2016 CITY OF SPOKANE COMMUNITY AND LOCAL GOVERNMENT OPERATIONS GREENHOUSE GAS (GHG) EMISSIONS INVENTORY REPORT

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EXECUTIVE SUMMARY

This report provides an updated, 2016 greenhouse gas (GHG) emissions inventory for the City of Spokane. Though one document, this report is comprised of two GHG emissions inventories for the 2016 reporting year: a local government operations inventory and a city-wide (or community-scale) inventory. The local government operations GHG emissions inventory accounts for emissions resulting from activities under the operational control of the local government, while the community-wide inventory accounts for emissions resulting from a broader range of activities within the city. To be clear, these two inventories are not cumulative. The community-wide inventory represents the total GHG emissions generated from all reportable emissions within the municipal boundary, while the local government operations inventory is considered a subset of this total.[1]

Results from each inventory have been broken down by both local government and community-wide sectors according to the inventory protocols used to calculate emissions. Figure 1 provides a summary of the community-wide GHG emissions by sector for the 2016 reporting year in metric tons (MT) of CO_2e.[2]

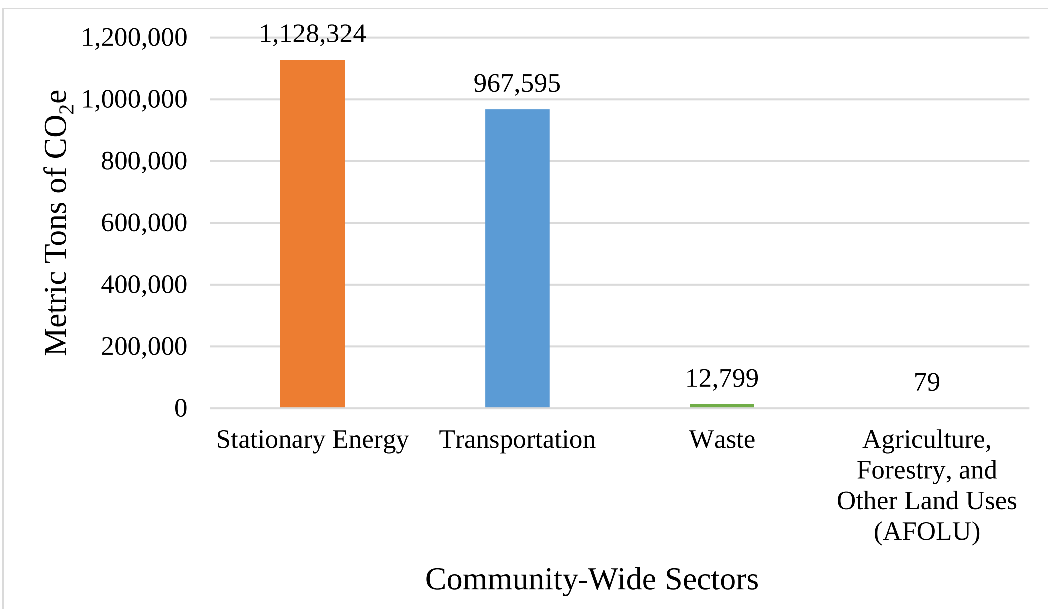

Figure 1 – Summary of 2016 community-wide GHG emissions by sector

In 2016, the total community-wide GHG emissions amounted to 2,108,797 MT CO_2e. Emissions associated with the Stationary Energy sector, which accounted for the emissions from fuel

[1] For more details on the inventory protocols used and scope of each inventory, see chapters 2 and 3, respectively.
[2] As noted in the glossary of terms, CO_2e is a universal unit of measurement to indicate the global warming potential (GWP) of each GHG, expressed in terms of the GWP of one unit of carbon dioxide. It is used to evaluate the climate impact of releasing (or avoiding releasing) different greenhouse gases on a common basis.

combustion and fugitive emissions released in the process of generating, delivering, and consuming energy, made up the majority (~54%) of the total emissions in the community-wide inventory. Most of the emissions in the Stationary Energy sector came from residential buildings and commercial & institutional buildings, ~46% and ~41% respectively (see Figure 2).

