City of Victoria 2017 GPC BASIC+ Community Greenhouse Gas (GHG) Emissions Inventory Report

Prepared for:
City of Victoria
770 Vernon Ave.
Victoria, BC V8X 2W7

Prepared by:
Stantec Consulting Ltd.
400-655 Tyee Road
Victoria, BC, V9A 6X5

Project: 123220845

June 28, 2018

Limitation of Liability

This document entitled City of Victoria 2017 GPC BASIC+ Community Greenhouse Gas (GHG) Emissions Inventory Report was prepared by Stantec Consulting Ltd. ("Stantec") for the account of City of Victoria (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.

Table of Contents

EXECUTIVE SUMMARY ..... **V**

ABBREVIATIONS ..... **VII**

GLOSSARY ..... **IX**

1.0 INTRODUCTION **1**
1.1 CLIMATE CHANGE AND GREENHOUSE GAS EMISSIONS 1
1.2 CITIES AND GREENHOUSE GAS EMISSIONS 1
1.3 PURPOSE OF THIS REPORT 2

2.0 GLOBAL PROTOCOL FOR COMMUNITY (GPC) SCALE EMISSION INVENTORIES PROTOCOL **3**
2.1 OVERVIEW 3
2.2 GPC PROTOCOL STRUCTURE 3
2.3 GHG EMISSION CATEGORIES 5
2.3.1 Stationary Energy 5
2.3.2 Transportation 6
2.3.3 Waste 7
2.3.4 Industrial Processes and Product Use (IPPU) 7
2.3.5 Agriculture, Forestry, and Other Land Use (AFOLU) 8
2.3.6 Other Scope 3 Emissions 8
2.4 ACCOUNTING AND REPORTING PRINCIPLES 8
2.5 BASELINE AND REPORTING YEAR RECALCULATIONS 9
2.6 DATA QUALITY 10

3.0 GHG ASSESSMENT BOUNDARIES **11**
3.1 SPATIAL BOUNDARIES 11
3.2 TEMPORAL BOUNDARIES 12
3.2.1 2007 Baseline 12
3.2.2 2017 GHG Boundary 13
3.3 GHG EMISSION SOURCES AND SCOPES 14
3.4 GHG REPORTING 15

4.0 GHG METHODOLOGIES BY SOURCE CATEGORY **19**
4.1 STATIONARY ENERGY 19
4.1.1 Overview 19
4.1.2 Scope 2: Market Based Method 19
4.1.3 Activity Data 19
4.1.4 Assumptions and Disclosures 20
4.1.5 Calculation Methodology 21
4.2 TRANSPORTATION 22
4.2.1 Overview 22

4.2.2 Activity Data ... 23
4.2.3 Assumptions and Disclosures ... 23
4.2.4 Calculation Methodology ... 25
4.3 WASTE ... 35
4.3.1 Activity Data ... 36
4.3.2 Assumptions and Disclosures ... 36
4.3.3 Calculation Methodology ... 37
4.4 INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU) ... 39
4.4.1 Overview ... 39
4.4.2 Activity Data ... 40
4.4.3 Assumptions and Disclosures ... 40
4.4.4 Calculation Methodology ... 40
4.5 AGRICULTURE, FORESTRY, AND OTHER LAND USE (AFOLU) ... 40
4.5.1 Overview ... 40
4.5.2 Activity Data ... 41
4.5.3 Assumptions and Disclosures ... 41
4.5.4 Calculation Methodology ... 42

5.0 2017 GHG REPORTING YEAR RESULTS ... 47
5.1 OVERVIEW ... 47
5.2 SUMMARY ... 48
5.3 TOTAL GHG EMISSIONS ... 52
5.4 COMPARATIVE ANALYSIS ... 53
5.5 SECTORAL GHG EMISSIONS ANALYSIS ... 54
5.5.1 Stationary Energy ... 54
5.5.2 Transportation ... 56
5.5.3 Waste ... 59
5.5.4 Industrial Processes and Product Use (IPPU) ... 61
5.5.5 Agriculture, Forestry, and Other Land Use ... 61

6.0 QUALITY ASSURANCE AND QUALITY CONTROL ... 64

7.0 RECOMMENDATIONS ... 65
7.1 INVENTORY ASSUMPTIONS, ASSESSMENT, AND RECOMMENDATIONS ... 65

8.0 REFERENCES ... 71

LIST OF TABLES

Table 1 GPC Protocol Recalculation Thresholds ... 9
Table 2 GPC Protocol Data Quality Assessment Notation Keys ... 10
Table 3 Inventory Information for the City ... 12
Table 4 Original And Updated BASIC+ Baseline ... 13
Table 5 Summary of Emissions Scope and GPC Protocol Reporting Sector ... 14
Table 6 GPC Protocol Summary Table ... 16
Table 7 Heating Oil Units, Estimated Heating Oil Floor Space, and Heating Oil Energy Intensity Values ... 21

Table 8 Stationary Energy GHG Emission Factors 22
Table 9 On-Road In-Boundary/Transboundary Split 25
Table 10 Estimated VKT And Fuel Efficiencies by Vehicle Class 26
Table 11 Total Registered Vehicles & Estimated Fuel Use For Reporting Year 27
Table 12 Reporting Year Fuel Use Allocation by Vehicle Classification and Split 28
Table 13 Vehicle GHG Emission Factors 29
Table 14 Aircraft Type, Estimated Percentage of Total Reported Movements, And Estimated Fuel Use 30
Table 15 Aviation GHG Emission Factors 31
Table 16 Aircraft Type, Estimated Percentage of Total Reported Movements, And Estimated Fuel Use 31
Table 17 Marine Aviation GHG Emission Factors 32
Table 18 BC Ferries GHG Emission Factors 32
Table 19 Coho and the Victoria Clipper Ferries Estimated GHG Emissions 33
Table 20 Year 2000 Other Watercraft Population Breakdown And Estimated Fuel Use 33
Table 21 Reporting Year Other Watercraft Population Breakdown and Estimated Fuel Use 34
Table 22 Watercraft GHG Emission Factors 34
Table 23 Composting Emission Factor 38
Table 24 Wastewater Volumes and BOD Values 38
Table 25 Wastewater Volumes and TKN Values 39
Table 26 Hierarchal Land-Cover Classification of HAT Forest and Land Cover Mapping and its Relation to IPCC Land Use Category 42
Table 27 2011–2017 Land-use Change Vector Table (Hectares) 43
Table 28 Land-Use Change Emission Factors 43
Table 29 City of Victoria 2017 GHG Emissions by GPC Reporting Method 47
Table 30 Breakdown of Victoria's 2017 GHG Emissions in GPC Reporting Format 49
Table 31 Breakdown of the City of Victoria's 2017 BASIC+ GHG Emissions in the GPC Protocol Reporting Format 50
Table 32 Total Energy and GHG Emissions Per Person by Sector 52
Table 33 Change in GHG Emissions from Prior Year 53
Table 34 2017 Energy and GHG Emissions by Stationary Energy Sector 54
Table 35 Stationary Energy—Energy and GHG Emissions Trends 56
Table 36 2017 On-Road Transportation Energy And GHG Emissions by Fuel Type 56
Table 37 2017 Aviation, Waterborne, and Off-Road Transportation Energy and Emissions by Fuel Type 57
Table 38 2017 Energy and Emissions by Transportation Sub-Sector 58
Table 39 Transportation—Energy and GHG Emissions Trends 59
Table 40 Summary of Waste Sub-Sector GHG Emissions 60
Table 41 Product Use GHG Emissions for the 2007 and 2017 Reporting Years 61
Table 42 Summary of Land-Use Change Between 2016 and 2017 62
Table 43 Total AFOLU GHG Emissions for 2017 63
Table 44 Summary of GHG Inventory Assumptions, Estimated Impacts, and Recommended Improvements 65

LIST OF FIGURES

Figure 1 Sources and Boundaries of a City's GHG Emissions (GPC 2014) 5
Figure 2 City of Victoria Municipal Boundary 11
Figure 3 2017 GHG Emissions Summary by GPC Reporting Level 48

Figure 4 Total City of Victoria BASIC+ GHG Emissions by Emissions Scope 53
Figure 5 Stationary Energy GHG Emissions Contribution to the GHG Inventory 55
Figure 6 Total Stationary Energy Use By Sub-Sector 55
Figure 7 Breakdown of On-Road GHG Emissions by Vehicle Type 57
Figure 8 Summary of Transportation GHG Emissions by Sub-Sector 58
Figure 9 2017 GHG Emissions from Waste (tCO_2e) 60
Figure 10 Comparison of GHG Emissions from Land-use Change Between 2016 and 2017 62

LIST OF APPENDICES

APPENDIX A GPC REPORTING TABLE A.1

Executive Summary

There is increasing evidence that global climate change resulting from emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs) is having a significant impact on the ecology of the planet. Delayed actions to respond to the effects of climate change are expected to have serious negative impacts on global economic growth and development.

Beyond the costs associated with delayed climate action, there are cost savings to be realized through efforts to improve energy efficiency, conserve energy, and reduce GHG emissions intensity. To make informed decisions on reducing energy use and GHG emissions at the community scale, community managers must have a good understanding of these sources, the activities that drive them, and their relative contribution to the total. This requires the completion of an energy and GHG emissions inventory. To allow for credible and meaningful reporting locally and internationally, the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (the GPC Protocol) was developed. The GPC Protocol has been adopted by the Global Covenant of Mayors—an agreement led by city networks to undertake a transparent and supportive approach to measure GHG emissions community-wide. The Global Covenant of Mayors promotes the use of the GPC Protocol as a standardized way for municipalities to collect and report their actions on climate change.

This project set out to compile a detailed GHG inventory for the City of Victoria (the City) for the 2017 reporting year using the GPC Protocol. Following the requirements of the GPC Protocol, the GHG inventories considered emissions from all reporting Sectors, including Stationary Energy, Transportation, Waste, Industrial Process and Product Use (IPPU), and Agriculture, Forestry and Other Land Use (AFOLU). The purpose of this document is to describe the quantification methodologies used by the City to calculate GHG emissions for the 2017 reporting year, and to present the City's 2017 community GHG emissions.

Following the requirements of the GPC Protocol BASIC+ reporting level, the City's 2017 community GHG emissions are estimated to be 479,039 tCO_2e. A summary of the 2017 GHG emissions is presented in Table E-1.

Table E-1 BASIC+ 2007 Baseline and 2017 Reporting Year GHG Emissions

Sector	Sub-Sector	2007 GHG Emissions (tCO_2e)	2017 GHG Emissions (tCO_2e)
Stationary Energy	Residential Buildings	84,817	72,632
	Agriculture, Forestry, And Fishing Activities		
	Manufacturing Industries, and Construction		
	Non-Specified Sources		
	Commercial / Institutional Buildings	120,528	123,370
	Energy Industries		

Sector	Sub-Sector	2007 GHG Emissions (tCO_2e)	2017 GHG Emissions (tCO_2e)
	Fugitive Emissions: Oil and Natural Gas Systems	1,370	1,093
Transportation	On-Road Transportation	40,274	42,211
	Transboundary Transportation	100,290	105,883
	Off-Road Transportation: Aviation, Railways, and Other Off-Road	56,959	57,738
Waste	Waste: Solid Waste Disposal, Biological Treatment of Waste, Wastewater Treatment and Discharge	58,072	33,480
AFOLU	AFOLU: Livestock, Land, and Other Agriculture	822	(574)
IPPU	IPPU: Industrial Processes, and Product Use	17,859	29,649
Total GHG Emissions		**480,991**	**465,482**
Change from Baseline Year			**-3.2%**
Total Per Capita GHG Emissions		**6.1**	**5.4**
Change from Baseline Year			**-12.2%**

Data in the table above is depicted in Figure E-1.

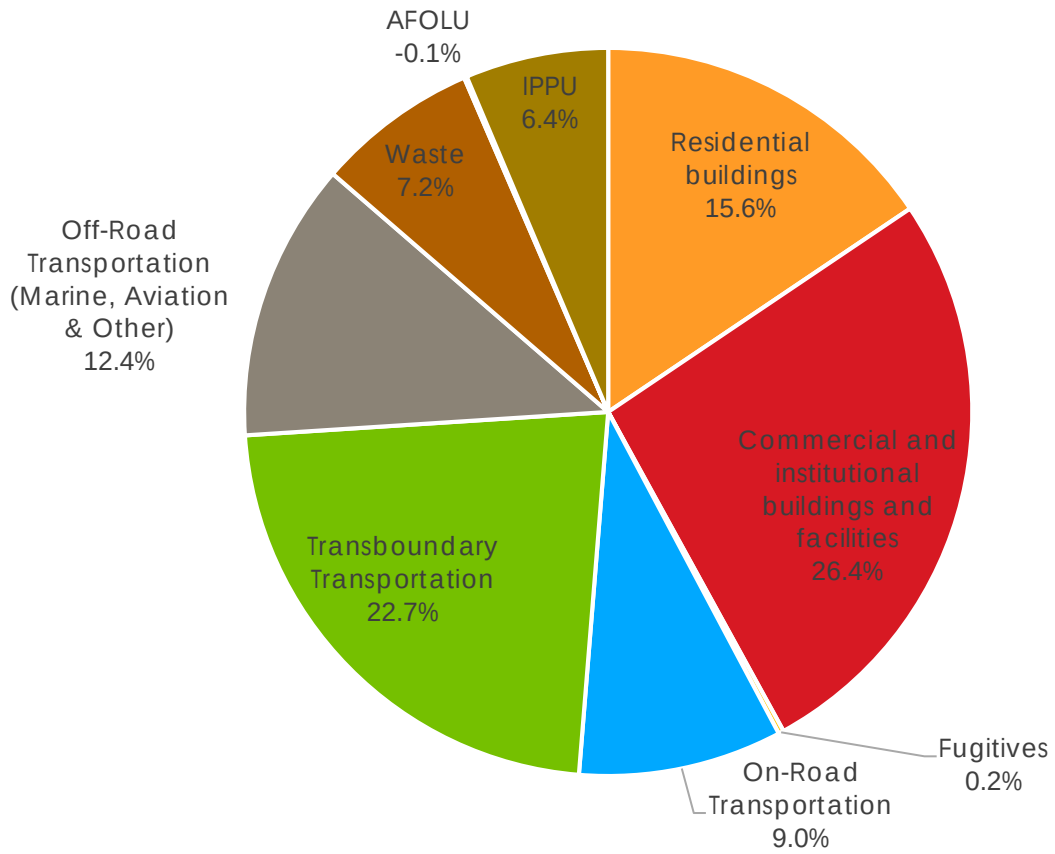

Figure E-1 City of Victoria's BASIC+ GHG Emissions Profile

Abbreviations

ACERT	Airport Carbon Emissions Reporting Tool
AFOLU	Agriculture, Forestry, and Other Land Use
C40	C40 Cities Climate Leadership Group
CH_4	Methane
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalents
CRD	Capital Regional District
VIA	Victoria International Airport
eMWh	megawatt hours equivalents
FCM	Federation of Canadian Municipalities
GDP	gross domestic product
GHG	greenhouse gas
GJ	Gigajoules
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
GWP	global warming potentials
HFC	Hydrofluorocarbons
ICAO	International Civil Aviation Organization
ICLEI	International Council for Local Environmental Initiatives
IE	included elsewhere
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Process and Product Use
ISO	International Organization for Standardization

kg	Kilograms
kW	Kilowatt
kWh	kilowatt hours
L	Litres
MWh	megawatt hours
N_2O	nitrous oxides
NE	not estimated
NIR	National Inventory Report
NPRI	National Pollutant Release Inventory
NO	not occurring
PCP	Partnership for Climate Protection
PFC	Perfluorocarbons
SC	Other Scope 3
SF_6	sulfur hexafluoride
VIA	Victoria International Airport
WIP	waste-in-place
WRI	World Resources Institute

Glossary

Air pollution	The presence of toxic chemicals or materials in the air, at levels that pose a human health risk.
Baseline	This is the reference or starting year to which targets and GHG emissions projections are based.
BASIC	An inventory reporting level that includes all Scope 1 sources except from energy generation, imported waste, IPPU, and AFOLU, as well as all Scope 2 sources (GPC, 2014).
BASIC+	An inventory reporting level that covers all GPC BASIC sources, plus Scope 1 AFOLU and IPPU, and Scope 3 in the Stationary Energy and Transportation Sectors (GPC, 2014).
Biogenic emissions	Emissions produced by living organisms or biological processes, but not fossilized or from fossil sources (GPC, 2014).
Carbon dioxide equivalent (CO_2e)	The amount of carbon dioxide (CO_2) emissions that would cause the same integrated radiative forcing, over a given time horizon, as an emitted amount of a greenhouse gas (GHG) or a mixture of GHGs. The CO_2e emission is obtained by multiplying the emission of a GHG by its Global Warming Potential (GWP) for the given time horizon. For a mix of GHGs, it is obtained by summing the CO_2e emissions of each gas (IPCC 2014).
Climate change	Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2014).
Emission	The release of GHGs into the atmosphere (GPC, 2014).
Emission factor(s)	A factor that converts activity data into GHG emissions data (GPC, 2014).
Flaring	The burning of natural gas that cannot be used.
Fossil fuels	A hydrocarbon deposit derived from the accumulated remains of ancient plants and animals which is used as an energy source.
Fugitive emission	Emissions that are released during extraction, transformation, and transportation of primary fossil fuels. These GHG emissions are not combusted for energy.
Geographic boundary	A geographic boundary that identifies the spatial dimensions of the inventory's assessment boundary. This geographic boundary defines the physical perimeter separating in-boundary emissions from out-of-boundary and transboundary emissions (GPC, 2014).

Gigajoule (GJ)	A gigajoule (GJ), one billion joules, is a measure of energy. One GJ is about the same energy as: • Natural gas for 3-4 days of household use • The electricity used by a typical house in 10 days
Global warming	A gradual increase in the Earth's temperature which is attributed to the greenhouse effect caused by the release of greenhouse gas (GHG) emissions into the atmosphere.
Global warming potential (GWP)	An index measuring the radiative forcing following an emission of a unit mass of a given substance, accumulated over a chosen time horizon, relative to that of the reference substance, carbon dioxide (CO_2). The GWP thus represents the combined effect of the differing times these substances remain in the atmosphere and their effectiveness in causing radiative forcing. The Kyoto Protocol is based on global warming potentials over a 100-year period (IPCC 2014).
Greenhouse gas (GHG)	GHGs are the seven gases covered by the UNFCCC: carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); sulphur hexafluoride (SF_6); and nitrogen trifluoride (NF_3) (GPC, 2014).
GHG intensity	The annual rate to which GHG emissions are released in the atmosphere, relative to a specific intensity.
Gross domestic product (GDP)	An economic measure of all goods and services produced in an economy.
In-boundary	Occurring within the established geographic boundary (GPC, 2014).
Reporting year	The year for which emissions are reported (GPC, 2014).
Scope 1	Emissions that physically occur within a city.
Scope 2	Emissions that occur from the use of electricity, steam, and/or heating/cooling supplied by grids which may or may not cross City boundaries.
Scope 3	Emissions that occur outside a city but are driven by activities taking place within a city's boundaries.
Tonne of CO_2e	A tonne of greenhouse gases (GHGs) is the amount created when we consume: • 385 litres of gasoline (about 10 fill-ups) • $200 of natural gas (a month of winter heating) • Enough electricity for three homes for a year (38,000 kWh)
Transboundary GHG emissions	Emissions from sources that cross the geographic boundary (GPC, 2014).

1.0 INTRODUCTION

1.1 CLIMATE CHANGE AND GREENHOUSE GAS EMISSIONS

There is increasing evidence that global climate change resulting from emissions of carbon dioxide and other greenhouse gases (GHGs) is having an impact on the global climate system. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), states the following consensus of scientific opinion about climate change and its causes and effects (IPCC, 2014):

- Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.
- Anthropogenic GHG emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in human-caused GHG concentrations.
- Continued emission of GHG will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive, and irreversible impacts for people and ecosystems.
- There is high agreement and much evidence that with current climate change mitigation policies and practices, global GHG emissions will increase over the next few decades.

