



**Broadway Subway Project
Climate Lens Assessment**

Final GHG Report

March 8, 2019

Prepared for:

South Coast British Columbia
Transportation Authority
"TransLink"

Prepared by:

Stantec Consulting Ltd.
500-4730 Kingsway
Burnaby, BC V5H 0C6

Sign-off Sheet

This document entitled Broadway Subway Project Climate Lens Assessment was prepared by Stantec Consulting Ltd. ("Stantec") for the account of Ministry of Transportation and Infrastructure (the "Client"). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by Sandra Banholzer Digitally signed by Sandra Banholzer
Date: 2019.03.11 10:44:57 -07'00'

(signature)

Sandra Banholzer, M.Sc.

Reviewed by Sana Talebi Sana Talebi
2019.03.11 10:42:59 -07'00'

(signature)

Sana Talebi, B.Sc., P.Eng.

Approved by Frank Bohlken Digitally signed by Frank Bohlken
Date: 2019.03.11 11:59:22 -07'00'

(signature)

Frank Bohlken, B.Sc., MRM



Table of Contents

EXECUTIVE SUMMARY	I
ABBREVIATIONS	III
1.0 INTRODUCTION	1
1.1 PURPOSE OF THE REPORT.....	1
1.2 PROJECT OVERVIEW.....	2
1.3 REGULATORY SETTING	3
2.0 METHODOLOGY	6
2.1 BOUNDARY OF THE ASSESSMENT – REVIEW AREA.....	6
2.1.1 Spatial	6
2.1.2 Temporal.....	6
2.2 GREENHOUSE GASES CONSIDERED	6
2.3 EMISSION SCOPES	7
2.4 DATA SOURCES.....	8
2.5 GHG EMISSION CALCULATION PROCEDURES.....	9
2.6 ASSUMPTIONS.....	11
2.6.1 Construction	11
2.6.2 Operation.....	11
3.0 BUSINESS-AS-USUAL SCENARIO	12
3.1 CONSTRUCTION.....	13
3.2 OPERATION.....	14
4.0 ESTIMATED PROJECT EMISSIONS	15
4.1 CONSTRUCTION.....	15
4.1.1 Indicative Listing of Construction Grouping.....	15
4.1.2 Project Construction GHG Emissions	17
4.2 OPERATION AND MAINTENANCE.....	18
4.2.1 Change in Vehicle Kilometers Travelled	18
4.2.2 Maintenance.....	20
4.2.3 Project Operation and Maintenance GHG Emissions	20
5.0 ESTIMATED NET CHANGE IN GHG EMISSIONS	24
6.0 MITIGATION MEASURES	25
7.0 CONCLUSION	26
8.0 REFERENCES	27



LIST OF TABLES

Table 1	Project Emissions Summary for Construction and Operation.....	ii
Table 2	Project Emissions Summary for 2030	ii
Table 3	Physical Components of the Project.....	3
Table 4	Government GHG Reduction Strategies	4
Table 5	Sources and Removals of GHG Emissions.....	8
Table 6	GHG Emission Factors	10
Table 7	BAU GHG Emission Sources and Subcategories.....	12
Table 8	2020-2024 Baseline GHG Emissions for Metro Vancouver.....	13
Table 9	2025-2054 Baseline GHG Emissions for Metro Vancouver.....	14
Table 10	Construction Fleet Composition	16
Table 11	Year-by-Year Construction Greenhouse Gas Emissions.....	17
Table 12	Construction GHG Emissions Comparison to BAU	17
Table 13	Annual Vehicle Kilometers Travelled (VKT) Changes	19
Table 14	Operation Maintenance Fleet	20
Table 15	Year-by-Year Operation and Maintenance Greenhouse Gas Emissions	21
Table 16	Operation GHG Emissions Comparison to BAU	23
Table 17	Cumulative Summary.....	24

LIST OF FIGURES

Figure 1	Broadway Subway Project Alignment and Location	2
----------	--	---

LIST OF APPENDICES

APPENDIX A	BAU REGULATORY AND POLICY MEASURES.....	A.1
APPENDIX B	ATTESTATION OF COMPLETENESS	B.1



Executive Summary

The Ministry of Transportation and Infrastructure (MOTI) is funding and delivering the Broadway Subway Project (Project) to meet current and future ridership demands along the Broadway Corridor in Vancouver, British Columbia (BC). The proposed Project will extend the existing Millennium Line SkyTrain by 5.7 km from the current terminus at the VCC-Clark SkyTrain station to a new terminal station located at West Broadway and Arbutus Street. Construction of the Project is anticipated to begin in 2020, with service operation commencing in 2025. The Project is expected to operate for 30 years or more. This assessment however is limited to a 30-year operation phase.

Since the Project is a proposed major public infrastructure project that will be supported by federal funding, MOTI has completed a Climate Lens Assessment following Infrastructure Canada requirements (Infrastructure Canada 2018). The Climate Lens Assessment includes two components: a greenhouse house gas (GHG) mitigation assessment and a climate change resilience assessment. The objective of this report is to meet the GHG mitigation assessment requirements. It contains the methodology used to estimate GHG emissions resulting from the construction and operation of the Project and estimates the net GHG emission reductions compared to a functionally equivalent baseline scenario. While the Project will be constructed entirely within the boundaries of the City of Vancouver, the Project effects related to GHG emissions are expected to extend beyond the City of Vancouver due to predicted transportation mode shifts that will extend into other Metro Vancouver communities. Therefore, the Project's spatial boundaries have been aligned with the boundaries of Metro Vancouver.

The Project is designed to address current and forecasted transportation challenges in the area, related to population and employment growth, traffic congestion, sustainable transportation targets, and access to transit. The Project is expected to result in a net decrease in personal vehicle and bus traffic and increase in transit use in Metro Vancouver

Construction GHG emissions are estimated to be 22,111 t CO₂e per year, which equates to 110,557 t CO₂e over the five-year construction period. Cumulative construction emissions over the five-year construction period represent a 4.2% increase of the GHG emissions baseline when compared to the currently forecasted cumulative construction emissions for Metro Vancouver (see Table 1).

Operation and maintenance GHG emissions are estimated to be 545.5 t CO₂e per year, which equates to 16,356 t CO₂e over the 30-year operation period. Emission reductions resulting from reduced personal vehicle and bus travel are estimated to be between 8,687 to 10,736 t CO₂e per year, equating to 291,324 t CO₂e over the 30-year period. Total net operation (i.e. adding emission sources and deducting emission removals) reduction emissions are estimated to be between 8,141 and 10,191 t CO₂e per year, totaling 274,968 t CO₂e over the Project operation. This represents a 0.3% reduction of the GHG emission baseline when compared to the currently forecasted cumulative emissions for Metro Vancouver (see Table 1).

Inclusive of construction and operation related emissions, the Project will result in an estimated net decrease of GHG emissions of 164,410 tCO₂e from 2020-2054 (Table 2).



Table 1 Project Emissions Summary for Construction and Operation

Scenario	Value
Construction	
BAU baseline construction emissions for Metro Vancouver 2020-2024 ^a	2,648,607 t CO ₂ e
Net Project construction emissions 2020-2024	110,557 t CO ₂ e
Percentage contribution of Project construction emissions to BAU	+4.2%
Operation	
BAU baseline light-duty vehicles (LDV) emission for Metro Vancouver 2025-2054 ^a	84,056,904 t CO ₂ e
Net Project operation emissions 2025-2054	-274 ,968 t CO ₂ e
Percentage contribution of Project operation emissions to BAU	-0.3%
Net	
Net Cumulative Project Emissions 2020-2054	-164,410 t CO ₂ e
NOTE:	
^a Based on GHG forecast from Metro Vancouver (2018)	

During the 2015 COP21 in Paris (UNFCCC 2015), Canada committed to a 30% reduction of national GHG emissions below the 2005 level by 2030. If this target is achieved, the national GHG total will be 517,000,000 t CO₂e. In 2030, the Project is estimated to reduce baseline GHG emissions by 9,837 tCO₂e/year which represents 0.0019% of Canada’s 2030 GHG reduction target (Table 2).