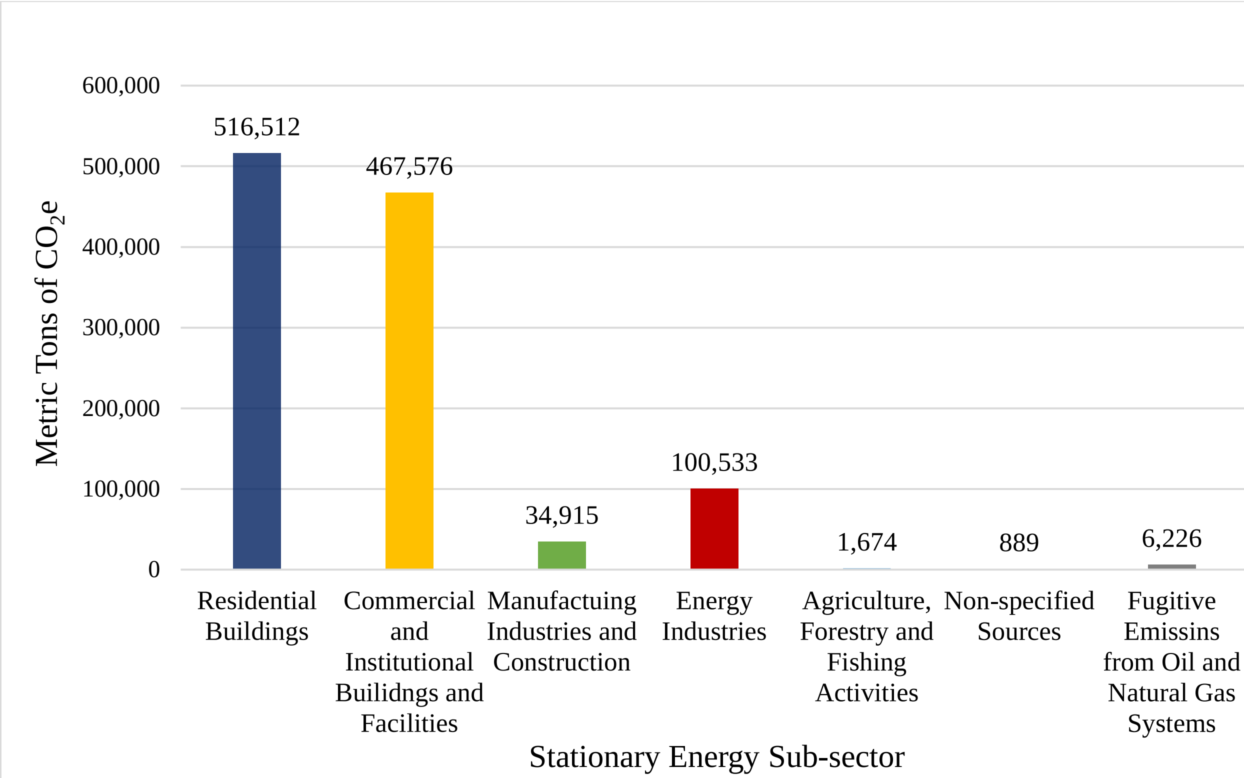

Figure 2 – Summary of 2016 stationary energy GHG emissions by sub-sector

The emissions from energy industries, which included emissions from the Waste-to-Energy Facility, accounted for ~9% of the total stationary energy emissions in the 2016 community-wide inventory.

Emissions attributed to the Transportation sector accounted for a bulk (~46%) of the remaining emissions in the 2016 community-wide inventory. Of these emissions, most (~73%) came from on-road transportation (see Figure 3).

