organization (WHO)
  - Air Quality Guidelines (AQG) updated in 2005
  - AQG designed to offer guidance for reducing the health impacts of air pollution
  - Updated AQG based on extensive body of scientific evidence relating to air pollution and its health consequences
  - AQG are based on:
    - sensitive indicators (such as physiological measures – e.g. changes in lung function, inflammation markers)
    - most critical population health indicators such as mortality and unscheduled hospitalizations
- Ontario Ministry of the Environment (MOE)
  - has Ambient Air Quality Criteria (AAQC's) for Ontario - effects-based levels in air, based on health and/or other effects, and used to assess potential for adverse effects

Environment and Health

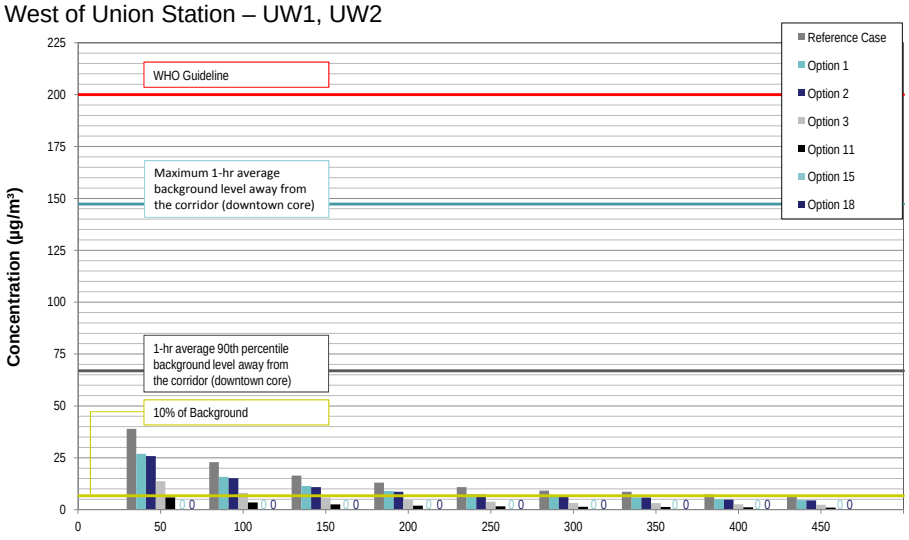
Comparison of Air Quality Guideline Values

Pollutant	Averaging Time	WHO AQG (ug/m^3)	MOE AAQC (ug/m^3)
$PM_{2.5}$	1 year	10	n/a
	24 h	25 (99th percentile)	50 (98th percentile)*
PM_{10}	1 year	20	n/a
	24 h	50 (99th percentile)	50
Ozone, O_3	8 h, daily max	100	n/a
	1 h		165
NO_2	1 year	40	n/a
	24 h	n/a	200
	1 h	200	400
SO_2	24 h	20	275
	10 min	500	n/a
	1 h		690
	annual		55

* Canada-Wide Standard

1-hr Average NO_2

West of Union Station – UW1, UW2



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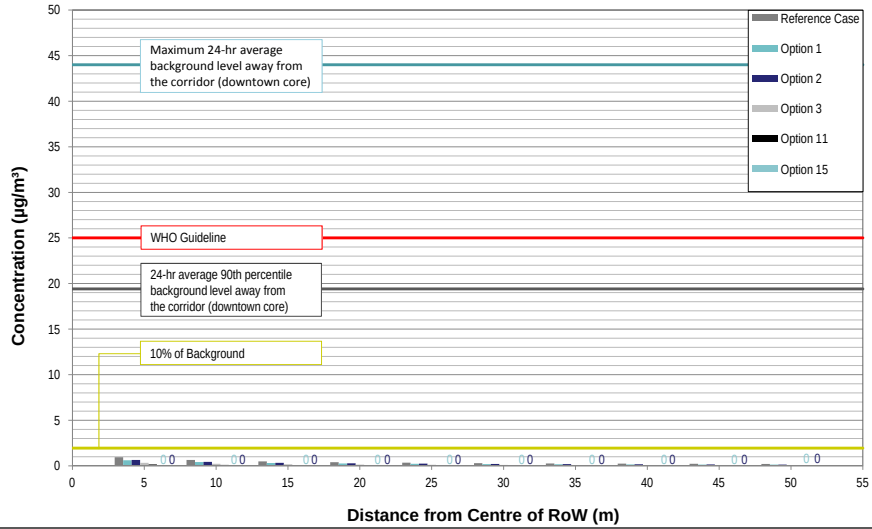
Electrification Study