Table 2 Project Emissions Summary for 2030

Scenario	Value
Paris Agreement - GHG Emissions in 2030 (30% below 2005)	517,000,000 t CO ₂ e
Operations emissions for the year 2030	-9,837 t CO ₂ e
Percentage contribution of Project operation emissions to 2030 GHG Emissions	0.0019%



Abbreviations

BAU	Business-as-usual
BC	British Columbia
BCRTC	British Columbia Rapid Transit Company
CH ₄	Methane
CO ₂	Carbon dioxide
CO ₂ e	Carbon dioxide equivalent
ESR	Environmental and Socio-Economic Review
GHG	Greenhouse gas
Guidance	Infrastructure Canada's Climate Lens General Guidance v.1.
HDV	Heavy-duty vehicle
HFCs	Hydrofluorocarbons
ICIP	Investing in Canada Infrastructure Program
LDV	Light-duty vehicle
MOTI	Ministry of Transportation and Infrastructure
NF ₃	Nitrogen trifluoride
N ₂ O	Nitrous oxide



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

NIR	National Inventory Report
PFCs	Perfluorocarbons
Project	Broadway Subway Project
RTM	Regional Transportation Model
SF ₆	Sulphur hexafluoride
t	Tonne
T&D	Transmission and Distribution
UBC	University of British Columbia
UNFCCC	United Nations Framework Convention on Climate Change
VKT	Vehicle kilometre travelled



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Introduction
March 8, 2019

1.0 INTRODUCTION

A Climate Lens Assessment is a requirement of infrastructure projects receiving federal funding through the Investing in Canada Infrastructure Program (ICIP). The ICIP is a bilateral agreement between Infrastructure Canada and the individual provinces and territories. The Climate Lens Assessment requirement applies to major public infrastructure projects, including public transit projects, with a total estimated cost of over \$10 million.

The Climate Lens Assessment includes two components: a greenhouse gas (GHG) mitigation assessment and a climate change resilience assessment. This report summarizes the GHG mitigation assessment.

Given these requirements, the Broadway Subway Project (the Project) is conducting this GHG mitigation assessment in support of meeting federal funding requirements. This report has been prepared in accordance with Infrastructure Canada's Climate Lens General Guidance v.1.1 (the Guidance) (Infrastructure Canada 2018). The information contained in the GHG mitigation assessment includes:

- Methodologies used to estimate GHG emissions for the Project (see Section 2.0)
- Description of a baseline scenario against which the emissions from the Project are compared against (see Section 3.0)
- GHG emission estimates for the construction and operation phase of the Project (see Section 4.0)
- Comparison between the estimated Project GHG emissions and the baseline emissions (see Section 5.0)
- Applicable mitigation measures for the Project (see Section 6.0)
- Concluding remarks (see Section 7.0)

1.1 PURPOSE OF THE REPORT

The purpose of the GHG mitigation assessment is to assess if the Broadway Subway Project will result in a net increase or decrease in GHG emissions. The scope of the evaluation presented in this assessment includes Project construction and operations activities.

In accordance with the Infrastructure Canada's Guidance, the following components are included in this GHG mitigation assessment.

- Definition of the review area
- Characterization of the baseline conditions within the review area, including:
 - Baseline conditions for construction emission
 - Baseline conditions for operation emissions
- Characterization of GHG emissions from Project construction
- Characterization of GHG emissions from Project operation
- Mitigation measures to reduce/limit GHG emissions



Introduction
March 8, 2019

1.2 PROJECT OVERVIEW

The Ministry of Transportation and Infrastructure (MOTI) is proposing to develop the Broadway Subway Project to meet current and future ridership demands along the Broadway Corridor in Vancouver, British Columbia (BC). The proposed Project will extend the existing Millennium Line SkyTrain by 5.7 km from the current terminus at the VCC-Clark SkyTrain station to a new terminal station located at West Broadway and Arbutus Street. Construction of the Project is anticipated to begin in 2020, with service operation commencing in 2025. The Project is expected to operate for 30 years or more.

The Project will include an elevated guideway extending approximately 700 m westward from the existing terminus at VCC-Clark Station to the new underground station at Great Northern Way. From Great Northern Way Station, the alignment continues underground to the station location at Broadway and Main Street. The remainder of the alignment travels west, under Broadway, to a new terminus at Arbutus Street. Figure 1 illustrates the Project alignment. Construction will be lying primarily within the limits of previously-developed urban roadways.

The Broadway Subway Project will be fully integrated with existing SkyTrain systems in Metro Vancouver and will extend the Millennium Line to provide rapid transit service to residential areas, businesses, medical facilities, and educational institutions throughout the Broadway Corridor. Project planning has been supported by significant consultation on potential alternative technology and alignment options for rapid transit along the Broadway Corridor and represents a priority for MOTI for improving public transportation in Metro Vancouver (Metro Vancouver 2011a,b, TransLink 2013). The Project is expected to result in a net decrease in light duty vehicles (LDV)¹ traffic, remove buses off the road, and increase transit use.



Figure 1 Broadway Subway Project Alignment and Location

Key Project components include elevated guideway and tunnel, six stations, and power, control and communications systems. The Broadway Subway Project will be integrated into the existing SkyTrain network and once operational it will support the same train vehicles as used elsewhere on the Millennium Line. See Table 3 for more details.

¹ Defined as passenger cars and trucks, light commercial trucks, and motorcycles with gross vehicle weight rating less than 8500lb (Metro Vancouver 2018)



Introduction
 March 8, 2019

Table 3 Physical Components of the Project

Project Feature	Components
Elevated guideway and tunnel	<ul style="list-style-type: none"> • Elevated guideway extending westward from VCC-Clark Station • Underground alignment from approximately Great Northern Way and Thornton Street to Arbutus Street
Six stations	<ul style="list-style-type: none"> • Six underground stations including platforms that are accessible by elevator and escalators • Stations in the vicinity of Great Northern Way and Thornton Street, and along Broadway at Main, Cambie, Oak, Granville, and Arbutus streets.
Power, control and communications systems	<ul style="list-style-type: none"> • Extension and upgrade of existing systems for the Millennium Line

The main construction activities associated with the Project include property acquisition and land access, site preparation and utility relocation, tunnel and station excavation, station construction, management and disposal of waste and excavated materials and commissioning and start up. GHG emissions are expected from the operation of heavy-duty on-road and off-road diesel construction equipment.

During the operation phase, the Project will be operated and maintained by the British Columbia Rapid Transit Company (BCRTC), which is a wholly owned operating subsidiary of TransLink. BCRTC operates and maintains the existing Expo and Millennium Lines and will assume the same responsibilities for the Project, including the maintenance of guideway, stations, track, electrical and mechanical systems, and rail vehicles. GHG emission are expected from the operation of the Broadway Subway and include indirect GHG emissions from electricity consumption, direct GHG emissions from maintenance activities (diesel powered equipment), and GHG emission reductions resulting from reduced bus use (direct emission) and personal vehicle use (indirect emissions).

1.3 REGULATORY SETTING

Federal, provincial, and municipal jurisdictions have committed to implementing strategies towards achieving GHG reductions. Federal approaches include agreements, commitments and legislation made at a national and international level. The Province’s Climate Action Plan, a voluntary tripartite agreement between the Province, the Union of BC Municipalities and each local government signatory also provides a tool to reduce the Province’s GHG emissions. Both the Province’s Climate Action Plan and the Climate Leadership Plan have established sustainable transportation targets towards achieving reductions in GHG emissions.

See Table 4 for a list of applicable GHG reduction programs from a federal to local level.