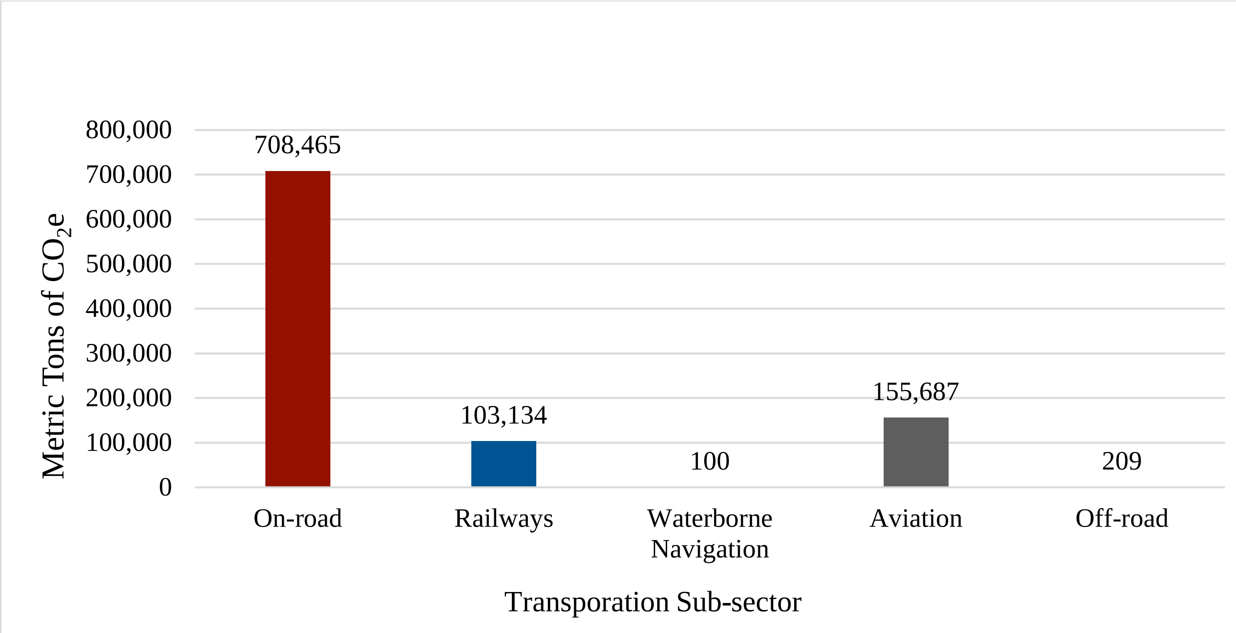

Figure 3 – Summary of 2016 transportation GHG emissions by sub-sector

Figure 4 provides a summary of the local government operations GHG emissions by sector for the 2016 reporting year in MT of CO_2e.