1.2 CITIES AND GREENHOUSE GAS EMISSIONS

Cities are centers of communication, commerce, and culture. They are, however, also a significant and growing source of energy consumption and GHG emissions. On a global scale, cities are major players in GHG emissions: Cities are responsible for more than 70% of global energy-related carbon dioxide emissions. Therefore, cities represent the single greatest opportunity for tackling climate change.

For a city to act on mitigating climate change and monitor its progress, it is crucial to have good quality GHG emissions data to build a GHG inventory. Such an inventory enables cities to understand the breakdown of their emissions and plan for effective climate action. The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC Protocol) seeks to support exactly that, by giving cities the standards and tools that are needed to measure the emissions, build more effective emissions reduction strategies, set measurable and more ambitious emission reduction goals, and to track their progress more accurately and comprehensively.

Until recently there has been no internationally recognized way to measure city-level emissions. Inventory methods that cities have used to date around the globe vary significantly. This

inconsistency has made comparisons between cities and over the years difficult. The GPC Protocol offers an internationally accepted, credible emissions accounting and reporting practice that will help cities to develop comparable GHG inventories.

1.3 PURPOSE OF THIS REPORT

The purpose of this document is to describe the quantification methodologies used by the City to calculate its BASIC+ GHG emissions for the 2017 reporting year.

2.0 GLOBAL PROTOCOL FOR COMMUNITY (GPC) SCALE EMISSION INVENTORIES PROTOCOL

2.1 OVERVIEW

The GPC Protocol is the result of a collaborative effort between the GHG Protocol at the World Resources Institute (WRI), C40 Cities Climate Leadership Group (C40), and ICLEI—Local Governments for Sustainability (ICLEI). The GPC Protocol is recognized as one of the first set of standardized global rules for cities to measure and publicly report city-wide GHG emissions. It sets out requirements and provides guidance for calculating and reporting city-wide GHG emissions, consistent with the 2006 IPCC guidelines on how to estimate GHG emissions (IPCC, 2006). Specifically, the GPC Protocol seeks to:

- Help cities develop a comprehensive and robust GHG inventory to support climate action planning.
- Help cities establish a base year GHG emissions inventory, set GHG reduction targets, and track performance.
- Ensure consistent and transparent measurement and reporting of GHG emissions between cities, following internationally recognized GHG accounting and reporting principles.
- Enable city-wide GHG inventories to be aggregated at subnational and national levels.
- Demonstrate the important role that cities play in tackling climate change and facilitate insight through benchmarking—and aggregation—of comparable GHG data.

2.2 GPC PROTOCOL STRUCTURE

The GPC Protocol sets several assessment boundaries which identify the restrictions for gases, emission sources, geographic area, and time span covered by a GHG inventory:

- The GHG inventory is required to include all seven Kyoto Protocol GHGs occurring within the geographic boundary of a city. These include:
  - Carbon dioxide (CO_2)
  - Methane (CH_4)
  - Nitrous oxide (N_2O)
  - Hydrofluorocarbons (HFCs)
  - Perfluorocarbons (PFCs)
  - Sulfur hexafluoride (SF_6)
- The GHG emissions from city-wide activities must be organized and reporting under the following five Sectors, based on the selected reporting level:
  - Stationary Energy
  - Transportation
  - Waste

- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry, and Other Land Use (AFOLU)

The GPC Protocol also requires that a city define an inventory boundary, identifying the geographic area, time span, gases, and emission sources.

Under the GPC Protocol, a city has the option of reporting GHG emissions under three different levels:

- **GPC BASIC—**This level covers emissions Scopes 1 and 2, from stationary energy and transportation, as well as emissions Scopes 1 and 3 from waste. The BASIC level aligns with the Community Energy and Emissions Inventories (CEEI) that have been released in the past for local governments by the Province of BC.
- **GPC BASIC+—**This level covers the same scopes as BASIC and includes more in-depth and data dependent methodologies. Specifically, it expands the reporting scope to include emissions from Industrial Process and Product Use (IPPU), Agriculture, Forestry, and Other Land-Use (AFOLU), and transboundary transportation. The sources covered in BASIC+ also align with sources required for national reporting in IPCC guidelines.
- **GPC BASIC+ Scope 3 (SC)—** This inventory extends beyond the BASIC+ GHG inventory to include Other Scope 3 (SC) emissions such as GHG emissions from goods and services production and transportation.

Activities taking place within a city can generate GHG emissions that occur inside the City boundary as well as outside the City boundary. To distinguish between these, the GPC Protocol groups emissions into three categories based on where they occur: Scope 1, Scope 2, or Scope 3 emissions. The GPC Protocol distinguishes between emissions that physically occur within the City (Scope 1), from those that occur outside the City but are driven by activities taking place within the City's boundaries (Scope 3), from those that occur from the use of electricity, steam, and/or heating/cooling supplied by grids which may or may not cross city boundaries (Scope 2). Scope 1 emissions may also be termed "territorial" emissions, because they are produced solely within the territory defined by the geographic boundary (see Figure 1).

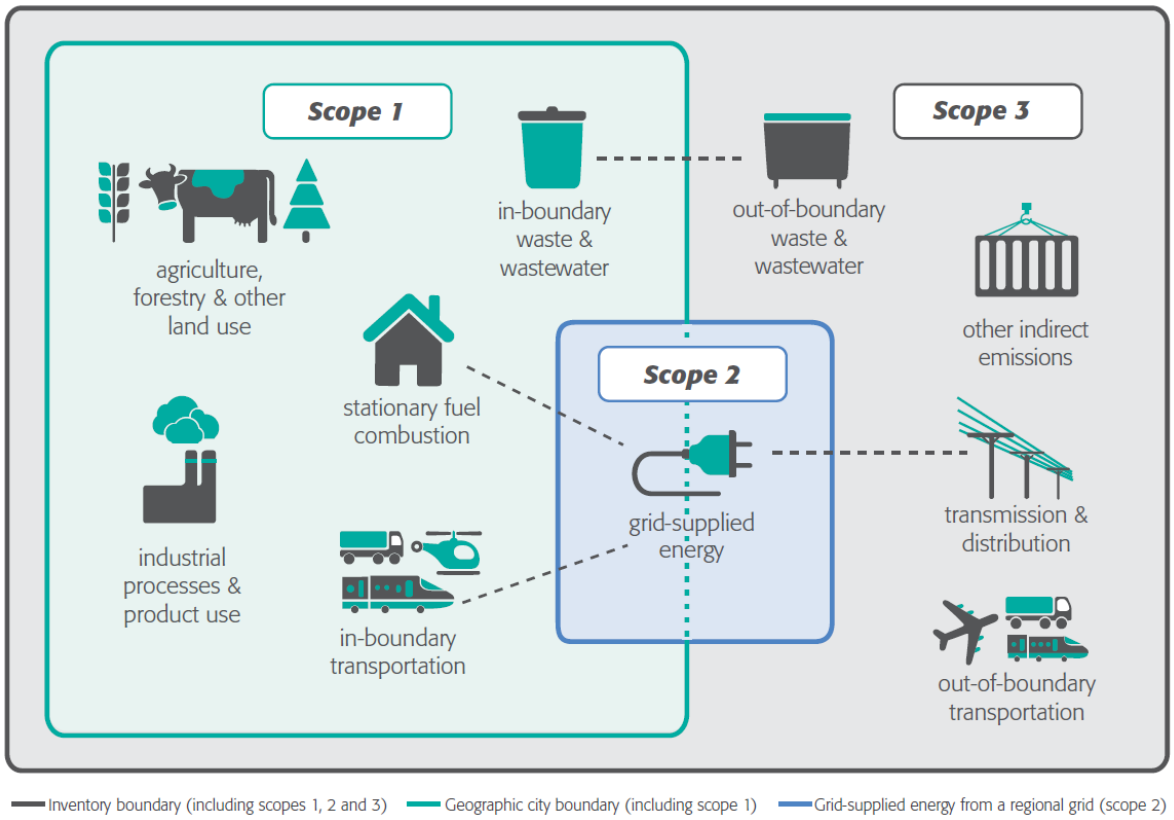

Figure 1 Sources and Boundaries of a City's GHG Emissions (GPC 2014)

2.3 GHG EMISSION CATEGORIES

As noted previously, the GPC Protocol requires that different emission sources to be categorized into six main reporting Sectors. These high-level categories are described in more detail in Section 2.3.1 to Section 2.3.6. More information on how GHG emissions are captured within the GPC Protocol is available on the Greenhouse Gas Protocol website.

2.3.1 Stationary Energy

Stationery energy sources are typically one of the largest contributors to a city's GHG emissions. In general, these emissions come from fuel combustion and fugitive emissions. They include the emissions from energy to heat and cool residential, commercial, and industrial buildings, as well as the activities that occur within these residences and facilities, such as off-road transportation emissions from construction equipment. Emissions associated with distribution losses from grid-

supplied electricity/steam/heating/cooling are also included, as are some fugitive emissions from sources such as coal piles, and natural gas distribution systems.

The Stationary Energy Sector includes the following Sub-Sectors:

- Residential buildings
- Commercial and institutional buildings and facilities
- Manufacturing industries and construction
- Energy industries
- Energy generation supplied to the grid*
- Agriculture, forestry, and fishing activities
- Non-specific sources
- Fugitive emissions from mining, processing, storage, and transportation of coal
- Fugitive emissions from oil and natural gas systems

*Emissions related with electricity generation activities occurring within a city's boundaries are to be reported; however, the GHG emissions from these sources are not included in the total GHG inventory to prevent double counting (GPC 2014).

Under the GPC Protocol, cities are to report off-road GHG emissions under the Off-road Transportation Sub-Sector if and only if the GHG emissions are occurring at transportation facilities (e.g., airports, harbors, bus terminals, train stations, etc.). Other off-road transportation GHG emissions that occur on industrial premises, construction sites, agriculture farms, forests, aquaculture farms, and military premises, etc., are to be reported under the most relevant Stationary Energy Sub-Sector (GPC, 2014). For example, GHG emissions from commercial building off-road construction equipment would be included in the Commercial And Institutional Buildings And Facilities Sub-Sector, whereas GHG emissions from residential lawn mowers would be reported under the Residential Buildings Sub-Sector.

2.3.2 Transportation

The GHGs released to the atmosphere to be reported in the Transportation Sector are those from combustion of fuels in journeys by on-road, railway, waterborne navigation, aviation, and off-road. GHG emissions are produced directly by the combustion of fuel, and indirectly using grid-supplied electricity. Unlike the Stationary Energy Sector, transit is mobile and can pose challenges in both accurately calculating GHG emissions and allocating them to a specific Sub-Sector. This is particularly true when it comes to transboundary transportation, which includes GHG emissions from trips that either start or finish within a city's boundaries (e.g., departing flight emissions from an airport outside the City boundaries) (GPC, 2014). Transboundary GHG emissions are only required for GPC BASIC+ GHG reporting.

The Transportation Sector includes the following Sub-Sectors:

- On-road

- Railways
- Waterborne
- Aviation
- Off-road

As noted previously, cities are to report off-road GHG emissions under the Off-road Transportation Sub-Sector if and only if the GHG emissions are occurring at transportation facilities (e.g., airports, harbors, bus terminals, train stations, etc.). For example, off-road railway maintenance support equipment GHG emissions are reported under the Off-Road Transportation Sub-Sector.

2.3.3 Waste

Cities produce GHG emissions that arise from activities related to the disposal and management of solid waste. Waste does not directly consume energy, but releases GHG emissions because of decomposition, burning, incineration, and other management methods.

The Waste Sector includes the following Sub-Sectors:

- Solid waste disposal
- Incineration and open burning
- Biological treatment of waste
- Wastewater treatment and discharge

Under the GPC Protocol, the Waste Sector includes all GHG emissions that result from the treatment or decomposition of waste regardless of the source of the waste (e.g., another city's waste in the City's landfill). However, the GHG emissions that are associated with waste from outside a City's boundary that is treated or decomposes within the City boundary are deemed to be "reporting only" emissions and do not contribute to the GHG inventory (GPC 2014).

Any GHG emissions that result from the combustion of waste or waste related gases to generate energy, such as a methane capture and energy generation system at a landfill, are reported under Stationary Energy Generation Supplied To The Grid Sub-Sector (GPC, 2014). Any waste related GHG emissions that are combusted but not related to energy generation are reported in the appropriate Waste Sub-Sector. Lastly, any waste GHG emissions that are released to the atmosphere are also captured in the appropriate Waste Sub-Sector.

2.3.4 Industrial Processes and Product Use (IPPU)

Emissions from this Sector are only required for BASIC+ GHG reporting under the GPC Protocol. This Sector encompasses GHG emissions produced from industrial processes that chemically or physically transform materials and using products by industry and end-consumers (e.g., refrigerants, foams, aerosol cans) (GPC, 2014).

The IPPU Sector includes the following Sub-Sectors:

- Industrial processes
- Product use

Any GHG emissions associated with energy use for industrial processes are not reported in the IPPU Sector; rather, they are reported under the appropriate Stationary Energy Sub-Sector.

2.3.5 Agriculture, Forestry, and Other Land Use (AFOLU)

Emissions from the AFOLU Sector are only required for BASIC+ GHG reporting. AFOLU GHG emissions are those that are captured or released because of land-management activities. These activities can range from the preservation of forested lands to the development of crop land. Specifically, this Sector includes GHG emissions from land-use change, manure management, livestock, and the direct and indirect release of nitrous oxides (N_2O) from soil management, rice cultivation, biomass burning, urea application, fertilizer, and manure application (GPC, 2014).

The AFOLU Sector is organized into the following Sub-Sectors:

- Livestock
- Land
- Aggregate sources and non-CO_2 emission sources on land

2.3.6 Other Scope 3 Emissions

Cities, by their size and connectivity, inevitably give rise to GHG emissions beyond their boundaries. The GPC Protocol already includes the following Scope 3 emissions in other Sectors:

- On-road, waterborne, and aviation transboundary transportation
- Transmission and distribution losses associated with grid-supplied energy
- Solid waste disposal
- Biological treatment of solid waste
- Wastewater treatment and discharge

Cities may voluntarily report on other Scope 3 emissions as they are estimated. In the case of the City, no other Scope 3 GHG emissions, other than those listed above, have been estimated.

2.4 ACCOUNTING AND REPORTING PRINCIPLES

All GHG inventories following the GPC Protocol are required to meet GHG accounting principles. Specifically, these inventories should be relevant, consistent from year to year, accurate and transparent about methodologies, assumptions, and data sources. The transparency of

inventories is fundamental to the success of replication and assessment of the inventory by interested parties.

The GHG inventories must also properly account for key energy and GHG emission sinks, sources, and reservoirs (SSR) that are occurring within municipal boundaries. The SSRs are a convenient way to identify and categorize all the GHG emissions to determine if they should be included or excluded from a GHG inventory. A "Source" is something that releases GHG emissions to the atmosphere, such as a diesel generator. A "Sink" is a process or item that removes GHG from the atmosphere, such as photosynthesis and tree growth. Finally, a "Reservoir" is a process or item with the capability to store or accumulate a GHG removed from the atmosphere by a GHG sink, such as a wetland or a peat bog. By assessing and reporting on the applicable SSRs, users of the GHG inventory can have confidence that the inventory is complete and representative of the types and quantities of the GHGs being released within city limits.

2.5 BASELINE AND REPORTING YEAR RECALCULATIONS

As cities grow and expand, significant changes to the GHG emissions profile of a community can alter materially thus making it difficult to meaningfully assess GHG emission trends and changes over time. The GPC Protocol has requirements on how to treat changes in a community's GHG profile—this is presented in Table 1.

Table 1 GPC Protocol Recalculation Thresholds

Threshold	Example Change	Recalculation Needed	No Recalculation Needed
Changes in the assessment boundary	A community is annexed in or removed from a city's administrative boundary	X	
	Change in protocol reporting method (e.g., from BASIC to BASIC+, addition of GHGs reported, etc.)	X	
	Shut down of a power plant		X
	Building a new cement factory		X
Changes in calculation methodology or improvements in data accuracy	Change in calculation methodology for landfilled municipal solid waste (MSW)	X	
	Adoption of more accurate local emission factors, instead of a national average emission factors	X	
	Change in electricity emission factor due to energy efficiency improvement and growth of renewable energy utilization		X
Discovery of significant errors	Discovery of mistake in unit conversion in formula used	X	

2.6 DATA QUALITY

Data collection and the assessment of its quality is an integral component of compiling any GHG inventory. Like the IPCC, the GPC Protocol requires users to establish first whether a source exists, and then assess the data availability and quality. To support GHG reporting, the following notation keys are used.

- If the GHG sink, source or reservoir does not exist, a "NO" is used to indicate it is "not occurring". For example, in the City, there is no biomass burning and thus "NO" was reported.
- If the GHG sink, source or reservoir does occur in the City, and data is available, then the emissions are estimated. However, if the data is also included in another emissions source category or cannot be disaggregated, the notation key "IE" would be used to indicate "included elsewhere" to avoid double counting. For example, in the City, GHG emissions from stationary energy—agriculture is included in stationary energy—residential as the utility data provider does not disaggregate the energy use amongst these categories.
- When GHG emissions are occurring in the City, but data is not available, then the notation key "NE" would be used to indicate "not estimated".

For GHG data that does exist, in accordance with the GPC Protocol, an assessment of quality is also made on emission factors and GHG estimation methodologies deployed. The GPC Protocol data quality assessment notation keys are summarized in Table 2.

Table 2 GPC Protocol Data Quality Assessment Notation Keys

Data Quality	Activity Data	Emission Factor
High (H)	Detailed activity data	Site-specific emission factors
Medium (M)	Modeled activity data using robust assumptions	More general emission factors
Low (L)	Highly-modeled or uncertain activity data	Default emission factors

3.0 GHG ASSESSMENT BOUNDARIES

This section sets out the reporting boundaries of the City's GHG inventory.

3.1 SPATIAL BOUNDARIES

This GHG inventory is defined geographically by the City municipal boundaries, as shown in Figure 2.