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Introduction
March 8, 2019

Table 4 Government GHG Reduction Strategies

Context	Law, Regulation, or Policy	Description
Federal	Paris Agreement	During the 2015 21 st Conference of Parties in Paris (UNFCCC 2015), Canada committed to a 30% reduction of national GHG emissions below the 2005 level by 2030. As a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), Canada is reporting annual national GHG totals to the UNFCCC.
	Pan Canadian Framework	In December 2015, the federal government working with the province and territorial governments committed to the Pan Canadian Framework designed to address climate change, provide a clean economy and reach Canada's GHG reduction target of 30% emissions reduction below 2005 levels by 2030.
	Clean Fuel Standard and Zero Emissions Vehicle strategy	The Government of Canada is committed to developing a standard that will reduce carbon emissions from all fuels by 30million tones in 2030, contributing to Canada's effort to achieve its overall GHG mitigation target of 30% emission reduction below 2005 levels by 2030.
Province	<i>Greenhouse Gas Reduction Targets Act</i>	This Act sets legislated GHG reduction targets for BC, requiring a 40% reduction by 2030 below the 2007 level. By 2040 and 2050, GHG emissions will be 60% and 80% respectively below 2007 levels (Government of BC 2018a). In accordance with this Act, the Province reports annually on its GHG inventory for the National Inventory Report. Emissions from the transportation sector are captured in this report.
	<i>Carbon Tax Act</i>	The <i>Carbon Tax Act</i> prices carbon via a provincial carbon tax introduced in 2008. The tax rate will increase each year by \$5 per tonne until it reaches \$50 per tonne in 2021. This provides an economy-wide incentive to use less fossil fuel and reduce emissions. It is a broad-based tax that applies to the purchase and subsequent combustion of fuels such as gasoline, diesel and natural gas (Government of BC 2018b).
	<i>Low Carbon Fuel Standards</i>	Under the Renewable and Low-Carbon Fuel Requirements Regulation, fuel suppliers are required to reduce the GHG emission intensity of the transportation fuel they supply. British Columbia is the only Canadian jurisdiction with an existing Low Carbon Fuel Standard (LCFS) which aims to reduce carbon intensity of the transportation fuel mix in BC by 10% by 2020 relative to 2010 (BC MEM 2017).
Metro Vancouver	Integrated Air Quality and Greenhouse Gas Management Plan	The vision of this plan in regard to GHGs is to minimize the region's contribution to global climate change. Reduction goals are set to 33% reduction by 2020 from 2007 levels and 80% by 2050, in accordance with the provincial GHG reduction target act (Metro Vancouver 2011b). Metro Vancouver specifically identified that reducing GHG emissions from the transportation sector poses a significant opportunity to lower the overall GHG footprint (Metro Vancouver 2011a, Metro Vancouver 2014). In 2010 36% of Metro Vancouver's GHG emissions were from transportation sources (i.e., light and heavy-duty vehicles) (Metro Vancouver 2013)



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Introduction
March 8, 2019

Table 4 Government GHG Reduction Strategies

Context	Law, Regulation, or Policy	Description
City of Vancouver	Greenest City Action Plan	Project is expected to contribute to the advancement of the City of Vancouver's Greenest City Action Plan, which includes reducing community GHGs by 33% by 2020 from 2007 levels (including through the reduction of transportation fuel use), and improving transit such that it is fast, frequent, reliable, and accessible (City of Vancouver 2018). The action plans also aims to make the City of Vancouver more green operating through reducing GHGs by 50% from 2007 levels by 2020 (City of Vancouver 2018).
TransLink	TransLink's Goal from Mayor's Council 2018	Commitments to align with Canada's GHG target to reduce GHGs by at least 80% by 2050, and the commitment to procure only zero emissions buses from 2050.



2.0 METHODOLOGY

The methods used to estimate GHG emissions from the Project are based on accounting and reporting principles of the GHG Protocol developed by the World Resource Institute and the World Business Council for Sustainable Development (2013). This protocol is an internationally accepted accounting and reporting standard for quantifying and reporting GHG emissions. The guiding principles of the protocol for compiling an inventory of GHG data are relevance, completeness, consistency, transparency, and accuracy which align with ISO-14064-2 (WCI 2013).

2.1 BOUNDARY OF THE ASSESSMENT – REVIEW AREA

2.1.1 Spatial

While the Project will be constructed entirely in the City of Vancouver, the Project effects related to GHG emissions are expected to extend beyond the boundaries of the City of Vancouver due to predicted transportation mode shifts that will extend into other Metro Vancouver communities. Therefore, the Project’s spatial boundaries have been aligned with the municipal boundaries of Metro Vancouver.

Because GHG emissions disperse in the atmosphere, the “boundaries” of this assessment were used to depict the limits of this assessment and are not the physical boundaries of Project emissions.

2.1.2 Temporal

The temporal boundaries considered for the GHG Assessment included the Project construction and operations phases. Construction and commissioning of the Project were anticipated to take five years between 2020 and 2024. Project operation was scheduled to begin in 2025 and to continue for a period of at least 30 years. For the purpose of this assessment, the operation phase was limited to 30 years from 2025 until 2054. Thirty years was selected because beyond that timeframe, the certainty of forecasting baseline and project emissions decreases, as regulatory impact and Project specific details (e.g., fleet profile of the future) were not available.

Consistent with the Guidance, the assessment excluded assessing anticipated major rehabilitative maintenance or decommissioning activities, supply chain, and embodied GHG emissions.

2.2 GREENHOUSE GASES CONSIDERED

A GHG is any atmospheric gas that absorbs and re-emits infrared radiation, thereby acting as a thermal blanket for the planet and warming the lower levels of the atmosphere. GHGs are released to the atmosphere from several natural and anthropogenic (human activity) sources (IPCC 2013).



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Methodology
March 8, 2019

As per the Guidance, the GHG mitigation assessment considered all GHGs tracked through Canada's National Inventory Report (NIR), including:

- Carbon dioxide (CO₂)
- Methane (CH₄)
- Nitrous oxide (N₂O)
- Perfluorocarbons (PFCs)
- Hydrofluorocarbons (HFCs)
- Sulphur hexafluoride (SF₆) and,
- Nitrogen trifluoride (NF₃)

However only CO₂, CH₄ and N₂O were included in this assessment, since the remaining gases listed above were not expected to be emitted during construction or operation of the Project.

Final reported emissions were converted into tonnes (t) CO₂ equivalent (CO₂e) by multiplying each GHG by their global warming potentials from the most recent NIR (ECCC 2018) (i.e. CO₂= 1, CH₄=25 and N₂O= 298):

$$\text{CO}_2\text{e} = (\text{mass CO}_2 \times 1.0) + (\text{mass CH}_4 \times 25) + (\text{mass N}_2\text{O} \times 298)$$

2.3 EMISSION SCOPES

In accordance with the Guidance, this GHG mitigation assessment considered Project-related direct and indirect GHG emissions as well as any emission reductions linked to the Project. Direct and Indirect emissions are defined by Infrastructure Canada as follows:

- **Direct GHG Emissions:** GHG emissions or removals from sources or sinks that are owned or controlled by the Project applicant and within the Project boundary. Direct emissions are also commonly referenced as Scope 1 emissions (Infrastructure Canada 2018).
- **Indirect GHG Emissions:** GHG emissions or removals that are a consequence of the Project but occur at GHG sources or sinks not owned or controlled by the applicant (Infrastructure Canada 2018). For example, increased electricity consumption would be considered an indirect effect as the GHG emissions generated to create the electricity are outside of a Project's boundaries. These are often classified as a Scope 2 emission source. Indirect emissions can also include Scope 3 emissions. Scope 3 emissions include emissions occurring in a Project's value chain, including both upstream and downstream emissions. In the context of the Project, Scope 3 emissions include reductions in personal vehicle and bus use as a result of increased SkyTrain capacity.

For the GHG mitigation assessment for the Project the following direct and indirect GHG emission sources and removals have been included (see Table 5).