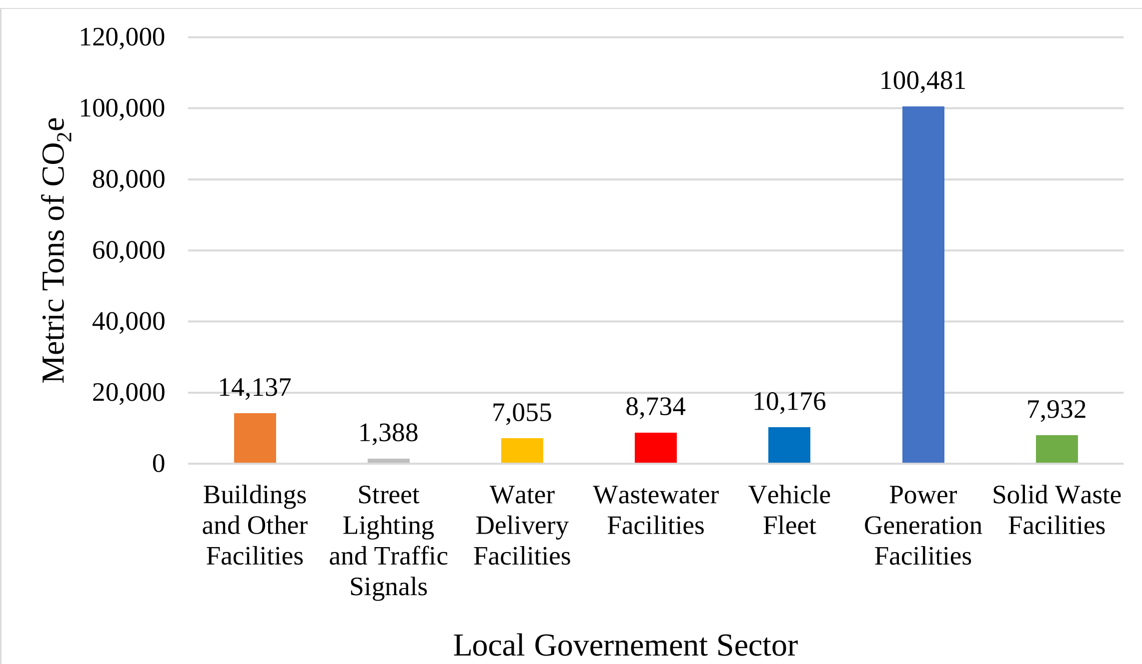

Figure 4 – Summary of 2016 local government operations GHG emissions by sector

In 2016, local government operations resulted in the emission of 149,903 MT of CO_2e (~ 7% of the community-wide emissions mentioned above). Emissions from power generation facilities (100,481 MT CO_2e) accounted for the majority (~67%) of the total emissions, while emissions from buildings and other facilities, fleet vehicles, and wastewater facilities accounted for an additional ~9.4%, ~6.8%, and ~5.8% of the total emissions from local government operations, respectively. The emissions from the remaining local government sectors each accounted for less than ~5.5% of the total.

More detailed results on emissions by sub-sector and sources (e.g., electricity, natural gas, etc. consumption) are included in chapters 6 and 7 of this report. Also included in this report is a detailed summary of the methodologies used to calculate emissions for each inventory, including notes on data sources used, emissions factors, assumptions, and calculation methodologies (see chapters 4 and 5 for more details). As noted in previous City of Spokane inventory reports (City of Spokane, 2009, 2016d), the process of conducting a GHG emissions inventory is a challenging one, as methodologies improve, science advances, and more data becomes available to expand the scope of each inventory. It was the aim of this report to provide the most comprehensive, up-to-date, and transparent accounting of GHG emissions from local government operations and community-wide activities as possible.

As described in subsequent chapters of this report, these inventories were generated using the latest inventory protocols and emissions factors, and the most complete datasets available for the 2016 inventory year. Additionally, this work was reviewed by a third party reviewer (Mr. Erik Budsberg, Sustainability Coordinator at Eastern Washington University) to externally validate all calculations methodologies, assumptions, and results included as part of this report.

It is the hope of the report authors that the work included in this report can be used by the local government and citizens of Spokane to identify energy savings and emissions reductions strategies that continue to move Spokane forward towards a more sustainable future.

ABBREVIATIONS

ACC	American Community Census Data	**ICLEI**	ICLEI - Local Governments for Sustainability
AFOLU	Agriculture, forestry and Other land use	**IPCC**	Intergovernmental Panel on Climate Change
ARB	California Air Resources Board	**IPPU**	Industrial Processes and Product Use
BOD	Biochemical oxygen demand	**kWh**	Kilowatt hours
BTU	British Thermal Unit	**LFG**	Landfill gas
C40	C40 Cities Climate Leadership Group	**LGO**	Local Government Operations
CCAR	California Climate Action Registry	**LGO Protocol**	Local Government Operations Protocol
CDP	Carbon Disclosure Project	**MMBTU**	Million British Thermal Unit
CH_4	Methane	**MOVES**	U.S. EPA's Motor Vehicle Emission Simulator
CIRIS	City Inventory Reporting and Information System	**MSW**	Municipal solid waste
CNG	Compressed natural gas	**MT**	Metric ton
CO_2	Carbon dioxide	**MWh**	Megawatt hour
CO_2e	Carbon dioxide equivalent	**N**	Nitrogen
DNR	Washington State Department of Natural Resources	**N_2O**	Nitrous oxide
DOE	Washington State Department of Ecology	**NF_3**	Nitrogen trifluoride
DOL	Washington State Department of Licensing	**NSLF**	Northside Landfill
EF	Emission factor	**PFCs**	Perfluorocarbons
eGRID	Emissions & Generation Resource Integrated Database	**RA**	Residential Agriculture
EIA	U.S. Energy Information Administration State Statistics	**RPWRF**	Riverside Park Water Reclamation Facility
EPIC	Educational Partnerships for Innovations in Community	**SF_6**	Sulphur hexafluoride
GHG	Greenhouse Gas	**SFF**	Spokane Felts Field
GIS	Geographic information system	**SIA**	Spokane International Airport
GPC	Global Protocol for Community-scale Greenhouse Gas Emission Inventories	**SRTC**	Spokane Regional Transportation Council
GWP	Global warming potential	**SSLF**	Southside Landfill
HA	Hectare	**STA**	Spokane Transit Authority
HFCs	Hydrofluorocarbons	**T&D**	Transmission and distribution
UNEP	United Nations Environment Programme	**TBTU**	Trillion British Thermal Units
UNFCCC	United Nations Framework Convention on Climate Change	**U.S. EPA**	United States Environmental Protection Agency