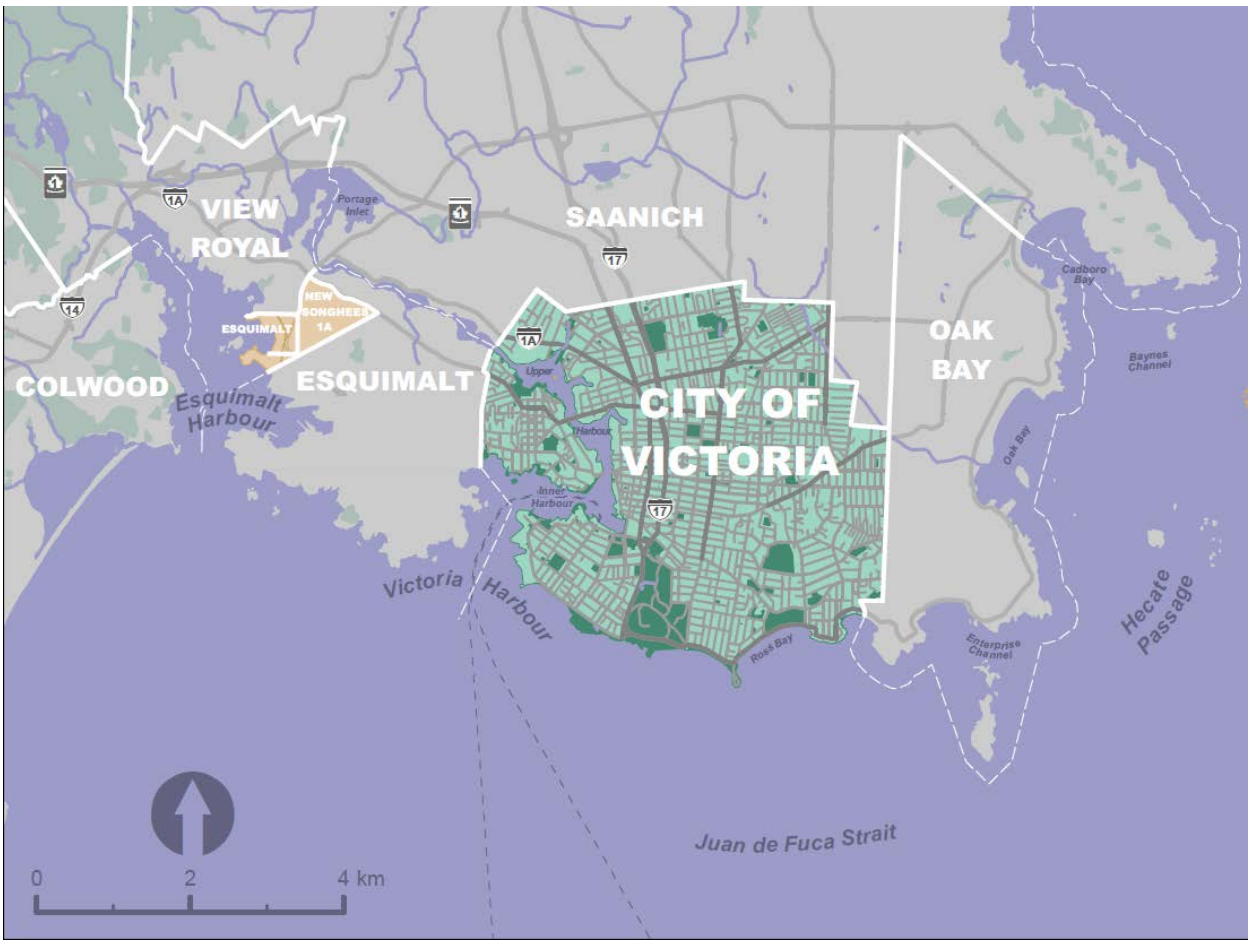

Figure 2 City of Victoria Municipal Boundary

Table 3 Inventory Information for the City

Inventory Boundary	City Information
Name of City	City of Victoria
Country	Canada
Inventory Year	2017
Geographic Boundary	See Figure 2
Land Area (km^2)	19.47
Resident population	86,529
GDP (US$)	Unknown at time of reporting
Composition of Economy	Government
Climate	Temperate, warm summer

3.2 TEMPORAL BOUNDARIES

3.2.1 2007 Baseline

Federal and provincial initiatives and legislation have been implemented to support local governments in acting to advance energy efficiency, promote energy conservation, and reduce GHG emissions. The City has already been working to address sustainability and climate change through several initiatives over the past decade including the development of a Climate Action Plan in 2010 and the Climate Change Adaptation Plan in 2011. The Climate Plans established a baseline GHG emissions inventory in 2007 and committed to a corporate target of 50% GHG emission reductions by 2020 and a community target of 33% GHG emission reductions by 2020 from 2007 levels. Victoria is in the process of updating the Climate Action Plan and has recently committed to reducing GHG emissions 80%, below 2007, by 2050, and has committed itself to operating on 100% renewable energy by 2050.

To maintain consistency with the current reporting year, and as required by the GPC Protocol, the City has updated its 2007 GHG baseline to be consistent with the GPC Protocol BASIC+ reporting level. Between the current reporting year and the 2007 baseline, there were no boundary changes (e.g., annexes) and thus no additional modifications were made. All methods and assumptions, adjusted for the 2007 reporting year, are the same.

Table 4 summaries the original 2007 baseline and the updated 2007 baseline. Like the reporting year (2017), the baseline also uses the same GWPs from the 4th IPCC report.

Table 4 Original And Updated BASIC+ Baseline

Aspect	Quantification Protocol	2007 GHG Baseline (tCO_2e)
Original Baseline	B.C. Best Practices Methodology for Quantifying Greenhouse Gas Emissions	383,383
Updated Baseline	GPC Protocol BASIC+	480,991

3.2.2 2017 GHG Boundary

This inventory covers all GHG emissions for the 2017 reporting year. Where 2017 data was not available, the most recent year's data have been used, and the timescale noted accordingly. These are as follows:

- **Global Warming Potentials (GWP)**. The BC government is currently applying GWPs from the fourth IPCC report in light of the fact that there are updated GWPs in available in the fifth IPCC report. On this basis, the City is applying GWPs from the fourth IPCC report.
- **Emission Factors.** Environment and Climate Change Canada publishes emission factors annually in the National Inventory Report (NIR). Currently, these emission factors from the 2018 NIR are for the 2016 reporting year, and as such, any emission factors that are used in the 2017 reporting year have been carried forward from 2016 or have been recalibrated as necessary.
- **Stationary Energy: Residential, Commercial and Institutional Buildings.** Propane, and wood GHG emissions were estimated using linear regression methods. The data used in the estimate included historical propane and wood energy data published in the 2007, 2010 and 2012 CEEIs, and heating degree days (HDD) published by Environment Canada. Heating oil GHG emissions were estimated based on the number of known tanks, average heated floor areas and estimated average fuel volumes collected by the City through onsite energy audits.
- **Stationary Energy: Fugitive Emissions.** Fortis BC who provides the fugitive emission estimates from natural gas systems has not provided the 2017 data at the time of reporting. On this basis, the 2016 values are applied for the 2017 reporting year.
- **Transportation: On-Road.** The Insurance Corporation of BC (ICBC) has not been able to provide registered vehicle data post 2012. As such, 2012 CEEI screened data was used to estimate total number of registered vehicles using the change in Victoria's population between 2012 and 2017.
- **Transportation: Off-Road.** The off-road transportation emissions are based on the 1990–2018 NIR as prepared by Environment and Climate Change Canada. The 2016 BC reported off-road emissions in the NIR were prorated to the City on a per capita basis.
- **Transportation: Aviation**. 2017 GHG emissions were estimated using 2015 aircraft flight profiles, and the total number of aircraft movements reported in 2017.
- **Transportation: Waterborne.** BC Ferries has not yet published 2017 total diesel fuel values, and therefore the 2016 value was applied and pro-rated to the City on a per capita basis. **Transportation: Waterborne**. GHG emissions from recreational watercraft and US/Can ferries

were estimated based on a publicly available year 2000 study for the Victoria, Vancouver, and Washington harbors.

- **Waste: Solid Waste Disposal.** The 2016 fugitive GHG emissions from the Hartland Landfill were used for the reporting year as the 2017 data is not yet available.
- **IPPU: Product Use.** The product use emissions are based on the published 2016 values in the NIR as prepared by Environment and Climate Change Canada. These are pro-rated to the City on a per capita basis.
- **AFOLU**: **Aggregate Sources And Non-CO_2 Emission Sources On Land.** The total area of farm land for Canada and provinces is from the Statistics Canada Census of Agriculture and is from 2016. The 2016 data was used to estimate urea application, indirect and direct emissions from N_2O under the AFOLU Sector.

3.3 GHG EMISSION SOURCES AND SCOPES

The following table summarizes the City's GHG emissions by source and GHG emission scope.

Table 5 Summary of Emissions Scope and GPC Protocol Reporting Sector

GHG Emissions Scope	GPC Protocol Reporting Sector
Scope 1	The GHG emissions occurring from sources located within City limits: • Stationary fuel combustion: – Residential buildings – Agriculture, forestry, and fishing activities – Commercial and institutional buildings, and facilities – Fugitive emissions from oil and natural gas systems • Transportation: – On-road – Aviation – Waterborne – Off-road • Industrial processes and product use (IPPU): – Product use • Agriculture, Forestry, and Other Land Use (AFOLU): – Land – Aggregate sources and non-CO_2 emission sources on land
Scope 2	The GHG emissions occurring from using grid-supplied electricity, heating and/or cooling within the City boundary: • Stationary fuel combustion: – Residential buildings – Commercial and institutional buildings, and facilities • Transportation: – On-road
Scope 3	Other GHG emissions occurring outside of the City limits as a result of City activities: • Stationary Energy: – Transmission, Distribution, and Line Losses • Transportation:

GHG Emissions Scope	GPC Protocol Reporting Sector
	– On-road – Aviation – Waterborne – Off-road • Waste: – Solid waste disposal – Biological treatment of solid waste – Wastewater treatment and discharge

3.4 GHG REPORTING

Where relevant, the GPC Protocol recommends using methodologies that align with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

The GHG inventory is required to include all seven Kyoto Protocol GHGs occurring within the geographic boundary of the City. These include:

- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride (SF_6)

Each GHG listed above has a different global warming potential (GWP) due to its ability to absorb and re-emit infrared radiation. This chemical property is recognized by the GWP set out by the IPCC Fourth Assessment Report. A larger GWP value means the substance has a greater affinity to absorb and re-emit infrared radiation. The GWP of these GHGs are CO_2 = 1.0, CH_4 = 25, N_2O = 298 (IPCC, 2007).

Total GHG emissions are normally reported as CO_2e, whereby emissions of each of the GHGs are multiplied by their GWP and are reported as tonnes of CO_2e.

The GHG inventory results following the GPC Protocol reporting table format are presented in Appendix A. The GPC Protocol reporting format is presented in Table 6 below which also indicates the reporting level (BASIC / BASIC+) for each source.

Table 6 GPC Protocol Summary Table

GPC Protocol Reference Number	Reporting Level	Emissions Scope	GHG Emissions Source
I	**Stationary Energy Sources**		
I.1	**Residential Buildings**		
I.1.1	BASIC	1	Emissions from in-boundary fuel combustion
I.1.2	BASIC	2	Emissions from consumption of grid-supplied energy
I.1.3	BASIC+	3	Transmission and distribution losses from grid-supplied energy
I.2	**Commercial and Institutional Buildings/Facilities**		
I.2.1	BASIC	1	Emissions from in-boundary fuel combustion
I.2.2	BASIC	2	Emissions from consumption of grid-supplied energy
I.2.3	BASIC+	3	Transmission and distribution losses from grid-supplied energy
I.3	**Manufacturing Industry and Construction**		
I.3.1	BASIC	1	Emissions from in-boundary fuel combustion
I.3.2	BASIC	2	Emissions from consumption of grid-supplied energy
I.3.3	BASIC+	3	Transmission and distribution losses from grid-supplied energy
I.4	**Energy Industries**		
I.4.1	BASIC	1	Emissions from in-boundary production of energy used in auxiliary operations
I.4.3	BASIC+	3	Transmission and distribution losses from grid-supplied energy
I.5	**Agriculture, Forestry, and Fishing Activities**		
I.5.1	BASIC	1	Emissions from in-boundary fuel combustion
I.5.2	BASIC	2	Emissions from consumption of grid-supplied energy
I.5.3	BASIC+	3	Transmission and distribution losses from grid-supplied energy
I.7	**Fugitive Emissions from Mining, Processing, Storage, And Transportation of Coal**		
I.7.1	BASIC	1	In-boundary fugitive emissions
I.8	**Fugitive Emissions from Oil and Natural Gas Systems**		
I.8.1	BASIC	1	In-boundary fugitive emissions
II	**Transportation**		
II.1	**On-road Transportation**		
II.1.1	BASIC	1	Emissions from in-boundary transport
II.1.2	BASIC	2	Emissions from consumption of grid-supplied energy
II.1.3	BASIC+	3	Emissions from transboundary journeys
II.2	**Railways**		
II.2.1	BASIC	1	Emissions from in-boundary transport
II.2.2	BASIC	2	Emissions from consumption of grid-supplied energy
II.2.3	BASIC+	3	Emissions from transboundary journeys

Table 6 GPC Protocol Summary Table

GPC Protocol Reference Number	Reporting Level	Emissions Scope	GHG Emissions Source
II.3	**Water-borne Navigation**		
II.3.1	BASIC	1	Emissions from in-boundary transport
II.3.2	BASIC	2	Emissions from consumption of grid-supplied energy
II.3.3	BASIC	3	Emissions from transboundary journeys
II.4	**Aviation**		
II.4.1	BASIC	1	Emissions from in-boundary transport
II.4.2	BASIC	2	Emissions from consumption of grid-supplied energy
II.4.3	BASIC+	3	Emissions from transboundary journeys
II.5	**Off-road**		
II.5.1	BASIC	1	Emissions from in-boundary transport
II.5.2	BASIC	2	Emissions from consumption of grid-supplied energy
III	**Waste**		
III.1	**Solid Waste Disposal**		
III.1.1	BASIC	1	Emissions from waste generated and treated within the City
III.1.2	BASIC	3	Emissions from waste generated within but treated outside of the City
III.2	**Biological Treatment of Waste**		
III.2.1	BASIC	1	Emissions from waste generated and treated within the City
III.2.2	BASIC	3	Emissions from waste generated within but treated outside of the City
III.3	**Incineration and Open Burning**		
III.3.1	BASIC	1	Emissions from waste generated and treated within the City
III.3.2	BASIC	3	Emissions from waste generated within but treated outside of the City
III.4	**Wastewater Treatment and Discharge**		
III.4.1	BASIC	1	Emissions from wastewater generated and treated within the City
III.4.2	BASIC	3	Emissions from wastewater generated within but treated outside of the City
IV	**Industrial Processes and Product Use (IPPU)**		
IV.1	BASIC+	1	In-boundary emissions from industrial processes
IV.2	BASIC+	1	In-boundary emissions from product use
V	**Agriculture, Forestry, and Other Land Use (AFOLU)**		
V.1	BASIC+	1	In-boundary emissions from livestock
V.1	BASIC+	1	In-boundary emissions from land

Table 6 GPC Protocol Summary Table

GPC Protocol Reference Number	Reporting Level	Emissions Scope	GHG Emissions Source
V.1	BASIC+	1	In-boundary emissions from other agriculture
VI	**Other Scope 3 Emissions**		
VI.1	BASIC / BASIC+	3	Other indirect emissions

4.0 GHG METHODOLOGIES BY SOURCE CATEGORY

The following sections describe the reporting source category, assumptions, activity data applied, and quantification methodology. The results of the analysis is presented in Section 5.0.

4.1 STATIONARY ENERGY

4.1.1 Overview

Stationery energy sources are one of the largest contributors to the City's community GHG emissions. For the City, the Stationary Energy Sector encompasses the following GHG emissions scopes and Sub-Sectors:

- Scope 1 Emissions:
  - Residential buildings
  - Commercial and institutional buildings, and facilities
  - Fugitive emissions from oil and natural gas systems
- Scope 2 Emissions:
  - Emissions from the consumption of grid-supplied electricity, steam, heating, and cooling.
- Scope 3 Emissions:
  - Transmission and distribution losses of electricity, steam, heating, and cooling.

4.1.2 Scope 2: Market Based Method

As per the GPC Protocol, cities can report on Scope 2 GHG emissions using either the market-based, or the location-based method. A market-based method utilizes utility-specific grid emission intensity factor, whereas a location-based method uses a regional or Provincial average grid emission intensity factor. At present, the fuel mix and GHG emissions data relative to the City's energy consumption is not available. As such, the City is defaulting to the BC Provincial electricity grid consumption intensity factor of 0.0117 tCO_2e/MWh reported by Environment and Climate Change Canada in the 2018 National Inventory Report (NIR).

4.1.3 Activity Data

BC Hydro and Fortis BC provided the electricity and natural gas consumption data in MWh and GJ, respectively. Based on the utility provider descriptions of the data, each is categorized as follows:

- Residential Buildings based on the BC Hydro and Fortis BC descriptor: "Residential"
- Commercial and Institutional Buildings/Facilities based on BC Hydro and Fortis BC descriptors: "Commercial", and "CSMI"

The Province developed residential propane and wood GHG energy use estimates from the number and type of dwellings and the aver-age dwelling consumption by authority and region from the BC Hydro Conservation Potential Review. This data was used to estimate the reporting year GHG emissions.

To calculate heating oil use, the City provided a heating oil tracking database, which contained addresses, size of tank, and whether a tank had been removed or not. Heating oil GHG emissions were estimated based on the number of known tanks, estimated heated floor areas and estimated average heating oil energy use reported by NRCan.

Fortis BC who provides the fugitive emission estimates from natural gas systems has not provided the 2017 data at the time of reporting. On this basis, the 2016 values are applied for the 2017 reporting year.

Applicable, off-road GHG emissions included in the Stationary Energy Sector are based on the 1990–2018 NIR as prepared by Environment and Climate Change Canada. These emissions are pro-rated to the City on a per capita basis.

4.1.4 Assumptions and Disclosures

The following assumptions were made in the calculation of the 2017 GHG emissions:

- It is assumed that the all data provided to the City from third party providers is accurate.
- As the energy utilities, do not provide energy data on agriculture, forestry, and fishing activities, it is assumed that this activity data (mainly agricultural) is lumped into the residential category. The notation key for “Included Elsewhere” has been used to indicate that the data for this category is included in City-wide electricity and natural gas consumption.
- BC Hydro estimates that the combined energy losses- transmission and distribution- to be approximately 7.5%. This value was used to calculate the Scope 3 emissions for each Stationary Energy Sub-Sector. It is assumed that this is accurate.
- It is assumed that the 2016 natural gas fugitive emissions will be similar in nature to the 2017 emissions.
- The off-road transportation emissions included in the Stationary Energy Sector are based on the 1990–2018 NIR as prepared by Environment and Climate Change Canada. This is deemed to be the best available data.
- Propane, and wood GHG emissions were estimated using linear regression methods. The data used in the estimate included historical propane and wood energy data published in the 2007, 2010 and 2012 CEEIs, and heating degree days (HDD) published by Environment Canada.
- Heating oil GHG emissions were estimated based on the number of known tanks, estimated heated floor areas and estimated average heating oil energy use reported by NRCan.

- Based on work completed by the City, a 62% reduction was applied to the total commercial square footage that is heated by heating oil. The reduction is based on the outcome of a representative sample of commercial properties that the City has confirmed to no longer have heating oil tanks.

4.1.5 Calculation Methodology

The Province of BC developed residential propane and wood GHG energy use estimates for the 2007, 2010 and 2012 reporting years, using the number and type of dwellings and the average dwelling consumption by authority and region contained in the BC Hydro Conservation Potential Review. Actual electricity and natural gas consumption values were subtracted from the total energy use, with the remainder assumed to be propane, or wood. To estimate 2017 propane and wood energy use, historical 2007, 2010 and 2012 values and the number of heating degree days (HDD) were linearly regressed to estimate future propane and wood energy use using reporting year HDD values. This resulted in the development of the following equations:

- Propane (L) = 38748.33 + 26.8943 * HDD
- Wood (GJ) = 84682.76 + 58.11731 * HDD

To calculate total heating oil use for the reporting year, the City provided BC Assessment building data, zoning GIS data, and a database of addresses with heating oil tanks. The data was used to estimate the total oil heated square footage for the City categories. In conjunction with this GJ/ft^2 data, the NRCAN Comprehensive Energy Use Database for BC was used to estimate the total heating oil energy use in GJ. This data is presented in Table 7.

Table 7 Heating Oil Units, Estimated Heating Oil Floor Space, and Heating Oil Energy Intensity Values

Stationary Energy Sub-Sector	Number of Heating Oil Units	Total Estimated Square Feet Heated (ft^2)	Energy Intensity (GJ/ft^2)
Residential buildings	1,675	3,085,350.00	0.14974329
Commercial and institutional buildings and facilities	39	340,912.82	0.359921421

To calculate GHG emissions from electricity, natural gas, heating oil, propane, and wood, the total net annual energy values (where applicable, less transmission, distribution, and line losses of 7.5%) were multiplied by applicable emissions factors. These values were then multiplied by the pollutant's GWP to give total CO_2e emissions in tonnes.