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Methodology
March 8, 2019

Phase	Item	Description	Source/ Removal	Direct/ Indirect	Emissions Scope a
Construction	Construction – Mobile Equipment	GHG emissions from the operation of construction equipment and vehicles	Source	Direct	Scope 1
Operation	Operation - SkyTrain	GHG emissions from SkyTrain vehicles due to increased VKTs travelled and hence increased electricity consumption including electricity for maintenance activities.	Source	Indirect	Scope 2
		GHG emissions from transmission and distribution (T&D) loss of electricity consumed	Source	Indirect	Scope 3
	Operation - Bus	GHG emissions from reduced bus service	Removal	Direct	Scope 1
	Operation - Automobile	GHG emissions from reduced personal vehicle use	Removal	Indirect	Scope 3
	Operation – Mobile Emissions	GHG emissions from the operations of diesel-powered maintenance equipment	Source	Direct	Scope 1
<p>NOTE:</p> <p>^a Scope 1: All direct emissions; Scope 2: Indirect emissions from consumption of purchased electricity, heat or steam; Scope 3: Other indirect emissions, e.g., transport related activities in vehicles not owned or controlled by the Project.</p>					

2.4 DATA SOURCES

The following data sources were used in the GHG Mitigation Assessment:

- GHG emissions for the baseline scenarios for the construction and operation phase were obtained from Metro Vancouver’s 2018 GHG emission inventory.
- GHG emissions for the construction phase were prepared based on the information provided in the Environmental and Socio-Economic Review (ESR) undertaken for the Broadway Subway Project.
- GHG emission for the operation phase were prepared with input from the ESR, the regional transportation model (RTM), and the business case (BC Ministry of Transportation 2018).



2.5 GHG EMISSION CALCULATION PROCEDURES

Direct (Scope 1) GHG emissions resulting from off-road and on-road mobile equipment were calculated based on the number and type of units of mobile equipment, fuel consumption, total annual working hours, and GHG emission factors (e.g., for CO₂, CH₄, and N₂O) for each off-road and on-road equipment from the 2018 NIR (ECCC 2018) (see Table 6). Off-road GHG emissions sources included equipment, engines or vehicles that are primarily used for construction activities. These emission sources are typically not approved to be driven on highways or public roads. On-road equipment are mobile sources that are approved to travel on highways and public roads.

Indirect GHG emissions from electricity consumption were estimated by using electricity intensity emission factors from the 2018 NIR (ECCC 2018) multiplied by the amount of electricity consumed (see Table 6).

Direct and indirect emissions resulting from a change in VKTs travelled either by the Broadway Subway, bus or personal vehicles, were estimated by multiplying the amount of VKTs by the respective emission factor (see Table 6). These emission factors were provided by Metro Vancouver and applied in a range of rapid transit business cases. It was assumed that emission factors will be lower in the future as technology advances such as improved fuel efficiency and tailpipe emission standards.



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Methodology
 March 8, 2019

Table 6 GHG Emission Factors

Source		GHG	Units	Emission Factor
Off-Road Mobile Equipment ^a		CO ₂	g/L of fuel	2,681
		CH ₄	g/L of fuel	0.073
		N ₂ O	g/L of fuel	0.022
On-Road Mobile Equipment (Heavy Duty Diesel Vehicle, uncontrolled, Type VIIIb) ^{a,b}		CO ₂	g/L of fuel	2,681
		CH ₄	g/L of fuel	0.15
		N ₂ O	g/L of fuel	0.075
Electricity Generation Intensity ^c		CO ₂ e	g/kWh	11.1
Electricity Consumption Intensity ^c		CO ₂ e	g/kWh	11.7
Bus ^{d,e}	2015	CO ₂ e	g/km	1,920
	2030	CO ₂ e	g/km	1,823
	2045	CO ₂ e	g/km	1,827
SkyTrain	2015	CO ₂ e	g/km	93
	2030	CO ₂ e	g/km	88
	2045	CO ₂ e	g/km	88
Automobile ^e	2015	CO ₂ e	g/km	287
	2030	CO ₂ e	g/km	201
	2045	CO ₂ e	g/km	164

NOTES:

- ^a GHG emission factors are based on the most recent NIR (ECCC 2018)
- ^b Includes only the vehicle type VIIIb (vehicles > 60,000 pounds) applicable to the Project construction (US EPA 2008)
- ^c The difference in generation and consumption intensity represents the emissions associated with transmission and distribution loss.
- ^d The emission factor of the bus is based on a mix of diesel and electricity
- ^e Based on SDG (2017a)



2.6 ASSUMPTIONS

Assumptions for construction and operational emission sources and removals as listed in Table 5 are outlined below.

2.6.1 Construction

- Duration of construction was assumed to last up to five years from 2020-2024.
- Construction emissions were estimated for the peak construction year, which assumed that construction equipment was active at the same time at three stations.
- All on-road and off-road equipment was assumed to be powered with diesel fuel.
- Cumulative construction emissions were established by multiplying peak annual emissions by five years. This is considered conservative, as it is unlikely that peak construction activities will be consistently implemented over the entire five-year period.
- The baseline emissions against which the Project construction emissions are compared were represented by the forecasted Metro Vancouver construction emissions. Metro Vancouver's construction emissions are captured in a subcategory of the non-road engine/equipment category (Metro Vancouver 2018).
- Since the forecasted Metro Vancouver baseline emissions are only available in five-year increments, annual emissions were obtained by linearly interpolating between the forecasted years. It was assumed that the emissions follow a linear trend between the forecasted years.

2.6.2 Operation

- The assessment assumed a 30-year life-span from opening year 2025 until 2054.
- Changes in VKTs by the Broadway Subway were estimated based on the 2030 and 2045 AM peak frequencies and the service distance changes i.e. increase in distance for the Broadway Subway. The addition of the Broadway Subway will lead to positive SkyTrain VKTs when compared to the BAU scenario. The number of vehicles affected were multiplied by the difference in distance travelled to obtain daily VKTs (note that a 4-vehicle train configuration was assumed for the SkyTrain). This was expanded to annual estimates based on the current Millennium SkyTrain weekday/weekend schedule.
- Currently, the 99-B Line is running from Commercial-Broadway station to University of British Columbia (UBC). After Project implementation, the 99-B Line will only run between Arbutus and UBC. This truncation of the 99 B-Line will lead to a reduction in bus VKTs when compared to the BAU scenario. Changes in VKTs by the bus were estimated based on the 2030 and 2045 AM peak frequencies and the service distance changes (i.e. reduction in distance). The number of vehicles affected were then multiplied by the difference in distance travelled to obtain daily VKTs. This was expanded to annual estimates based on the current 99 B-Line weekday/weekend schedule.
- Changes in VKTs by personal vehicles were estimated based on the difference between the auto VKT in the BAU and the Broadway Subway scenario. The auto VKT were estimated from the Regional Transportation Model (RTM) Phase 2.2 analysis and were consistent with the Broadway Subway business case (SDG 2017b). RTM is a 4-stage transportation forecasting model of Metro Vancouver for the years 2030 and 2045 based on future population and employment based on the Regional Growth Strategy. This reduction in personal vehicle use will lead to a reduction in VKTs when compared to the BAU scenario. RTM outputs for the 2030 and 2045 AM Peak (7:30AM to 8:30AM) were annualized based on a factor for 3,973² and values were interpolated between 2030 and 2045 and extrapolated between 2025 and 2030 and 2030 to 2054 based on 2030-2045 growth profile.

² 3,973 is an expansion factor to obtain an annual number from an AM peak hour number (SDG 2017a).



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Business-as-Usual Scenario
March 8, 2019

- Maintenance related electricity consumption was assumed to be 7.8% of the total electricity consumption for train propulsion (TransLink 2018). Total electricity was estimated based on the assumed energy consumption per train car-km of 3.5 kWh (TransLink 2010).
- Emissions related with commissioning of SkyTrain vehicles were assumed negligible.
- The baseline emissions against which the Project operation emissions were compared are represented by the forecasted Metro Vancouver light-duty vehicle (LDV) emissions (mainly personal transportation vehicles). LDV emission are a subcategory of the mobile emissions category (Metro Vancouver 2018).
- Since the forecasted Metro Vancouver baseline emissions are only available in five-year increments, annual emissions were obtained by linearly inter- or extrapolating the appropriate trend profile. It was assumed that the emissions follow a linear trend between the forecasted years.

3.0 BUSINESS-AS-USUAL SCENARIO

The Project construction and operation GHG emissions were assessed against comparable and functionally equivalent GHG emissions that would occur in the absence of the Project. This is referred to the baseline scenario or a business as usual (BAU) which was used to determine if the Project results in a net increase or decrease in GHG emissions.