24-hr Average $PM_{2.5}$

West of Union Station – UW1, UW2



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Electrification Study

Environment and Health

Local Air Quality

- FINDING: Contribution of NO_X, $PM_{2.5}$, and other contaminants from the Reference Case number of trains (Tier 4 Diesel) is very small compared to background levels and WHO guidelines
- FINDING: The background monitors in the GTHA for the 1-hr and 24-hr NO2 levels never exceed the WHO guideline or MOE AAQC's
- FINDING: For $PM_{2.5}$, the 90 percentile background level is below the WHO guideline at GTA monitoring stations
  - but the background level does exceed the guideline level ~ 4% of the time, and exceeds the CWS level 1 day/year [MOE, Air Quality in Ontario Report, 2008]

Environment and Health

Local Air Quality

- FINDING: Ultra Fine Particulate Matter – the air quality thresholds have not been established by the WHO
- FINDING: For 24-hr SO_2, the 90^{th} percentile background level is below the WHO guideline
  - but the background level does occasionally exceed the guideline. It never exceeds the MOE's AAQC [MOE, Air Quality in Ontario Report, 2008]

Environment and Health

Electromagnetic Fields (EMF)

- Consultants investigated the potential impact of electromagnetic fields (EMF)
- Numerous epidemiological studies on the topic have been conducted
- EMF measurements of electric and magnetic fields along an electrified railroad showed readings below the American Conference of Industrial Hygienists (ACGIH) and Institute of Electrical and Electronic Engineers (IEEE) limits
  - DOT/FRA/RDV-06/01, EMF Monitoring on Amtrak's Northeast Corridor: Post-Electrification Measurements and Analysis, October 2006
- FINDING: No consensus on the relationship between magnetic fields from an electrified rail corridor and health issues
- References:
  - National Cancer Institute (NCI) website www.cancer.gov
  - World Health Organization (WHO) website www.who.int

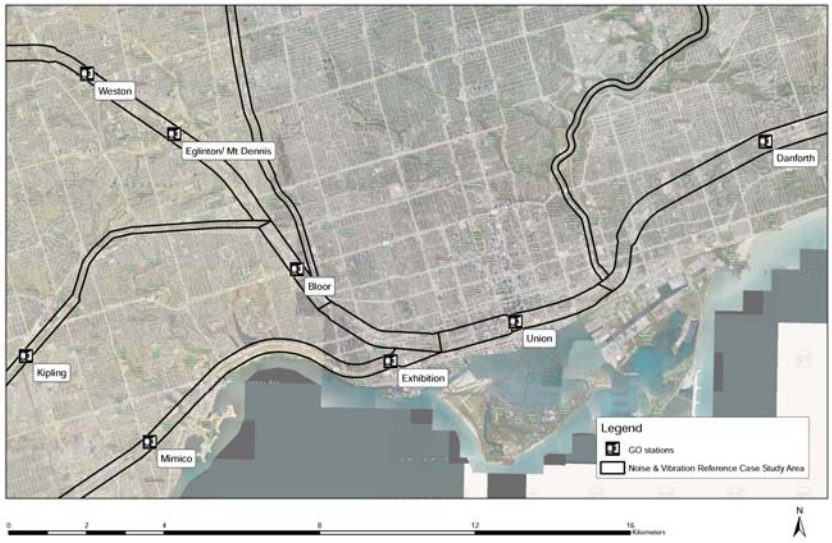
Environment and Health

Noise and Vibration

Methodology

- Determine noise levels for each technology immediately adjacent to the corridor:
  - 82 decibels for bi-level EMU
  - 86 decibels for electric loco
  - 89 decibels for diesel loco
  - 82 decibels for ARL EMU
- Background defined for both daytime and nighttime periods:
  - Assumed daytime urban background noise level 55db
  - Assumed nighttime urban background noise level 50db
- Noise levels decrease as one moves further away from the rail corridor
- Noise level changes are discernible to the human ear at about 5db or greater
- The study area :
  - Defined by modeling
  - Defined as the area where the train noise would be heard
  - Based on max speed along that section

Noise & Vibration Study Area (Reference Case)



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Electrification Study

Environment and Health

Noise and Vibration

- FINDING: The difference between diesel and electric loco's is 3 dB (89 vs. 86 dB), which would be barely perceptible by an average human
- FINDING: The difference between the diesel locomotive and 12 car EMU's is 7 dB (89 vs. 82 dB), which is perceptively quieter