These quantification methods are captured as follows:

$$Energy_{Stationary\ Energy\ -\ Electricity} = Electricity * (1 - Line\ Loss\ (\%))$$

Energy $_{\text{Stationary Energy – Transmission, Distribution, and line Losses}}$ = *Electricity * Line Loss (%)*

Emissions $_{\text{Stationary Energy – Electricity}}$ = *Fuel (MWh) * EF_{tCO2e}*

Emissions $_{\text{Stationary Energy – Natural Gas}}$ = *(Fuel (GJ) * EF_{CO2}) + (Fuel (GJ) * EF_{CH4} * GWP_{CH4}) + (Fuel (GJ) * EF_{N2O} * GWP_{N2O})*

Emissions $_{\text{Stationary Energy – Propane}}$ = *(Fuel (GJ) * EF_{CO2}) + (Fuel (GJ) * EF_{CH4} * GWP_{CH4}) + (Fuel (GJ) * EF_{N2O} * GWP_{N2O})*

Emissions $_{\text{Stationary Energy – Wood}}$ = *(Fuel (GJ) * EF_{CO2}) + (Fuel (GJ) * EF_{CH4} * GWP_{CH4}) + (Fuel (GJ) * EF_{N2O} * GWP_{N2O})*

Emissions $_{\text{Stationary Energy – Heating Oil}}$ = *(Fuel (GJ) * EF_{CO2}) + (Fuel (GJ) * EF_{CH4} * GWP_{CH4}) + (Fuel (GJ) * EF_{N2O} * GWP_{N2O})*

The emission factors used in the 2017 reporting year are from the 2018 NIR. These are summarized in Table 8.

Table 8 Stationary Energy GHG Emission Factors

Emission Factor	Units	CO_2	CH_4	N_2O	tCO_2e
Electricity (BC Hydro)	tCO_2e / MWh				0.0117000
Natural Gas	tonne CO_2e/m3	0.0019260	0.0000000	0.0000000	0.0019374
Propane	tonne CO_2e/L	0.0015150	0.0000000	0.0000001	0.0015478
Heating Oil	tonne CO_2e/GJ	0.0681200	0.0000007	0.0000008	0.0683759
Wood	tonne CO2e / kg	-	0.0000150	0.0000002	0.0004227

Fortis BC estimated the GHG emissions based upon the number of customer meter sets at the municipality relative to the total region. This factor was then applied to the total vented and fugitive emission to determine the fugitive and vented related emission for the City.

4.2 TRANSPORTATION

4.2.1 Overview

Transportation covers all GHG emissions from combustion of fuels in journeys by on-road, railways, waterborne navigation, aviation, and off-road. GHG emissions are produced directly by the combustion of fuel, and indirectly using grid-supplied electricity. For the City, the Transportation Sector encompasses the following GHG emissions scopes and Sub-Sectors:

- Scope 1 Emissions:
  - On-road
  - Waterborne
  - Aviation
  - Off-road

- Scope 2 Emissions:
  - Emissions from the consumption of grid-supplied electricity.
- Scope 3 Emissions:
  - On-road
  - Waterborne
  - Aviation
  - Off-road

4.2.2 Activity Data

The Province of BC provided the 2012 vehicle registration data which was used in conjunction with reported population counts from the Province of BC to estimate the City's 2017 vehicle registration count.

BC Transit provided total diesel fuel use for the reporting year. Published GHG Emissions Per Service Hour, and BC Transit Service Hours for the reporting year were pulled from published BC Transit documents. This data was used to estimate GHG emissions from busses serving the City.

The 2017 CRD Origin Destination Travel Survey was used to estimate on-road in-boundary and transboundary split for registered vehicles and busses. The CRD Origin Destination Travel Survey is based on travel patterns observed in the Capital Regional District (CRD) level.

Aviation GHG emissions from the Victoria International Airport were estimated using 2015 aircraft flight profiles, and the total number of aircraft movements reported in 2017. These data sets were provided by the Victoria International Airport.

Victoria harbour aviation GHG emissions were estimated using Victoria harbor aircraft movement statistics, estimated taxi times, and estimated fuel use for the DHC-6 Twin Otter type of plane. This data was taken from Statistics Canada.

Marine watercraft GHG emissions were estimated using published BC Ferries fuel statistics. GHG emissions from the Coho Ferry, the Victoria Clipper Ferry, personal and commercial watercraft, were estimated based on a Study entitled "Marine Vessel Air Emissions in BC and Washington State Outside of the GVRD and FVRD for the Year 2000". The Transport Canada Vessel Registration System provided the total number of registered waterborne vehicles for the reporting year.

Off-road transportation emissions are based on the 2018 NIR as prepared by Environment and Climate Change Canada.

4.2.3 Assumptions and Disclosures

The following assumptions were made in the calculation of the Transportation Sector GHG emissions:

- The Insurance Corporation of BC (ICBC) has not been able to provide registered vehicle data. As such, 2012 CEEI screened data was used to estimate total number of registered vehicles using the change in Victoria's population between 2012 and 2017. This method is not likely to result in a material overstatement (>10%) in the total GHG inventory but it is likely to have a misstatement between vehicle fuel use categories. For example, in 2012 there were 3 recorded electric cars, whereas in the reporting year, electric cars have become more popular and this number is estimated to be more than 100. However, with the method deployed no electric vehicles are being recognized, and as such, gasoline GHG emissions are likely to be overestimated, and electricity GHG emissions understated.
- Vehicle fuel consumption rates were taken from the document entitled "2017 Community Energy and Emissions Inventory (CEEI) Initiative - Technical Methods and Guidance Document 2007-2012 Reports". These fuel consumption rates are estimated and will vary on a vehicle by vehicle basis.
- The estimated Vehicle Kilometer Travelled (VKT) data, by vehicle type, was taken from the "2009 Canadian Vehicle Survey" completed by Natural Resources Canada. This was a Canada wide study and likely over-estimates the VKT, and thus GHG emissions for the City.
- BC Transit tracks total diesel use, but not total gasoline use. Gasoline use from busses was estimated by calculating total GHG emissions using reported GHG emissions per service hour factor, and BC transit service hours, and by backing out GHG emissions from diesel. This is likely to result in an over estimate of gasoline use as the GHG emissions as the GHG emissions per service hour factor also include natural gas and electricity use.
- Gasoline and diesel GHG emissions from BC Transit busses are pro-rated to the City based on the City's proportion of population in the CRD. A more accurate estimation method would be to prorate fuel use based on total bus service kilometers in the City. However, this data is not available, and thus the method applied provides the best estimate at the time of reporting.
- It is assumed that the 2015 aircraft flight profiles at the Victoria International Airport are representative of the 2017 reporting year.
- Statistics Canada stopped collecting Victoria Harbor aircraft movement data in 2016. To estimate 2017 marine aviation GHG emissions, the 2016 Victoria data was applied and adjusted using the change in aircraft traffic between the 2016 and 2017 reporting years at the Victoria International Airport. It is assumed that the activity at both airports would be corelated, but not causational.
- The Aviation GHG emissions are prorated based on the total Victoria population relative to the CRD population.
- BC Ferries has not published its 2017 fuel statistics, and thus 2016 fuel statistics were applied to estimate Marine GHG emissions. These GHG emissions are prorated based on the total Victoria population relative to the Vancouver Island population.
- As there is currently no publicly available energy or GHG related information on the operation of the Coho and the Victoria Clipper Ferries, it was assumed that the GHG emissions for these ferries calculated in the Study entitled "Marine Vessel Air Emissions in BC

and Washington State Outside of the Greater Victoria Regional District (GVRD) and FVRD for the Year 2000".

- The Transport Canada Vessel Registration System provided the total number of registered waterborne vehicles for the reporting year; however, it does not provide any detail on the type, size, use, and owner of the watercraft. It was therefore assumed that the watercraft would have been similar to those in the referenced study.
- No cruise ship emissions have been estimated due to a lack of available data. These are expected to be a significant source of GHG emissions that would be allocated to the Scope 3 category.
- No Railway GHG emissions are occurring in the City and the notation key "Not Occurring" was used.
- The off-road transportation emissions are based on the 2018 NIR as prepared by Environment and Climate Change Canada. This is deemed to be the best available data.

4.2.4 Calculation Methodology

4.2.4.1 On-Road

The GPC Protocol identifies several methods for determining on-road emissions. The vehicle kilometers travelled (VKT) methodology was utilized to estimate the GHG emissions from on-road transportation (Scope 1) and transboundary transportation (Scope 3). The VKT uses the number and type of vehicles registered in a geopolitical boundary, the estimated fuel consumption rate of individual vehicles, and an estimate of the annual vehicle kilometres traveled (VKT) by various vehicle classes. ICBC provided the number of registered vehicles in the City by style, and by fuel type for 2012. To estimate the split between on-road in-boundary and transboundary traffic, data from the 2017 CRD Origin Destination Survey was applied. The results of the survey as it applies to Victoria is presented in Table 9

Table 9 On-Road In-Boundary/Transboundary Split

Aspect	By Vehicle	By Transit
Estimated proportion of on-road in-boundary travel	29%	24%
Estimated proportion of on-road transboundary travel	71%	76%

To quantify on-road and transboundary GHG emissions, the following steps were taken:

1. Screen ICBC dataset to pull out only Victoria registered vehicles, and to eliminate duplicates. Any changes to a vehicle's insurance policy in a reporting year can create another occurrence of the vehicle in the same dataset. As such, if a vehicle record included a change of location during a quarter, the vehicle was assigned to the location where it was insured for the greatest portion of the quarter. The objective of this screening is to increase the accuracy of the GHG estimate.

2. Identify vehicle characteristics using Identification Number (VIN) and other data fields to assign a fuel class and vehicle sector. As the 2012 data was used, the Province completed steps 1 and 2 of this process.
3. Grow the 2012 vehicle population based on the change between the City's 2012 and 2017 population.
4. Assign estimated NRCan vehicle fuel consumption rates, and estimated VKT from the Transport Canada study to each of the registered vehicle classes (Table 10). The estimated vehicle fuel consumption rates were taken from the document entitled "2017 Community Energy and Emissions Inventory (CEEI) Initiative - Technical Methods and Guidance Document 2007-2012 Reports". The estimated VKT data, by vehicle type, was taken from the 2009 Canadian Vehicle Survey completed by Natural Resources Canada.
5. Estimate total fuel use by vehicle classification (Table 11).
6. Summate and allocate estimated fuel use, by vehicle class using the applicable in-boundary and transboundary split (Table 12).
7. Estimate total gasoline use from BC Transit busses. Gasoline use from busses was estimated by calculating total GHG emissions using reported GHG emissions per service hour factor (28.8 kg CO2e/hr), and BC transit service hours (941,000), and by backing out GHG emissions from diesel (based on 8,383,509 Liters of diesel). It is estimated that BC Transit used 1,783,692 liters of gasoline in the reporting year.
8. Pro-rate the gasoline and diesel fuel use from busses to the City based on the total City population relative to the total CRD population.
9. Summate and allocate estimated bus fuel use using the applicable in-boundary and transboundary split (Table 12).

Table 10 Estimated VKT And Fuel Efficiencies by Vehicle Class

Vehicle Classification	Estimated VKT / Year	Estimated Fuel Efficiency (L/100 km)
Diesel-HDV	68,125	34
Diesel-LDT	14,914	11
Diesel-LDV	11,172	7
Diesel-ORVE	3,500	9
E10-LDT	16,500	13
E10-LDV	11,859	9
Electric-HDV	6,700	32
Electric-LDT	16,500	7
Electric-LDV	16,500	7
Gasoline-HDV	42,725	33
Gasoline-HYBRID-LDT	16,500	10
Gasoline-HYBRID-LDV	14,400	7
Gasoline-LDT	11,075	12
Gasoline-LDV	37,402	9

Vehicle Classification	Estimated VKT / Year	Estimated Fuel Efficiency (L/100 km)
Gasoline-ORVE	3,500	9
Motorcycle - Electric	4,054	6
Motorcycle - Non-catalyst	4,054	6
Natural Gas-LDT	12,973	8
Natural Gas-LDV	63,058	5
Natural Gas-ORVE	3,500	9
Propane-HDV	56,588	35
Propane-LDT	13,495	13
Propane-LDV	37,701	8

Table 11 Total Registered Vehicles & Estimated Fuel Use For Reporting Year

Vehicle Classification	Total Registered Vehicles	Total Estimated Fuel Use	Units
Electric	1	2,139	Kilowatt Hours (kWh)
Diesel-LDV	752	612,417	Liters (L)
Diesel-LDT	767	1,385,544	Liters (L)
Diesel-HDV	156	6,226,739	Liters (L)
Gasoline-HDV	488	1,520,649	Liters (L)
Gasoline-LDT	15,031	20,795,093	Liters (L)
Gasoline-LDV	29,002	28,740,989	Liters (L)
Gasoline-HYBRID-LDV	3	3,065	Liters (L)
Gasoline-HYBRID-LDT	1	1,672	Liters (L)
E10-LDV	2	2,140	Liters (L)
E10-LDT	2	4,415	Liters (L)
E10-HDV			Liters (L)
Propane-LDV	24	34,608	Liters (L)
Propane-LDT	57	79,626	Liters (L)
Propane-HDV	7	51,288	Liters (L)
Natural Gas-LDV			kilograms (kg)
Natural Gas-LDT	15	12,512	kilograms (kg)
Natural Gas-HDV			kilograms (kg)
Motorcycle - Non-catalyst	1,789	413,369	Liters (L)
Motorcycle - Electric			Liters (L)
Gasoline-ORVE			Liters (L)
Diesel-ORVE			Liters (L)

Vehicle Classification	Total Registered Vehicles	Total Estimated Fuel Use	Units
Natural Gas-ORVE			kilograms (kg)
Total	**48,097**	**N/A**	**N/A**

Table 12 Reporting Year Fuel Use Allocation by Vehicle Classification and Split

Vehicle Class	In-Boundary	Transboundary	Total	Units
Electric	614	1,525	2,139	Kilowatt Hours (kWh)
Diesel-LDV	175,764	436,653	612,417	Liters (L)
Diesel-LDT	397,651	987,893	1,385,544	Liters (L)
Diesel-HDV	1,696,826	4,529,914	6,226,739	Liters (L)
Diesel-ORVE				Liters (L)
Gasoline-LDV	8,248,664	20,492,325	28,740,989	Liters (L)
Gasoline-LDT	5,968,192	14,826,901	20,795,093	Liters (L)
Gasoline-HDV	417,225	1,103,424	1,520,649	Liters (L)
Gasoline-HYBRID-LDV	880	2,185	3,065	Liters (L)
Gasoline-HYBRID-LDT	480	1,192	1,672	Liters (L)
Gasoline-ORVE				Liters (L)
E10-LDV	614	1,526	2,140	Liters (L)
E10-LDT	1,267	3,148	4,415	Liters (L)
E10-HDV				Liters (L)
Propane-LDV	9,932	24,675	34,608	Liters (L)
Propane-LDT	22,853	56,773	79,626	Liters (L)
Propane-HDV	14,720	36,569	51,288	Liters (L)
Natural Gas-LDV				kilograms (kg)
Natural Gas-LDT	3,591	8,921	12,512	kilograms (kg)
Natural Gas-HDV				kilograms (kg)
Natural Gas-ORVE				kilograms (kg)
Motorcycle - Non-catalyst	118,637	294,732	413,369	Liters (L)

Once the fuels were allocated amongst the vehicle classes and sectors, the GHG emissions were calculated accordingly. The GHG quantification method is captured, for all fuel types, is as follows:

$$\textbf{Emissions}_{\textbf{On-road}} = \text{In-Boundary Split \%} * ((\text{Vol. Fuel} * EF_{CO2}) + (\text{Vol. Fuel} * EF_{CH4} * GWP_{CH4}) + (\text{Vol. Fuel} * EF_{N2O} * GWP_{N2O}))$$

$$Emissions_{Transboundary} = Transboundary\ Split\ \% * ((Vol.\ Fuel * EF_{CO2}) + (Vol.\ Fuel * EF_{CH4} * GWP_{CH4}) + (Vol.\ Fuel * EF_{N2O} * GWP_{N2O}))$$

The emission factors used in the reporting year GHG inventory are from the 2018 NIR. These are summarized in Table 13.

Table 13 Vehicle GHG Emission Factors

Vehicle Class	Units	CO_2	CH_4	N_2O	tCO_2e
Electricity (BC Hydro)	tonne / MWh	-	-	-	0.0117000
Diesel-LDV	tonne / L	0.0026810	0.0000001	0.0000002	0.0027478
Diesel-LDT	tonne / L	0.0026810	0.0000001	0.0000002	0.0027483
Diesel-HDV	tonne / L	0.0026810	0.0000001	0.0000002	0.0027287
Diesel-ORVE	tonne / L	0.0026810	0.0000001	0.0000000	0.0026894
Gasoline-LDV	tonne / L	0.0023070	0.0000001	0.0000002	0.0023761
Gasoline-LDT	tonne / L	0.0023070	0.0000001	0.0000002	0.0023761
Gasoline-HDV	tonne / L	0.0023070	0.0000001	0.0000002	0.0023683
Gasoline-HYBRID-LDV	tonne / L	0.0027380	0.0000130	0.0000005	0.0032031
Gasoline-HYBRID-LDT	tonne / L	0.0027380	0.0000130	0.0000005	0.0032031
Gasoline-ORVE	tonne / L	0.0027380	0.0000130	0.0000005	0.0032031
E10-LDV	tonne / L	0.0020763	0.0000001	0.0000002	0.0021454
E10-LDT	tonne / L	0.0020763	0.0000001	0.0000002	0.0021454
E10-HDV	tonne / L	0.0020763	0.0000001	0.0000002	0.0021376
Propane-LDV	tonne / L	0.0015150	0.0000006	0.0000000	0.0015393
Propane-LDT	tonne / L	0.0015150	0.0000006	0.0000000	0.0015393
Propane-HDV	tonne / L	0.0015150	0.0000006	0.0000000	0.0015393
Natural Gas-LDV	tonne / kg	0.0000019	0.0090000	0.0000600	0.2428819
Natural Gas-LDT	tonne / kg	0.0000019	0.0090000	0.0000600	0.2428819
Natural Gas-HDV	tonne / kg	0.0000019	0.0090000	0.0000600	0.2428819
Natural Gas-ORVE	tonne / kg	0.0000019	0.0090000	0.0000600	0.2428819
Motorcycle - Non-catalyst	tonne / L	0.0023160	0.0000023	0.0000000	0.0023878

4.2.4.2 Aviation: Victoria International Airport

The Victoria International Airport (VIA) estimated its 2015 airplane GHG emissions following the ACI ACERT standard. This includes GHG emissions from aircraft and GHG emissions from auxiliary power units (APU). APUs provides electricity to the aircraft prior to the engine start up. Within the ACERT model, it is assumed all aircraft have APUs and the duration of the APU operation (of five

minutes per aircraft) was generically applied to every landing take-off (LTO) cycles. It should also be noted that the EIA has quantified aircraft GHG emissions from planes up to 3,000 ft. to avoid double counting with other airports and cities. This is consistent with the ACERT standard.

The City's 2017 aviation emissions estimate is based on the 2015 aircraft flight profiles, which included the estimated landing and takeoff (LTO) and auxiliary power unit (APU) fuel use, and an estimated percentage allocation of total flights to the following aviation class groupings (Table 14). The total reported flight movements for the reporting year (123,078) provided by the VIA and the aircraft flight profile data was used to estimate aviation GHG emissions for the reporting year at the VIA.

Table 14 Aircraft Type, Estimated Percentage of Total Reported Movements, And Estimated Fuel Use

Aviation Class	Aircraft Type	Estimated Percentage of Annual Movements	Estimated LTO Fuel Use by Aircraft Type (kg)	Estimated APU Fuel Use by Aircraft Type (kg/min)
Jet	Large: 2-aisle, long-haul	0.01%	1,853	4.00
	Medium: 2-aisle, medium-haul	0.01%	1,321	4.00
	Small: 1-aisle, small/medium haul	7.95%	565	1.78
	Regional: 1-aisle, short-haul	0.01%	315	1.78
	Business: 2-eng business jets	0.01%	41	1.78
Turboprop	Turboprop (all engines)	22.29%	46	1.78
Piston	Piston (all engines)	66.30%	41	0.00
Helicopter	Helicopter small (1 engine/turbine)	1.72%	13	0.00
	Helicopter large (2 engine/turbine)	1.72%	8	0.00

Calculating fuel use for each aviation class applied the following equation:

$$\textbf{Fuel Use}_{\text{Per Aviation Class}} = \textit{Number of Aircraft Movements} * (\textit{LTO Fuel Use} + (\textit{APU Fuel Use} * 15\ \textit{minutes}))$$

Lastly, as the VIA does not collect origin traveler data, aviation emissions were prorated based on the City population relative to the CRD population. These were reported in the Scope 3 category as the VIA is located outside of the City boundaries.