The baseline scenario assumed that the Project did not proceed. Baseline emissions were represented by the published GHG inventory for Metro Vancouver (Metro Vancouver 2018). This GHG inventory forecasts emissions for the entire region of Metro Vancouver and accounts for all known sources (e.g., mobile sources, industrial sources etc. (see Table 7)). It also accounts for any known and confirmed federal, provincial and regional regulatory and policy measures as they relate to energy and GHG emissions, as well as new anticipated emission sources (see Appendix A) (Metro Vancouver 2018).

Table 7 BAU GHG Emission Sources and Subcategories

Source Category	Subcategories
Mobile Sources	On-road vehicles (cars, buses, trucks) and off-road vehicle (i.e. train locomotives), construction equipment, marine vessels and aircrafts
Area Sources	Agriculture, chemical products use, fugitive dust, heating, natural sources, vegetative burning, waste, miscellaneous sources
Industrial Sources	Bulk shipping terminals, chemical manufacture, concrete batch plants, electric power generation, heating/cogeneration utilities, metal industries, non-metallic mineral processing, paper and allied products, petroleum products, wood products, and miscellaneous industrial sources
SOURCE: Metro Vancouver 2018	

Metro Vancouver's forecasted BAU scenario assumes that TransLink does not undertake any significant changes to its bus or rail routes within the region. Therefore, the emissions forecasted by Metro Vancouver (2018) were considered a representable baseline against which the Project emission could be compared.



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Business-as-Usual Scenario
March 8, 2019

In the baseline scenario, there would be no construction or operation GHG emissions from the Project. Therefore, comparison of Project construction and operation GHG emissions against the forecasted emissions of Metro Vancouver was used to determine if the Project results in a net increase or decrease in GHG emissions.

Section 3.1 and 3.2 provide a detailed description of the construction and operation baseline scenario for the review area of Metro Vancouver (Metro Vancouver 2018).

3.1 CONSTRUCTION

Forecasted construction emissions for Metro Vancouver (i.e. not including the construction emissions from the Broadway Subway Project) were considered as a baseline against which the Project construction emissions were compared. Table 8 presents the 2020-2024 forecasted GHG emissions for construction activities in Metro Vancouver. Over the Project's five-year construction period, Metro Vancouver's forecasted total emissions from construction activities were estimated to amount to 2,648,607 t CO₂e. For context, these construction emissions represent 7% of the total mobile emissions, which account for 49% of all of Metro Vancouver's GHG emission (all sources combined i.e. mobile, area and industrial). The cumulative construction emissions from the Metro Vancouver inventory from 2020 – 2024 were used as a BAU for the estimated Project's construction emissions.

Table 8 2020-2024 Baseline GHG Emissions for Metro Vancouver

Year ^{a,b}	GHG Emissions (t CO ₂ e/year)		
	Metro Vancouver – Total Emissions	Metro Vancouver – Mobile Emissions	Metro Vancouver – Construction Emissions ^c
2020	14,703,385	7,305,861	511,531
2021	14,674,387	7,259,197	520,626
2022	14,645,389	7,212,532	529,721
2023	14,616,392	7,165,868	538,817
2024	14,587,394	7,119,204	547,912
Cumulatively over construction period from 2020-2024	73,226,947 (100%)	36,062,662 (49% of Total Emissions)	2,648,607 (7% of Mobile Emissions)
NOTES:			
^a Metro Vancouver forecasted GHG emissions were provided by Metro Vancouver (2018)			
^b Forecasted emissions are only available in five year increments i.e. for 2020 and 2025. Emissions of the years in between 2020 and 2025 were linearly interpolated.			
^c Construction emission are a subcategory of non-road engine/equipment within the mobile emissions category			



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Business-as-Usual Scenario
March 8, 2019

3.2 OPERATION

Forecasted Metro Vancouver LDV emissions were considered as a baseline against which Project operation emissions were compared. Table 9 presents the 2025-2054 forecasted GHG emissions from LDV in Metro Vancouver.

Over the 30- year Project operation period Metro Vancouver's total LDV emissions were estimated to amount to 84,056,904 t CO₂e. For context, these LDV emission represent 41% of total mobile emissions, which account for 47% of all of Metro Vancouver's GHG combined (all sources combined i.e. mobile, area and industrial). These cumulative LDV emissions from the Metro Vancouver inventory from 2025- 2054 were used as a BAU for the estimated Project's operation emissions.

Table 9 2025-2054 Baseline GHG Emissions for Metro Vancouver

Year ^{a,b}	GHG Emissions (t CO ₂ e/year)		
	Metro Vancouver – Total Emissions	Metro Vancouver – Mobile Emissions	Metro Vancouver – LDV Emissions ^c
2025	14,558,396	7,072,539	3,648,795
2026	14,549,026	7,046,698	3,576,091
2027	14,539,657	7,020,856	3,503,387
2028	14,530,287	6,995,014	3,430,684
2029	14,520,917	6,969,172	3,357,980
2030	14,511,548	6,943,330	3,285,276
2031	14,525,039	6,933,846	3,233,303
2032	14,538,530	6,924,363	3,181,330
2033	14,552,022	6,914,880	3,129,357
2034	14,565,513	6,905,396	3,077,384
2035	14,579,005	6,895,913	3,025,411
2036	14,592,496	6,886,429	2,973,437
2037	14,605,988	6,876,946	2,921,464
2038	14,619,479	6,867,462	2,869,491
2039	14,632,970	6,857,979	2,817,518
2040	14,646,462	6,848,496	2,765,545
2041	14,659,953	6,839,012	2,713,572
2042	14,673,445	6,829,529	2,661,599
2043	14,686,936	6,820,045	2,609,626
2044	14,700,428	6,810,562	2,557,652
2045	14,713,919	6,801,078	2,505,679
2046	14,727,410	6,791,595	2,453,706
2047	14,740,902	6,782,112	2,401,733
2048	14,754,393	6,772,628	2,349,760



Estimated Project Emissions
March 8, 2019

Table 9 2025-2054 Baseline GHG Emissions for Metro Vancouver

Year ^{a,b}	GHG Emissions (t CO ₂ e/year)		
	Metro Vancouver – Total Emissions	Metro Vancouver – Mobile Emissions	Metro Vancouver – LDV Emissions ^c
2049	14,767,885	6,763,145	2,297,787
2050	14,781,376	6,753,661	2,245,814
2051	14,794,868	6,744,178	2,193,841
2052	14,808,359	6,734,694	2,141,867
2053	14,821,850	6,725,211	2,089,894
2054	14,835,342	6,715,728	2,037,921
Cumulatively over operation period from 2025-2054	439,534,400 (100%)	205,842,496 (47% of total emissions)	84,056,904 (41% of mobile emissions)

NOTES:

^a Metro Vancouver forecasted GHG emissions were provided by Metro Vancouver (2018)

^b Forecasted emissions are only available in five year increments i.e. for 2025, 2030 and 2035. Emissions for the years in between i.e. 2025-2030 and 2030-2035 and for the years outside of the forecasted range i.e. 2035-2054 were linearly inter- or extrapolated from the emissions reported for 2025, 2030 and 2035.

^c LDV emission are a subcategory of the mobile emissions category

4.0 ESTIMATED PROJECT EMISSIONS

This section presents estimated Project GHG emissions during the construction and operation phase.

4.1 CONSTRUCTION

This section presents the assessment of the direct GHG emissions of the Project construction phase for each calendar year, and the cumulative total. Construction GHG emissions mostly originate from heavy-duty off-road and on-road construction equipment.

4.1.1 Indicative Listing of Construction Grouping

The Project’s estimated construction fleet composition is summarized in Table 10, with the fleet broken out into four construction components: station box construction, portal/tunneling, above ground rail construction, and other miscellaneous activities. As outlined in Section 2.6.1, this assessment assumed that construction activities will occur simultaneously at three stations during the peak construction year.



