Application of PAS 2070: City of Edmonton

Discussion Paper

Final

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Executive Summary

Cities are centers of communication, commerce, and culture. They are also responsible for more than 70% of global energy-related greenhouse gas (GHG) emissions, and therefore, represent the single greatest opportunity for tackling climate change. Recognizing its ability to influence and reduce ~~the~~ Edmonton's GHG emissions, the City of Edmonton (the City) has been tracking and reporting on its territorial, or production based (PB) GHG emissions since the early 1990's. With the recent release of the consumption based (CB) inventory accounting standard - PAS 2070:2013 Specification for the Assessment of Greenhouse Gas Emissions of a City (PAS 2070) – the City sought to explore how a dual approach to inventorying GHG emissions may provide a more comprehensive overview of the City's contributions to global GHG emissions, and how these inventory approaches differ.

As with current best practice, the City's PB inventory accounts for direct GHG emissions based on the physical location to which the GHG emissions are released within the City's municipal boundaries. These in-boundary GHG emissions sources include building heating and/or cooling, the consumption of grid-supplied electricity, vehicle fuel consumption, and the disposal of waste. In 2016, the City's PB GHG emissions were 18.3 $MtCO_2e$ to which stationary energy and transportation accounted for 94% of these GHG emissions. Due to the reliance on fossil fuel-powered energy in Alberta, more than 40% of the City's GHG emissions came from electricity use. Natural gas mainly used to heat buildings accounted for more than 20% of the GHG inventory, and fuels used in the operation of on-road and off-road vehicles accounted for more than 25% of the GHG inventory. On per capita basis, the City's PB emissions are 19.6 tCO_2e/person. Had the City's municipal boundary extended to include Strathcona County, the proportion of energy use and City's GHG emissions would be significantly higher (likely >3 $MtCO_2e$) and proportionally different due to the number of large industrial emitters located in Strathcona.

The strength in the current PB inventory approach deployed by the City is that it relies on local energy, transportation, land-use, and waste data for the reporting year which is generally accessible and can provide insight into energy production, and energy-intensive consuming industries and specific sectors – e.g. the number of light duty gasoline vehicles in a city. These are often referred to as direct and indirect GHG emission sources. However, the approach is limited in that it does not capture 'outsourced' or 'other indirect' GHG emission sources associated with the creation and transport of manufactured products, such as electrical appliances and furniture, food, clothing, and services provided as these are often manufactured, assembled, transported in other cities and countries. These 'outsourced' GHG emission sources are captured in CB GHG inventories which allocate both direct and life cycle GHG emissions for all goods and services consumed by residents, governments, and businesses within a city. The strength of the CB inventory approach is that it can create accountability by providing cities with a better understanding of their consumption choices, which can lead to the implementation of policies that mitigate associated, but generally unregulated GHG emissions. The drawback is that CB inventories are complex and resource intensive as they require urban metabolism data (e.g., actual waste consumed, total materials recycled, total roads, buildings, and other infrastructure constructed) also known as a bottom-up approach, or the use of environmentally extended input-output models (EEIO) (a top-down approach) which require financial flow data from national or regional economic accounts, along with applicable life cycle-based emission factors. Each approach also has specific drawbacks – for instance, the top-down or economic-based approach does not account for GHG emissions from land use as there is no economic value assigned to goods and services provided by ecosystems as this is not tracked in most accounting systems. The bottom-up approach may not adequately capture all waste sources such as electronics and plastic recycling as these are not typically tracked by cities. In Canada, the publicly available data sources are not granular enough to support a high level of precision when compared to a PB inventory which relies on actual energy consumption data. With the rising trend in global GHG emissions and a contrasting decline in global city PB reported GHG emissions – an indication that cities may be unassumingly outsourcing their GHG emissions – there is likely to be a greater demand for CB inventory data and associated inventories over the long-term.

In the case of the City's CB inventory, since there was inadequate urban metabolism data available, a top down approach using EEIO data was deployed. For the 2016 reporting year, the City's consumption based GHG emissions were estimated at 26.8 $MtCO_2e$ to which construction, manufacturing and wholesale trade accounted for 53% of the City's GHG emissions of which 37% of these GHG emissions resulted from household consumption. Of the total consumption based GHG emissions, household consumption accounted for 61% of total emissions, followed by private sector capital investment at 22%, and then government spending at 17%. This breakdown is comparable with the breakdown of Canada's 2016 GDP by expenditure, which was: household consumption (56%), private sector capital spending (21%), government spending (21%), other (1%) (Statistics Canada, CANSIM Table 380-0064). On a per-capita basis, the City's consumption GHG emissions amount to 28.7 tCO_2e/person which is 47% higher than the City's per-capita production GHG emissions. On an absolute basis, the City's consumption GHG emissions are 32% higher than the production based GHG emissions which is within the range of other comparable CB GHG emissions inventories. For example, the State of Oregon's are estimated to be 19% higher than their estimated production GHG emissions (Oregon, 2015) and the San Francisco Bay Area's consumption based GHG emissions are 35% higher (UC Berkley, 2015). On the higher end, the City of Vancouver's CB emissions are estimated to be 94.2% higher than its PB GHG emissions, and London, England's CB emissions estimated to be 157% higher (PAS, 2018). The relation between the City's GHG inventories is presented in Figure E-1.

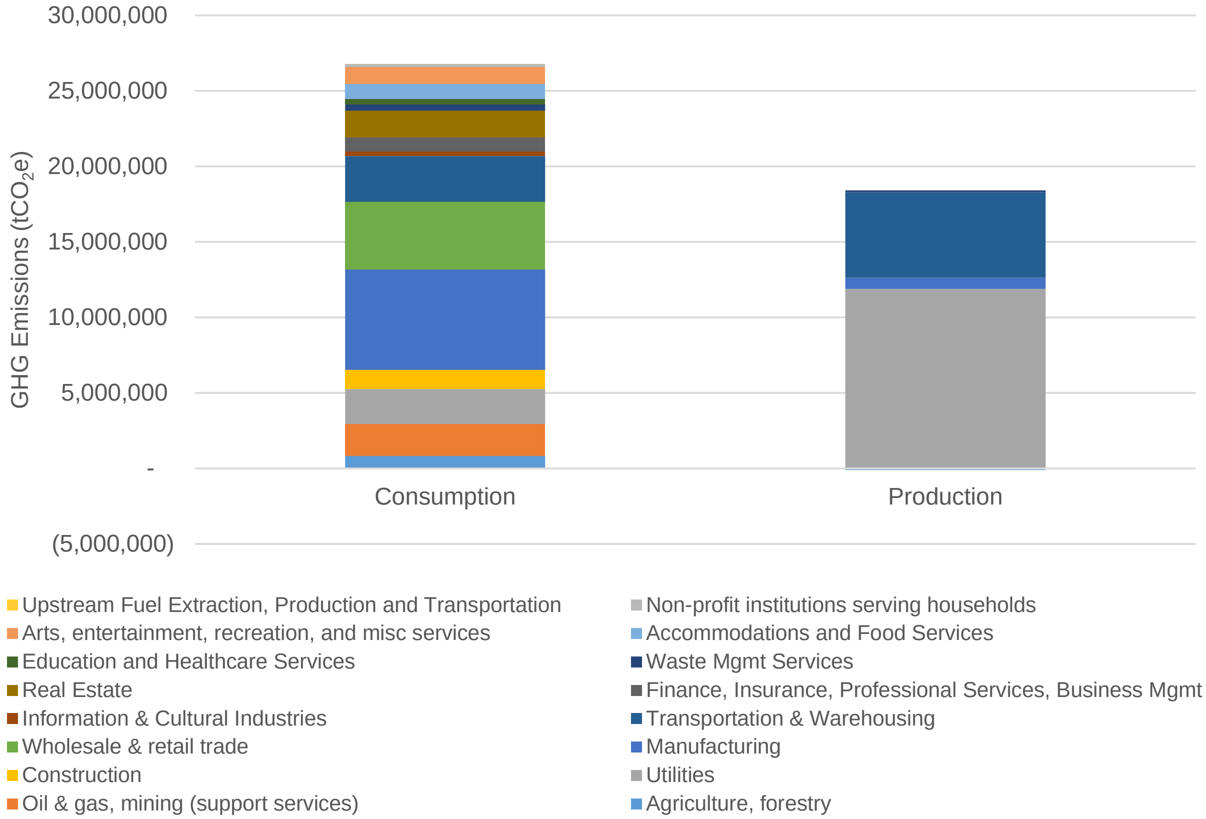

Figure E-1. Comparison of GHG Inventory Approaches

The CB inventory reiterates what the City's PB inventories have historically shown – i.e., the City should continue to focus on reducing GHG emission from buildings and road transport. The CB inventory also shows that the consumption of manufactured goods and services, and food are sources of significant GHG emissions in the City, and further exploration of these GHG emissions sources is warranted. However, the data available to support the preparation of a localized City-based CB inventory is not granular enough to identify where in the supply chain the GHG emissions are likely to arise and thus is limited in its ability to support GHG related policy and program decisions that the City may wish to take. On this basis, it is recommended that the City expand its current PB inventory to include the GHG emission sources required under the PAS 2070 direct plus supply chain (DPSC) approach which includes accounting for GHG emissions from the consumption of food and drink, water, construction materials. Specifically, a bottom-up data collection approach, rather than top-down (as applied in the CB assessment) is recommended to capture local consumption trends and GHG emission sources in the supply chain. It is still recommended that the City continue to follow the GPC Protocol which is a requirement for cities that have committed to the Global Covenant of Mayors. Should the City include the sources under PAS 2070, the City would be reporting under the BASIC+SC level. Lastly, it is recommended that the City complete a complete CB inventory every 5-years, which would align with National Census reporting, to assess general consumption trends and patterns over time.

Abbreviations

AFOLU	Agriculture, Forestry, and Other Land Use
C40	C40 Cities Climate Leadership Group
CB	Consumption-Based
CH_4	Methane
CIRAIG	The International Reference Centre for the Life Cycle of Products, Processes and Services
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalents
DPSC	direct plus supply chain
EEIO	Environmentally extended input-output model
EPCOR	Edmonton Electric Lighting and Power Company
GDP	gross domestic product
GHG	greenhouse gas
GIS	Geographic Information Systems
GJ	Gigajoules
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
GWP	global warming potentials
HFC	Hydrofluorocarbons
ICLEI	Local Governments for Sustainability
IPPU	Industrial Process and Product Use
IOIC	Input-Output Industry Codes
IOFDC	Input-Output Final Demand Codes (IOFDC)
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LCA	Life cycle analysis

MWh	Megawatt hour
NAICS	North American Industry Classification System
N_2O	nitrous oxides
NIR	National Inventory Report
PAS	Publicly Available Specification
PB	Production-Based
PFC	Perfluorocarbons
POA	Province of Alberta
SC	Other Scope 3
SF_6	sulfur hexafluoride
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

Glossary

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 Core (GPC BASIC) sources, plus Scope 1 AFOLU and IPPU, and Scope 3 in the Stationary Energy and Transportation Sectors (GPC, 2014).
BASIC+SC	An inventory reporting level that covers all Expanded (GPC BASIC+) sources, plus Other Scope 3 GHG emission sources (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).
Consumption-Based Inventory	A GHG inventory based on economic final expenditure by households, and national, regional and/or local governments, and business capital investment within a set geographical boundary.
Cradle to Gate	The life cycle stages from the extraction or acquisition of raw materials and other inputs to the point at which the good or service enters the city boundary (PAS 2070, 2013)
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).
Environmentally extended input-output model (EEIO)	A model based on financial flow data from national or regional economic accounts, combined with environmental account data (PAS 2070, 2013)
Flaring	The burning of natural gas and other hydrocarbon gases that cannot be used.
Fossil fuels	A hydrocarbon deposit derived from the accumulated remains of ancient plants and animals that 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).

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). These are also applied in this GHG inventory.
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).
Life cycle emissions analysis	The calculation of GHG emissions related to all the processes to create (extraction and processing), use and dispose of a good or service. This includes direct, indirect, and other indirect GH emissions sources.
Production-Based Inventory	A GHG inventory based on the direct and indirect use of fossil fuels within a set geographical boundary.
Reporting year	The year for which emissions are reported (GPC, 2014).
Scope 1 (Direct)	Emissions that physically occur within the City.
Scope 2 (Indirect)	Emissions that occur from the use of electricity, steam, and/or heating/cooling supplied by grids which may or may not cross the City boundaries.
Scope 3 (Other Indirect)	Emissions that occur outside the City but are driven by activities taking place within the City's boundaries.
Tonne	Measure of weight equal to 1,000 kilograms.
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)
Transboundary GHG emissions	Emissions from sources that cross the geographic boundary (GPC, 2014).

1.0 INTRODUCTION & CONTEXT

1.1 INTRODUCTION

Cities are centers of communication, commerce, and culture. They are also a significant and growing source of energy consumption and GHG emissions. On a global scale, cities are major players in greenhouse gas (GHG) emissions: cities are responsible for more than 70% of global energy-related carbon dioxide emissions, and therefore, represent the single greatest opportunity for tackling climate change (GPC, 2014). For a city to act on mitigating climate change and monitor its progress, it is crucial to have quality GHG emissions data to account for sources and quantities of GHG emissions generated by community activities. GHG inventories enable cities to understand the breakdown of their GHG emissions and plan for effective climate action.

This report includes two distinct GHG inventories for the City of Edmonton (the City): a production-based (PB) inventory, and a consumption-based (CB) inventory. Following the Global Protocol for Community-Scale Greenhouse Gas Emissions (GPC Protocol), the PB inventory assigns GHG emissions to the producers of those GHG emissions within the City's municipal boundaries. It includes in-boundary energy consuming activities, like building and vehicle fuel consumption, the consumption of grid-supplied electricity, heating and/or cooling, and the disposal of waste. The CB inventory does the inverse. Rather than assigning GHG emissions to the producers of GHG emissions within a set municipal boundary, it allocates GHG emissions from the extraction of raw materials, manufacture, distribution, retail and disposal to the final consumers of the goods and services located within a city's boundary. To avoid double counting, a CB inventory does exclude the exported or non-consumed goods and services. The City's CB inventory, which follows the PAS 2070:2013 Specification for the Assessment of Greenhouse Gas Emissions of a City (PAS 2070), accounts for the GHG emissions associated with the goods and services consumed by the City (corporately), residents, and businesses located within the City's municipal boundaries. Although different in approach, both of the GHG accounting methodologies – i.e., the GPC Protocol and PAS 2070 – specify similar requirements for identifying the assessment boundaries, the sources of GHG emissions to be included, the data requirements for carrying out the analysis, and the calculation of the results to develop a community GHG inventory.

The dual approach to inventorying GHG emissions provides a more comprehensive overview of the City's contributions to global GHG emissions, and how these inventories differ (Figure 1). For example, the use of both GHG inventories can help the City assess if GHG reductions are occurring locally as a result of local policy, or whether they are shifting the GHG emissions outside of the cities set boundaries (referred to a leakage). Looking at a City's GHG emission through these two lenses can broaden a city's understanding of the sources of GHG emissions and identify a wider range of emission reduction opportunities when compared to a single GHG inventory approach.