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Electrification Study

User Benefits / Quality of Life

Journey Time Savings

- An operating plan was developed using the Reference Case service levels
- Based on this scenario an estimate of journey times was modelled using the different locomotives
- Modelling was done to estimate the impact on auto users and estimate the increased ridership due to the 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

User Benefits / Quality of Life

Journey Time Savings

- FINDING: There is approximately a 5% increase in ridership (depending on the option) due to transit time savings and these additional riders generate additional revenue
- FINDING: Electric locomotives produce journey time savings of approximately 7-9% On the ARL, Barrie, Richmond Hill, Stouffville this is less - around 3%-5%
- FINDING: EMU's produce additional journey time savings compared with the diesel locomotives
- FINDING: Maximum benefits of electric locomotives cannot be achieved with existing speed limits and the bottlenecks getting into and out of Union Station

User Benefits / Quality of Life

Social and Community

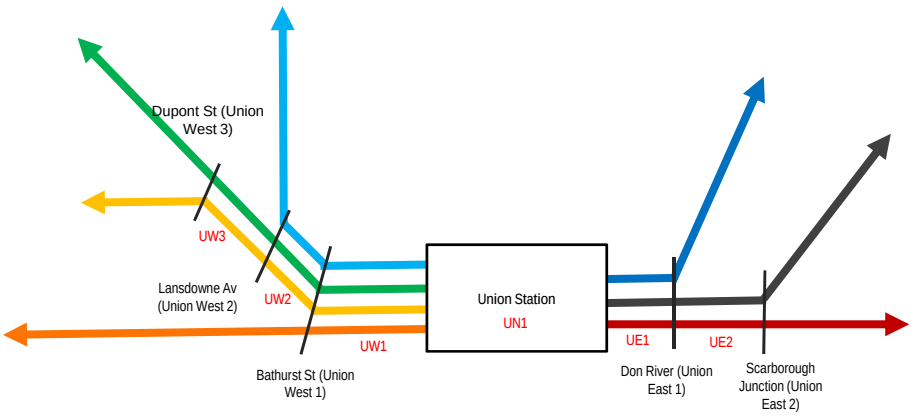
- This is a qualitative assessment
- Includes impact on safety, visual impacts, and nuisance effects
  - FINDING: Electrified systems have safety issues due to the power supply but these can be mitigated by appropriate signage, protection and education
  - FINDING: Construction of overhead catenary system, substations and autotransformers has a negative visual impact; this would be addressed in an Environmental Assessment
  - FINDING: No significant difference in nuisance effects (noise, odour and dust)

Capital Cost Estimating Methodology

- Cost elements consistent with Benefits Case Analysis (BCA) framework
- Benchmarking against current practices
- Costs compiled by sections
  - 25 corridor sections
  - 37 cost sections: to account for varying numbers of tracks

Corridor Sections

Downtown Toronto Detailed Sections



Infrastructure Capital Cost Elements

- Systems
  - Traction power supply
  - Traction power distribution (overhead catenary system , cross bonding, support)
  - Maintenance and layover facilities, maintenance vehicles
- Track and track elements
  - Overhead structures rework:
    - Jacking of bridges
    - Undercutting ballast
    - Replacement of bridges
  - Infrastructure rework:
    - Architectural/structural enhancements
    - Modifications of signal bridges
    - Rework at level crossings
    - Signalling modifications, USRC cabling
    - Control center

Infrastructure Capital Cost Elements

- Site work and special conditions
  - Demolition/clearing/earthwork
  - Site utilities, utility relocation
  - Security fencing, retaining walls
  - Temporary facilities
  - Environmental mitigation
  - Bonding/grounding
- Professional services