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Estimated Project Emissions
March 8, 2019

Table 10 Construction Fleet Composition

Equipment Type	Number of Units	Operating details per unit of equipment			
		Engine Power (hp)	Fuel Consumption (L/h) ^b	Operating Time ^a	
				(h/d)	(d/y)
Station Construction					
Articulated Dump Truck (17 m ³)	2	464	40	13/10	365
Concrete Pumper (Stationary)	2	27	7.2	13/10	365
Excavator	2	160	19.2	13/10	365
Compressor	2	283	30.3	13/10	365
Rock Drill / Soil Nail Drills	2	200	22.8	13/10	365
Crane	1	230	30.3	13/10	365
Vibratory Piling	1	270	40.0	13/10	365
Portable Light Generator	2	30	2.0	13/10	365
Portal/tunnel					
66 000 lb HDD rig	1	200	22.8	13/10	365
Centrifuge, S/S High Speed	1	27	40.0	13/10	365
Mud Pump	1	1000	40.0	13/10	365
Zoom Boom	1	100	40.0	13/10	365
Backhoe	2	268	17.0	13/10	365
Backup Alarm	2	-		13/10	365
Portable Light Generator	2	30	2.0	13/10	365
Above ground construction					
Vibratory Tamper	1	-		13/10	365
Bulldozer	1	190	40.0	13/10	365
Skid Steer	1	120	9.0	13/10	365
Backhoe	1	83	17.0	13/10	365
Grader	1	120	18.5	13/10	365
Front End Loader - Towing	1	247	17.0	13/10	365
Welding Rig	1	350	22.8	13/10	365
Track Lifting Rig	1	160	22.8	13/10	365
Backup Alarm ^b	4	-		13/10	365
Portable Light Generator	2	30	2.0	13/10	365
Miscellaneous					
Articulated Dump Truck (17 m ³) - Idle for Loading	1	464	40	13/10	365
Portable Light Generator	1	30	2.0	13/10	365
NOTES:					
^a Operating time varies. The equipment will operate 13 hours per day Mon-Sat and 10 hours on Sunday.					
^b The unit of L/100km is used for some equipment. In these cases, the average speed was assumed to be 25km/hr.					



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Estimated Project Emissions
March 8, 2019

4.1.2 Project Construction GHG Emissions

Table 11 presents annual and cumulative construction GHG emission expected to occur during the five-year construction period. There are no expected construction activities that would result in any GHG reductions or removals (see Table 11).

Table 11 Year-by-Year Construction Greenhouse Gas Emissions

Year	Total Project Construction Emissions (A) t CO ₂ e/ year	Total Project Construction Removals (B) t CO ₂ e/ year	Total Net Project Emissions and Removals (A-B) t CO ₂ e/ year
2020	22,111	0	22,111
2021	22,111	0	22,111
2022	22,111	0	22,111
2023	22,111	0	22,111
2024	22,111	0	22,111
Cumulative Total	110,557	0	110,557

The net Project construction emission totals were compared against the forecasted baseline emissions in Table 12. It was estimated that the cumulative Project construction emissions would increase construction baseline GHG emissions by 4.2%.

Table 12 Construction GHG Emissions Comparison to BAU

Year	Total Net Project Construction Emissions (tCO ₂ e) ^a	BAU Baseline Emissions - Metro Vancouver Construction Emissions (tCO ₂ e) ^b	Percentage Contribution (%) when compared to Metro Vancouver Construction Emissions
2020	22,111	511,531	4.3
2021	22,111	520,626	4.2
2022	22,111	529,721	4.2
2023	22,111	538,817	4.1
2024	22,111	547,912	4.0
Cumulative Total	110,557	2,648,607	4.2

NOTE:

^a Emissions from work completed for the ESR (Stantec 2018) but with updated emission factors from NIR (ECCC 2018)

^b See Section 3.1



4.2 OPERATION AND MAINTENANCE

This section presents the estimated operational GHG emissions resulting from the Project. The operational GHG emissions estimates were based on the following factors:

- Increased use of SkyTrain services from the Broadway Subway Project (change in VKT, i.e. increase)
- Reduction in bus services, primarily from the truncation of 99 B-Line services between Arbutus and UBC (change in VKT, i.e. reduction)
- Reduction in personal vehicle use (change in VKT, i.e. reduction) as a result of increased transit capacity
- Maintenance emissions

4.2.1 Change in Vehicle Kilometers Travelled

Table 13 presents the change in SkyTrain, bus, and personal vehicle VKTs as a result of the Project. Estimated GHG emissions associated with the change in VKTs shown in Table 13 are presented in Table 15.



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Estimated Project Emissions
 March 8, 2019

Table 13 Annual Vehicle Kilometers Travelled (VKT) Changes

Year	Annual VKT Changes (000's)		
	SkyTrain	Bus	Personal Vehicle
2025	4,840	-542	-45,381
2026	4,840	-542	-45,653
2027	4,840	-542	-45,925
2028	4,840	-542	-46,197
2029	4,840	-542	-46,468
2030	4,840	-542	-46,740
2031	4,840	-542	-47,012
2032	4,840	-542	-47,284
2033	4,840	-542	-47,555
2034	4,840	-542	-47,827
2035	4,840	-542	-48,099
2036	4,840	-542	-48,371
2037	4,840	-542	-48,642
2038	4,840	-542	-48,914
2039	4,840	-542	-49,186
2040	4,840	-542	-49,458
2041	4,840	-542	-49,730
2042	4,840	-542	-50,001
2043	4,840	-542	-50,273
2044	4,840	-542	-50,545
2045	4,840	-542	-50,817
2046	4,840	-542	-51,088
2047	4,840	-542	-51,360
2048	4,840	-542	-51,632
2049	4,840	-542	-51,904
2050	4,840	-542	-52,175
2051	4,840	-542	-52,447
2052	4,840	-542	-52,719
2053	4,840	-542	-52,991
2054	4,840	-542	-53,262
Total	145,200	-16,260	-1,479,656



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Estimated Project Emissions
March 8, 2019

4.2.2 Maintenance

Table 14 identifies the estimated diesel-powered maintenance equipment that will be used during the operation phase. Each equipment was assumed to run approximately two hours a day. Estimated GHG emissions associated with the maintenance equipment shown in Table 14 are presented in Table 15.

Table 14 Operation Maintenance Fleet

Equipment Type ^a	Number or units	Operating details per unit of equipment		
		Fuel Consumption (L/100km)	Operating Time	
			(h/d)	(d/y)
One tonne truck	1	10.6	2	365
Five tonne bucket truck	1	40	2	365
Speeder	1	40	2	365
NOTE: ^a Equipment information supplied by TransLink (TransLink 2018)				

Emissions associated with electricity consumption for the propulsion of the SkyTrains are already accounted for in Section 4.2.1, as the emission factors listed in Table 6 account for electricity usage of the trains. However, not included in that emission factor is the electricity used for maintenance related activities as well as emissions associated with transmission and distribution (T&D) losses of electricity consumption.

The electricity needs of the Project will be drawn from the BC Hydro grid. The BC Hydro grid includes some electricity that is not generated from renewable sources and therefore the grid has a small GHG intensity (i.e. tonnes of CO₂e/kWh) associated with electrical consumption.

Indirect GHG emissions from electricity consumption were calculated for the Project consistent with the approach adopted on the Evergreen Line project (TransLink 2010, TransLink 2018). Based on these assumptions, the total annual electricity consumption for the Project is 52,110 MWh. Based on this electricity consumption indirect GHG emissions for maintenance activities as well as emissions from T&D losses were estimated. These estimated GHG emissions are presented in Table 15.

4.2.3 Project Operation and Maintenance GHG Emissions

The annual GHG emission sources, removals and net changes from the Project operation including effects from operation (changes in VKTs) and maintenance activities from 2025 to 2054 are presented in Table 15.