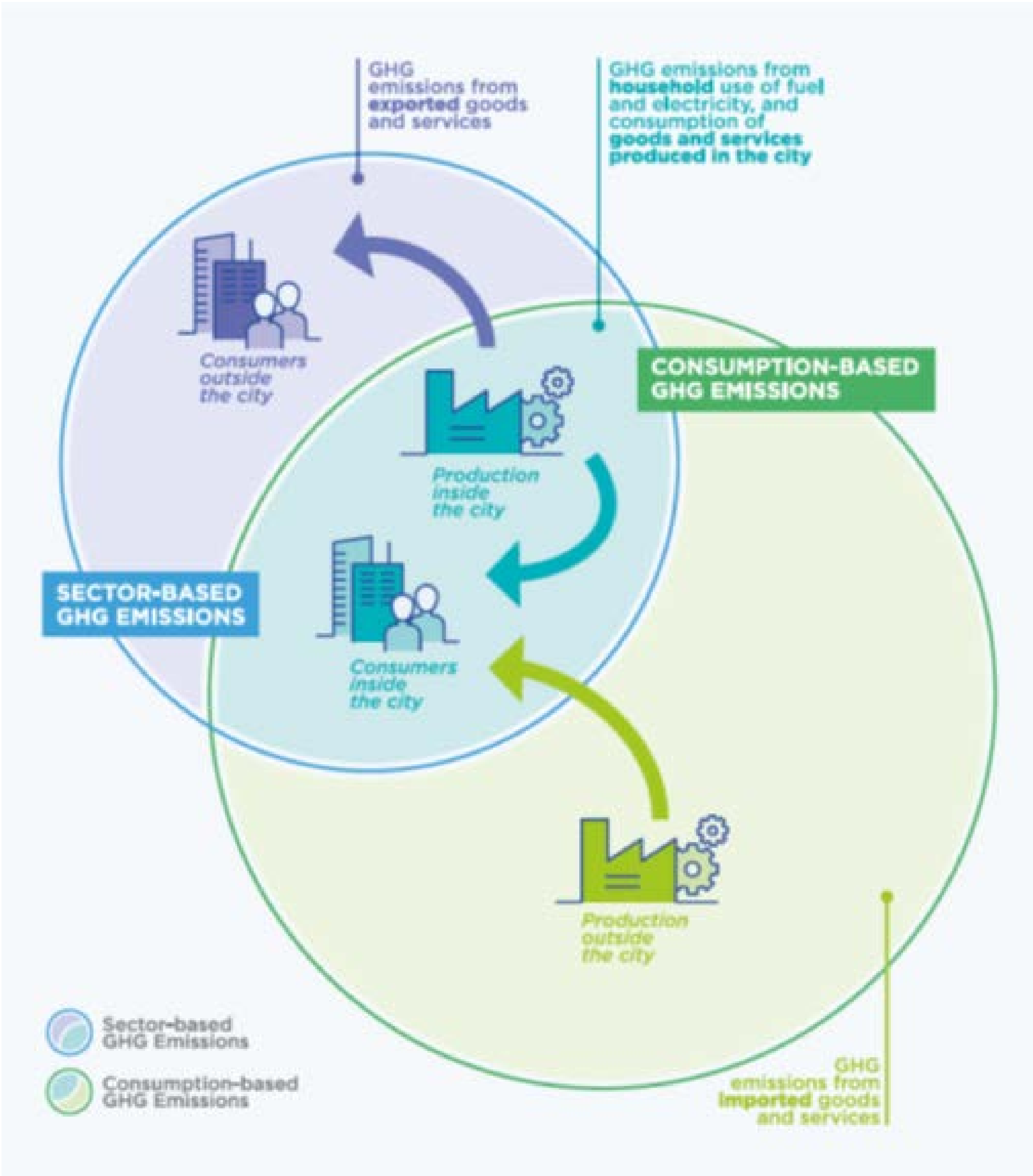

Figure 1 Overlap of Production- (Sector) and Consumption-Based GHG Inventories (C40, 2018)

1.2 ROADMAP OF THIS REPORT

This report reviews the scope and methods of each GHG inventory approach and presents the findings of the PB and CB 2016 GHG emissions inventories. Specifically, Section 2 presents a summary and breakdown of the PB 2016 GHG inventory. Unlike Section 3, which presents the 2016 CB GHG inventory, Section 2 does not present the methodologies, assumptions, uncertainties, and other limitations of the PB inventory as this material has been prepared in separate annual GHG reports This section concludes with an overview of the two inventory methods. Section 4 includes a series of recommendations for the City to consider should it transition to preparing CB inventories.

1.3 GHG EMISSIONS ACCOUNTING

GHG emissions of organizations are generally categorized as either Scope 1, Scope 2 or Scope 3 emissions. These categorizations are based upon where the GHG emissions arise and their relationship with GHG emissions reporter, in this case, the City. These definitions are important for the assignment of GHG emissions that occur outside the city to activities within the city's geopolitical boundary. The World Resources Institute (WRI) / World Business Council for Sustainable Development (WBCSD) 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 (Figure 2).

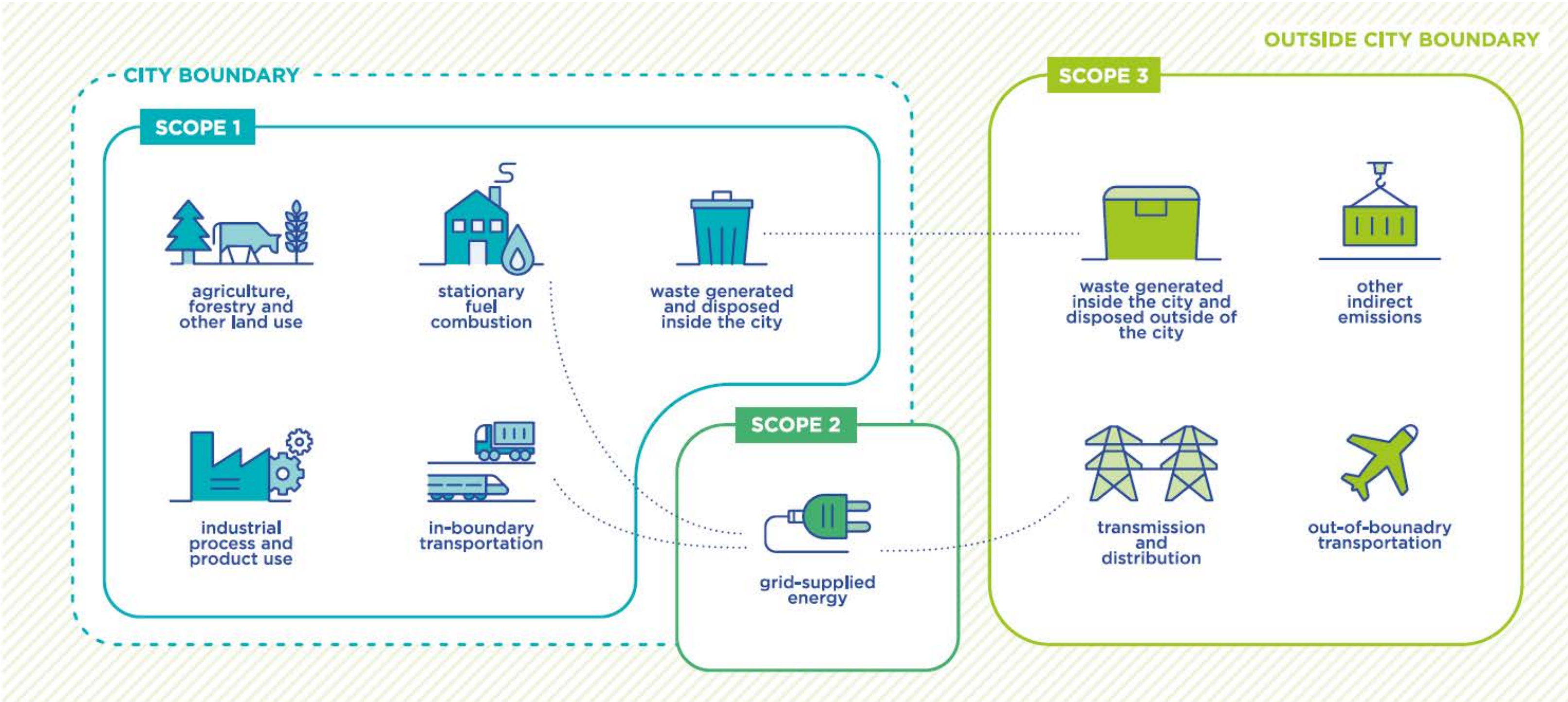

Figure 2 **Sources and Boundaries of a City's GHG Emissions (C40, 2018)**

PB inventories focus on capturing Scope 1, Scope 2 and some Scope 3 GHG emissions (i.e., waste, transboundary transportation, and transmission distribution and line losses), whereas CB inventories aim to capture nearly all GHG emissions scopes. CB inventories, however, do not capture all downstream GHG emissions, such as waste disposal which can be a Scope 1 or Scope 3 GHG emissions source depending on where the GHG emissions are released. To address some of the inherent limitations in each approach and for the purposes of standardization, GHG methodologies or protocols have been developed for international use. At the time of reporting, two protocols are deemed to be best practice: GPC Protocol, and PAS 2070.

1.3.1 Global Reporting Protocol for Communities

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 IPCC guidelines on how to estimate GHG emissions (IPCC, 2014).

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. Specifically, the GHG inventory is required to include all seven Kyoto Protocol GHGs occurring within the geographic boundary of a city, and 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)

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.

- **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. **The City currently reports at the BASIC+ level.**

- **GPC BASIC+ Scope 3 (SC)**— This inventory extends beyond the Expanded GHG inventory to include Other Scope 3 (SC) emissions such as GHG emissions from goods and services production and transportation. Depending on the depth and breadth of the Scope 3 GHG emissions assessment by the GHG emissions reporter, this reporting level could align with the PAS 2070 direct plus supply chain (DPSC) methodology (discussed below). However, at present the GPC Protocol provides no guidance on how to align a BASIC+SC GHG inventory with the PAS 2070 DPSC GHG inventory.

Internationally, GHG emissions are currently calculated and reduction targets set using the PB method. The strength in the PB inventory method is that it relies on local energy, transportation, and waste data for the reporting year which is generally accessible, and can provide insight into energy production, and energy-intensive consuming industries and specific sectors – e.g. the number of light duty gasoline vehicles in a city. The PB inventory method is limited in that it does not capture GHG emissions associated with the use of manufactured products, such as electrical appliances and furniture, food, clothing, and services provided as these are often manufactured, assembled, transported in other cities and countries. As reporting cities mature and evolve in their GHG emissions reporting, and begin to consider political acceptability, social equity and justice considerations, such cites may shift to using CB inventories to attribute responsibility of GHG emissions based on consumption instead of production. This shift may occur sooner than later as there has been a global trend in declining PB based GHG emissions, and a rise in CB based GHG emissions which is likely the result of increased globalization and the outsourcing of GHG emissions-based activities.

1.3.2 PAS 2070:2013 Specification for the Assessment of Greenhouse Gas Emissions of a City

PAS 2070 is a GHG emissions quantification standard that sets out requirements for the assessment of GHG emissions of a city using two distinct methodologies: the direct plus supply chain (DPSC) methodology, and the consumption-based (CB) methodology.

The DPSC methodology is similar to the GPC Protocol methodology in that it requires the assessment and reporting of GHG emissions by sector:

- Stationary Energy
- Transportation
- Industrial Processes And Product Use (IPPU)
- Agriculture, Forestry And Other Land Uses (AFOLU)
- Waste And Wastewater Treatment
- Goods And Services – Water Provision, Food And Drink And Construction Materials

The DPSC differs in that it goes beyond the GPC Protocol requirements by requiring reporters to account for upstream GHG emissions, such as fuel extraction, production, and transportation GHG emissions, as well as cradle-to-gate GHG emissions associated with the consumption of goods and services like food and drink, water, construction materials, and other goods and services that are estimated to make a material contribution to a city's GHG inventory (>2%). Ultimately, the DPSC method is a hybrid PB and CB inventory.

The CB methodology is distinctly different from the prior methodologies. It allocates direct and life cycle GHG emissions for all goods and services consumed by residents, governments, and businesses within a city. The strength of the CB inventory approach is that it can create accountability by providing cities with a better understanding of their consumption choices, which can lead to the implementation of policies that mitigate associated, but generally unregulated GHG emissions.

As it relates to the data used, CB inventories either use a bottom-up approach, which relies on urban metabolism data (e.g., actual waste consumed, total materials recycled, total roads, buildings, and other infrastructure constructed), or a top-down approach which requires the use of environmentally extended input-output models (EEIO). EEIO models take financial flow data from national or regional economic accounts and estimate GHG emissions using average GHG emission factors for each consumption category (i.e. in the city, rest of the country, or rest of the world). EEIO models are cradle-to-gate which means that they do not evaluate the downstream impacts of consumption activities – for example, unlike a bottom-up approach, the top-down approach does not include the processes required to produce, use, dispose a good or service. As the top-down CB method uses an EEIO model, they are limited in that they rely on the homogeneity principle which assumes that each sector in an economy produces a single or homogeneous good or service and carries an identical embodied environmental impact (Kitzes, 2013). Further, the data is typically collected at the national level for both financial and GHG emission accounts to which assumptions have to be made to apply it to a city reporting level which can introduce biases and uncertainties. The bottom-up method is also subject to its limitations in that it is not likely to capture all of the goods and services being consumed within a City and is likely to underestimate consumption GHG emissions. Due to the nature of how the EEIO data is reported, a top-down CB inventory cannot be cleanly organized into reporting sectors, like a city can under the GPC Protocol. The reason is that the EEIO data is organized by financial trade accounts (e.g. finance and insurance, real estate and rental and leasing, professional, scientific and technical services, etc.) and represent emissions over the complete life-cycle of the material, energy or service assessed. This can make comparability to other CB inventories limited without understanding how each of the CB inventory trade accounts and the GHG emission factors, determined on an \$/tCO_2e value, are developed. Both the CB top-down and bottom-up approaches rely on LCA GHG emission factors which may be outdated or limited in their scope. For example, the estimation of electricity GHG emissions under the PB and CB inventories can lead to significantly different results. Under the PB inventory for the City, electricity GHG emissions would be estimated using the Alberta grid-intensity average for the year, whereas under the CB inventory, the electricity GHG emissions are likely to be based on a Canadian or global average.

In light of these challenges, top-down approaches to estimate CB GHG emissions are more commonly deployed than bottom-up approaches as there is often significant effort and cost in collecting this information, and there is no standardized approach to implementing urban metabolism studies (Beloin-Saint-Pierre et al., 2018). The benefit to a bottom-up approach is that it provides a direct link between policy intervention and GHG emission outputs at the city scale, allows for forecasting and modelling out predictive reductions as a result of policy, and can be more clearly organized by sector and emissions source.

It is important to note that both the PB and CB inventory methods suffer from a degree of uncertainty. For example, PB inventories can suffer from a lack of available data to estimate transportation movements, in terms of vehicle kilometers travelled, and assigning transboundary transportation GHG emissions, or a lack of land use GHG emission factors, both of which can be a constraining factor in producing an accurate GHG emissions inventory. In addition, both the PB and CB methods are not likely to capture all energy consuming activities occurring in an economy (e.g. cutting down and burning firewood for heat),

In the case of the City, since the data to support a bottom-up approach was not available, a top down approach using EEIO data was deployed. As it relates to the City's PB and CB inventories, the differences in the two inventory approaches are presented in the following table.