The GHG quantification method, that was applied to each aviation class, is as follows:

$$\textbf{Emissions}_{\text{Per Aviation Class}} = (\textit{City Population} / \textit{CRD Population}) * ((\textit{Vol. Fuel} * \textit{Aviation Class } EF_{CO2}) + (\textit{Vol. Fuel} * \textit{Aviation Class } EF_{CH4} * GWP_{CH4}) + (\textit{Vol. Fuel} * \textit{Aviation Class } EF_{N2O} * GWP_{N2O}))$$

The ACERT GHG calculator used by the VIA utilized emission factors from the 2018 NIR. Actual airplane emission factors are from the International Civil Aviation Organization (ICAO) GHG database. These are summarized in Table 15.

Table 15 Aviation GHG Emission Factors

Airplane Type	Units	CO_2	CH_4	N_2O	tCO_2e
Jet	tCO_2e/kg fuel	0.0031380	0.0000001	0.0000003	0.0032254
Turbo Propeller	tCO_2e/kg fuel	0.0031380	0.0000001	0.0000003	0.0032254
Piston	tCO_2e/kg fuel	0.0032530	0.0000031	0.0000003	0.0034154
Helicopter	tCO_2e/kg fuel	0.0031380	0.0000001	0.0000003	0.0032254

4.2.4.3 Aviation: Victoria Harbour

Victoria harbor aviation emissions were estimated using 2016 NAV Canada airplane movement statistics, estimated taxi times, and estimated fuel use for the DHC-6 Twin Otter type of plane (Table 14).

Table 16 Aircraft Type, Estimated Percentage of Total Reported Movements, And Estimated Fuel Use

Aviation Class	Aircraft Type	Estimated Percentage of Annual Movements	Estimated LTO Fuel Use by Aircraft Type (kg)	Estimated APU Fuel Use by Aircraft Type (kg/min)
Turboprop	DHC-6 Twin Otter	100%	56	0.00

Statistics Canada stopped collecting Victoria Harbor aircraft movement data in 2016. To estimate 2017 Victoria harbor aviation GHG emissions, the 2016 Victoria data was applied and adjusted using the change in aircraft traffic between the 2016 and 2017 reporting years at the Victoria International Airport. This amounted to an increase of 9.95% between 2016 and 2017 which resulted in an estimated 30,456 movements.

Calculating aviation fuel use in the Victoria harbor for applied the following equation:

$$\textbf{Fuel Use}_{\text{Per Aviation Class}} = \textit{Number of Aircraft Movements} * (\textit{LTO Fuel Use} + (\textit{APU Fuel Use} * 15 \textit{ minutes}))$$

Lastly, as there is no publicly available origin traveler data for harbor flights, the aviation GHG emissions were prorated based on the City population relative to the CRD population. These were reported in the Scope 3 category as the Victoria Harbor is located outside of the City boundaries.

The GHG quantification method is as follows:

$$\textbf{Emissions}_{\text{Per Aviation Class}} = (\text{City Population} / \text{CRD Population}) * ((\text{Vol. Fuel} * \text{Aviation Class } EF_{CO2}) + (\text{Vol. Fuel} * \text{Aviation Class } EF_{CH4} * GWP_{CH4}) + (\text{Vol. Fuel} * \text{Aviation Class } EF_{N2O} * GWP_{N2O}))$$

The airplane emission factors are from the International Civil Aviation Organization (ICAO) GHG database. These are summarized in Table 17.

Table 17 Marine Aviation GHG Emission Factors

Airplane Type	Units	CO_2	CH_4	N_2O	tCO_2e
Turbo Propeller	tCO_2e/kg fuel	0.0031380	0.0000001	0.0000003	0.0032254

4.2.4.4 Waterborne Transportation

4.2.4.4.1 BC Ferries

Marine waterborne transportation emissions encompass GHG emissions from the use of the BC Ferries. As noted previously, no personal watercraft GHG emissions were estimated based on a lack of available data. GHG emissions from BC Ferries are estimated using total reported fuel use 115,400,000 liters of diesel for the 2016 reporting year (as 2017 is not yet available), and a provincially derived GHG emissions factor (Table 18).

Table 18 BC Ferries GHG Emission Factors

Aspect	Units	CO_2	CH_4	N_2O	tCO_2e
Ferry	tonne CO_2e / L	0.0025820	0.0000002	0.0000011	0.0029136

As BC Ferries operate outside of the City's boundary, the GHG emissions were allocated to Scope 3 based on the proportion of the City population relative to Vancouver Island population.

4.2.4.4.2 Other Watercraft

The GHG emissions from the Coho Ferry, the Victoria Clipper Ferry, and personal and commercial watercraft were estimated based on a publicly available year 2000 study for the Victoria, Vancouver, and Washington harbors and the Transport Canada Vessel Registration System. As there is currently no publicly available energy or GHG related information on the operation of the Coho and the Victoria Clipper Ferries, it was assumed that the GHG emissions for these ferries calculated in the Study entitled "Marine Vessel Air Emissions in BC and Washington State Outside of the GVRD and FVRD for the Year 2000". The GHG emissions for these ferries are summarized in Table 19.

Table 19 Coho and the Victoria Clipper Ferries Estimated GHG Emissions

Aspect	Units	CO_2	CH_4	N_2O	tCO_2e
Coho Ferries	Tonnes	1,160.00	0.10	0.40	1,281.70
Victoria Clipper	Tonnes	1,895.00	0.10	0.80	2,135.90

The Transport Canada Vessel Registration System provided the total number of registered waterborne vehicles which was 3,708 vessels for the Victoria harbor; however, the registration system does not provide any detail on the type, size, use, and owner of the watercraft. It was therefore assumed that the watercraft would have been similar to those in the referenced study. To estimate the personal / watercraft GHG emissions, the breakdown of vessels and total fuel use by category were used to estimate what the current population and fuel use might be in the reporting year. To do this, the following steps were taken.

1. Calculate the percentage of the population and per unit fuel use of the year 2000 population (Table 20).
2. Take the total number of registered vessels (3,708), and the percentage breakdown of the year 2000 population, and apply the per unit fuel use factor to determine the total gasoline and diesel fuel use (Table 21).
3. Using NIR emission factors estimate the GHG emissions from other watercraft.

Table 20 Year 2000 Other Watercraft Population Breakdown And Estimated Fuel Use

Type of Watercraft from Year 2000 Study	Year 2000 Study Vancouver Island Population	Percentage of Population	Fuel Use (m^3/Year)	Fuel Use Per Unit (m^3/Year)
Inboard: 4 stroke - gasoline	1,689	0.19%	175	0.10
Inboard: Diesel	199	0.02%	62	0.31
Outboard: 2 stroke - gasoline	23,494	2.66%	1,632	0.07
Outboard: 4 stroke - gasoline	622	0.07%	7	0.01
Stemdrive: 2 stroke - gasoline	68	0.01%	8	0.12
Stemdrive: 4 stroke - gasoline	6,576	0.74%	535	0.08
Stemdrive: Diesel	784	0.09%	216	0.28
Personal Watercraft: 2 stroke - gasoline	848,492	96.00%	342	0.00
Sailboat Auxiliary Inboard: 4 stroke - gasoline	428	0.05%	1	0.00
Sailboat Auxiliary Inboard: Diesel	1,088	0.12%	6	0.01
Sailboat Auxiliary Outboard: 2 stroke - gasoline	396	0.04%	1	0.00
Sailboat Auxiliary Outboard: Diesel	1	0.00%	0	0.01

Table 21 Reporting Year Other Watercraft Population Breakdown and Estimated Fuel Use

Type of Watercraft	Estimated Breakdown of Currently Registered Vessels	Estimated Fuel Use (L/year)
Inboard: 4 stroke - gasoline	4	414
Inboard: Diesel	0	0
Outboard: 2 stroke - gasoline	57	3,959
Outboard: 4 stroke - gasoline	2	23
Stemdrive: 2 stroke - gasoline	0	0
Stemdrive: 4 stroke - gasoline	16	1,302
Stemdrive: Diesel	2	551
Personal Watercraft: 2 stroke - gasoline	2,058	830
Sailboat Auxiliary Inboard: 4 stroke - gasoline	1	1
Sailboat Auxiliary Inboard: Diesel	3	17
Sailboat Auxiliary Outboard: 2 stroke - gasoline	1	1
Sailboat Auxiliary Outboard: Diesel	0	0

To calculate the GHG emissions, for the other watercraft, provincially derived GHG emissions factors were used (Table 22).

Table 22 Watercraft GHG Emission Factors

Aspect	Units	CO_2	CH_4	N_2O	tCO_2e
Marine Gasoline	tonne CO2e / L	0.0022000	0.0000013	0.0000001	0.0022522
Marine Diesel	tonne CO2e / L	0.0025820	0.0000002	0.0000011	0.0029136

Due to a lack of detailed registration data, GHG emissions were allocated to scope 1 and scope 3 based on the proportion of the Victoria population relative to Regional District population.

The GHG quantification method, that was applied to the BC Ferries and other watercraft was as follows:

$$\textbf{Emissions}_{\textbf{Waterborne}} = (\text{Victoria Population / CRD Population}) * ((\text{Vol. Fuel} * EF_{CO2}) + (\text{Vol. Fuel} * EF_{CH4} * GWP_{CH4}) + (\text{Vol. Fuel} * EF_{N2O} * GWP_{N2O}))$$

Cruise ship GHG emissions were not estimated due to a lack of available data.

4.2.4.5 Off-Road

Currently, there is limited data available on off-road GHG emissions. As such, a GHG emissions per capita estimate for each off-road category was developed using Provincial emissions data from the 2018 NIR, and BC's population from Statistics Canada. To develop each off-road factor, the total BC GHG emissions for each reporting category was divided by the BC population for the NIR reporting year (2016). Each derived per-capita value was applied to the current reporting year City population (2017) to estimate off-road GHG emissions.

The NIR currently reports the following off-road emissions:

- Total BC off-road agriculture and forestry GHG emissions
- Total BC off-road commercial and institutional GHG emissions
- Total BC off-road manufacturing, mining, and construction GHG emissions
- Total BC off-road residential GHG emissions
- Total BC other off-road GHG emissions

Other than other off-road GHG emissions, which is reported in the Off-Road Transportation Sub-Sector, the remaining off-road GHG emissions are reported in the Stationary Energy Sector as required by the GPC Protocol.

The GHG quantification method is presented below:

$$\textbf{Emissions}_{\textbf{Off-Road}} = (\text{NIR Off-Road GHG Emissions}_{BC} / \text{NIR Population}_{BC}) * \text{Current Reporting Year Population}_{Victoria}$$

4.3 WASTE

Cities produce GHG emissions because of the disposal and management of solid waste, incineration and open burning of waste, the biological treatment of waste, and through wastewater treatment and discharge. Waste does not directly consume energy, but releases GHG emissions because of decomposition, burning, incineration, and other management methods.

For the City, the Waste Sector encompasses the following GHG emissions scopes and Sub-Sectors:

- Scope 3: Emissions:
  - Solid waste disposal
  - Biological treatment of waste
  - Wastewater treatment and discharge

No GHG emissions from incineration and open burning are occurring and thus the notation key for "Not Estimated" has been used to indicate this.

4.3.1 Activity Data

The CRD provided landfill and GHG related data for the Hartland landfill, the estimated proportion of City solid waste, total CRD wastewater volumes and annual biological oxygen demand (BOD) average of the wastewater for both the Macaulay and Clover Outfalls for the reporting year, and a baseline/forecast wastewater study estimating each of the CRD local governments proportion of wastewater.

Some GHG emissions from incineration and open burning are occurring in the City, but cannot readily be estimated, and thus the notation key for "Not Estimated" has been used to indicate this.

4.3.2 Assumptions and Disclosures

The following assumptions were made in the calculation of the 2017 GHG emissions:

- To quantify GHG emissions from the Hartland Landfill, the CRD utilized the waste-in-place method which is accepted under the GPC Protocol. The Waste-in-place (WIP) assigns landfill emissions based on total waste deposited during that year. It counts GHGs emitted that year, regardless of when the waste was disposed. GHG emissions from the Hartland Landfill for the reporting year are allocated based upon the percentage of City waste, relative to total waste received at to the Hartland Landfill. Using this allocation method, the City may over, or underestimate associated solid waste GHG emissions as the current year landfill GHG emissions are based upon cumulative waste over time, and the City may have contributed more waste in past years than the current year (and vice versa).
- The estimated 2017 fugitive emissions at the Hartland Landfill were not available, and thus the 2016 value was applied.
- Composting GHG emissions are estimated based on the total tonnage reported by the City. This is likely to be an underestimate of GHG emissions as the City does not have a mechanism in place to track how much organic waste is being collected by third party waste haulers at commercial and multi-unit residential facilities.
- Wastewater is not currently treated. Rather, wastewater is sent to one of two outfalls: Macaulay and Clover. As such, IPCC wastewater methane (CH_4) producing capacity and methane correction default factors were used. These factors used are for untreated wastewater being deposited into deep or moving waters. It is likely that ocean sequesters more CH_4 than is estimated.
- Wastewater allocation volumes to the City are taken from the 2015 Report "Capital Regional District Core Area Liquid Waste Management Plan - Wastewater Treatment System Feasibility and Costing Analysis. Technical Memorandum #1". It is assumed that these volumes are

reasonably estimated for the 2017 reporting year. It was also assumed that the proportion of City wastewater is the same in the baseline.

4.3.3 Calculation Methodology

4.3.3.1 Solid Waste

The Hartland Landfill serves most of the CRD. There is a landfill gas (LFG) collection and destruction system at the Hartland Landfill to which the LFG is either combusted in a flare, or in an engine to generate electricity which is exported to the grid. However, the CRD has not disclosed how much energy was generated, and what proportion of those GHG emissions are energy generation related. As such, GHG emissions from energy generation category under stationary energy was not reported, and the notation key for "Not Estimated" has been used to indicate this.

The GHG emissions estimates have been generated using the waste-in-place (WIP) method which is accepted under the GPC Protocol. The WIP assigns landfill emissions based on emissions during that year. It counts GHGs emitted that year, regardless of when the waste was disposed. The City's proportion of landfill GHG emissions for the reporting year are based on the recorded allocation of City waste delivered, relative to the total regional waste delivered. In 2017, this amounted to 50,820 tons or 32.3%.

As the Hartland Landfill is outside of the City's city limits, the GHG emissions were assigned to the solid waste Scope 3 category. The City's proportion of stationary energy GHG emissions are assumed to all be flared and thus are reported in solid waste scope 3 as well.

The GHG quantification methods are captured as follows:

$$\textbf{Emissions}_{\textbf{Solid Waste}} = Percent_{City\ Waste} * Hartland\ Landfill\ Fugitive_{CH4} * GWP_{CH4}$$

4.3.3.2 Biological Treatment of Solid Waste

The City collects and diverts all organic waste from entering the landfill – in 2017, the City estimates that 1,173,832 kg of organic waste was diverted from the landfill. Approximately two-thirds of the organic material is treated anaerobically, and one-third is treated aerobically.

The composting emission factors used in the estimation of GHG emissions from the biological treatment of solid waste is from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Volume 5, Chapter 4: Biological Treatment of Solid Waste) (Table 23).

Table 23 Composting Emission Factor

Emission Factor	Units	CO_2	CH_4	N_2O	tCO_2e
Composting	t / kg waste		0.0000010		0.0000250
Anaerobic	t / kg waste		0.0000040	0.0000003	0.0001894

As the treatment facilities are outside of the City limits, the GHG emissions were assigned to the Scope 3 category. To quantify GHG emissions from the biological treatment of solid waste, the following GHG quantification methods are deployed:

$$Emissions_{Anaerobic\ Waste} = 2/3 * Waste_{Total} * EF_{CH4} * GWP_{CH4}$$

$$Emissions_{Aerobic\ Waste} = 1/3 * Waste_{Total} * EF_{CH4} * GWP_{CH4}$$

4.3.3.3 Wastewater Treatment And Discharge

Wastewater is not currently treated on Vancouver Island. Rather, wastewater is sent to one of two ocean-based outfalls: Macaulay and Clover. Wastewater allocation volumes to the City are taken from the 2015 Report "Capital Regional District Core Area Liquid Waste Management Plan - Wastewater Treatment System Feasibility and Costing Analysis. Technical Memorandum #1". It is assumed that the volumes proportioned to the City are reasonably estimated for the 2017 reporting year. It was also assumed that the proportion of City wastewater is the same in the baseline. For the reporting year, it was assumed that 11% of all wastewater volumes sent to the Macaulay outfall are from the City, and that 67% of all wastewater sent to the Clover outfall is from the City. The CRD provided the 2017 wastewater volumes (m^3), and annual biological oxygen demand (BOD) average of the wastewater (mg/L) for both the Macaulay and Clover Outfalls. Total wastewater volumes and BOD were used to calculate the total BOD in kg as summarized in Table 24 for the 2017 reporting year.

Table 24 Wastewater Volumes and BOD Values

Aspect	Volume (m^3)	BOD (mg/L)	BOD (kg)
Macaulay Outfall	16,447,764	286	4,704,061
Clover Outfall	16,490,311	254	4,188,539

IPCC default wastewater methane (CH_4) producing capacity (0.6 kg CH_4/kg BOD) and methane correction factor (MCF) (0.1 – unit less) were used to estimate CH_4 from the wastewater. These factors used are for untreated wastewater being deposited into deep or moving waters. It is likely that ocean sequesters more CH_4 than what has been estimated.

To estimate N_2O from the wastewater, the Total Kjeldal Nitrogen (TKN) sampled values (mg/L) from the wastewater study was used in conjunction with the total wastewater volumes to calculate the total TKN in kg as summarized in Table 24 for the 2017 reporting year.

Table 25 Wastewater Volumes and TKN Values

Aspect	Volume (m^3)	TKN (mg/L)	TKN (kg)
Macaulay Outfall	16,447,764	54.4	894,758
Clover Outfall	16,490,311	40.0	659,612

The IPCC default conversion value of 0.01 kg N_2O-N/kg sewage-N was used to estimate N_2O from the wastewater.

To quantify GHG emissions from the wastewater treatment, the following GHG quantification method is deployed:

$$\textbf{Emissions}_{\textbf{Wastewater CH4}} = ((Percent_{City\ Wastewater} * Wastewater_{m^3} * (BOD_{ml/L} / 1000) * (0.06_{kg\ CH4/kg\ BOD} * 0.01)) / 1000) * GWP_{CH4}$$

$$\textbf{Emissions}_{\textbf{Wastewater N2O}} = ((Percent_{City\ Wastewater} * Wastewater_{m^3} * (TKN_{ml/L} / 1000) * 0.01_{kg\ N2O\text{-}N/kg\ sewage\text{-}N}) / 1000) * GWP_{N2O}$$

4.4 INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)

4.4.1 Overview

Emissions from the IPPU Sector are only required for BASIC+ GHG reporting under the GPC Protocol. This Sector encompasses GHG emissions produced from industrial processes that chemically or physically transform materials and using products by industry and end-consumers (e.g., refrigerants, foams, and aerosol cans) (GPC, 2014).

For the City, the IPPU encompasses the following GHG emissions scopes and Sub-Sectors:

- Scope 1 Emissions:
  - Product use

No GHG emissions from Industrial Processes are occurring and thus the notation key for “Not Occurring” has been used to indicate this.

4.4.2 Activity Data

As there is limited data available on Product Use GHG emissions, the GHG Emissions estimate was derived on a per capita basis using the NIR 2018 GHG data and Statistics Canada population data for the reporting year.