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Estimated Project Emissions
 March 8, 2019

Table 15 Year-by-Year Operation and Maintenance Greenhouse Gas Emissions

Year	Total Project operation emissions (A) (t CO ₂ e/year)				Total project operation removals (B) (t CO ₂ e/year)	Total net project emissions and removals (A-B) (t CO ₂ e/year)
	Maintenance (diesel powered equipment)	Change in VKT (SkyTrain)	Electricity related emissions (Maintenance and T&D losses)	Total	Change in VKT (Bus, Personal Vehicle)	
2025	45	427	73	545	10,736	-10,191
2026	45	427	73	545	10,665	-10,120
2027	45	427	73	545	10,594	-10,049
2028	45	427	73	545	10,523	-9,978
2029	45	427	73	545	10,453	-9,908
2030	45	427	73	545	10,382	-9,837
2031	45	427	73	545	10,311	-9,766
2032	45	427	73	545	10,241	-9,696
2033	45	427	73	545	10,170	-9,625
2034	45	427	73	545	10,099	-9,554
2035	45	427	73	545	10,028	-9,483
2036	45	427	73	545	9,958	-9,413
2037	45	427	73	545	9,887	-9,342
2038	45	427	73	545	9,816	-9,271
2039	45	427	73	545	9,745	-9,200
2040	45	427	73	545	9,675	-9,130
2041	45	427	73	545	9,604	-9,059
2042	45	427	73	545	9,533	-8,988
2043	45	427	73	545	9,463	-8,918
2044	45	427	73	545	9,392	-8,847
2045	45	428	73	546	9,323	-8,777



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Estimated Project Emissions
 March 8, 2019

Table 15 Year-by-Year Operation and Maintenance Greenhouse Gas Emissions

Year	Total Project operation emissions (A) (t CO ₂ e/year)				Total project operation removals (B) (t CO ₂ e/year)	Total net project emissions and removals (A-B) (t CO ₂ e/year)
	Maintenance (diesel powered equipment)	Change in VKT (SkyTrain)	Electricity related emissions (Maintenance and T&D losses)	Total	Change in VKT (Bus, Personal Vehicle)	
2046	45	428	73	546	9,252	-8,706
2047	45	428	73	546	9,182	-8,636
2048	45	428	73	546	9,111	-8,565
2049	45	428	73	546	9,040	-8,494
2050	45	428	73	546	8,970	-8,424
2051	45	428	73	546	8,899	-8,353
2052	45	428	73	546	8,828	-8,282
2053	45	428	73	546	8,757	-8,211
2054	45	428	73	546	8,687	-8,141
Lifespan Totals	1,343	12,820	2,194	16,356	291,324	-274,968



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Estimated Project Emissions
March 8, 2019

The Project's annual net operation emission totals are compared against the annual forecasted Metro Vancouver LDV baseline GHG emissions (i.e. the operation BAU scenario) in Table 16. It is estimated that the Project operation emissions would reduce baseline LDV emissions by 274,968 tCO_{2e} or by 0.3% when compared to the forecasted LDV emissions of Metro Vancouver.

Table 16 Operation GHG Emissions Comparison to BAU

Year	Total Net Project Operation Emissions (tCO _{2e})	BAU Baseline Emissions – LDV Metro Vancouver (tCO _{2e}) ^a	Percentage Contribution (%) Metro Vancouver LDV Emissions
2025	-10,191	3,648,795	-0.3
2026	-10,120	3,576,091	-0.3
2027	-10,049	3,503,387	-0.3
2028	-9,978	3,430,684	-0.3
2029	-9,908	3,357,980	-0.3
2030	-9,837	3,285,276	-0.3
2031	-9,766	3,233,303	-0.3
2032	-9,696	3,181,330	-0.3
2033	-9,625	3,129,357	-0.3
2034	-9,554	3,077,384	-0.3
2035	-9,483	3,025,411	-0.3
2036	-9,413	2,973,437	-0.3
2037	-9,342	2,921,464	-0.3
2038	-9,271	2,869,491	-0.3
2039	-9,200	2,817,518	-0.3
2040	-9,130	2,765,545	-0.3
2041	-9,059	2,713,572	-0.3
2042	-8,988	2,661,599	-0.3
2043	-8,918	2,609,626	-0.3
2044	-8,847	2,557,652	-0.3
2045	-8,777	2,505,679	-0.4
2046	-8,706	2,453,706	-0.4
2047	-8,636	2,401,733	-0.4
2048	-8,565	2,349,760	-0.4
2049	-8,494	2,297,787	-0.4
2050	-8,424	2,245,814	-0.4
2051	-8,353	2,193,841	-0.4
2052	-8,282	2,141,867	-0.4
2053	-8,211	2,089,894	-0.4
2054	-8,141	2,037,921	-0.4
Cumulative Total	-274,968	84,056,904	-0.3

NOTE:
^a See Section 3.2



Estimated Net Change in GHG Emissions
 March 8, 2019

5.0 ESTIMATED NET CHANGE IN GHG EMISSIONS

As identified in Section 4.0, during construction GHG emissions are expected to be released by heavy duty on-road and off-road mobile equipment. During operation GHG emissions are expected from SkyTrain operation, maintenance related mobile equipment, maintenance related energy consumption, as well as T&D losses of total energy consumption. GHG emission are also expected to be reduced through reducing personal vehicle and bus traffic along West Broadway due to this Project.

Table 17 summarizes the cumulative net Project emission including construction and operation emissions over the 2020 to 2054 period. The construction phase is expected to add a total of 110,557t CO_{2e} and the operation phase is expected to reduce emissions by approximately 274,968 tCO_{2e}, resulting in a net reduction of 164,410 t CO_{2e} over the construction and operation phase.

Table 17 Cumulative Summary

Year	Cumulative Net Project Emissions (tCO _{2e})
Construction (2020-2024)	110,557
Operation (2025-2054)	-274,968
Total (2020-2054)	-164,410

Indirect and direct GHG emissions from Project operations including maintenance will be generated but will be small in comparison to the expected “removals” from the reduction in the number of diesel busses and LDVs (i.e. personal vehicles) along the alignment. The Project aligns with federal, provincial, regional, and local government initiatives (see Table 4) to reduce GHG emissions through the increased usage of public transit within the region compared to LDV and buses. It also contributes towards the federal reduction target of the Paris Agreement. During the 2015 COP21 in Paris (UNFCCC 2015), Canada committed to a 30% reduction of national GHG emissions below the 2005 level by 2030. If this target is achieved, the national GHG total will be 517,000,000 t CO_{2e}. In 2030, the Project is estimated to reduce baseline GHG emissions by 9,837 tCO_{2e}/year which represents 0.0019% of Canada’s 2030 GHG reduction target.



6.0 MITIGATION MEASURES

During construction, the Contractor will be required to develop and implement an Air Quality and Greenhouse Gas Management Plan to minimize Project construction GHG emissions where possible and practical. Examples of best management practices to be contained with the Air Quality and Greenhouse Gas Management Plan and implemented by the contractor responsible for the construction of the Project in order to minimize construction related GHG emissions, include those noted below.

- Construction fleet will meet requirements of Metro Vancouver Non-Road Diesel Engine Emission Regulation Bylaw No. 1161
- Construction fleet will undergo regular tuning and maintenance
- A no-idling policy will be implemented
- Road closures and traffic restrictions will be limited where possible to minimize congestion-related idling

While these best practices represent proven methods of reducing GHG emissions through fuel consumption reduction, the overall GHG emissions generated by the construction phase will be strongly influenced by the construction practices/methods selected by the contractor.



Conclusion
March 8, 2019

7.0 CONCLUSION

Project activities that can produce GHG emissions include the use of heavy-duty diesel equipment and vehicles used during the construction phases. Further, operation of the Broadway Subway during the operation phase will produce GHG emissions. Regular maintenance activities (i.e. diesel-powered equipment as well as maintenance related electricity consumption and T&D losses) during the operation phase will also result in GHG emissions. However, overall, GHG emission reductions are expected due to anticipated decreases in personal vehicle and bus VKTs as a result of increased rapid transit capacity provided by the Project.

Project construction activities will result in an increase in Metro Vancouver construction GHG emissions of 110,557t CO₂e or 4.2% over the five-year construction phase. Construction-related emissions will be short-term and cease once the Project moves into the operation phase.

During operation, the mode shift to increased transit usage will result in a reduction of 274,968t CO₂e or 0.3% of the forecasted LDV emissions of Metro Vancouver over the 30-year operation phase. The main contributor to the estimated reduction of GHG is the forecasted reduction of personal vehicle and bus traffic along West Broadway.