Table 1 Production- and Consumption-Based GHG Inventory Comparison

Aspect	Production–Based GHG Inventory	Consumption-Based GHG Inventory
General Description	In-boundary GHG emissions from Stationary Energy, Transportation, Waste, Industrial Processes and Product Use (IPPU), and Agriculture, Forestry, and Other Land Use (AFOLU)	Globally-distributed consumption GHG emissions associated with economic final demand by Edmonton.
Inventory Years Available	2005-2017	2016
Gases Included	CO_2, CH_4, N_2O Note that HFCs, PFCs, SF_6, and NF_3 ideally should be included in a PB inventory but there is limited data to quantify these GHG emission sources. This is disclosed in the City's annual GHG reports.	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3
Stationary Energy	Indirect Alberta-based electric power GHG emissions (includes production, transmission, distribution and losses) used directly by residents, businesses, households and governments. Direct use of fossil fuels related to the operation of in-boundary buildings, and off-road equipment. Fugitive GHG emissions resulting from the operation of in-boundary natural gas distribution systems.	Life-cycle emissions of electricity and other fossil fuels used directly by residents, businesses, governments. This includes direct, indirect, and other indirect GH emissions sources. All electricity and fossil fuels used in the provision and supply chains of goods and services consumed by residents, businesses, governments.
Transportation	GHG emissions from in-boundary and transboundary transportation fuels by all users and sources (on-road, off-road, rail, aviation) (not-life cycle)	Life-cycle emissions from purchased transportation fuels and transport services used by residents, businesses, and governments; all transportation emissions associated with the movement and supply chains of goods and services consumed.
Waste	In-boundary solid waste fugitive GHG emissions, wastewater treatment and discharge GHG emissions, and biological treatment of waste (composting) GHG emissions.	The lifecycle GHG emissions from solid waste, water, and wastewater operations. No fugitive GHG emissions.
IPPU	In-boundary IPPU GHG emissions.	Life cycle GHG emissions from IPPU GHG emissions.
AFOLU	Land-use change GHG emissions included Biogenic CO_2 GHG emissions excluded.	Not included
Other GHG Emissions Sources	Not included.	All other emissions from supply chains of goods and services consumed by City residents, businesses, and governments (e.g. food,
Primary Data Sources	Numerous reporting year local utility and governmental data	Economic consumption data from Statistics Canada,

	sets, and the National Inventory Report (NIR).	Government of Alberta, the City, and other data sources.

2.0 2016 PRODUCTION BASED GHG INVENTORY

2.1 INTRODUCTION

The City's 2016 PB inventory meets the GPC Protocol BASIC+ reporting requirements as it estimates GHG emissions occurring within the City of Edmonton's municipal boundary by GPC reporting sector which includes Stationary Energy, Transportation, Waste, IPPU, and AFOLU. The City's PB inventory for the 2016 reporting year is summarized below to allow for comparison to the CB inventory (Section 3.0).

2.2 METHODOLOGY

As part of reporting to the Carbon Disclosure Project (CDP), the City has prepared a detailed methodology manual which identifies data sources, limitations, assumptions and emission factors and thus will not be presented here.

2.3 GREENHOUSE GASES (GHG) CONSIDERED

A GHG can be any atmospheric gas that absorbs and re-emits infrared radiation, thereby acting as a thermal blanket for the planet and warming the lower levels of the atmosphere. GHGs are released to the atmosphere from several natural and anthropogenic (human activity) sources (IPCC, 2014).

Emissions of each of the specific GHGs are multiplied by their 100-year global warming potential (GWP) and are reported as carbon dioxide equivalent (CO_2e). The GWP of these GHGs are:

- Carbon dioxide (CO_2) = 1.0
- Methane (CH_4) = 25
- Nitrous oxide (N_2O) = 298
- Sulphur hexafluoride (SF_6) = 22,800
- Nitrogen trifluoride (NF_3) = 17,200
- Hydrofluorocarbon (HFC) gases range from 12 to 14,800
- Perfluorocarbon (PFC) gases range from 7,390 to 17,340 (IPCC 2012).

Not all GHGs listed above are applicable to the GHG inventory. Those included in the PB inventory are CO_2, CH_4 and N_2O. The other gases have not been included due to limited data availability.

On this basis, carbon dioxide equivalents (CO_2e) for the GHG inventory are calculated as:

$$CO_2e = (\text{mass } CO_2 \times 1.0) + (\text{mass } CH_4 \times 25) + (\text{mass } N_2O \times 298)$$

2.4 EMISSIONS FACTORS

Under the PB inventory approach, emissions from energy consumption are calculated using emission intensity values (or emissions factors), which specify the amount of CO_2e produced per kilowatt hour (kWh) of electricity consumed. The emissions factor is then multiplied by the total energy (kWh) used to determine the total amount of CO_2e produced.

$$CO_2e\ (kg) = Energy\ Use\ (kWh) * coefficient\ (kg\ of\ CO_2e/kWh)$$

A detailed list of emission factors can be found in Appendix A.

2.5 2016 INVENTORY SUMMARY

Following the requirements of the GPC Protocol, BASIC+ reporting level, the City's 2016 community PB GHG emissions are estimated to be 18,305,588 tCO_2e. Like most cities, the stationary energy and transportation sectors account for the largest portion of the City's GHG emissions (Figure 1). Because more than 40% of Alberta's generation capacity is natural gas-fired and 60% is coal-fired, more than 40% of the City's GHG emissions come from electricity use (Government of Alberta, 2018) (Figure 4). Natural gas mainly used to heat buildings accounting for more than 20% of the GHG inventory, and lastly fuels used in the operation of on-road and off-road vehicles accounted for more than 25% of the GHG inventory.

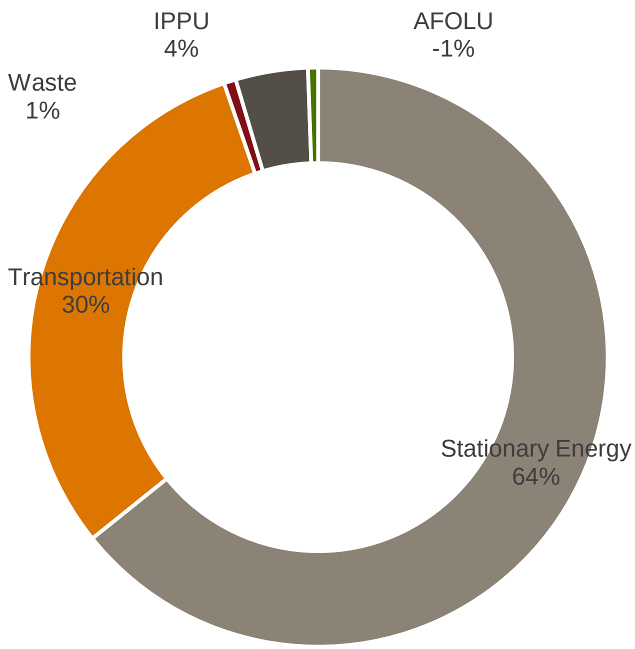

Figure 3 Edmonton's GHG Emissions By Sector

2016 Production Based GHG Inventory

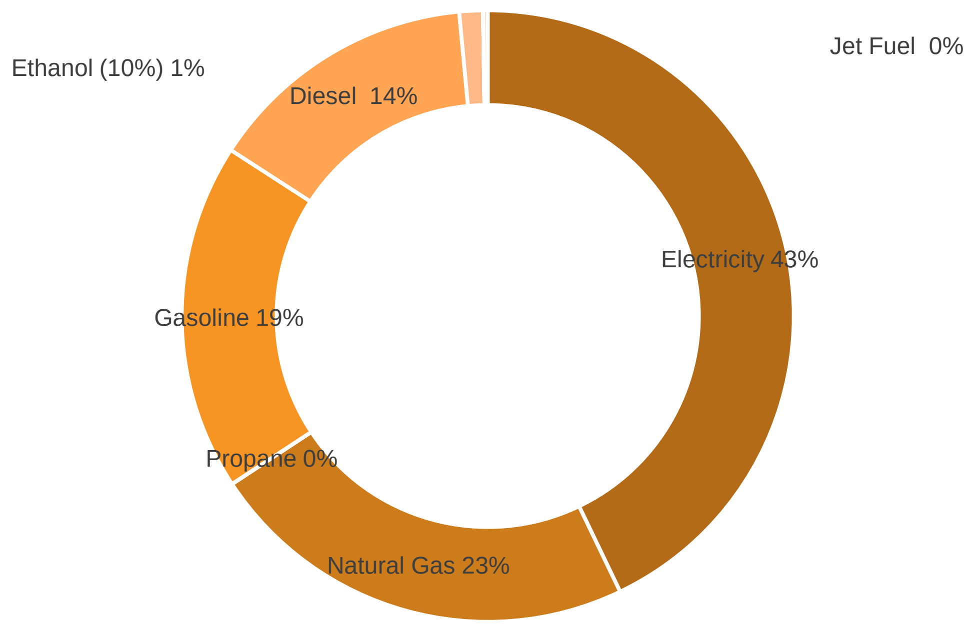

Figure 4 Edmonton's GHG Emissions By Fuel Consumption

A breakdown of the City's 2016 GHG emissions by sector and sub-sector is presented in Table 2.

Table 2 Breakdown of Edmonton's Community PB 2016 GHG Emissions

Sector	Sub-Sector	2016 GHG Emissions (tCO_2e)	Contribution to the GHG Inventory (%)
Stationary Energy	Residential Buildings	3,280,925	17.9%
	Agriculture, Forestry, And Fishing Activities	574,984	3.1%
	Manufacturing Industries, and Construction	4,243,184	23.2%
	Non-Specified Sources	-	0.0%
	Commercial / Institutional Buildings	3,275,991	17.9%
	Energy Industries	490,399	2.7%
	Fugitive Emissions: Oil and Natural Gas Systems	25,819	0.1%
Transportation	On-Road Transportation	2,869,996	15.7%
	Transboundary Transportation	1,601,451	8.7%
	Off-Road Transportation: Aviation, Railways, and Other Off-Road	1,175,726	6.4%
Waste	Waste: Solid Waste Disposal, Biological Treatment of Waste, Wastewater Treatment and Discharge	123,838	0.7%
AFOLU	AFOLU: Livestock, Land, and Other Agriculture	(103,910)	-0.6%
IPPU	IPPU: Industrial Processes, and Product Use	747,185	4.1%
Total City GHG Emissions		**18,305,588**	**100.00%**

Of the City's community GHG emissions, 513,304 tCO_2e (2.8%) are the direct result of corporate operations which came from the operation of City owned and operated buildings like recreation centers and pools, and waste management facilities, corporate service vehicles and transit fleet, the operation of streetlights and traffic signals and the decomposition of waste at City operated landfills.

2.5.1 Stationary Energy

Stationery energy sources are the largest contributors to the City's GHG emissions. In 2016, stationary energy emissions sources accounted for 65% of the GHG inventory and included emissions from energy to heat and cool residential, commercial, and industrial buildings, as well as the activities that occur within these residences and facilities. Emissions associated with distribution losses from grid-supplied electricity/steam/heating/cooling are also included, as are fugitive emissions from sources such as coal piles, natural gas pipelines, and related off-road transportation GHG emission sources.

In the 2016 reporting year, residential, commercial and industrial buildings and associated energy use activities accounted for 90% of total stationary energy emissions and 65% of the City's GHG inventory (Figure 5).

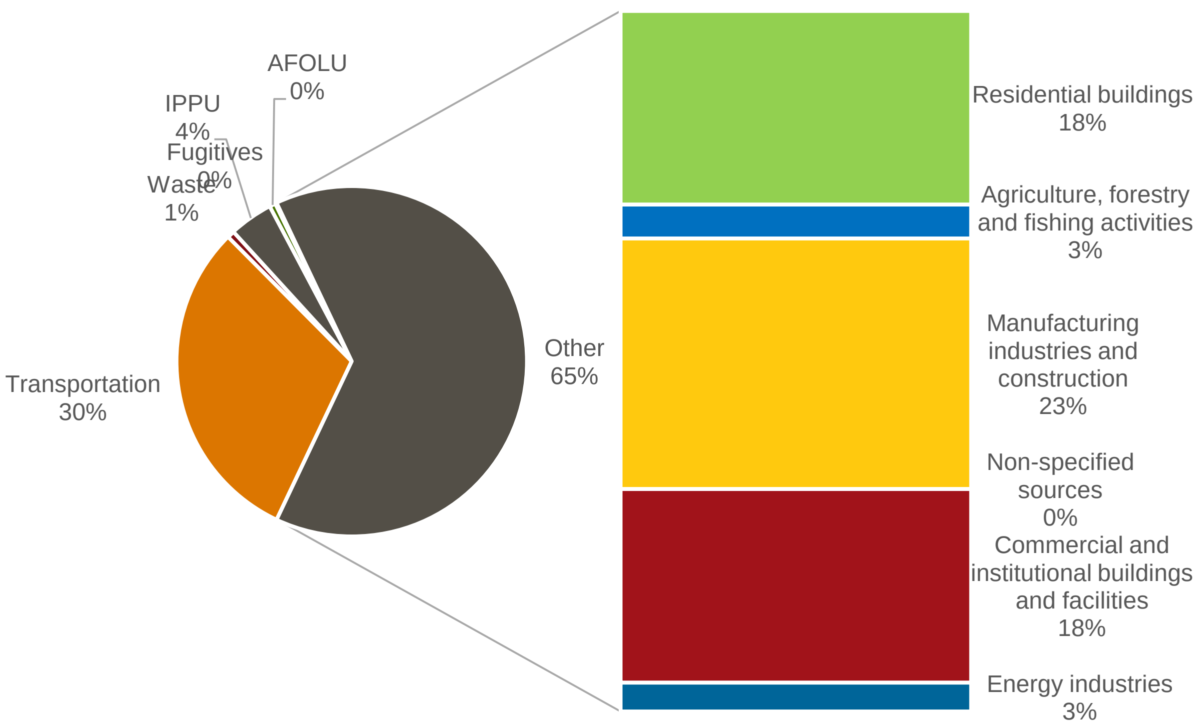

Figure 5 Breakdown of Stationary Energy GHG Emissions

2.5.2 Transportation

Transportation GHG emission sources include on-road, railway, waterborne navigation, aviation, and off-road. These 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). 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.). For example, off-road railway maintenance support equipment GHG emissions are reported under the off-road transportation sub-sector.

In 2016, transportation activities accounted for 30% of the City's GHG emissions with almost 80% of the transportation GHG emissions (on-road and transboundary) resulting from the operation and use of gasoline and diesel powered on-road vehicles (Figure 6 and Figure 7).

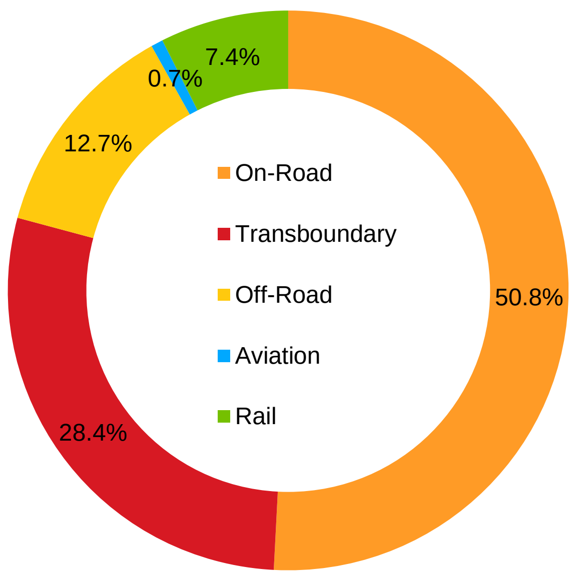

Figure 6 Breakdown of Transportation Energy GHG Emissions

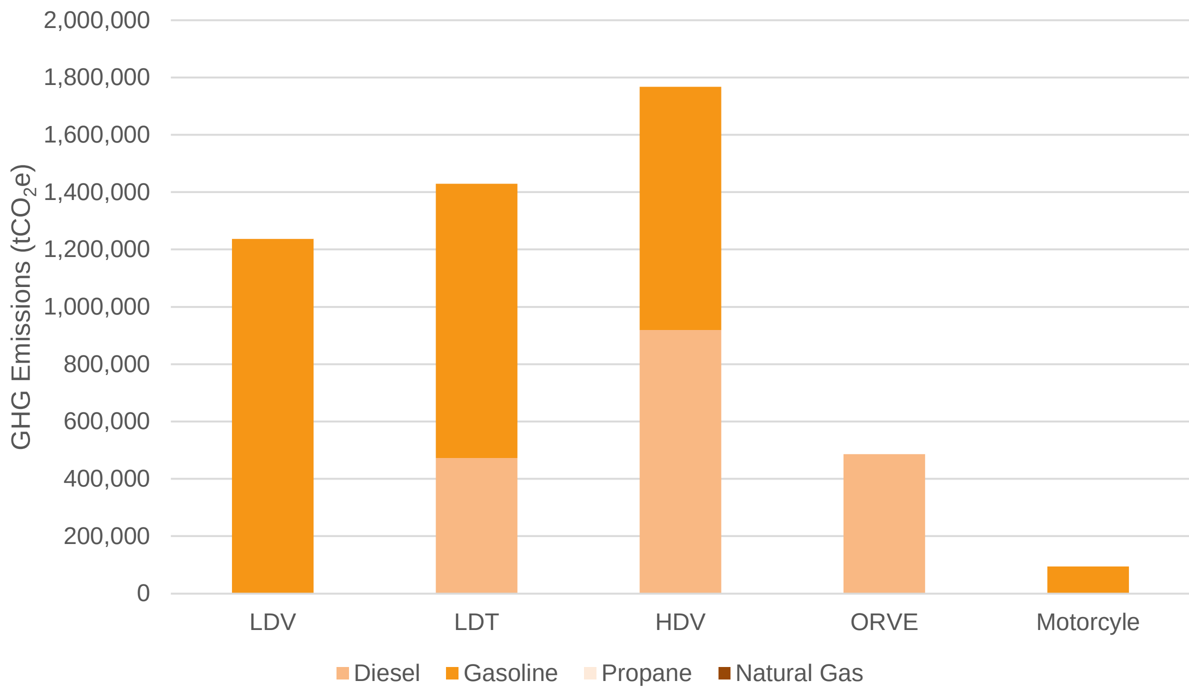

Figure 7 Examination of On-Road GHG Emissions and Energy Usage

2.5.3 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. 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.