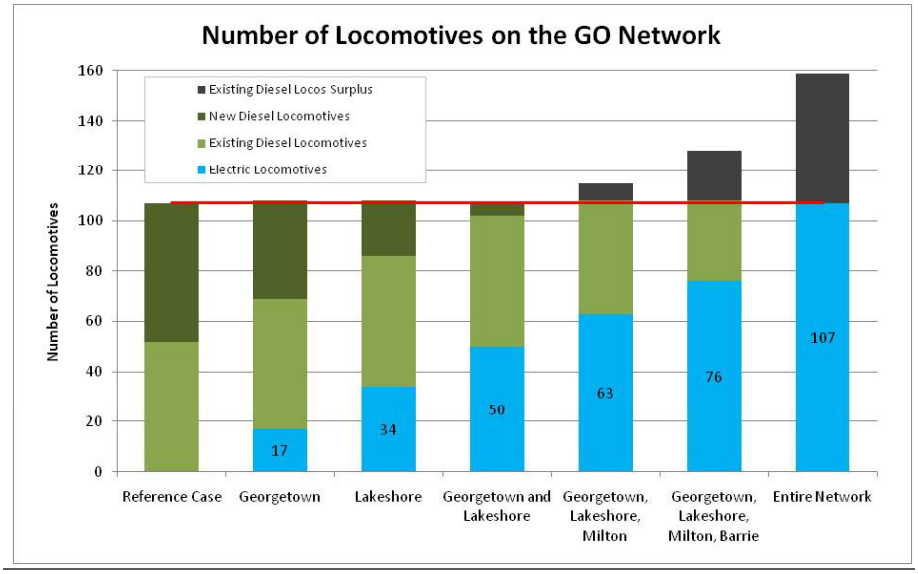
Rolling Stock Capital Costs

- Capital costs for each vehicle type compiled by reviewing the industry for recent sales of comparable equipment
- Considered Metrolinx requirements as compared to the most recently awarded North American procurements
- In some cases, direct comparisons could be found. In others, extrapolations had to be made. Unique vehicle types include:
  - Diesel locomotive (Tier 4 compliant)
  - Electric locomotive
  - Single-level DMU
  - Single-level EMU

Rolling Stock Estimates

- Diesel Locomotive
  - based on GO Transit's purchase of Motive Power Industries (MPI) MP40PH-3C locomotives in 2008, plus an up-charge for Tier 4 compliant engine(s)
- Electric Locomotive
  - based on average of New Jersey Transit's (NJ Transit) purchase of Bombardier ALP-46A locomotives in 2008 and Amtrak's purchase of Siemens ACS64 locomotives in 2010
- DMU (ARL)
  - based on LTK engineering estimates for Denver Regional Transportation District (RTD), NJ Transit, and Sonoma Marin Area Rail Transit (SMART) in 2010
- EMU (ARL)
  - based on LTK engineering estimates and RTD's purchase of single-level EMUs in 2010

Rolling Stock Requirements



Operating & Maintenance Cost

Methodology

- Costs compiled by sections
- Three categories of costs included in the annual Operations and Maintenance estimates:
  - Rolling Stock
  - Wayside (Electrification Infrastructure)
  - Energy Costs
- Assumption that several annual maintenance costs are the same across technologies
  - Track maintenance for corridor infrastructure same regardless of technologies (excluding Overhead Catenary System)
  - Number of staff operating a vehicle is the same regardless of technology
  - Contract administration costs required for the operation of the reference case service is the same regardless of technology

Operating & Maintenance Costs

Rolling Stock

- Defined a comprehensive Life Cycle Maintenance (LCM) program
- The maintenance operation was broken down into the following categories:
  - Daily Maintenance and Inspection
  - Vehicle Cleaning
  - Scheduled Maintenance Program (also called Programmed LCM), which incorporates:
    - Running Repair and Corrective Maintenance
    - Heavy Repair
    - Mid-Life Overhaul
    - Unscheduled Maintenance

Wayside Maintenance

- Overhead catenary
- Power supply equipment (such as sub-stations)

Operating & Maintenance Costs

Energy Costs

- Diesel fuel was assumed to cost $0.75/L, based on current 2010 costs paid by Metrolinx
- Electricity was assumed billed at an average rate of $0.108/kWh, based on the electricity prices on the Hydro One website. No discounts or peak-use premiums were applied.
- Operation model produced total diesel fuel consumption per option
- Energy modeling, based on operating plan, produced total electricity consumption per option

Economic and Financial

- Major Financial Factors include:
  - Incremental rolling stock costs
  - Fuel v. electricity costs
  - Energy cost escalation
  - Capital cost and capital cost contingency
  - O&M cost savings
  - Demand levels
  - Inflation
  - Fare box revenue
- Economic Factors include:
  - Construction employment
  - Operating employment
  - Increased tax revenue

Responses to Frequently Asked Questions

- ARL incorporated throughout analysis?
- Costs of converting to Tier 4 included?
- Incremental costs of rolling stock considered?
- Full consideration of potential for EMUs?

Next Steps

- Completion of financial/ costing analysis; sensitivity analysis
- Completing risk assessment, example risks:
  - Corridor ownership
  - Clearances
- Phasing and implementation plan
  - assuming construction will be completed in shorter time blocks during the night to avoid the disruption in service
- Final report posted for public comments on study website (January)
- Board meeting to consider study findings (February 18)

Video

Discussion Questions for Small Groups

- What feedback do you have on the detailed assessment and key preliminary findings? Has anything been missed?

- In view of the key findings, what are your thoughts on the phasing and implementation of electrification on the GO rail network going forward?