4.4.3 Assumptions and Disclosures

The following assumptions were made in the calculation of the 2017 GHG emissions:

- The product use emissions are based on the 2018 NIR product use GHG emissions as prepared by Environment and Climate Change Canada.
- The NIR uses the Tier 1 methodology to estimate these emissions and thus uncertainty around their accuracy remains quite high.

4.4.4 Calculation Methodology

4.4.4.1 Product Use Emissions

For the 2017 reporting year, only the emissions estimated were production and consumption of halocarbons, SF_6 and NF_3 were estimated for the Province. To estimate product use GHG emissions for the City, a per capita estimate was developed using the Provincial emissions data from the 2018 NIR, and BC's NIR reporting year (2016) population from Statistics Canada. This value was applied to the 2017 reporting year City population for the reporting year to estimate the total product use emissions for the City.

The GHG quantification method is presented below:

$$\textbf{Emissions}_{\text{Product Use}} = (\text{NIR Product Use GHG Emissions}_{BC} / \text{NIR Population}_{BC}) * \text{Current Reporting Year Population}_{City}$$

4.5 AGRICULTURE, FORESTRY, AND OTHER LAND USE (AFOLU)

4.5.1 Overview

The AFOLU Sector includes emissions from livestock, land-use, and all other agricultural activities occurring within a city's boundaries. For the City, the AFOLU encompasses the following GHG emissions scopes and Sub-Sectors:

- Scope 1 Emissions:
  - Land
  - Emissions from Aggregate Sources and Non-CO2 Emission Sources on Land

4.5.2 Activity Data

The City used remotely sensed imagery to estimate land-cover change. This data included building metadata from Victoria, and 2007-2011 land use data prepared by the Habitat Acquisition Trust (HAT), both of which are publicly available for use.

Aggregate sources and non-CO_2 emissions sources on land were estimated using GHG emissions data from the 2018 NIR, and land-use data from the 2016 Statistics Canada Census of Agriculture, to create a GHG emissions per hectare value. This per hectare value was applied to a total urban farm land value derived by the City.

No GHG emissions from livestock are not deemed to be occurring in the City and thus the notation key for "Not Occurring" has been used to indicate this.

4.5.3 Assumptions and Disclosures

The following assumptions were made in the calculation of the 2017 GHG emissions:

- It is conservatively assumed that all cropland applies urea on agricultural lands.
- The following assumptions are made in the land-use change emissions category:
  - For land uses that result in the complete conversion of natural capital to settlements, or other, the total loss of natural capital is reported as the sink as it is assumed to no longer exist (this includes soil).
  - Following IPCC guidance, below-ground biomass is assumed to remain constant after a disturbance when the conversion is from one ecosystem class to another. This is consistent with the treatment of GHG emissions in the NIR.
  - For land uses that were not converted (colored in red in Table 27), only the applicable sequestration factor was applied. For lands that were converted, the change in land use is accounted for by taking the converted land-class emissions storage factor and dividing by 20 to account for the time it takes to re-accumulate the capital after the land use change occurs. The rationale is that it is not conservative to use the land use emission factor (storage, not annual sequestration) for the newly converted land as the emission factor is based on "established" land. Therefore, for instances where land use changes, the IPCC requires dividing the emission factor by 20 years.
  - Land-use emissions estimates do not account for harvested wood products (HWP) which may have been generated with the deforestation of forested areas. Not accounting for HWP results in a more conservative estimate of GHG emissions.
  - There are no active peat extraction wetlands within the City.

4.5.4 Calculation Methodology

4.5.4.1 Land Use

Remotely sensed imagery was used to estimate land-cover changes during the 2011-2017 period. Using the remotely sensed imagery, which included building metadata from Victoria, and 2007-2011 land use data prepared by the Habitat Acquisition Trust (HAT), an annual average land-use change between land classes (e.g. cropland forestland, etc.) was determined and applied to BC-based emission factors to estimate GHG emissions resulting from changes between land-uses for the reporting year.

To align with the IPCC land classification definitions (as required by the GPC Protocol), the following HAT data categories were re-assigned to the most appropriate IPCC land class. This is summarized in Table 26 below.

Table 26 Hierarchal Land-Cover Classification of HAT Forest and Land Cover Mapping and its Relation to IPCC Land Use Category

Primary Class	Land Class	HAT Forest and Land Cover Mapping	GHGE Land use
Vegetated Landscape (VEG)	Modified (MOD)	Agricultural fields	Cropland
	Naturally Wooded(NAW)	Tree	Forest
	Wetland (WET)	Riparian Tree	Wetland
		Riparian Herb	Wetland
	Naturally Non-Wooded (NNW)	Grass	Grassland
		Herb	Grassland
Non-Vegetated(NVE)	Natural (NAT)	Shadow	Other
		Ocean	Other
		Lake	Other
		Pond	Other
		River	Other
		Sand/Gravel Shoreline	Other
		Bedrock Shoreline	Other
		Exposed Soil	Other
		Exposed Bedrock	Other
	Developed(DEV)	Dock	Settlement
		Pavement/Building	Settlement

The analysis resulted in the following land use change table where the bottom total (in orange) represents the total land in hectares (ha) for each class as of the 2017 reporting year, and the right outermost column total (in green) represents the total land in hectares (ha) for each class

as of the 2011 reporting year. The data within the table (white cells) represents the total change in land use between 2011 and 2017. For example, 4.8 hectares (ha) of cropland was converted to settlements between 2011 and 2017.

Table 27 2011–2017 Land-use Change Vector Table (Hectares)

Category	Cropland	Forestland	Grassland	Other	Settlements	Wetlands	Total
Cropland	414.3				23.9		438.2
Forestland							-
Grassland			359.9		20.7		380.7
Other				1.5			1.5
Settlements					1,081.0		1,081.0
Other					13.0	26.0	39.0
Total	414.3	-	359.9	1.5	1,138.7	26.0	-

Using the data in the land-use matrix table above, an annual average change in hectares' value for each conversion type (where applicable) was determined. Once the land use change values were determined for the reporting year, BC-based and IPCC emission factors were applied to estimate the GHG emissions from land use (Table 28). The treatment ranged for three different scenarios:

- For land uses that were not converted (colored in red in Table 27), only the applicable sequestration factor was applied.
- For lands that were converted to from one class to another (e.g. forestland converted to settlements), the change in land use was accounted for by taking the converted land-class emissions storage factor and dividing by 20 to account for the time it takes to re-accumulate the capital after the land use change occurs. The 20-year factor is applied under guidance from the IPCC.
- For land uses that result in the complete conversion of natural capital to settlements, or other, the total loss of natural capital is reported as the sink as it is assumed to no longer exist (this includes soil).

Table 28 Land-Use Change Emission Factors

Sector	Emission Factor	Units	Source / Notes
Forestland	556.33	tonnes / ha	Coastal Douglas-fir uproot and decay emission factor developed by Caroline Dymond (Forests, Lands, and Natural Resource Operations), using deforestation data, for Vancouver Island (2013). https://www.for.gov.bc.ca/hfd/pubs/Docs/Srs/Srs06.pdf
Cropland	239.80	tonnes / ha	David Suzuki Foundation - http://www.davidsuzuki.org/publications/DSF_Peace_natcap_web_July_29%20copy.pdf

Sector	Emission Factor	Units	Source / Notes
Grassland	205.70	tonnes / ha	David Suzuki Foundation - http://www.davidsuzuki.org/publications/DSF_Peace_natcap_web_July_29%20copy.pdf. Treed wetlands were assumed (this is a more conservative estimate than shrubbed wetlands).
Wetlands	471.50	tonnes / ha	David Suzuki Foundation - http://www.davidsuzuki.org/publications/DSF_Peace_natcap_web_July_29%20copy.pdf. Perennial cropland/pasture was assumed.
Settlements	0.00	tonnes / ha	No land use sink assumed.
Other	0.00	tonnes / ha	No land use sink assumed.
Forestland	0.66	tonnes / ha / year	2006 IPCC Guidelines for National Greenhouse Gas Inventories - Volume 4 - Agriculture, Forestry, and Other Land Use - Chapter 4: Forests
Cropland	9.79	tonnes / ha / year	2006 IPCC Guidelines for National Greenhouse Gas Inventories - Volume 4 - Agriculture, Forestry, and Other Land Use - Chapter 5: Grasslands
Grassland	8.05	tonnes / ha / year	2006 IPCC Guidelines for National Greenhouse Gas Inventories - Volume 4 - Agriculture, Forestry, and Other Land Use - Chapter 7: Wetlands
Wetlands	6.50	tonnes / ha / year	2006 IPCC Guidelines for National Greenhouse Gas Inventories - Volume 4 - Agriculture, Forestry, and Other Land Use - Chapter 5: Croplands
Settlements	0.00	tonnes / ha / year	No land use sink assumed.
Other	0.00	tonnes / ha / year	No land use sink assumed.

The GHG quantification methods for land use change is presented below:

$$\textbf{Emissions}_{\textbf{Lands Not Converted}} = Land\ Type_{ha} * EF_{Sequestration\ Original\ Land\text{-}Use}$$

$$\textbf{Emissions}_{\textbf{Lands Converted to Forestland, Cropland, or Grassland, excluding Wetlands}} = (Land\ Type_{ha} * (EF_{Storage\ Original\ Land\text{-}Use} - EF_{Storage\ New\ Land\text{-}Use}) / 20_{Years})) + (Land\ Type_{ha} * EF_{Sequestration\ New\ Land\text{-}Use})$$

$$\textbf{Emissions}_{\textbf{Wetlands Converted to Forestland, Cropland, or Grassland}} = (-) * (Land\ Type_{ha} * (EF_{Storage\ Original\ Land\text{-}Use} - EF_{Storage\ New\ Land\text{-}Use}) / 20_{Years})) + (Land\ Type_{ha} * EF_{Sequestration\ New\ Land\text{-}Use})$$

$$\textbf{Emissions}_{\textbf{Lands Converted to Settlement or Other}} = (-) * Land\ Type_{ha} * EF_{Storage\ Original\ Land\text{-}Use}$$

4.5.4.2 Emissions from Aggregate Sources and Non-CO_2 Emission Sources on Land

Emissions from Aggregate Sources and Non-CO_2 Emission Sources on Land includes direct N_2O emissions from agricultural soil management and indirect N_2O emissions from applied nitrogen. To estimate these GHG emissions, the total area of farm land for Canada was used in conjunction with 2018 NIR data to develop a tCO_2e / ha value estimates for:

- Direct N_2O from managed soils (e.g. crops direct)
- Indirect N_2O from managed soils

To calculate GHG emissions from urea application, the calculated total crop land in hectares – 1.575 ha for the reporting year – was applied against an IPCC GHG emissions factor of 0.20 tCO_2e / ha. This emission factor is also applied in the 2018 NIR.

The GHG quantification method is presented below:

$$\textbf{Emissions}_{\textbf{Direct \& Indirect N2O}} = ((Canada_{\text{Direct N2O Emissions}} + Canada_{\text{Indirect N2O Emissions}} + Canada_{\text{Indirect N2O Manure Management Emissions}}) / Canada_{\text{Land In Crops ha}})) * City\ Cropland_{ha}$$

$$\textbf{Emissions}_{\textbf{Urea Application}} = Cropland_{ha} * 0.66\ tCO_2e / ha$$

5.0 2017 GHG REPORTING YEAR RESULTS

5.1 OVERVIEW

This section presents the 2017 reporting year GHG emissions for the City. The following table classifies each of the GPC Protocol GHG emission categories by scope and reporting level. Note that these are cumulative.

Table 29 City of Victoria 2017 GHG Emissions by GPC Reporting Method

GHG Emissions Scope	BASIC Reporting Level	BASIC+ Reporting Level
Scope 1	• Emissions from in boundary fuel combustion • In boundary fugitive emissions • Emissions from in boundary transport	Everything in the box at left, plus in-boundary emissions from: • Industrial process and product use • Livestock • Land use • Emissions from Aggregate Sources and Non-CO_2 Emission Sources on Land
Scope 2	• Emissions from consumption of grid-supplied energy	• Emissions from consumption of grid-supplied energy
Scope 3	• Emissions from solid waste, and composting generated within but treated outside of the City	Everything in the box at left, plus: • Transmission, distribution, and line losses from grid-supplied energy • Emissions from transboundary journeys
Outside of Reporting Scopes & GPC Protocol	• Upstream fuel emission extraction, processing, and transport • Food and drink imports • Construction materials (imports) • Other supply chain emissions • Vehicle fuel exports	

5.2 SUMMARY

Total BASIC, and BASIC+ emissions for the City for the 2017 reporting year are presented in the Figure 3 below.

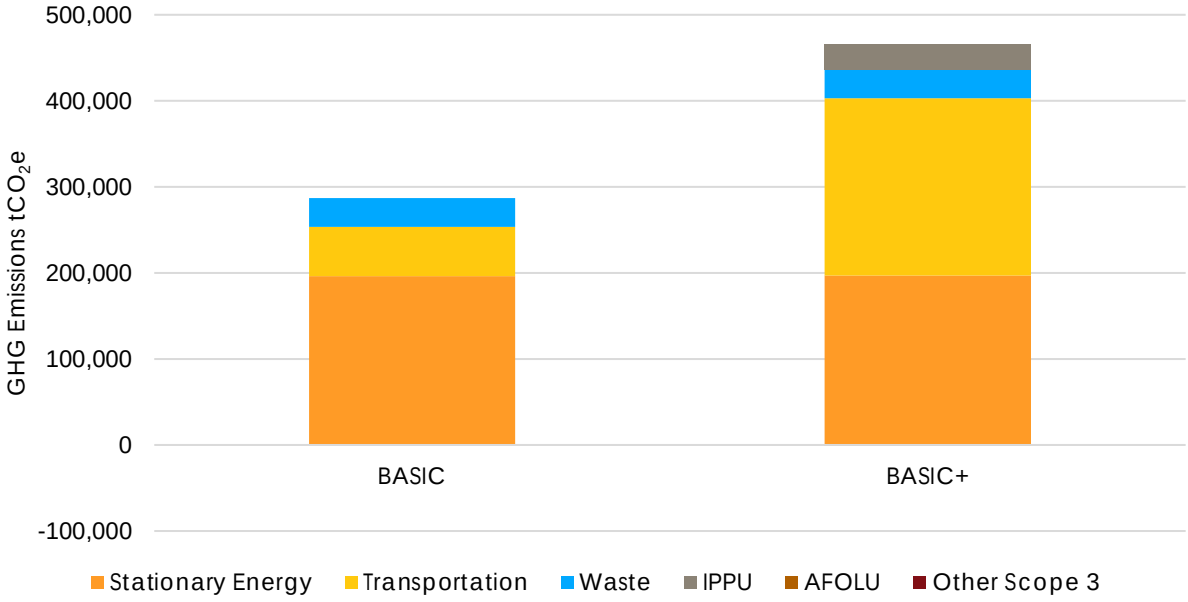

Figure 3 2017 GHG Emissions Summary by GPC Reporting Level

Emission by reporting level are presented in the Table 30 below which shows a difference in emissions under the GPC Protocol's BASIC, and BASIC+ reporting levels. This is due to the inclusion of additional sources in BASIC+ which are very significant for almost any growing city. These additional emissions include transboundary emissions, industrial and product use emissions, and emissions from land-use change. Under the GPC Protocol, emissions included within each higher reporting level are cumulative from lower levels.

Table 30 Breakdown of Victoria's 2017 GHG Emissions in GPC Reporting Format

GHG Emissions Source (by Sector)		Total GHGs (metric tonnes CO_2e)					
		Scope 1	Scope 2	Scope 3	BASIC	BASIC+	BASIC+ S3
Stationary Energy	Energy use (all emissions except I.4.4)	186,975	9,361	759	196,336	197,095	197,095
	Energy generation supplied to the grid (I.4.4)	NE					
Transportation	(all II emissions)	57,095	0	148,737	57,095	205,832	205,832
Waste	Waste generated in the City (III.X.1 and III.X.2)	0		33,480	33,480	33,480	33,480
	Waste generated outside city (III.X.3)	NO					
IPPU	(all IV emissions)	29,649				29,649	29,649
AFOLU	(all V emissions)	-574				-574	-574
Other Scope 3 (S3)	(all VI emissions)						0
TOTAL		**273,145**	**9,361**	**182,976**	**286,911**	**465,482**	**465,482**

NOTES:
Notation Keys: IE = Included Elsewhere; NE = Not Estimated; NO = Not Occurring.
Cells in green are required for BASIC reporting
Cells in green and blue are required for BASIC+ reporting
Cells in purple are for disclosure purposes only but <u>are not included</u> in the summary totals as required by the GPC Protocol.
Cells in orange are not required for BASIC or BASIC+ reporting

Table 31 presents the breakdown of the City's BASIC+ GHG emissions by Sector and Sub-Sector. The full GPC Protocol disclosure table has been included in Appendix A.

Table 31 Breakdown of the City of Victoria's 2017 BASIC+ GHG Emissions in the GPC Protocol Reporting Format

GPC ref No.	GHG Emissions Source (by Sector and Sub-Sector)	Total GHGs (metric tonnes CO_2e)			
		Scope 1	Scope 2	Scope 3	Total
I	**Stationary Energy**				
I.1	Residential buildings	68,779	3,565	289	72,632
I.2	Commercial and institutional buildings and facilities	117,103	5,796	470	123,370
I.3	Manufacturing industries and construction	0	0	0	0
I.4.1/2/3	Energy industries	NO	NO	NO	NO
I.4.4	Energy generation supplied to the grid	NE			
I.5	Agriculture, forestry, and fishing activities	IE	IE	IE	IE
I.6	Non-specified sources	IE	IE	IE	IE
I.7	Fugitive emissions from mining, processing, storage, and transportation of coal	NO			NO
I.8	Fugitive emissions from oil and natural gas systems	1,093			1,093
Sub-Total	(city induced framework only)	**186,975**	**9,361**	**759**	**197,095**
II	**Transportation**				
II.1	On-road transportation	42,211	0	105,883	148,094
II.2	Railways	NO	NO	NO	NO
II.3	Waterborne navigation	379	IE	36,835	37,214
II.4	Aviation	608	IE	6,019	6,627
II.5	Off-road transportation	13,897	IE	IE	13,897
Sub-total	(city induced framework only)	**57,095**	**0**	**148,737**	**205,832**
III	**Waste**				
III.1.1/2	Solid waste generated in the City	NO		26,837	26,837
III.2.1/2	Biological waste generated in the City	NO		94	94
III.3.1/2	Incinerated and burned waste generated in the City	NO		NO	NO
III.4.1/2	Wastewater generated in the City	NO		6,550	6,550
III.1.3	Solid waste generated outside the City	NO			
III.2.3	Biological waste generated outside the City	NO			
III.3.3	Incinerated and burned waste generated outside city	NO			
III.4.3	Wastewater generated outside the City	NO			

Table 31 Breakdown of the City of Victoria's 2017 BASIC+ GHG Emissions in the GPC Protocol Reporting Format

GPC ref No.	GHG Emissions Source (by Sector and Sub-Sector)	Total GHGs (metric tonnes CO_2e)			
		Scope 1	Scope 2	Scope 3	Total
Sub-total	(city induced framework only)	**0**		**33,480**	**33,480**
IV	**Industrial Processes and Product Uses**				
IV.1	Emissions from industrial processes occurring in the City boundary	NO			NO
IV.2	Emissions from product use occurring within the City boundary	29,649			29,649
Sub-Total	(city induced framework only)	**29,649**			**29,649**
V	**Agriculture, Forestry, and Other Land Use**				
V.1	Emissions from livestock	NO			NO
V.2	Emissions from land	-575			-575
V.3	Emissions from aggregate sources and non-CO_2 emission sources on land	2			2
Sub-Total	(city induced framework only)	**-574**			**-574**
VI	**Other Scope 3**				
VI.1	Other Scope 3			NE	NE
Total	(city induced framework only)	**273,145**	**9,361**	**182,976**	**465,482**

NOTES:
Cells in green are required for BASIC reporting
Cells in green and blue are required for BASIC+ reporting
Cells in purple are for disclosure purposes only but are not included in the summary totals as required by the GPC Protocol.
Cells in orange are not required for BASIC or BASIC+ reporting

5.3 TOTAL GHG EMISSIONS

Under the BASIC+ method, the City's GHG emissions totaled 479,039 tCO_2e. On a per capita basis, this works out to 5.54 tCO_2e per person.