For the 2016 reporting year waste accounted for 1% of the City's GHG emissions with more than 95% coming from solid waste fugitive GHG emissions (Figure 8).

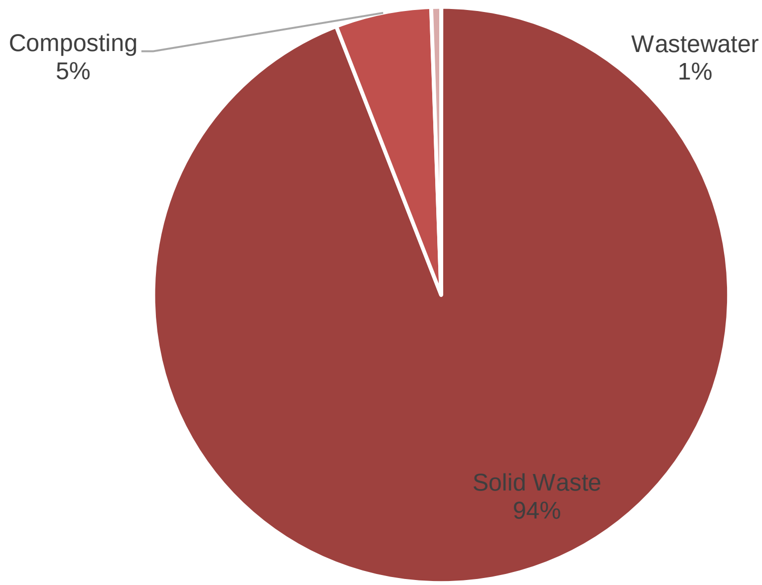

Figure 8 City Waste GHG Emissions Profile

2.5.4 Industrial Processes and Product Use (IPPU)

Emissions from the IPPU sector are required for BASIC+ reporting. 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. Also, reported in the IPPU sector are 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.

It should be noted that the inclusion of different GHG emissions sources in the reported total varies by reporting GHG protocols and standards selected by a reporting City, and the GHG emissions sources will also vary in their level of potential influence depending on the geographic location and constraints, energy supplies available (e.g., hydro vs coal power), climate, and economic base. With respect to influence, it should also be noted that the City has limited control over certain emissions sectors and sub-sectors. For example, GHG emissions associated with IPPU GHG emissions or off-road GHG emissions are typically consumer driven and not under the control of the City, whereas on-site power generation can be much more easily affected through local decision-making and zoning.

For the 2016 reporting year, the City's IPPU GHG emissions accounted for 4% of the City's GHG emissions with 47% of these GHG emissions coming from reported industrial process activities, and the remaining from product use to which the latter was estimated on a per capita basis on the lack of available information.

2.5.5 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).

Like most cities, the inclusion of AFOLU GHG emissions in the inventory results in an overall reduction of GHG emissions as the reporting city is capturing GHG emissions reductions from the preservation of greenspace (forestlands, grasslands, etc.). In 2016, the City reported a reduction of 103,910 tCO_2e from the AFOLU sector.

Table 3 Breakdown of 2016 AFOLU GHG Emissions

Sub-Sector	tCO_2e
Emissions from land	(109,796)
Emissions from aggregate sources and non-CO_2 emission sources on land	5,886
Total	**(103,910)**

2.6 2016 INVENTORY GHG REPORTING METRICS

Table 4 summarizes the City's reporting metrics for the 2016 reporting year.

Table 4 Key Reporting Metrics for Reporting Year

Aspect	2016
City Population	932,546.0
Energy (eGJ in Millions)	169.1
Energy (eGJ / Capita)	181.3
Electricity (Millions of MWh)	7.6
Energy (MWh / Capita)	8.2
Natural Gas (GJ in Millions)	70.1
Natural Gas (GJ / Capita)	75.2
Transportation (GJ in Millions)	56.6
Transportation (GJ / Capita)	60.6
Community GHG Emissions ($MtCO_2e$)	18.3
GHG Emissions (tCO_2e / Person)	19.6
Corporate GHG Emissions ($MtCO_2e$)	0.5

3.0 CONSUMPTION BASED GHG INVENTORY

3.1 INTRODUCTION

The City's CB inventory has been prepared in accordance with the requirements of the PAS 2070:2013 Specification for the Assessment of Greenhouse Gas Emissions of a City (PAS 2070). The CB methodology requires the use of an environmentally extended input-output model (EEIO) which takes financial flow data from national economic accounts and estimates GHG emissions using average GHG emission factors for each consumption category depending on where the goods and services consumed in the City are produced. The GHG inventory boundaries, methodology, and results are presented below.

3.2 GHG INVENTORY BOUNDARIES

The CB inventory was prepared for the 2016 year and is defined geographically by the City of Edmonton municipal boundaries, as shown in Figure 9. This treatment is consistent with the PB inventory boundary.

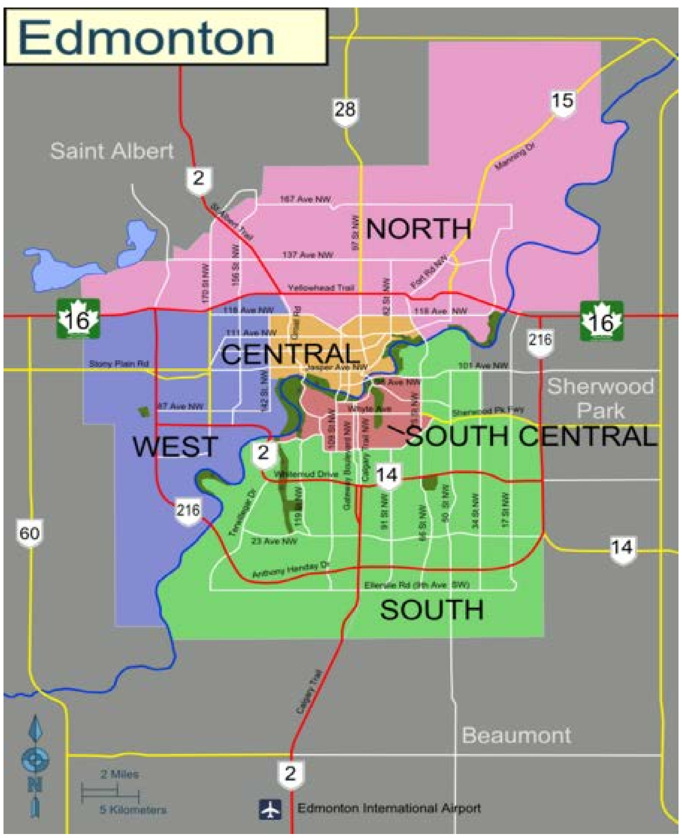

Figure 9 City of Edmonton Municipal Boundary

3.3 METHODOLOGY

3.3.1 Approach

With the CB methodology, GHG emissions are estimated using a top-down approach and is based on emissions associated with the production of goods and services consumed by households, government, and business capital investment within the City. The CB method is based on disaggregated final demand information (i.e. expenditures at the point of end-use, and not including intermediate use) as well as GHG emission factors for the various goods and services industries.

The quantification method is involves estimating disaggregated household, capital investment, government, and other spending and then applying GHG intensity factors to estimate overall GHG emissions. A break-down of the method is provided below.

3.3.1.1 Household Expenditures GHG Emissions

Statistics Canada Table 11-100222-01 reports average household spending in Canada, disaggregated by expenditure categories. Household expenditures within the City, by expenditure category, are estimated using the 2016 Census of the Population (Census) Profile information for the City while applying an adjustment factor that accounts for differences in average household income, and therefore propensity to spend, between residents of City and Alberta overall. Household expenditures are estimated using the following relationship:

$$HFD_{i\,(City)} = T_{io}\ [POP_{City}\ X\ HFD_{i\,(AB)}\ X\ [MFI_{City}/MFI_{ALB}]]$$

where:

$HFD_{i\,(City)}$ = 2016 average expenditure per household in City, by commodity code

POP_{City} = Population of City

$HFD_{i\,(AB)}$ = 2016 average expenditure per household in Alberta, by expenditure category i

MFI_{City} = Median family income in City

MFI_{ALB} = Median family income in Alberta

T_{io} = Mathematical transformation using symmetrical input-output model

This method assumes that household expenditures are proportional to household income, and that savings rates are the same across the province of Alberta.

Average household spending in Edmonton was estimated based on median total and after-tax income reported in the 2016 Census profile for the City. An estimated 89.9% of after-tax household income was assumed to be used for household consumption, based on the breakdown of Canadian household expenditure available in Statistics Canada Table 11-100222-01, with the balance of household expenditures being used for non-consumables, such as pension contributions, insurance payments, and charitable contributions. To estimate GHG emissions associated with household consumption, average household consumption expenditures were transformed into expenditures based on

NAICS commodity codes using a symmetric input-output table for Alberta and using the Input-Output Final Demand Codes (IOFDC) PEC00 (Household Consumption Expenditures) Table which is derived from the Statistics Canada Interprovincial Input-Output Model.

3.3.1.2 Private Sector Capital Spending GHG Emissions

Statistics Canada Table 34-10-0035-01 reports capital and repair expenditures, by province, disaggregated by North American Industry Classification System (NAICS). To estimate private sector capital investment within the City, the following steps were undertaken:

1. Estimate capital spending (capex) per employee, by industry, within Alberta using Statistics Canada NAICS capex and employment data.
2. Estimate capital expenditures by industries operating within City by applying per-employee estimates established above to NAICS employment estimates from the 216 Census Profile for City. In this calculation non-private sector industries (i.e. health, education, and government services are removed from the estimate).

Private sector capital spending was estimated using the following relationship:

$$PCS_{j\ (City)} = PCSiPE_{(AB)}\ X\ EMPi_{(City)}$$

where:

$PCS_{j\ (City)}$ = Private Sector Capital Spending in City for industries j

$PCSiPE_{(AB)}$ = Average capital spending per employee in Alberta for industries j

$EMPi_{(City),}$ = Employment within City by industries j

This method assumes that capex by industry is accurately represented at the local scale.

3.3.1.3 Government Spending GHG Emissions

Estimates of government spending need to account of local, provincial, and federal contributions. Data sources used in the calculations are as follows:

- Local government spending – 2016 City of Government spending was obtained from the City 2016 Annual Report (Edmonton, 2017). Operational spending was obtained from the Consolidated Statement of Operations and Accumulated Surplus, while capital spending was derived from Schedule 1 – Consolidated Schedule of Tangible Capital Assets.

- Provincial government spending - The Government of Alberta releases annual reports with budget results and consolidated financial statements, among other information. Expense information is summarized at the Ministry (e.g., Health, Education, Infrastructure) and object level (e.g., salaries, wages, employment contracts and benefits, grants, and materials and supplies).

- Federal government spending - Statistics Canada Table 36-10-0450-01 reports revenue, expenditure, and budgetary balance information for general governments at the federal, provincial, and territorial level. From this table, estimates of federal spending within Alberta were disaggregated (i.e., expenditure estimates associated with line item “General governments expenditure’ [when filtered by ‘Alberta’ and ‘federal general government’]).

To estimate government spending within the City expense information was taken from the above sources and classified against government-related Statistics Canada IOIC codes (i.e., IOIC codes with the naming convention GSXXXXXX). Classified expenditure information at the local level were also included in the calculations. For provincial and federal government spending, City per-capita provincial and federal 'spending proxies' (estimated by multiplying City Census population estimates against provincial and federal government per-capita spending within Alberta) were used. This approach is limited in that it assumes an even distribution of government spending across the province.

Government spending was estimated using the following relationship:

$$GS_{k\ (City)} = T_{io}\ [LGS_{k\ (City)} + (PCPGS_{k\ (AB)} \ X \ POP_{(City)}) + (PCFGS_{k\ (AB)} \ X \ POP_{(City)})]$$

where:

$GS_{k\ (City)}$ = Government spending in City for industries k

$LGS_{k\ (City)}$ = Local Government (City of Edmonton) spending in City for industries k

$PCPGS_{k\ (AB)}$ = Per-capita provincial government spending for industries k, within Alberta

$POP_{(City)}$ = Population of City

$PCFGS_{k\ (AB)}$ = Per-capita federal government spending for industries k, within Alberta

T_{io} = Mathematical transformation using symmetrical input-output model

To estimate GHG emissions associated with City operational spending, total 2016 operational expenditures were transformed into expenditures based on NAICS commodity codes and using the Input-Output Final Demand Codes (IOFDC) PEC00 (Household Consumption Expenditures) Table. Because expenditures on wages, salaries, and mixed income represent financial transfers to households these were netted out of total to avoid double-counting. Because GHG consumption due to municipal capital expenditure was estimated separately, it was also assumed that there are no GHG emissions associated with the gross operating surplus estimated for municipal operational expenditure.

GHG emissions from City of Edmonton expenditures were estimated directly from capital expenditure information available from the 2016 City Annual Report. GHG emissions from Province of Alberta (POA) capital spending were estimated based on information on changes in tangible assets from the POA's 2016/2017 Annual Report.

GHG emissions from City of Edmonton expenditures were estimated directly from capital expenditure information available from its 2016 City Annual Report. GHG emissions from Province of Alberta (POA) capital spending were estimated based on information on changes in tangible assets from the POA's 2016/2017 Annual Report.

3.3.1.4 Other GHG Emissions

Non-profits (NAICS code 81341) expenditures were included in the private sector estimates (Task 2 above). The NAICS industry amalgamation 'Other services (except public administration)' includes all NAICS code 81 except for code 814 (Private households) and was included in the analysis.