VMT	Vehicle miles traveled	**WSDOT**	Washington State Department of Transportation
WRI	World Resources Institute	**WWTP**	Wastewater treatment plant
WTE	Waste to Energy		
WSDA	Washington State Department of Agriculture		

GLOSSARY OF TERMS

Activity data	A quantitative measure of a level of activity that results in GHG emissions. Activity data is multiplied by an emission factor to derive the GHG emissions associated with a process or an operation. Examples of activity data include kilowatt-hours of electricity used, quantity of fuel used, output of a process, hours equipment is operated, distance traveled, and floor area of a building.
Allocation	The process of partitioning GHG emissions among various outputs.
Base year	A historical datum (e.g., year) against which a city's emissions are tracked over time.
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.
BASIC+	An inventory reporting level that covers all BASIC sources, plus scope 1 *AFOLU* and *IPPU*, and scope 3 in the *Stationary Energy* and *Transportation* sectors.
City	Used throughout the GPC to refer to geographically discernable subnational entities, such as communities, townships, cities, and neighborhoods
City boundary	See geographic boundary.
CO_2 equivalent (CO_2e)	The universal unit of measurement to indicate the global warming potential (GWP) of each GHG, expressed in terms of the GWP of one unit of carbon dioxide. It is used to evaluate the climate impact of releasing (or avoiding releasing) different greenhouse gases on a common basis.
Double counting	Two or more reporting entities claiming the same emissions or reductions in the same scope, or a single entity reporting the same emissions in multiple scopes.
Emission	The release of GHGs into the atmosphere.
Emission factor(s)	A factor that converts activity data into GHG emissions data (e.g., kg CO_2e emitted per liter of fuel consumed, kg CO_2e emitted per kilometer traveled, etc.).
Fuel Mix	The combination of fossil fuels and renewable energy sources used to supply energy to the grid.

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.
Global warming potential	A factor describing the radiative forcing impact (degree of harm to the atmosphere) of one unit of a given GHG relative to one unit of CO_2.
Greenhouse gas inventory	A quantified list of a city's GHG emissions and sources.
Greenhouse gases (GHG)	For the purposes of the GPC, 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)
In-boundary	Occurring within the established geographic boundary.
Inventory boundary	The inventory boundary of a GHG inventory identifies the gases, emission sources, geographic area, and time span covered by the GHG inventory.
Reporting	Presenting data to internal and external users such as regulators, the general public, or specific stakeholder groups.
Reporting year	The year for which emissions are reported.
Scope 1 emissions	GHG emissions from sources located within the city boundary.
Scope 2 emissions	GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the city boundary.
Scope 3 emissions	All other GHG emissions that occur outside the city boundary as a result of activities taking place within the city boundary.
Transboundary emissions	Emissions from sources that cross the geographic boundary.

1 INTRODUCTION

Cities, as home to over half the world's population, consume over two-thirds of the world's energy and account for more than seventy percent of global energy-related greenhouse gas (GHG) emissions (C40 Cities, 2019; UN-Habitat, 2011, 2012). Yet, cities and local governments are also uniquely positioned to take a leadership role in promoting sustainable development and curbing GHG emissions (Rosenzweig et al., 2015). However, a city and local government's ability to take effective action and monitor progress hinges on access to quality data and the development of GHG emissions inventories.