Table 32 Total Energy and GHG Emissions Per Person by Sector

Sector	Sub-Sector	Energy (GJ)	GHG Emissions (tCO_2e)	GJ Per Capita	tCO_2e Per Capita
Stationary Energy	Residential Buildings	2,450,157	72,632	28.32	0.84
	Agriculture, Forestry, And Fishing Activities				
	Manufacturing Industries and Construction				
	Non-Specified Sources				
	Commercial and Institutional Buildings and Facilities	4,123,145	123,370	47.65	1.43
	Energy Industries				
	Fugitives	600,664	1,093	6.94	0.01
Transportation	On-Road Transportation	1,506,724	42,211	17.41	0.49
	Transboundary Transportation	558,771	105,883	6.46	1.22
	Off-Road Transportation: Railways, Aviation, and Other Off-Road		57,738		0.67
Waste	Waste: Solid Waste Disposal, Biological Treatment of Waste, Wastewater Treatment and Discharge		33,480		0.39
AFOLU	AFOLU: Livestock, Land, and Other Agriculture		(574)		(0.01)
IPPU	IPPU: Industrial Processes, and Product Use		29,649		0.34
Total		**9,239,461**	**465,482**	**106.8**	**5.4**

Total GHG emissions for 2017 are 465,482 tCO_2e and have decreased 3.2% from the 2007 baseline year and increased 1.1% from the prior reporting year. Scope 1 and 2 Emissions are 58.7% and 2.0% of the total GHG inventory. Scope 1 emissions are the GHG emissions that result from the combustion of fuel in sources within the City limits, primarily from Stationary Energy and Transportation. Scope 1 GHG emissions also include IPPU and AFOLU GHG emissions. Scope 2 emissions result from the use of electricity supplied to the City which includes emissions associated with the generation of electricity and other forms of energy (e.g., heat and steam). Scope 2 emissions are low compared to other geographies, due to the predominance of

hydroelectric generation technologies in the BC. Scope 3 emissions are emissions from electricity line losses, transboundary traffic, and emissions associated with the City that are occurring outside of the City limits. For 2017, Scope 3 GHG emissions make up 39.3% of the GHG inventory. This breakdown by emission scope is depicted in Figure 4.

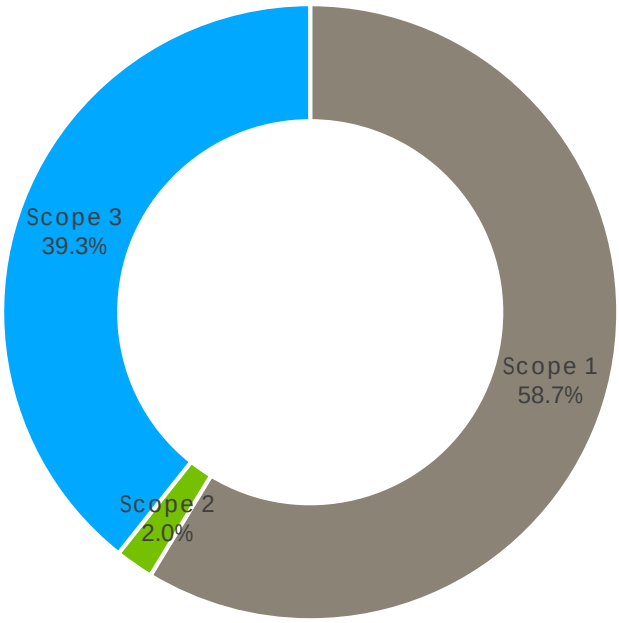

Figure 4 Total City of Victoria BASIC+ GHG Emissions by Emissions Scope

5.4 COMPARATIVE ANALYSIS

Compared to the 2016 reporting year, the City's 2017 GHG emissions have increased 5,080 tCO_2e or 1.1% (Table 33).

Table 33 Change in GHG Emissions from Prior Year

Emissions Scope	2016 GHG Emissions (tCO_2e)	2017 GHG Emissions (tCO_2e)	Change
Scope 1	262,809	273,145	3.93%
Scope 2	8,714	9,361	7.43%
Scope 3	188,880	182,976	-3.13%
Total	**460,402**	**465,482**	**1.10%**

5.5 SECTORAL GHG EMISSIONS ANALYSIS

5.5.1 Stationary Energy

Stationary energy sources are one of the largest contributors to the City's GHG emissions. In 2017, it contributed 42.3% of the community's GHG emissions. In general, stationary energy emissions include the energy to heat and cool residential, commercial, and industrial buildings, as well as the activities that occur within these residences and facilities. Fugitive methane emissions from natural gas pipelines and other distribution facilities, and related off-road GHG emissions, are also reported in this Sector. The table below shows the breakdown of energy use in the stationary energy reporting category.

Table 34 summarizes the energy and GHG emissions for the 2017 reporting year.

Table 34 2017 Energy and GHG Emissions by Stationary Energy Sector

Sector	Electricity (tCO_2e)	Natural Gas (tCO_2e)	Heating Oil (tCO_2e)	Propane (tCO_2e)	Wood (tCO_2e)	Other Sources (tCO_2e)	**Total GHG Emissions (tCO_2e)**	**Total Energy (GJ)**
Residential Buildings	3,854	21,446	31,590	7,148	5,999	2,594	**72,632**	**2,450,165**
Commercial & Institutional Buildings & Facilities	6,266	103,341	8,390	-	-	5,373	**123,370**	**4,123,145**
Fugitives						1,093	**1,093**	
Total GHG Emissions (tCO_2e)	**10,120**	**124,787**	**39,980**	**7,148**	**5,999**	**9,060**	**197,095**	
Total Energy (GJ)	**3,113,845**	**2,502,368**	**584,712**	**116,895**	**255,490**			**6,573,310**

It can be seen in Figure 5 that heating oil and natural gas use contribute to 35.4% of the City's GHG inventory.

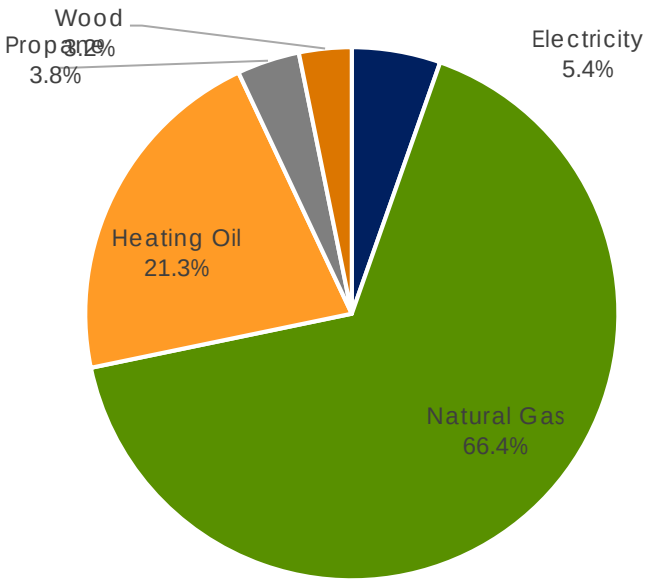

Figure 5 Stationary Energy GHG Emissions Contribution to the GHG Inventory

Figure 6 shows that more than 62.6% of the stationary GHG emissions arise from the operation of commercial and institutional buildings.

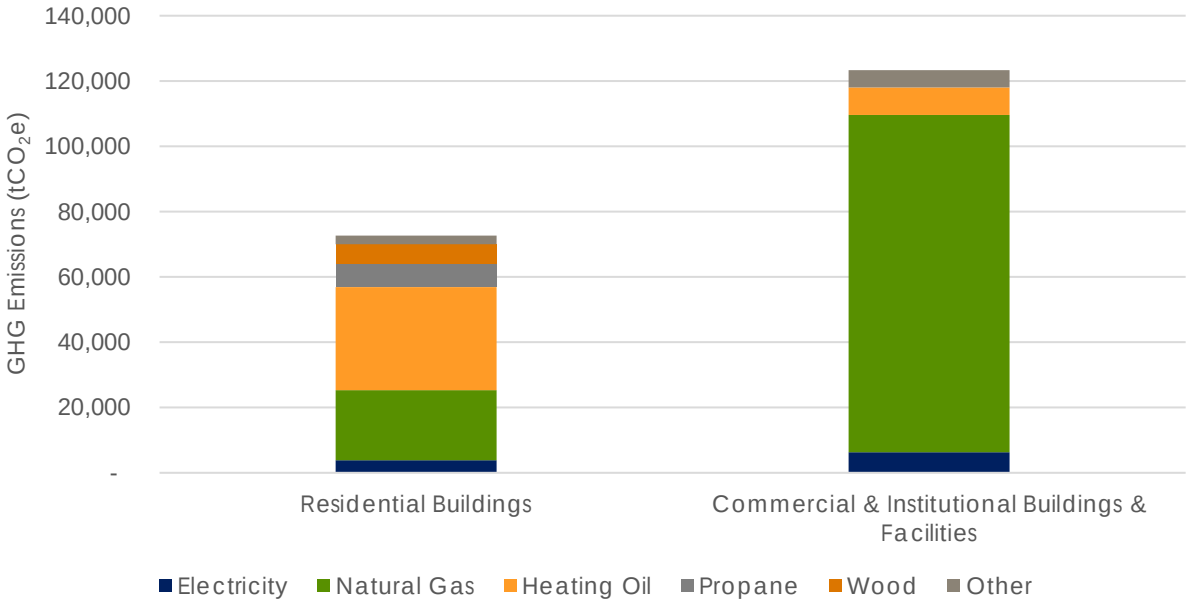

Figure 6 Total Stationary Energy Use By Sub-Sector

Stationary energy GHG emissions have decreased by 2.4% since the baseline year. Between the reporting years, there has been a 10.7% increase in GHG emissions and a 7.1% increase in energy use (Table 35). Overall, it appears that there was more natural gas use and electricity use between the 2016 and 2017 reporting years. There is also a downward trend in heating oil use through the tank replacement program. In 2007, there were 2,085 residential and commercial tanks, and in the reporting year, it is estimated that 1,714 tanks remain, a decline of 17.8%.

Table 35 Stationary Energy—Energy and GHG Emissions Trends

Sector	Change in GJ: 2007 & 2017	Change in GJ 2016 & 2017	Change in tCO_2e: 2007 & 2017	Change in tCO_2e: 2016 & 2017
Residential Buildings	-11.2%	5.0%	-13.7%	6.7%
Commercial & Institutional Buildings	6.3%	8.4%	6.0%	13.3%
Fugitives			-20.2%	0.0%
Total	**-1.0%**	**7.1%**	**-2.4%**	**10.7%**

5.5.2 Transportation

Transportation covers all emissions from combustion of fuels in journeys by road, rail, water, and air, including inter-city and international travel. For the 2017 reporting year, transportation GHG emissions accounted for 31.8% of the community GHG inventory with the bulk of transportation GHG emissions resulting from the on-road transportation sub-sector. The transportation GHG emissions are produced directly by the combustion of fuel or indirectly because of the use of grid-supplied electricity. Unlike stationary emission sectors, transit is mobile and can pose challenges in both accurately calculating emissions and allocating them to the cities linked to the transit activity. The following sections summarize energy and GHG emissions by on-road transportation, which is then followed by off-road transportation (marine, aviation, and other).

Table 36 summarizes the on-road energy and GHG emissions for the 2017 reporting year.

Table 36 2017 On-Road Transportation Energy And GHG Emissions by Fuel Type

Fuel Type	Total	Units	Energy (GJ)	GHG Emissions (tCO_2e)
Electricity	2,139	KWh	8	0
Gasoline	51,481,392	Liters (L)	1,784,340	122,318
Diesel	8,224,701	Liters (L)	318,131	22,482
Propane	165,522	Liters (L)	4,226	255
Compressed Natural Gas (CNG)	12,512	kilograms (kg)	683	3,039
Total			**2,107,388**	**148,094**

Overall, GHG emissions from transportation have increased by 5.4% and have decreased by 1.1%, compared to the 2007 baseline year and the 2016 reporting year respectively. Between 2016 and 2017, on-road transportation GHG emissions declined largely due to a decrease in the amount of fuel used by BC Transit. On a per capita basis, the number of registered vehicles per person has decreased by 1.74% since 2007. The majority of these GHG emissions (94.80%) are from passenger vehicles, light trucks, and SUVs (Figure 7).

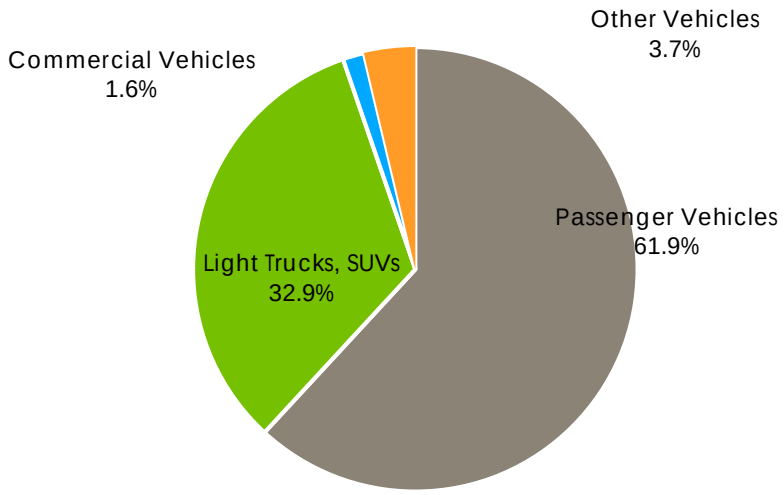

Figure 7 Breakdown of On-Road GHG Emissions by Vehicle Type

Table 37 summarizes the aviation, waterborne, and off-road transportation energy and emissions by fuel type. These GHG emissions contribute to 28.05% of the total transportation GHG emissions, and 12.05% to the total inventory (Figure 8).

Table 37 2017 Aviation, Waterborne, and Off-Road Transportation Energy and Emissions by Fuel Type

Fuel Type	Total	Units	Energy (GJ)	GHG Emissions (tCO_2e)
Marine Gasoline	6,530	Liters (L)	226	15
Marine Diesel	12,181,252	Liters (L)	471,171	37,199
Aviation Diesel	2,517,976	Liters (L)	87,374	6,627
Off-Road Fuels			Not Reported	13,897
Total			**558,771**	**57,738**

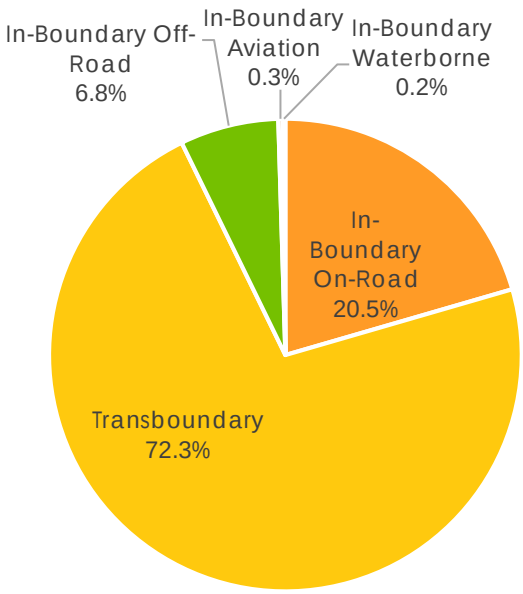

Figure 8 Summary of Transportation GHG Emissions by Sub-Sector

Table 38 below summarizes the total energy and GHG emissions by reported Transportation Sub-Sector.

Table 38 2017 Energy and Emissions by Transportation Sub-Sector

GPC Reporting Category	Energy (GJ)	GHG Emissions (tCO_2e)
On-road GHG emissions occurring in the City	600,664	42,211
On-road GHG emissions occurring outside the City	1,506,724	105,883
Off-road GHG emissions occurring in the City	Not Estimated	13,897
Off-road GHG emissions occurring outside the City	*Included Elsewhere (IE)*	*Included Elsewhere (IE)*
Aviation GHG emissions occurring in the City	8,097	608
Aviation GHG emissions occurring outside the City	79,277	6,019
Rail GHG emissions occurring in the City	*Not Occurring (NO)*	*Not Occurring (NO)*
Rail GHG emissions occurring outside the City	*Not Occurring (NO)*	*Not Occurring (NO)*
Waterborne GHG emissions occurring in the City	181	379
Waterborne GHG emissions occurring outside the City	471,216	36,835
Total	**2,666,159**	**205,832**

Overall, GHG emissions from transportation have increased by 4.21%, compared to the 2007 baseline reporting year, and have decreased 0.91% compared to the prior reporting year. The

increase in GHG emissions from the baseline is largely due to the increased off-road vehicle use (e.g. construction equipment) and the increased number of vehicles on the road in 2017 (48,097 vehicles) compared to 2007 (44,419 vehicles) - a 8.28% increase in the number of registered vehicles over the past decade. There have been notable declines in the aviation and waterborne emission sub-categories which is more likely attributable to changes in population in the City (compared to the CRD and Vancouver Island), rather than actual reduction in fuel usage and GHG emissions. These changes are presented in Table 39.

Table 39 Transportation—Energy and GHG Emissions Trends

Sector	Change in GJ: 2007 & 2017	Change in GJ 2016 & 2017	Change in tCO_2e: 2007 & 2017	Change in tCO_2e: 2016 & 2017
On-road transportation journeys occurring in the City	5.7%	0.6%	4.8%	-0.7%
On-road transboundary journeys occurring outside the City	6.4%	0.6%	5.6%	-0.7%
Off-road transportation occurring in the City			540.4%	0.6%
Off-road transportation occurring outside of the City				
Aviation traffic journeys occurring in the City		-10.5%		-10.5%
Aviation traffic transboundary journeys occurring outside the City	-47.7%	-10.2%	-47.6%	-10.2%
Rail traffic journeys occurring in the City				
Rail traffic transboundary journeys occurring outside the City				
Waterborne traffic journeys occurring in the City		4.1%		-0.6%
Waterborne traffic transboundary journeys occurring outside the City	-10.7%	-0.6%	-10.4%	-0.6%
Total	**-0.8%**	**0.0%**	**4.2%**	**-0.9%**

5.5.3 Waste

Cities produce solid waste, compost, and wastewater. Waste does not directly consume energy, but when deposited into landfills, or left exposed to the atmosphere, it decomposes and releases methane (CH_4) gas which is a potent GHG. The GHG emissions from the solid waste, composting, and waste water facilities for the reporting year is summarized in the following table. For the 2017 reporting year, the total waste emissions contribute to 7.2% of the GHG inventory.

A breakdown of the Waste Sub-Sector GHG emissions is presented in Table 40.

Table 40 Summary of Waste Sub-Sector GHG Emissions

Sector	2017 GHG Emissions (tCO_2e)	GHG Emissions Per Capita (tCO_2e / Capita)	Change from Baseline (2007)	Change from Prior Year (2016)
Wastewater Treatment And Discharge	6,550	0.08	-7.3%	-9.8%
Biological Treatment of Solid Waste	94	0.00	29.5%	-68.0%
Solid Waste	26,837	0.31	-47.3%	-11.2%
Total	**33,480**	**0.39**	**-42.3%**	**-11.4%**

For the 2017 reporting year, in scope GHG emissions from waste have decreased by 42.35% compared to the baseline and have decreased by 11.35% compared to the prior reporting year. Fluctuations in waste will occur over the reporting periods as waste is driven by both the population, as well as economic prosperity in the region. The Solid Waste Sub-Sector contributes more than 60% of total waste GHG emissions (Figure 9). To reduce the amount of waste landfilled, and thus GHG emissions, the City is making a significant effort to reduce waste going to landfills through organics diversion, and recycling.