3.3.1.5 GHG Emissions Factors

Emission factors used in the analysis were based on 2009 Canadian GHG emission factors, expressed in tCO_2e/$million obtained from the International Reference Centre for the Life Cycle of Products, Processes and Services (CIRAIG)™ open input output model. To account for 2009 to 2016 inflation, emission factors were divided by a factor of 1.1229 (Bank of Canada, 2018). The CIRAIG™ factors include those for 234 commodity classes based on NAICS classification. The current version of the CIRAIG™ model is only based on the LCA GHG emissions occurring within Canada and does not include imports from other countries. This assumption is thought to underestimate consumption-based GHG emissions by 29% (Weber and Matthews, 2008). To account for the higher carbon-intensity of imported goods, the emission factors were increased by 29%, after accounting for inflation.

The emission factors were weighted for 15 summary level expenditure groups (Table 5) based on expenditure information outlined in Table 6. The emission factors were weighted as the breakdown of final demand in the symmetrical input-output table does not line up with the breakdown of consumption based on end-use. For example, Albertan households spend on average 8.7% of their disposable income on food, and a further 6.2% on prepared food and non-alcoholic beverage services (i.e. restaurants). However, "food" is not one of the categories in the symmetrical input output table. Instead, food costs are captured by several industries, including "crop and animal production", "utilities", "manufacturing", "wholesale trade", "retail trade", and "accommodation and food services". To address this aspect, emission factors were based on assumed breakdown of cost inputs for final demand. These weighted factors, adjusted for inflation, were then used to in the GHG emissions analysis (Table 5).

Table 5 Weighted Emission Factors

Sector	tCO_2e/$million		
	Household Spending	**Private Capital Expenditure**	**Government Spending**
Agriculture, Forestry	1775	1775	1775
Oil & Gas, Mining	1000	1000	1000
Utilities	1549	1851	1953
Construction	393	349	408
Manufacturing	672	1006	945
Wholesale & Retail Trade	771	280	820
Transportation & Warehousing	891	1171	1005
Information & Cultural Industries	187	187	187
Finance, Insurance, Professional Services, Business Management	158	307	213
Real Estate	294	302	302
Waste Management Services	650	650	650
Education And Healthcare Services	239	272	272
Accommodations And Food Services	388	380	386

Sector	tCO_2e/$million		
	Household Spending	**Private Capital Expenditure**	**Government Spending**
Arts, Entertainment, Recreation, And Miscellaneous Services	472	472	472

3.3.1.6 GHG Emissions Analysis

The GHG emissions analysis involved deriving industry-specific GHG intensity factors, based on tCO_2e/$ of expenditures (by industry or commodity group), and then multiplying these factors by the estimates of household spending, private sector capital spending, and government spending, as described above in Tasks 1 – 4.

Overall GHG emissions for the City are estimated using the following relationship:

$$GHGe = SUM[(HFD_i \times GIF_i) + (PCS_j \times GIF_j) + (GS_k \times GIF_k) + (OS_l \times GIF_l)]$$

where:

GHGe = Greenhouse gas emissions

HFD_i = household final demand for goods and services within City, disaggregated by Statistics Canada Input-Output Industry Classification (IOIC) i, expressed in $

PCS_j = Private sector capital spending within City, for Statistics Canada IOIC j, expressed in $

GS_k = Government spending within City, within Statistics Canada IOIC k, expressed in $

OS_l = Other spending within City, within Statistics Canada IOIC l, expressed in $

$GIF_{i,j,k,l}$ = GHG intensity factors for Statistics Canada IOIC i, j, k, l, expressed in tCO_2e/$ million of expenditure

3.3.2 Assumptions

A number of assumptions were applied to facilitate the analysis, as identified below:

Emission factors – Consumption based emission factors were derived from those contained within the CIRAIG™ database, which are average 2009 reporting year factors for all of Canada and do not include GHG emissions from imports. To account for inflation between 2009 and 2016, and the fact that the CIRAIG model does not account for life cycle GHG emissions outside of Canada, the emission factors were adjusted by a factor of 1.0496 (0.29/1.1229). This may result in the over estimation of non-imported (Canada made/generated) goods and services.

Expenditure categories – The CB analysis was tailored so that expenditure categories used in the analysis matched those provided for emission factors available from the CIRAIG™ model. This involved the use of a symmetrical input-output table to transpose overall household, private sector, and government spending into industry sectors based on North American Industry Classification System (NAICS) commodity codes. At the level of analysis performed for this paper, the emission factors used to estimate GHG emissions were based on relatively aggregated assumptions of the breakdown of expenditure by commodity group. For example, it was assumed that household expenditures associated with manufacturing will be divided into the following for expenditure categories: “other food products”, “gasoline”, “household appliances”, “other motor vehicle parts”, “passenger cars,” “household furniture, and “miscellaneous manufactured products.” Because the relative costs of goods and services differs across the country, the actual consumption-based emission factors for the City may differ from those contained within the CIRAIG^{TM} database**.**

Emission factors homogeneity – It was assumed that GHG intensity of a disaggregated good or service will be the same for all end-users. By using a symmetrical input-output tables, goods and services consumed by households, private sector capital spending, and government spending are comparable based on the same breakdown of economic sectors that would experience a change in final demand.

Linearity of Household Consumption – It was assumed that the pattern of household consumption is linear at different income levels, and that the proportional breakdown of household expenditures of households with average after-tax income is representative of all households. In reality, households at different income levels likely exhibit differences in household consumption.

Private sector capital spending – It was assumed that the breakdown of private sector capital spending by industry is based on the proportion of each industry’s Albertan workforce that works in Edmonton. However, actual capital spending patterns within Edmonton may differ from those in Alberta overall for any given industrial sector.

Emission factor weighting – Emission factor weightings were based on assumed breakdown of spending for each expenditure category for household expenditure, private sector capital spending, and capital spending. While the weightings were informed by available expenditure information the spending breakdowns are aggregated, which may affect the accuracy of the estimated emission factors, and thus GHG estimates.

Government transfers, wages and salaries, and tax payments – It is assumed that government transfers, payment of wages and salaries, and tax payments do not contribute directly to GHG emissions. It is assumed that GHG emissions only occur at the point of final demand, via a good or service procured by a household, private organization, or government body.

Government spending – It is generally assumed that provincial and federal government spending within Edmonton is proportional to City’s population relative to Alberta overall. According to the 2016 Census, Edmonton had a population of 932,546 persons in 2016, approximately 22.9% of Alberta’s total (Statistics Canada, 2017).

3.3.3 Data Sources

3.3.3.1 Sources

Data used in the analysis came from the sources described in Table 6.

Table 6 Data Sources Used in Consumption Based GHG Inventory

Source	Type	Description
City of Edmonton	2016 Annual Report.	Consolidated Statement of Operations and Accumulated Surplus
		Schedule 1 - Consolidated Schedule of Tangible Capital Assets
Government of Alberta	2016/2017 Annual Report	Consolidated Statement of Operations
		Schedule 12 – Tangible Capital Assets
Statistics Canada	2013. Provincial Symmetrical Input-Output Tables. 2010.	Symmetrical input-output tables for Province of Alberta, for 40 expenditure categories (goods, services, taxes, government spending, etc.) for 40 industry/economic sectors.
Statistics Canada	2016 Census (Edmonton, Alberta)	2016 Census profile for Edmonton, Alberta Census sub-division.
Statistics Canada	Table 36-10-0035-01: Household Expenditure (Alberta)	Capital and repair expenditures, broken down by industry, for years: 2014 – 2018
Statistics Canada	Table 36-10-0225-01: Household Expenditure (Alberta)	Breakdown of total Alberta household expenditures on goods and services for years 2014 – 2017
Statistics Canada	36-10-0450-01: Government Spending (Federal)	Federal government revenue and expenditure in Alberta: 2014-2017

3.3.3.2 Data Quality Assessment

The analysis was based on a high-level breakdown of expenditures associated with household consumption, private sector capital spending, and government spending. Because it is based on highly aggregated information, there is low level of precision of CB GHG Inventory.

3.3.3.3 Limitations

The analysis undertaken is not based on the proportion of money spent on end-uses, but the proportion of economic activity associated with spending that would be reflected in industry output per major NAICS commodity classification codes. The data sets used in this analysis does not have the level of granularity needed to distinguish specific products produced in different areas. Furthermore, the data sets and assessment does not account for regional differences in income and cost of goods and services. This could be addressed by modifying the emission intensity factors based on purchasing power parity to account for regional differences in income and cost of goods and services, but this would require a very detailed economic trade assessment.

The assessment assumes that the production of goods and services imported into Canada and the City are equal in terms of intensity. However, in reality this is not the case and thus GHG emissions intensities are likely to be higher in some areas and countries than others. For example, using the Green Design Institute of Carnegie Mellon University

Life Cycle Assessment (LCA) GHG emission factors, the City's consumption GHG emissions are estimated to be an order of magnitude higher than the production based GHG emissions. An in-depth study of LCA GHG emissions specific to the City's economic goods and services accounts would need to be completed to improve the accuracy of the emission factors.

The CB assessment data cannot readily be re-organized into reporting sectors to allow for a comparison to the PB GHG inventory. On the flip-side, the PB inventory is also limited in this aspect as well as the specific sources of the data (e.g. postal code) is not available due to privacy requirements. More disaggregated models of household spending may improve the accuracy of the CB analysis. Such models could be developed using a variety of statistical or modeling techniques, including multiple regression analysis, econometric modelling, or sector end-use modelling. As it relates to improving the accuracy of the consumption-based analysis of GHG emissions, it may be possible to obtain from Statistics Canada custom releases of data aggregated at the level of a census subdivision and/or more highly disaggregated consumption and expenditure information.

3.4 RESULTS

3.4.1 Household Spending & GHG Emissions

In 2016 average household income within the City of Edmonton was $114,083 (Statistics Canada, 2017). Of this amount, approximately 17.9% was paid in income taxes resulting in average disposable household income of $93,682. Figure 10 illustrates the estimated breakdown of household expenditures in City of Edmonton, based on Statistics Canada household survey information (Statistics Canada, Table 36-10-0225-01). Shelter and transportation are the largest household expenditures, collectively accounting for 40% of all household expenditures (Figure 10).

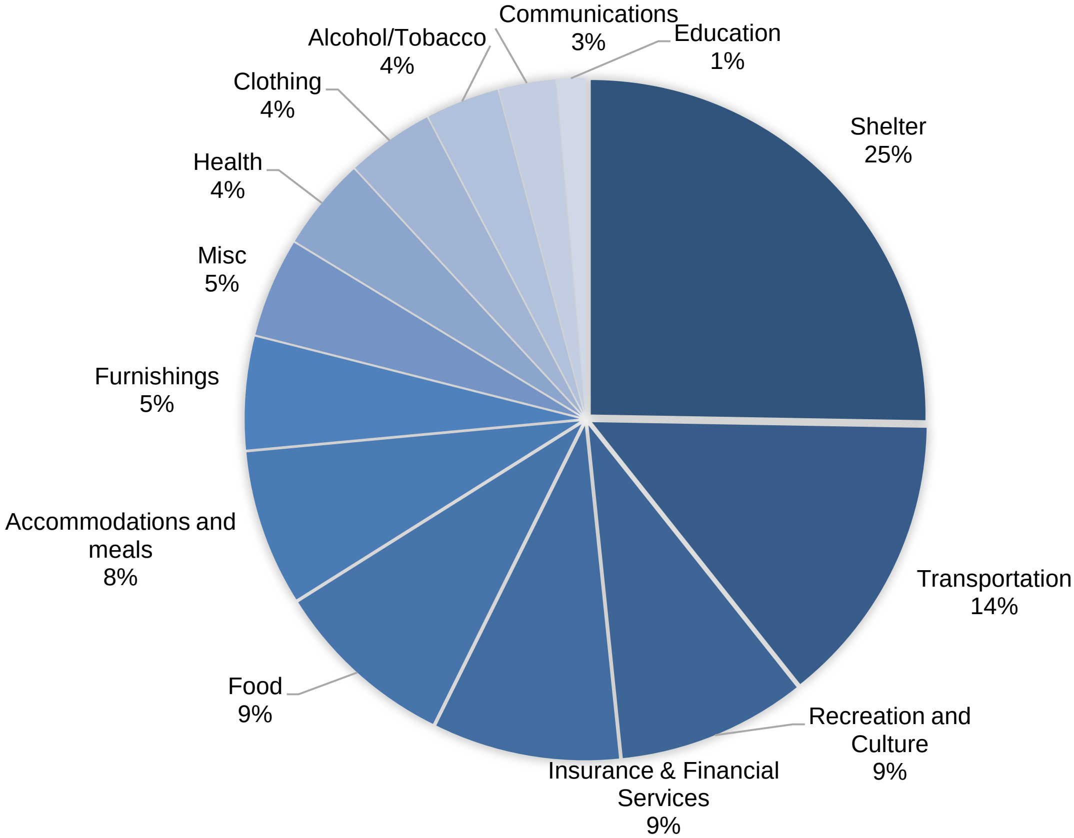

Figure 10 City of Edmonton 2016 Household Consumption Breakdown (Statistics Canada. Not dated (2))

Edmonton's 360,825 households purchased approximately $32.7 billion in goods and services in 2016. Consumption taxes accounted for an average of 6.3% of purchases, resulting in net of taxes purchases of $31,677 million. Figure 11 provides a breakdown of 2016 net household spending in Edmonton, organized by major economic commodity categories. Manufacturing, real estate, and wholesale/retail trade collectively account for 57% of all household consumption, with the remaining 12 sectors accounting for 43%.

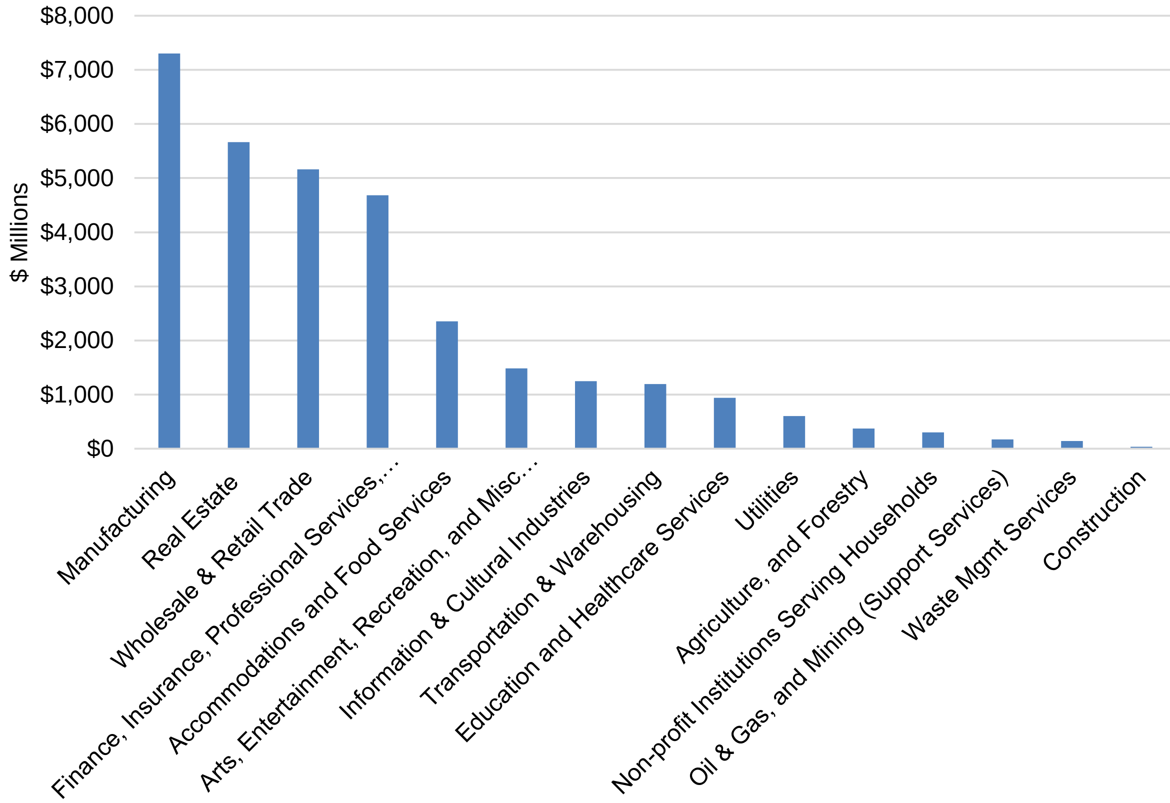

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Figure 11 Edmonton 2016 Household Consumption by Industry Sector

In 2016, household consumption accounted for an estimated 16.4 million tonnes of GHG emissions in the City, of which the top three sectors, manufacturing, wholesale and retail trade, and real estate accounted for over 64% of total emissions (Table 7).