Cumulative construction emissions represent approximately 40% of total net emission reductions of the operation phase. This number might be reduced with successful implementation of mitigation measures during the construction phase.

Cumulative net changes in Project-related GHG emissions, taking into account construction and operation phases, include a reduction of 164,410 t CO₂e over the construction and operation phase from 2020-2054 (i.e. construction emissions are offset throughout the 30 year operation span). This net reduction in GHG emissions aligns with federal, provincial, regional, and local government GHG reduction initiatives. .

Over the long-term, the Project will result in benefits for transit users, pedestrians, and cyclists, improvements in travel time savings, transit system connections, mobility and traffic safety by facilitating a shift from personal vehicle travel and towards less GHG intensive modes of transportation.



References

March 8, 2019

8.0 REFERENCES

BC Ministry of Transportation. 2018. Millennium Line Broadway Extension (MLBE) Project Business Case. March 2018.

City of Vancouver. 2018a. Greenest City Action Plan. Available at: <https://vancouver.ca/green-vancouver/greenest-city-action-plan.aspx>. Accessed July 24, 2018.

Environment and Climate Change Canada (ECCC). 2018. National inventory report. 1990-2016: Greenhouse gas sources and sinks in Canada. Part 1. Available online at: <https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/inventory.html>. Accessed October 2018.

Government of British Columbia. 2018a. Greenhouse Gas Reduction Targets Act. Available online at: http://www.bclaws.ca/Recon/document/ID/freeside/00_07042_01. Accessed October 2018.

Government of British Columbia. 2018b. British Columbia's Carbon Tax. Available online at: <https://www2.gov.bc.ca/gov/content/environment/climate-change/planning-and-action/carbon-tax>. Accessed October 2018.

Infrastructure Canada. Climate Lens. General Guidance. Version 1.1. June 2018. Available online at: <https://www.infrastructure.gc.ca/pub/other-autre/cl-occ-eng.html>. Accessed: September 2018).

Intergovernmental Panel on Climate Change (IPCC). 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Metro Vancouver. 2018. 2015 Lower Fraser Valley Air Emissions Inventory and Forecast. Personal communication with Derek Jennejohn. October 12, 2018.

Metro Vancouver. 2011a. Metro Vancouver 2040 Regional Growth Strategy Bylaw. Shaping Our Future. Regional Growth Strategy Bylaw No. 1136, 2010. Adopted July 29, 2011. Amended July 28, 2017. Available online at: <http://www.metrovancouver.org/services/regional-planning/PlanningPublications/RGSAdoptedbyGVRDBoard.pdf>. Accessed: October 2018.

Metro Vancouver. 2011b. Integrated Air Quality and Greenhouse Gas Management Plan. Available online at: <http://www.metrovancouver.org/services/air-quality/plans-reports/iaqggmp/Pages/default.aspx>. Accessed: October 2018.

Province of British Columbia. 2016. Climate Leadership Plan. Available online at: https://climate.gov.bc.ca/app/uploads/sites/13/2016/10/4030_CLP_Booklet_web.pdf. Accessed: October 2018.



BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

References

March 8, 2019

Unpublished Stantec 2018. Millennium Broadway Line Expansion Project. Air Quality and GHG Environmental Socio-Economic Report (ESR) Section 7.8.

Steer Davies Gleave (SDG). 2017a. Millennium Line Broadway Extension Quantified Benefits. September 6, 2017.

SDG. 2017b. Millennium Line Broadway Extension Ridership Forecast. September 6, 2017.

TransLink. 2018. Electricity consumption and Maintenance Equipment. Personal communication with John Wollenzin. October 15, 2018.

TransLink 2013. Regional Transportation Strategy: Strategic Framework July 2013. Available at: https://www.TransLink.ca//media/Documents/plans_and_projects/regional_transportation_strategy/rts_strategic_framework_07_31_2013.pdf. Accessed: November 2018.

TransLink. 2010. Evergreen Line Rapid Transit Project. Environmental Assessment Certificate Application.

United States Environmental Protection Agency (US EPA). 2008. Average In-Use Emissions from Heavy-Duty Trucks Oct , 2008 Available online at:

<https://nepis.epa.gov/Exe/ZyNET.exe/P100EYV6.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2006+Thru+2010&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C06thru10%5Ctxt%5C00000033%5CP100EYV6.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL#>. Accessed: October 2018.

UNFCCC (United Nations Framework Convention on Climate Change). 2015. The Paris Agreement. Available at: http://unfccc.int/paris_agreement/items/9485.php. Accessed: October 2018.

WCI (World Resource Institute). 2013. The Greenhouse Gas Protocol. A corporate accounting and reporting standard. Revised edition. Available at: <http://www.ghgprotocol.org>. Accessed: October 2018.



APPENDIX A

BAU Regulatory and Policy Measures

APPENDIX A BAU REGULATORY AND POLICY MEASURES

Metro Vancouver’s forecasted GHG emissions inventory accounts for regulatory policies and legislation as they relate to energy and GHG emissions. Included policy measures in the forecasted BAU scenario are listed in Table A-1.

Table A-1 Policy Measures included in GHG Emissions Forecast

Source Category	Policy Measures
Mobile Sources	<ul style="list-style-type: none"> • Aircraft NOx Standards (Federal) • BC Carbon Tax (BC) • Emission Control Area (ECA) (Federal) • Gasoline Vapour Control Regulation (BC) • Heavy Duty Vehicle and Engine Greenhouse Gas Regulation (Federal) • Tier 3 Engine and Fuel Standards for Light Duty Vehicles (Federal) • Light Duty Vehicles Greenhouse Gas Regulation (Federal) • Low Carbon / Renewable Fuel Standards (Federal / BC) • Non-Road Diesel Engine Bylaw (Metro Vancouver) • Non-Road Engine Emission Regulations (Federal) • Renewable and Low Carbon Fuel Requirements Regulation (Provincial) • Sulphur in Fuel Regulations (Federal)
Area Sources	<ul style="list-style-type: none"> • Agricultural Boilers Regulation (Metro Vancouver) • Architectural Coatings Regulations (Federal) • Automotive Refinishing Regulations (Federal, Metro Vancouver) • BC Carbon Tax (BC) • Boilers and Process Heaters Regulation (Metro Vancouver) • Concrete and Concrete Products Industries Emission Regulation (Metro Vancouver) • Dry Cleaning Regulations (Federal) • Landfill Gas Regulation (BC) • Gasoline Distribution Emission Regulation (Metro Vancouver) • Solid Fuel Burning Domestic Appliance Regulation (Provincial) • Wastewater Systems Effluent Regulations (Federal) • Woodstove Exchange Program (Metro Vancouver, Fraser Valley Regional District)
Industrial Sources	<ul style="list-style-type: none"> • Metro Vancouver permit changes (Metro Vancouver) • Boilers and Heaters Regulation (Metro Vancouver)
<p>SOURCE: Metro Vancouver 2018</p>	



APPENDIX B

Attestation of Completeness

BROADWAY SUBWAY PROJECT CLIMATE LENS ASSESSMENT

Appendix B Attestation of Completeness
March 8, 2019

APPENDIX B ATTESTATION OF COMPLETENESS

I/we the undersigned attest that this GHG mitigation assessment was undertaken using recognized assessment tools and approaches (i.e., ISO 14064-2: Specification with guidance at the project level for quantification, monitoring, and reporting of greenhouse gas emissions reductions or removal enhancements and, if chosen, the GHG Protocol for Project Accounting) and complies with the General Guidance and any relevant sector-specific technical guidance issued by Infrastructure Canada for use under the Climate Lens.

Prepared by: _____

Sana Talebi, B.Sc., P.Eng.

March 8, 2019

Validated by*: _____

[Name, Climate Action Secretariat] [Date]

*GHG mitigation assessments must be prepared, or at a minimum validated by, a qualified party (e.g., a licenced professional engineer or a professional GHG accounting specialist certified under the ISO 14064-3 or 14065 standard).