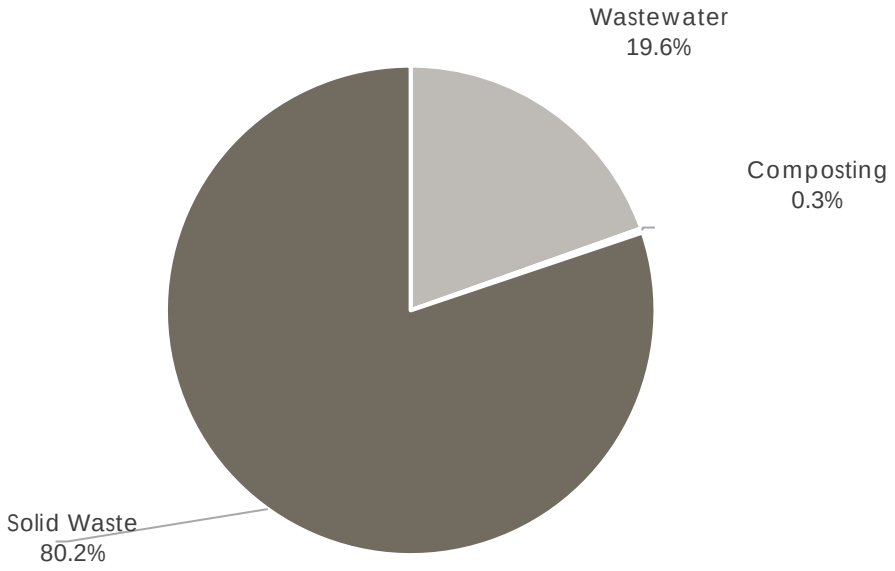

Figure 9 2017 GHG Emissions from Waste (tCO_2e)

5.5.4 Industrial Processes and Product Use (IPPU)

Reporting on IPPU GHG emissions are required for BASIC+ reporting only. Industrial GHG emissions are produced from a wide variety of non-energy related industrial activities which are typically releases from industrial processes that chemically or physically transform materials. During these processes, many different GHGs can be produced. There are no industrial GHG emissions occurring within the City's boundaries, and a "Not Occurring" notation is used.

Also included in the IPPU Sector is Product Use GHG emissions. Certain products used by industry and end-consumers, such as refrigerants, foams or aerosol cans, also contain GHGs which can be released during use and disposal and thus, as with best-practice, must be accounted for. For the reporting year, only the emissions estimated were production and consumption of halocarbons, SF_6 and NF_3 were estimated for the City on the basis that other GHG emissions sources identified in the NIR are not likely to be occurring in the City. To estimate Product Use GHG emissions for the City, a per capita estimate was developed using the Provincial emissions data from the 2018 NIR, and BC's NIR reporting year (2016) population from Statistics Canada. This value was applied to the 2017 reporting year City population to estimate the total Product Use emissions for the City.

It should be noted that the City has little influence over product use GHG emissions as these are consumption driven emissions.

Between the 2007 and 2017 reporting years, IPPU GHG emissions have increased 66.02%. The reason for the increase is more attributed to Environment Canada having better data available to make the estimate, than the actual GHG emissions increasing such an amount.

Table 41 Product Use GHG Emissions for the 2007 and 2017 Reporting Years

Sub-Sector	2007 (tCO_2e)	2017 (tCO_2e)	Change
Product Use Emissions	17,858.6	29,648.5	66.0%
Total	**17,858.6**	**29,648.5**	**66.0%**

5.5.5 Agriculture, Forestry, and Other Land Use

The AFOLU Sector includes GHG emissions from livestock, land use, and all other agricultural activities occurring within the City's boundaries. Using remotely sensed imagery, land cover data was used to estimate land use changes between the reporting years.

Overall, compared to the prior reporting year, land use development has resulted in the release of 2,456.2 tCO_2e, whereas greenspace has sequestered and stored approximately 3,001.8 tCO_2e, leaving a net reduction of 575.3 tCO_2e (Table 42).

Table 42 Summary of Land-Use Change Between 2016 and 2017

Land-Use Type	Average Change in Hectares (ha)	Sequestered (-) / Released (+) GHG Emissions in tCO_2e
Forest Land	(3.3)	(257.1)
Crop Land	-	-
Grassland	(2.9)	(2,734.7)
Wetlands	-	(10.1)
Settlements	8.0	2,426.5
Other Land	(1.8)	-
Total	**-**	**(575.3)**

The following figure presents the change in land use by sub Sector between the reporting years. The following figure presents the change in land use by sub sector between the reporting years. Negative red bars values show the sequestration and storage of carbon, whereas positive red bars show the release of stored carbon into the atmosphere. The orange line tracks the changes in land categories where positive values mean additions to a land class, whereas negative values are losses. Changes in land use directly affect if GHG emissions can continue to be sequestered, or whether they will be released as a result of a loss of this ecological function.

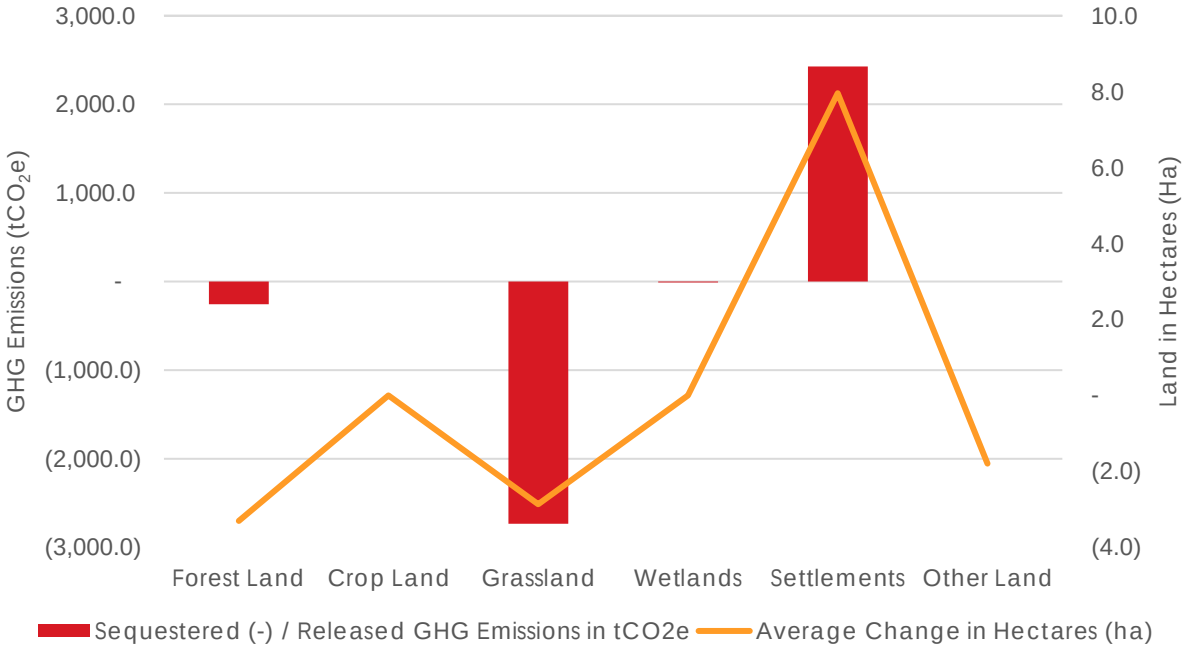

Figure 10 Comparison of GHG Emissions from Land-use Change Between 2016 and 2017

5.5.5.1 Livestock and Other Agriculture

In addition to land use change, GHG emissions from the AFOLU Sector are produced through a variety of non-land use pathways, including livestock (enteric fermentation and manure management), and aggregate sources and non-CO_2 emission sources on land (e.g., fertilizer application). Under this Sector, the City is reporting on GHG emissions from the following sources, and Sub-Sectors:

- Scope 1 GHG Emissions:
  - Livestock:
    - Methane (CH_4) Emissions from Enteric Fermentation
    - Methane (CH_4) Emissions from Manure Management
    - Direct Nitrous Oxide (N_2O) GHG Emissions
  - Aggregate Sources and Non-CO_2 Emissions Sources on Land
    - Direct Nitrous Oxide (N_2O) Emissions from Agricultural Soil Management
    - Indirect Nitrous Oxide (N_2O) Emissions from Applied Nitrogen

Table 43 summarizes AFOLU GHG emissions for the 2016 reporting year.

Table 43 Total AFOLU GHG Emissions for 2017

AFOLU Sub-Sector	GHG Emissions (tCO_2e)
Land Use Change	(575.3)
Aggregate Sources and Non-CO_2 Emissions Sources on Land	1.7
Total	**(573.6)**

6.0 QUALITY ASSURANCE AND QUALITY CONTROL

Quality Assurance and Quality Control (QA/QC) procedures are applied to add confidence that all measurements and calculations have been made correctly and to reduce uncertainty in data. Examples include:

- Checking the validity of all data before it is processed, including emission factors
- Performing recalculations to reduce the possibility of mathematical errors
- Recording and explaining any adjustments made to the raw data
- Documenting quantification methods, assumptions, emission factors and data quality

With respect to the GHG inventory, the data was subject to various quality assurance and quality control checks throughout the collection, analysis, and reporting phases. Specifically, the following procedures were followed:

- Upon receipt of data from third parties and the City, the data was checked for completeness (e.g., all months of data are present) and relevancy (e.g., the correct calendar year is presented). Incorrect or incomplete datasets were queried directly with the data provider
- Where estimates were used (e.g., per capita rail GHG emissions), all possible data sources were considered for their accuracy and relevance to the community before a final method and data source was selected
- All manual data transfers were double-checked for data transfer accuracy

7.0 RECOMMENDATIONS

To remain accurate and reflective of the current community conditions, the City should revise and improve its GHG emissions inventory annually, to which there are the following aspects should be focused on:

- Improving activity data collection and management, including Sector and Sub-Sector allocations
- Performing recalculations, where applicable, and tracking GHG emissions over time

The next section provides a summary of specific GHG inventory improvement recommendations.

7.1 INVENTORY ASSUMPTIONS, ASSESSMENT, AND RECOMMENDATIONS

In the preparation of the 2017 GHG emissions inventory, there are several assumptions were made in the analysis that will have some influence on accuracy of the City's estimate of community GHG emissions. Most emission sources have been calculated with a high level of confidence, due to the presence of utility records, and direct energy and emissions data being provided by stakeholders. Data sources and assumptions with medium to high uncertainty are presented in Table 44 which summarizes the main assumptions, possible impacts on the data, and recommended improvement. It is recommended that the City prioritize improvements for that are likely to have a material (>10%) improvement in the GHG inventory estimate.

Table 44 Summary of GHG Inventory Assumptions, Estimated Impacts, and Recommended Improvements

Sector	Assumption	Possible Impact on The GHG Inventory	Recommended Improvements
All Sectors	This GHG inventory relied on emission factors from the 2018 NIR which reported on emissions from 1990-2016. As such, the emission factors for 2016 is preliminary may be updated in the 2019 NIR.	Immaterial impact on the GHG Inventory as the NIR emission factors do not change materially from year to year.	The City is using the best available data at the time. It will endeavor to update the emission factors as new information is available.
Stationary Energy	The energy utility providers provide energy in lump sum amounts for: residential, commercial, and industrial. As such, other sectors, like agricultural buildings, could	No impact on the GHG inventory. The change would only happen	Work with the utility provider to get a more detailed breakdown of energy use by sub-sector.

Table 44 Summary of GHG Inventory Assumptions, Estimated Impacts, and Recommended Improvements

Sector	Assumption	Possible Impact on The GHG Inventory	Recommended Improvements
	not be split out. A related accuracy issue is the assignment of mixed use buildings without separate metering.	between emission sub-sectors.	
Stationary Energy	Propane, and wood GHG emissions were estimated based on 2007, 2010, and 2012 CEEI GHG emissions. Heating oil emissions were estimated based on the number of known tanks and the estimated square footage based on BC Assessment data, and the estimated average annual energy usage.	Immaterial impact on the GHG inventory (<5%)	Consider completing aa residential energy labelling program. With such a program, an energy and fuel profile for buildings could be developed so that a reasonable estimate of other fuel use be determined. Work with the Province on developing a methodology to estimate wood fuel use.
Transportation	ICBC has not been collecting off-road vehicle data so this source could not be estimated.	Possible material impact on the GHG inventory (>10%)	Work with ICBC to begin collecting this data regionally.
Transportation	ICBC did not provide reporting year vehicle registration data for the City. As such, 2012 vehicle registration data was used to estimate GHG emissions. Specifically, for the reporting year, the 2012 CEEI vehicle registration data was grown using the change in the City's population between 2012 and 2017.	It is likely that the estimate is within the materiality threshold (10%). However, the categories of vehicles and GHG emissions are likely to be materially different.	Work with ICBC to understand the data error and request a detailed registry database, that includes dates so that a better estimate of GHG emissions can be determined.
Transportation	Although annual fuel sales data was provided, only taxable fuel volumes are recorded at the Regional scale, and not municipal scale and only represents about 67% of taxable fuel sales (a value that fluctuates yearly). Without more detailed information, a fuel allocation amount could not be allocated to the City. As such, the City had to rely on vehicle registration data and estimated vehicle kilometers travelled (VKT) from a 2009 vehicle travel study for Canada.	Using the estimated VKT data, it is more than likely that the City is over-estimating the GHG emissions from transportation. This is the most conservative approach available to the City at this point.	If the City can get fuel sales data for Victoria, a more robust estimate of fuel use and GHG emissions, using vehicle registration data, can be determined. If the CRD can incorporate estimated travel data, in VKT, this data could be used to replace the 2009 study and be more specific to Victoria.

Table 44 Summary of GHG Inventory Assumptions, Estimated Impacts, and Recommended Improvements

Sector	Assumption	Possible Impact on The GHG Inventory	Recommended Improvements
Transportation	The Victoria International Airport does not collect origin traveler data. Therefore, the airport emissions were prorated based on the total City of Victoria population relative to the CRD population.	The impact will be immaterial to the GHG Inventory.	Work with the Victoria International Airport to determine a method (e.g. passenger survey) to better refine the onboarding number specific to the City of Victoria
Transportation	The Victoria International Airport does not report on GHG emissions from tenants or aircraft. Keeping in line with the GPC Protocol, only the aircraft GHG emissions were estimated using NAV Canada airplane movement statistics, estimated taxi times, and estimated fuel use. The fuel use only accounts for departing and arriving planes up to 3,000ft to avoid double counting with other cities.	The impact will be immaterial to the GHG Inventory.	The Victoria International Airport will not be collecting or reporting on GHG emissions from tenants or aircraft. This is the best available data at this point.
Transportation	The GHG emissions from recreational watercraft and US/Can ferries were estimated based on a publicly available year 2000 study for the Victoria, Vancouver, and Washington harbors. No cruise ship emissions were estimated as the Greater Victoria Harbor Authority (GVHA) is working on this aspect of the file. GHG emissions were allocated to scope 1 and scope 3 based on the proportion of the Victoria population relative to Regional District population.	Unknown impact to the GHG Assertion. Cruise ship emissions would be considered transboundary as travelers will be visiting Victoria.	Work with the Victoria Harbor Master as they begin to deploy a database tracking the types and number of boats entering the Victoria harbor.
Transportation	The GHG emissions from marine aviation are estimated based on Victoria Harbor NAV Canada air traffic movements for 2016. Statistics Canada stopped collecting Victoria Harbor aircraft movement data in 2016. To estimate 2017 marine aviation GHG emissions, the 2016 Victoria data was applied and adjusted	The impact will be immaterial to the GHG Inventory.	No recommended improvement currently.

Table 44 Summary of GHG Inventory Assumptions, Estimated Impacts, and Recommended Improvements

Sector	Assumption	Possible Impact on The GHG Inventory	Recommended Improvements
	using the change in aircraft traffic between the 2016 and 2017 reporting years at the Victoria International Airport. It is assumed that the activity at both airports would be corelated, but not causational.		
Waste	Composting GHG emissions are estimated based on the total tonnage reported by the City. This is likely to be an underestimate of GHG emissions as the City does not have a mechanism in place to track how much organic waste is being collected by third party waste haulers	The impact will be immaterial to the GHG Inventory.	Complete waste audits and work with third party waste haulers to get a better grasp on the volume of organic waste leaving the City.
Waste	To quantify GHG emissions from the Hartland Landfill, the CRD utilized the waste-in-place method which is accepted under the GPC Protocol. The Waste-in-place (WIP) assigns landfill emissions based on total waste deposited during that year. It counts GHGs emitted that year, regardless of when the waste was disposed. GHG emissions from the Hartland Landfill for the reporting year are allocated based upon the percentage of City waste, relative to total waste received, sent to the Hartland Landfill. Using this allocation method, the City may over, or underestimate associated solid waste GHG emissions as the current year landfill GHG emissions are based upon cumulative waste over time, and the City may have contributed more waste in past years than the current year (and vice versa).	The impact will be immaterial to the GHG Inventory.	The City could re-run the waste in place model with only City waste (in tonnes) to determine a better estimate of City only GHG emissions from the landfill.
Waste	The City's proportion of wastewater is based on the CALWMP WWT System Feasibility and Costing Analysis - Technical Memorandum #1 which was	The impact is likely to be immaterial.	No recommendations currently.

Table 44 Summary of GHG Inventory Assumptions, Estimated Impacts, and Recommended Improvements

Sector	Assumption	Possible Impact on The GHG Inventory	Recommended Improvements
	completed in 2015. Due to a lack of information, the same proportion was used in the baseline and may or may not be accurate.		
Waste	Hartland landfill stationary combustion emissions were available for the 2016 reporting year only. As such, it was assumed that the baseline and reporting year would have similar emissions.	The impact is likely to be immaterial.	Work with the CRD to get the stationary combustion emissions data, and energy generation data so that the GHG inventory can be more accurate.
IPPU	Product use emissions were estimated on a per capita basis using the 2018 National Inventory Report (NIR) estimates. The NIR is one year behind and as such, a 2016 value was applied to estimate 2017 GHG emissions. The product use emissions were estimated by the NIR using an IPCC Tier 1 approach and thus will have high uncertainty.	The impact is likely to be immaterial.	No recommendations currently.
AFOLU	GHG estimates for land use change are based on a period of years (2011-2017) and thus were averaged for each period. As there was no current data, land use change for the reporting year was estimated using the average value from 2011.	Immaterial impact on the GHG Inventory.	Work with the planning department to track land-use change annually so that a more refined estimate can be made.
AFOLU	The land-use sequestration and storage GHG emission factors are taken from the literature, for BC ecozones, and may not reflect the productivity, or lack thereof, of land uses in the City limits. The use of non-site emission factors may result in an over or underestimate of GHG emissions.	Immaterial impact on the GHG Inventory.	No recommendations currently.

8.0 REFERENCES

ACI (Airports Council International). 2014. Airport Carbon and Emissions Reporting Tool (ACERT). Available at: http://www.aci.aero/About-ACI/Priorities/Environment/ACERT

Environment and Climate Change Canada. 2018. National Inventory Report 1990 to 2016: Greenhouse Gas Sources and Sinks in Canada. Part 1-3. April 2018. Available at: https://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8812.php

GPC (Global Protocol for Community-Scale Greenhouse Gas Emission Inventories). 2014. Global Protocol for Community-Scale Greenhouse Gas Emission Inventories: An Accounting and Reporting Standard for Cities"; World Resources Institute, C40 Cities Climate Leadership Group, and ICLEI – Local Governments for Sustainability.

ICAO. International Civil Aviation Organization. 2017. Emissions Factors Database. Available at: https://www.icao.int/about-icao/Pages/default.aspx

IPCC (Intergovernmental Panel on Climate Change). 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/

IPCC (Intergovernmental Panel on Climate Change). 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

WRI (World Resource Institute/ World Business Council for Sustainable Development). 2004. The Greenhouse Gas Protocol. A Corporate Accounting and Reporting Standard. Revised Edition. Available at: http://www.ghgprotocol.org

APPENDIX A
GPC REPORTING TABLE

Appendix A GPC REPORTING TABLE