Table 7 Household Consumption GHG Emissions

Sector	Intensity Factor ($M / tCO_2e)	GHG Emissions (tCO_2e)
Agriculture, Forestry	1,775	668,085
Oil & Gas, Mining (Support Services)	1,000	174,930
Utilities	1,549	937,412
Construction	393	14,647
Manufacturing	672	4,904,841
Wholesale & Retail Trade	771	3,978,149
Transportation & Warehousing	891	1,067,730
Information & Cultural Industries	187	234,263
Finance, Insurance, Professional Services, Business Management	158	741,910
Real Estate	294	1,666,367

Sector	Intensity Factor ($M / tCO₂e)	GHG Emissions (tCO₂e)
Waste Management Services	650	91,993
Education And Healthcare Services	239	225,250
Accommodations And Food Services	388	911,347
Arts, Entertainment, Recreation, And Miscellaneous Services	472	702,780
Non-Profit Institutions Serving Households	319	96,577
Total		**16,416,282**

3.4.2 Private Sector Capital Spending & GHG Emissions

2016 private sector capital spending in Alberta was $55.8 billion (Statistics Canada Table 34-10-0035-01), of which an estimated $8.4 billion in capital expenditure occurred in City. The top three sectors: oil and gas, transportation, and utilities, accounted for an estimated 63% of all private sector capital spending within City, with 37% of spending spread over the other sectors (Figure 12).

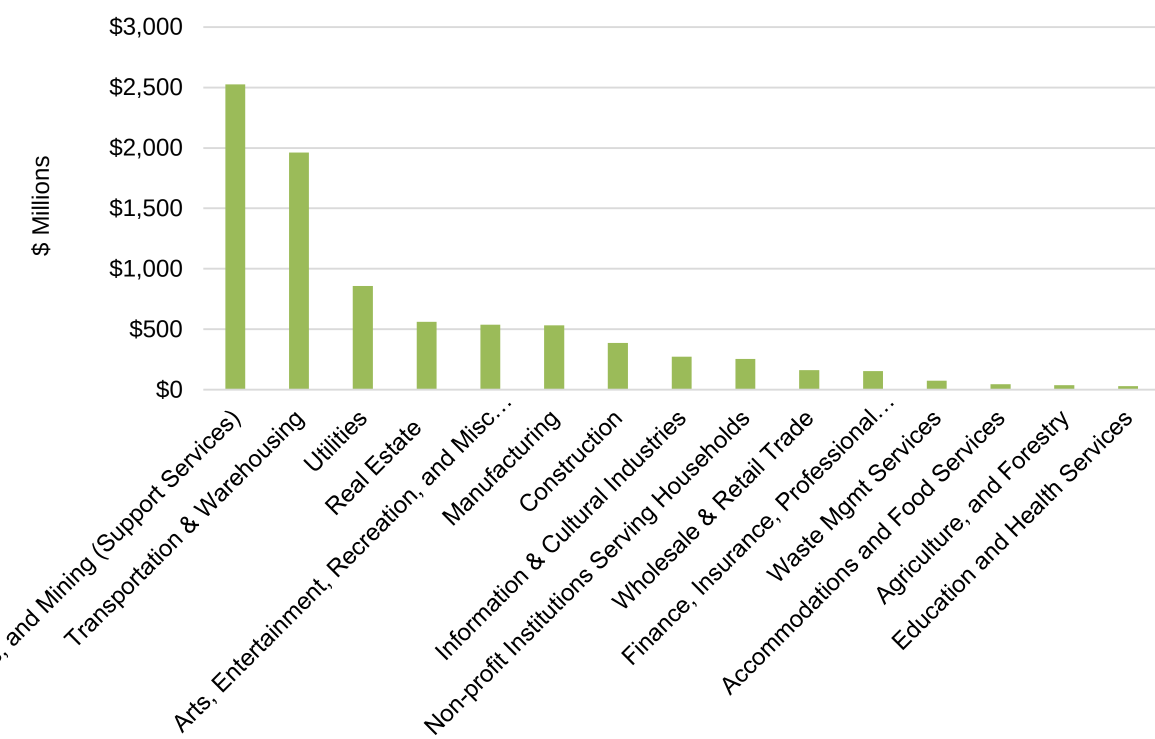

Figure 12 City of Edmonton 2016 Private Capital Expenditure Spending by Industry Sector

Of the $8.4 billion in private capital expenditure spending, an estimated 2.3% ($191 million) were taxes on products and production, while wages and salaries comprise an estimated 24% ($2.0 billion). Both taxation and wage payment are financial transfers and are assumed to take place with no GHG emissions.

In 2016, private sector capital spending accounted for an estimated 5.8 million tonnes of GHG emissions in the City (Table 8) of which oil and gas/mining, transportation/warehousing, and utilities account for 78% of all emissions.

Table 8 GHG Emissions from Private Sector Capital Spending

Sector	Intensity Factor ($M / tCO_2e)	GHG Emissions (tCO_2e)
Agriculture, Forestry	1,775	50,178
Oil & Gas, Mining (Support Services)	1,000	1,862,341
Utilities	1,851	1,171,953
Construction	349	99,271
Manufacturing	1,006	395,653
Wholesale & Retail Trade	280	33,203
Transportation & Warehousing	1,171	1,693,635
Information & Cultural Industries	187	37,603
Finance, Insurance, Professional Services, Business Management	307	34,921
Real Estate	302	125,177
Waste Management Services	650	35,690
Education And Healthcare Services	272	6,144
Accommodations And Food Services	380	12,959
Arts, Entertainment, Recreation, And Miscellaneous Services	472	186,954
Non-Profit Institutions Serving Households	319	59,761
Total		**5,805,442**

3.4.3 Government Spending & GHG Emissions

3.4.3.1 City of Edmonton Operational Spending

In 2016, the City incurred approximately $2.8 billion of operational spending (City of Edmonton 2017). Operational spending is spread over a number of city services, as summarized in Figure 13.

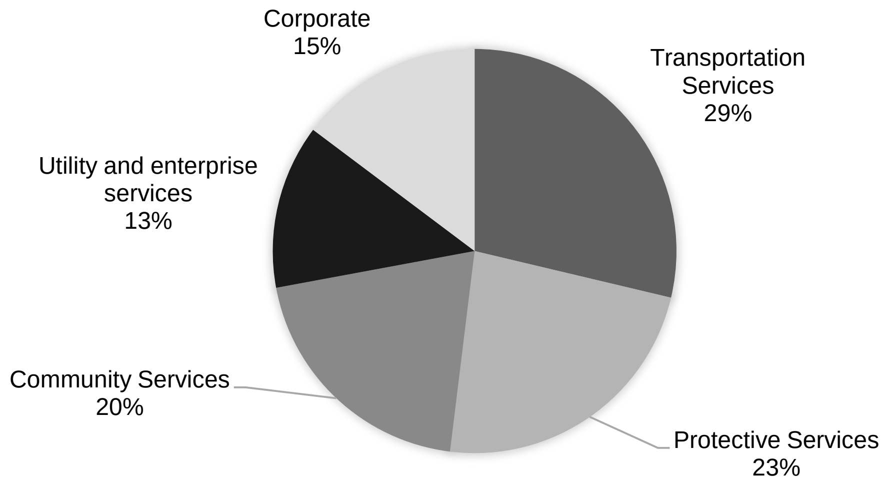

Figure 13 City of Edmonton 2016 Operational Spending (Edmonton, 2017)

In 2016, the City spent approximately $1.9 billion on capital assets, including assets and transfers. Of this, approximately 52% was spent on engineered systems (roadways, and drainage), 32% on buildings, and the balance on machinery, equipment, land, and other expenditures (Table 9).

Table 9 2016 City of Edmonton Capital Spending (Edmonton, 2017)

Sector	Additions / Transfers to Capital Assets ($ Thousands)
Buildings	$616,875
Roadway system	$592,851
Drainage system	$414,737
Machinery and equipment	$101,494
Land improvements	$72,618
Land	$63,967
Vehicles	$43,350
Light rail transit	$11,256
Bus system	$6,057
Waste	$4,473
Other	$1,595
Total	**$1,929,273**

3.4.3.2 Government of Alberta

In 2016 the Government of Alberta (the Province) spent $48.3 billion providing a wide variety of services within the province. Health care and education dominate provincial spending, accounting for over 67% of total spending, with all other government services and programs accounting for the balance (Figure 14). Assuming that provincial government operational spending is evenly distributed by population, the City accounts for $12.1 billion of the Province's operational spending, or approximately 22.9% of the total spend.

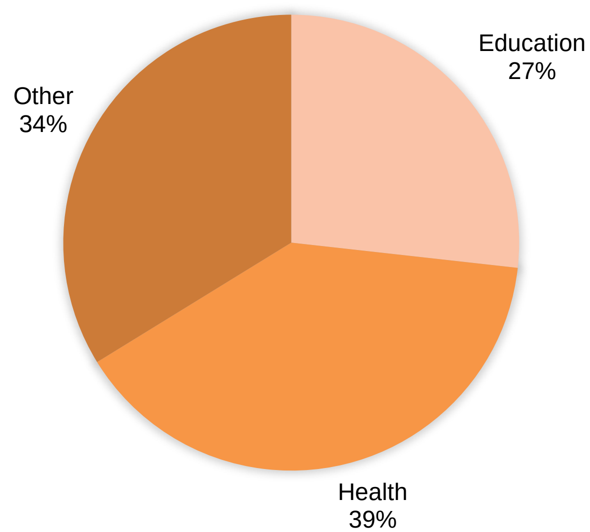

Figure 14 2016/2017 Government of Alberta Operational Spending (Alberta, 2017)

In 2016, the Province spent approximately $5.1 billion on capital assets, including assets and transfers. Of this, approximately 49% was spent on buildings, 20% on dams and water management works, and 18% on roads (32% on buildings, and the balance on machinery, equipment, land, and other expenditures) (Table 10).

Table 10 2016 Provincial Capital Spending (Alberta, 2017)

Sector	Additions / Transfers to Capital Assets ($ Thousands)
Buildings	$2,482
Dams/Water Management	$1,039
Highways and Roads	$902
Equipment	$405
Land	$101
Computers	$66
Bridges	$60
Land Improvements	$34
Total	**$5,089**

Assuming that 10% of Provincial spending on water management and roads occurs in the City, and 23% for other capital items, the Province spent an estimated $807 on capital expenditures occurring within City boundaries in 2016.

3.4.3.3 Federal Government Spending

In 2016, total federal spending in Alberta amounted to $27.3 billion. However, just 17.4% of federal spending ($4.7 billion) was on goods and services which would result in the release of GHG emissions. The bulk of federal spending in Alberta was transfers to households, other governments, and other organizations including childcare benefit, employment insurance payments, Old Age Security, and federal funding for healthcare and education. Such transfers are reflected in household, government, and non-government organization spending, and thus to avoid double-counting have not been not included in the assessment.

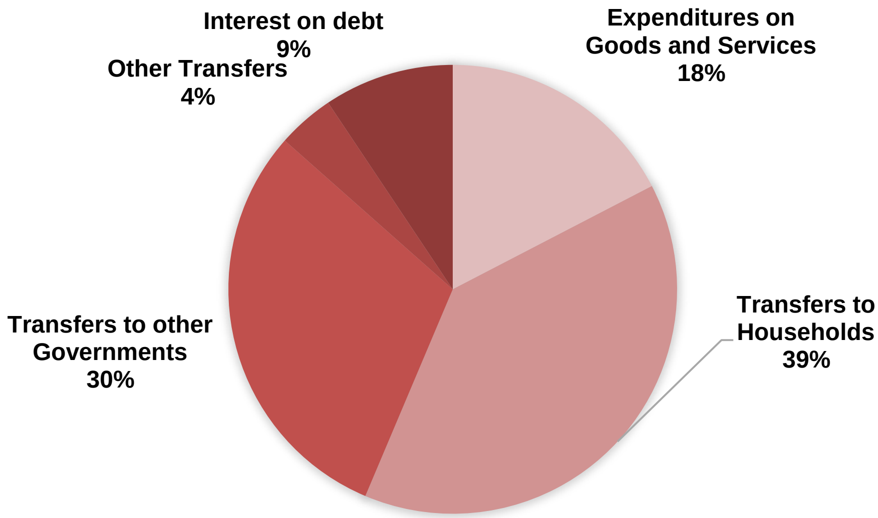

Figure 15 Federal Government Spending in Alberta 2016 (Statistics Canada Table 36-10-0450-01)

Assuming that federal government operational spending is evenly distributed by population, the City received approximately $1.1 billion worth of federal goods and services spending in 2016.

3.4.3.4 Total Government Spending

Total City 2016 spending, net of transfers and interest payments is estimated at $16.0 billion. Figure 16 illustrates the breakdown of expenditures between goods and services, taxes, wages and salaries, and gross operating surplus. The payment of wages and salaries is the largest expenditure item, accounting for over half of overall government spending. Because wage payment is a form of transfer to households, expenditures on wages and salaries are not included in the estimate of GHG emissions. Gross operating surplus includes funds used for capital spending as well as operational deficits or surpluses. In summary, for the 2016 reporting year, the three levels of government purchased approximately $6.0 billion in goods and services within the City's boundaries that would contribute to the CB inventory.

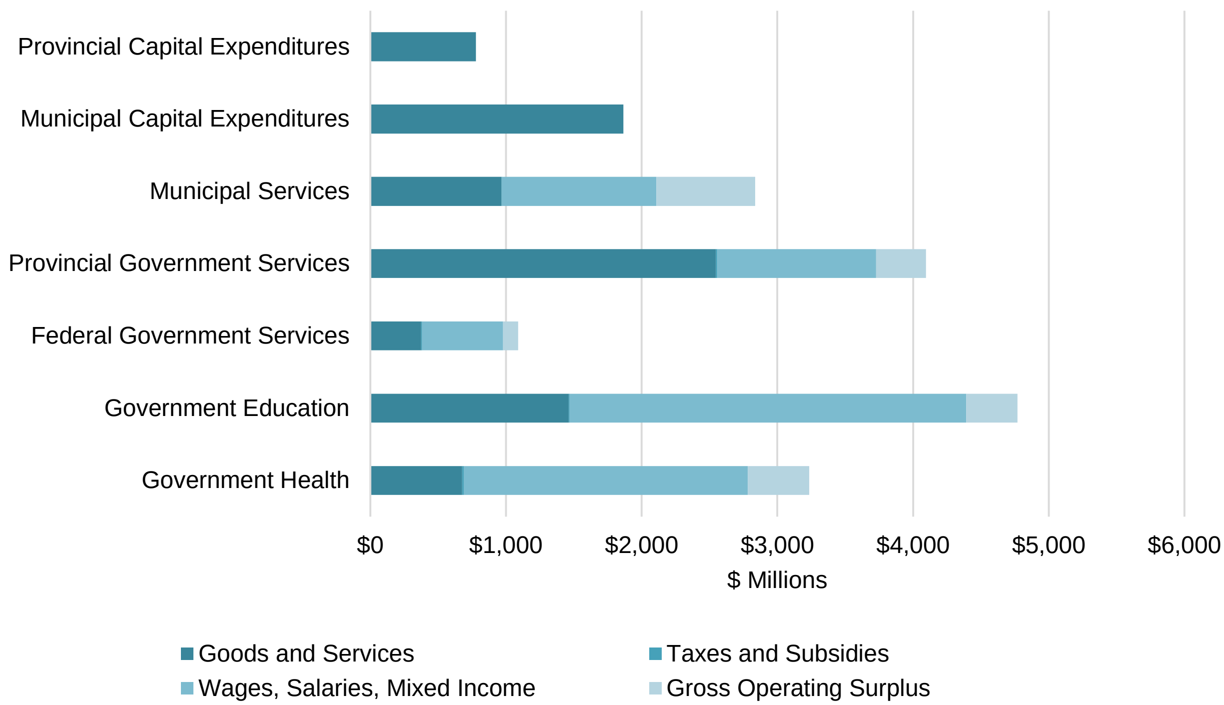

Figure 16 **Summary of 2016 Government Spending in Edmonton, Net of Transfers and Interest Payments**

In 2016, government spending accounted for an estimated 4.6 million tonnes of GHG emissions. Of these GHG emissions, City spending, inclusive of operational spending and capital expenditures accounted for an estimated 34% of emissions (1.5 $MtCO_2e$). Provincial spending, including spending on health, education, and other services, as well as capital expenditure accounted for an estimated 61% of government-related emissions (2.8 $MtCO_2e$). Federal government spending accounted for an estimated 244,326 tonnes of GHG emissions in 2016 (or 5% of total government GHG emissions). Expenditures related to the purchase of manufactured goods, construction, and wholesale and retail trade collectively accounted for over 65% of GHG emissions associated with government spending in 2016. A summary of government spending GHG emissions is presented in Table 11.

Table 11 GHG Emissions from Government Spending

Sector	Government Health GHG Emissions (tCO_2e)	Government Education GHG Emissions (tCO_2e)	Federal Government Services GHG Emissions (tCO_2e)	Provincial Government Services GHG Emissions (tCO_2e)	Municipal Services GHG Emissions (tCO_2e)	Municipal Capital Expenditures GHG Emissions (tCO_2e)	Provincial Capital Expenditures GHG Emissions (tCO_2e)	Total GHG Emissions (tCO_2e)
Agriculture, Forestry	2,433	15,734	1,129	94,432	1,628	-	-	**115,356**
Oil & Gas, Mining (Support Services)	14,935	13,134	2,246	10,533	30,270	-	-	**71,117**
Utilities	32,477	28,033	11,244	50,080	85,878	-	-	**207,713**
Construction	43,813	33,332	11,752	28,733	56,496	694,964	274,143	**1,143,232**
Manufacturing	104,455	540,032	68,954	280,422	138,087	136,888	101,411	**1,370,251**
Wholesale & Retail Trade	40,376	209,350	25,475	126,522	54,184	-	-	**455,906**
Transportation & Warehousing	102,731	35,109	38,737	29,172	45,169	17,397	-	**268,315**
Information & Cultural Industries	10,553	6,188	2,323	9,555	7,066	-	-	**35,686**
Finance, Insurance, Professional Services, Business Management	20,542	15,757	15,249	66,761	20,051	-	-	**138,359**
Real Estate	-	-	-	-	-	-	-	**-**
Waste Management Services	30,082	38,846	33,106	69,621	118,392	-	-	**290,045**
Education And Healthcare Services	12,868	17,320	14,331	34,459	50,636	-	-	**129,615**
Accommodations And Food Services	6,891	26,272	3,625	9,942	7,510	-	-	**54,240**
Arts, Entertainment, Recreation, And Miscellaneous Services	26,482	35,795	15,675	116,854	61,861	-	-	**256,668**
Non-Profit Institutions Serving Households	326	2,317	480	18,152	5,381	-	-	**26,656**
Total	**448,965**	**1,017,220**	**244,326**	**945,237**	**682,609**	**849,248**	**375,554**	**4,563,159**

3.4.4 Other Spending

GHG emissions resulting from spending by the non-profit sector are included in the estimated GHG emission inventory associated with household consumption, private sector capital spending, and government spending.

3.5 DISCUSSION

3.5.1 Summary

Total City consumption based GHG emissions are estimated at 26.8 $MtCO_2e$. As it relates to the total CB inventory, for the 2016 reporting year, construction, manufacturing and wholesale trade account for 53% of the City's GHG emissions to which 37% of these GHG emissions resulted from household consumption (Figure 17).

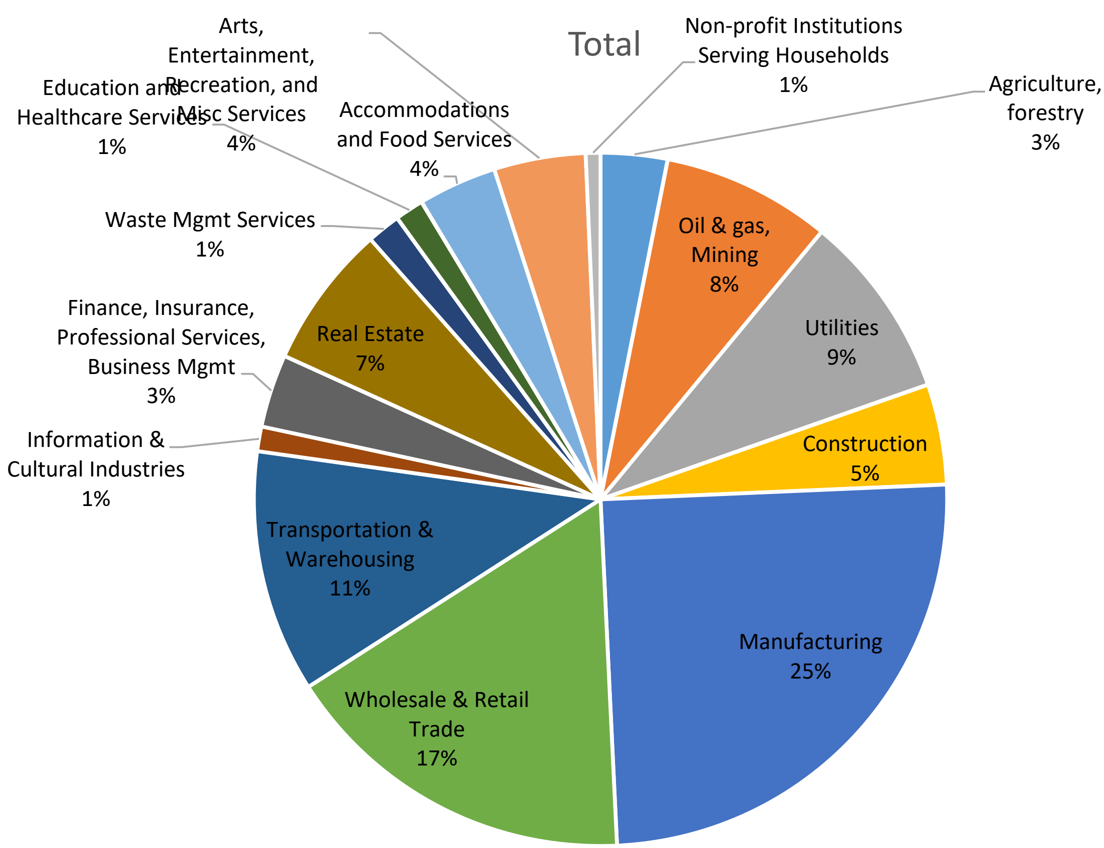

Figure 17. Breakdown of Total Consumption Based GHG Emissions

Of the total consumption based GHG emissions, household consumption accounted for 61% of total emissions, followed by private sector capital investment at 22%, and then government spending at 17%. This breakdown is comparable with the breakdown of Canada's 2016 GDP by expenditure, which was: household consumption (56%), private sector capital spending (21%), government spending (21%), other (1%) (Statistics Canada, CANSIM Table 380-0064).

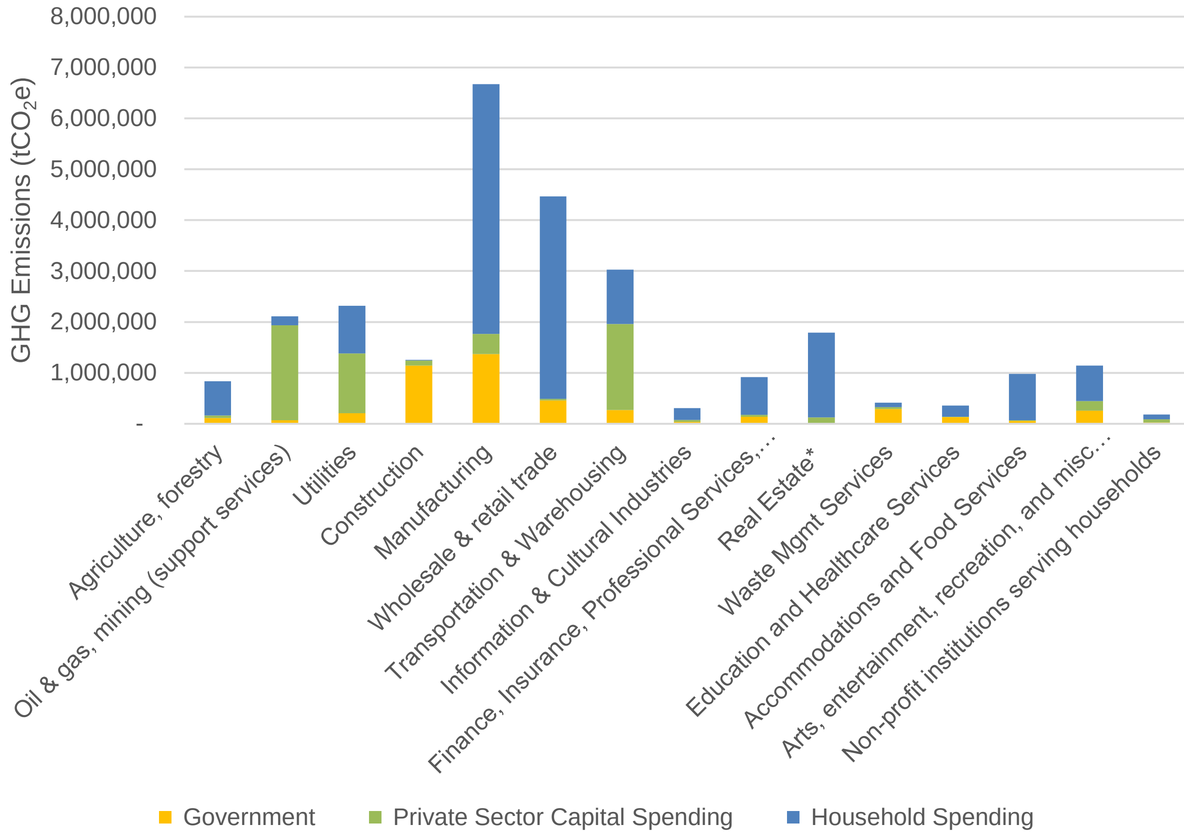

Figure 18 GHG Emissions associated with City of Edmonton, Consumption Based Estimate ($MtCO_2e$)

3.5.2 Comparison of GHG Inventory Results

The PB and CB inventories both estimate GHG emissions from numerous GHG sources, including residential, commercial, industrial, transportation, waste and land-use. But how they account for the GHG emissions differ significantly. The PB inventory accounts for all emissions that physically originate within the City's municipal boundaries, like building and vehicle fuel consumption, the consumption of grid-supplied electricity, heating and/or cooling, and the disposal of waste. The CB inventory includes all the GHG emissions resulting from the consumption or use of goods and services by residents, businesses, and governments located within the City's municipal boundaries. For the 2016 reporting year, the City's PB and CB GHG emissions amounted to 18.3 $MtCO_2e$ and 26.8 $MtCO_2e$, respectively.

On a per-capita basis, the City's consumption GHG emissions amount to 28.7 tCO_2e/person which is 47% higher than the City's per-capita production GHG emissions. On an absolute basis, the City's consumption GHG emissions are 32% higher than the production based GHG emissions which is consistent with other comparable consumption based GHG emissions inventories. For example, the State of Oregon's are estimated to be 19% higher than their estimated production GHG emissions (Oregon, 2015) and the San Francisco Bay Area's consumption based GHG emissions are 35% higher (UC Berkley, 2015). On the higher end, London, England's CB emissions are estimated to be 157% higher that the PB emissions (PAS, 2018). These results, in addition to other city and state results, are presented in Table 12.

Table 12 Other City And State PB and CB GHG Inventories

City	Production Based GHG Inventory Results	Consumption Based GHG Inventory Results	Difference (%)
City of London, UK	44,440,000 tCO_2e	114,100,000 tCO_2e	156.8%
District of Saanich, CAN	426,000 tCO_2e	881,000 tCO_2e	106.8%
City of Vancouver, CAN	2,847,507 tCO_2e	5,530,605 tCO_2e	94.2%
City of Victoria, CAN	387,694 tCO_2e	703,000 tCO_2e	81.3%
San Francisco Bay Area, US	86,600,000 tCO_2e	115,200,000 tCO_2e	33.0%
State of Oregon, US	62,800,000 tCO_2e	74,700,000 tCO_2e	18.9%

The relation between the City's GHG inventories is presented in Figure 19, and summarized in Table 12.

Consumption Based GHG Inventory

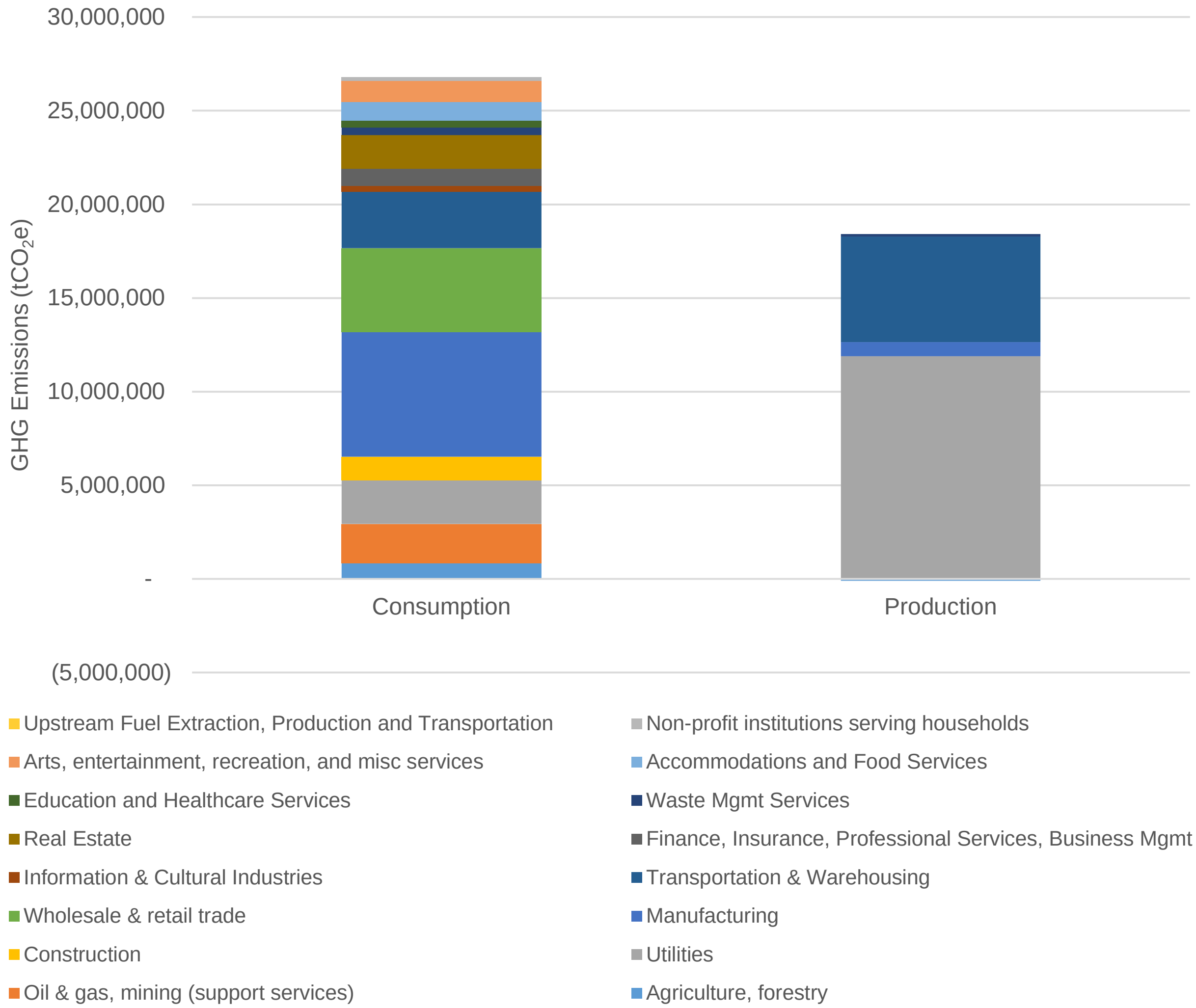

Figure 19. Comparison of GHG Inventory Approaches

Table 13 Summary of GHG Emissions (tCO_2e) by GHG Method And Sector

Method / Source	Agriculture, Forestry	Oil & Gas, Mining	Utilities	Construction	Manufacturing	Wholesale & Retail Trade	Transportation & Warehousing	Information & Cultural Industries	Finance, Insurance, Professional Services, Business Mgt.	Real Estate	Waste Management Services	Education And Healthcare Services	Accommodations and Food Services	Arts, entertainment, recreation, and Misc. services	Non-profit institutions serving households	Total GHG Emissions (tOC_2e)
Consumption GHG Emissions (tCO_2e)	833.6	2,108.4	2,317.1	1,257.2	6,670.7	4,467.3	3,029.7	307.6	915.2	1,791.5	417.7	361.0	978.5	1,146.4	183.0	26,784.9
Production GHG Emissions (tCO_2e)	(103.9)	-	11,891.3	-	747.2	-	5,647.2	-	-	-	123.8	-	-	-	-	18,305.6

Stationary energy and transportation GHG emission sources account for more than 95% of the City's PB GHG emissions inventory, whereas in the CB inventory, similar sources only account for 20% of the GHG inventory. A possible reason for the difference is that the PB inventory uses an Alberta based utility emission factor, whereas the CB GHG inventory uses a Canadian average which is expected to be quite lower. In the CB inventory, the consumption of food and beverages, vehicles, construction materials, air travel services, furnishings, electronics, and clothing are all significant consumption categories in the CB inventory (~57%); many of the GHG emissions are not captured in the PB inventory as they are out of scope. Transportation GHG emissions in the CB inventory are remarkably lower than the PB inventory. The most likely reason is that the transportation GHG emissions are spread out over a number of categories (e.g. waste management, construction, manufacturing) and due to the nature of the data, cannot be disaggregated to allow for better comparison. Lastly, the CB waste GHG emissions are expectedly higher than the PB inventory waste GHG emissions as the former includes the operation of waste facilities, equipment, and transportation related GHG emissions. However, the CB inventory does not include the downstream GHG emissions from waste like the PB inventory, and thus will result in an underestimate of GHG emissions.

3.5.3 Conclusion

The CB inventory reiterates what the City's PB inventories have historically shown – i.e., the City should continue to focus on reducing GHG emission from buildings and road transport. The CB inventory also shows that the consumption of manufactured goods and services, and food are sources of significant GHG emissions in the City, and further exploration of these GHG emissions sources is warranted. However, the data available to support the preparation of a localized City-based CB inventory is not granular enough to identify where in the supply chain the GHG emissions are likely to arise and thus is limited in its ability to support GHG related policy and program decisions that the City may wish to take. On this basis, it is recommended that the City expand its current GPC BASIC+ GHG inventory to include the GHG emission sources required under the PAS 2070 direct plus supply chain (DPSC) approach which includes accounting for GHG emissions from the consumption of food and drink, water, construction materials. Specifically, a bottom-up data collection approach, rather than top-down (as applied in the CB assessment) is recommended to capture local consumption trends and GHG emission sources in the supply chain. It is still recommended that the City continue to follow the GPC Protocol which is a requirement for cities that have committed to the Global Covenant of Mayors. Should the City include the sources under PAS 2070, the City would be reporting under the BASIC+SC level. Lastly, it is recommended that the City complete a complete CB inventory every 5-years, which would align with National Census reporting, to assess general consumption trends and patterns over time.

4.0 DIRECT PLUS SUPPLY CHAIN (DPSC) APPROACH

4.1 OVERVIEW

The DPSC approach captures direct GHG emissions from activities within the city boundary and indirect GHG emissions from the consumption of grid-supplied electricity, district heating or cooling, transboundary travel and the consumption of key goods and services produced outside the city boundary (PAS 2070, 2018). This includes the extraction, processing, refining and transport of primary fuels used for energy generation, as well as cradle-to-gate GHG emissions associated with the consumption of goods and services like food and drink, water, and construction materials. PAS 2070 recommends also including other goods and services that are estimated to make a material contribution to a city's GHG inventory (>2%), such as financial goods and services provided outside of the City to residents within the City. Based on the City's PB and CB inventories, no other sources are likely to exceed this threshold.

The following section provides an overview of how each of the additional GHG emissions sources identified under the PAS 2070 DPSC method could be quantified by the City.

4.1.1 GHG Emissions From The Extraction, Processing, Refining And Transport Of Primary Fuels

The data to estimate GHG emissions from the extraction, processing, refining and transport of primary fuels used for energy generation can be estimated using the energy data collected in the PB inventory and Alberta derived extraction, processing, and refining emission factors for gasoline, diesel and natural gas. These emission factors are presented in Table 13.

Table 14 Alberta Based Extraction, Processing, Refining And Transport Emissions Factors

Source	Emission Factor
Diesel Production (tCO_2e/L)	0.000411692
Gasoline Production (tCO_2e/L)	0.000411692
Natural Gas Production (tCO_2e/m^3)	0.000200086

Using 2016 diesel, gasoline and natural gas consumption values from the PB GHG inventory, these GHG emissions are estimated to be 1,181,965 tCO_2e. Under the GPC Protocol, as with PAS 2070, these GHG emissions are to be reported as Scope 3 GHG emissions sources.

4.1.2 GHG Emissions From Food And Drink Consumption

GHG emissions from food and drink consumption are to be disaggregated by (PAS 2070, 2018):

- Cradle to gate GHG emissions associated with economic final consumption of food and drink within the city; and

- Direct GHG emissions from food production on a non-commercial basis within the city boundary (i.e. food produced on small plots of land used by city residents and not sold to others).

PAS 2070 notes that the GHG emissions from the food and drink life cycles correlate well with final economic expenditure data and thus recommends this approach. However, PAS 2070 requires that this be limited to residents only and that consumption of food and drink by visitors be excluded from the assessment where possible. Cognisant of the limitations using economic data (noted in the prior section on the CB inventory), two other options to estimate food and drink consumption can be considered: top-down, and bottom-up.

A top-down method would involve using national food availability per person by year and applying food specific LCA GHG emissions factors. This disaggregated data is collected by Statistics Canada data and would need to be organized into larger food groups to estimate per-capita consumption by food type. The approach is limited in that it uses national consumption patterns, and non-localized life cycle emission factors.

A bottom up approach would involve completing localized food and waste surveys to estimate actual food and drink consumption as well as the amount of waste going to landfill. Although the approach would still use non-localized life cycle emission factors, it would provide the City with a better understanding of localized consumption patterns as well as a breakdown of waste streams. The data from thee surveys could also feed into City policy decisions and programs, such as a Solid Waste Management Plan. The challenge with this approach is that it is resource and finance intensive.

To estimate direct GHG emissions from food production on a non-commercial basis within the city boundary (i.e. food produced on small plots of land used by city residents and not sold to others), for both approaches, the City would need to use Geographic Information Systems (GIS) to estimate the total residential garden area (in hectares) and then apply a generalized agriculture land-use emission factor (also used in the PB inventory to estimate direct and indirect soil GHG emissions from crop land under the AFOLU sector).

4.1.3 GHG Emissions From Water

PAS 2070 (2018) requires that GHG emissions from water assessment be disaggregated by residential buildings, and commercial, industrial and government buildings and facilities, and must GHG emission sources from:

- mains water supply within the city boundary from sources within the city boundary;
- mains water supply outside the city boundary from supplies within the city boundary; and
- mains water supply within the city boundary from sources outside the city boundary.

To estimate GHG emissions from water, the City can use the EPCOR fuel consumption data used in the City Corporate Operations GHG inventory as the data is broken down by utility service (i.e. power, water, etc.). The fuel consumption volumes and GHG emissions for water will need to be deducted from the Stationary Energy Category as to avoid double counting.

4.1.4 GHG Emissions From Construction Materials

Under PAS 2070, cities are only required to report on the life cycle of GHG emissions associated with annual use of cement and steel materials as all other construction materials are likely to fall under the 2% threshold reporting requirement.

Due to the limitations in the granularity of the economic data, estimating the actual consumption of steel and concrete is challenging as a result of the poor granularity of the data, and that any estimate have a significant amount of uncertainty as it relates to the end-use. One option for the City to consider is to derive a set of building archetypes to estimate GHG emissions (e.g. condos are cast-in place concrete, single family residential are wood-framed, etc.). This would require the creation of building archetypes for each sector (residential, multi-family, commercial, institutional, etc.) and then use the Athena Building GHG estimator to quantify the GHG emissions associated with the construction of each archetype. The detail of the building archetype does not need to be overly onerous – for example, a commercial building could be identified as a cast in place concrete structure that includes mechanical and electrical services, washrooms, with no finishes. Using GIS and these architypes, for each reporting year, the City could then assess the number of new buildings, calculate their total height and gross square footage, by type, and then estimate the GHG emissions based on the calculated building archetypes already developed by the City. Over time, the City could require that any new commercial buildings over a set square footage complete a life cycle analysis of the building as part of a development permit application or zoning change.

There is likely to be additional concrete use as a result of City operations (pour in place, and the installation of sanitary sewer and storm water trunk lines) which could be tracked through the City's procurement department, or also estimated using GIS. Once the total volume of concrete has been determined, the GHG emissions can be estimated using a lifecycle emission factor for concrete.

4.1.5 PAS 2070 Reporting Requirements

PAS 2070 does not have any additional reporting requirements beyond what is already established in the GPC Protocol. Should the City include the DPSC reporting sectors, the City would be required to assess both data and emission factors on their level of uncertainty (Low, Medium, High) and data quality (Low, Medium, High) as well as document data sources and any assumptions.

4.1.6 Modifications to the Existing City Community GHG Inventory

Should the City wish to meet the PAS 2070 DPSC reporting requirements, the City would need to update its community GHG inventory to include reporting on the additional sectors noted herein. Specifically, in-boundary water GHG emissions would be reported under Scope 1 (and netted out of Stationary Energy to avoid double counting), and out of boundary water GHG emissions being reported under Scope 3. GHG emissions from the extraction, processing, refining and transport of primary fuels, food and drink, and construction materials would all be reported under Scope 3. As these additional GHG emissions sources are likely to be material (>10%) of the City's community GHG inventory, the City will need to update its base year and prior reporting years.

Meeting the PAS 2070 DPSC reporting requirements would shift the City to the BASIC+SC reporting level under the GPC Protocol.

5.0 CLOSURE

This report has been prepared for the sole benefit of the City of Edmonton. The report may not be used by any other person or entity without the express written consent of Stantec and the City of Edmonton. All parties are subject to the same limit of liability and other terms as agreed to in the Stantec project agreement under which the work was conducted.

Any use that a third-party makes of this report, or any reliance on decisions made based on it, is the responsibility of such third parties. Stantec accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made, or actions taken, based on this report. If this becomes a public document, members of the public and other third parties may only rely on this report, for its intended purposes, with the expressed written consent of Stantec.

The conclusions presented in this report represent the best technical judgment Stantec based on the data obtained from the work.

This report was prepared by Daniel Hegg. Quality review was provided by Nicole Flanagan.

We appreciate being of service to the City of Edmonton on this project. Should you have any questions, please contact the undersigned.

Sincerely,

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APPENDIX A

Production Based GHG Emission Factors

Appendix A PRODUCTION BASED GHG EMISSION FACTORS

The following emission factors were used in the quantification of the City's production based GHG inventory for the 2016 reporting year.

Table 15 Production Based Emission Factors

Fuel Type / Activity	Total CO_2e	Units
Reported Consumption Intensity for AB	0.9	t CO_2e/MWh
Reported Generation Intensity for AB	0.76	t CO_2e/MWh
Propane (Stationary)	0.001542784	tonnes CO_2e/L
Alberta - Natural Gas (Marketable) - Industrial	0.001938759	tonnes CO_2e/ m^3
Alberta - Natural Gas (Marketable) - Manufacturing Industries	0.001938759	tonnes CO_2e/ m^3
Alberta - Natural Gas (Marketable) - Residential, Commercial	0.001939355	tonnes CO_2e/ m^3
Fugitive Emissions (natural gas) - Transmission	0.00682588	Gg $CO_2e/10^6$ m^3 marketable gas
Fugitive Emissions (oil) - Oil Transport (pipelines)	0.00013549	Gg $CO_2e/10^3$ m^3 marketable gas
Gasoline-LDV	0.00246181	tonne CO_2e / L
Gasoline-LDT	0.00249484	tonne CO_2e / L
Gasoline-HDV	0.0023773	tonne CO_2e / L
Gasoline-ORVE	0.0023984	tonne CO_2e / L
E10-LDV	0.00223021	tonne CO_2e / L
E10-LDT	0.00226324	tonne CO_2e / L
E10-HDV	0.0021457	tonne CO_2e / L
E10-ORVE	0.0021668	tonne CO_2e / L
Diesel-LDV	0.002756835	tonne CO_2e / L
Diesel-LDT	0.00275726	tonne CO_2e / L
Diesel-HDV	0.002737748	tonne CO_2e / L
Diesel-ORVE	0.00299175	tonne CO_2e / L
Gasoline-HYBRID-LDV	0.00320306	tonne CO_2e / L
Motorcycle - Non catalyst	0.002387804	tonne CO_2e / L
Rail	0.0299175	tonne CO_2e / L
Jet Fuel	0.002581883	tonne CO_2e / L
Forestland	170.7	tonnes / ha
Grasslands	161	tonnes / ha
Wetlands	326	tonnes / ha
Cropland	195.86616	tonnes / ha
Settlements	0	tonnes / ha
Other	0	tonnes / ha
Forestland	170.7	tonnes / ha / year
Grasslands	161	tonnes / ha / year

Fuel Type / Activity	Total CO_2e	Units
Wetlands	326	tonnes / ha / year
Croplands	9.793308	tonnes / ha / year
Settlements	0	tonnes / ha / year
Other	0	tonnes / ha / year
Emission factor for boilers, heaters and furnaces based on fuel usage	0.001902248	tonne of CO_2e/m^3 fuel
Emission factor for flaring of natural gas	0.002553442	tonne of CO_2e/m^3 fuel
Emission factor for the industrial combustion of landfill gas	2.75474	tonne of CO_2e/t
Emission factor for N2O-N/kg sewage-N	2.98	kg N2O-N/kg sewage-N
Biological treatment emission factors - composting	189.4	g / kg waste