Over the past decade, the City of Spokane has calculated and published several GHG emissions inventories[3]. The first, published in 2009, inventoried the GHG emissions from the Spokane community and local government operations for the 1990 and 2005 inventory years (City of Spokane, 2009). The second report, published in 2016, inventoried GHG emissions from Spokane community activities and local government operations for the 2010 and 2012 inventory years (City of Spokane, 2016d). The primary purpose of this report was to build upon the City's previous inventory efforts by:

(1) Calculating and publishing updated local government operations and community-scale GHG emissions inventories using: (a) data from the inventory year for which the most complete information on community-scale and local government operations activities was available (i.e., data from the 2016 inventory year) and (b) the latest inventory methodologies (e.g., the *Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories*), which can help communities and local governments set energy and emissions targets, track progress over time, and compare emissions to other cities of similar size and characteristics from across the globe

(2) Streamlining the time it takes to update the City's GHG emissions report by leveraging largely untapped university resources to help collect quality data, and then calculate and analyze community-scale and local government operations emissions through applied learning experiences and workforce training

1.1 A Note on the City of Spokane-University Partnership and Educational Partnerships for Innovations in Community (EPIC) Model

Over the summer of 2018, a partnership was formed between the City of Spokane and Gonzaga University to assign an interdisciplinary team of seven engineering and environmental studies

[3] For more details on the *City of Spokane Greenhouse Gas Inventory Report for 2010-2012* and the *City of Spokane 1990 & 2005 Greenhouse Gas Inventory* please see the following links: https://static.spokanecity.org/documents/publicworks/environmental/2016/greenhouse-gas-inventory-report-for-2010-2012.pdf & https://static.spokanecity.org/documents/publicworks/environmental/1990-2005-greenhouse-gas-inventory.pdf.

students from Gonzaga University to complete this updated inventory report over the course of the 2018-2019 academic year as part of a senior capstone project course. Working in partnership with members from the City's Environmental Programs group and Erik Budsberg (Office of Sustainability, Eastern Washington University), and under the direction of a principle investigator, Dr. J. Alexander Maxwell (Civil Engineering Department, Gonzaga University), this report represents the outcome of this partnership.

This model of city-university partnership, known more broadly as the Educational Partnerships for Innovation in Communities (EPIC) model, is one that has slowly taken off in a network of communities and universities across the nation[4]. Using the EPIC model for city-university partnership, students involved in this work were not only able to produce professional deliverables for the benefit of the City and the broader Spokane community, but were also able gain valuable and transferable skills and experience.

1.2 Summary of Chapters

This report was divided into several chapters. Chapter 2 provides a brief review of the two protocols – the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (GPC) and the *Local Government Operations Protocol* (LGO Protocol) – used to complete the community-scale and local government operations GHG inventories included in this report. These summaries not only explain the purpose of the protocols but also why they were used to complete each inventory.

Chapter 3 details the inventory boundaries used to scope the community-scale and local government operations GHG inventories. Definitions of the boundaries and inventory year are provided, in addition to summaries of the GHG gases, emissions sources, and scopes included in each inventory.

Chapters 4 and 5 provide comprehensive summaries of methodologies used to quantify GHG emissions following the GPC and LGO protocols described in Chapter 2. The subsections in Chapters 4 and 5 comprise summaries of all scopes and sources included in each sector and details on the activity data, emissions factors, and calculation methodologies used to quantify GHG emissions.

Chapters 6 and 7 summarize the results and quantitative analysis of the 2016 community-scale and LGO inventories, with comparisons made to past City of Spokane GHG emissions inventories where possible and appropriate. And lastly, Chapter 8 proposes several recommendations from the students, principal investigator, and other project partners for future

[4] For more information on the EPIC model, visit: http://www.epicn.org/.

City of Spokane GHG emissions inventories based on lessons learned during the completion of this report.

2 GREENHOUSE GAS (GHG) EMISSIONS INVENTORY PROTOCOLS

GHG emissions inventory protocols (or methodologies) determine not only *what* will be measured in a GHG emission inventory (e.g., the types and sources of GHG emissions) but also *how* GHG emissions are calculated or estimated. While a variety of protocols exist (British Standards Institution, 2013; Fong et al., 2014; ICLEI - Local Governments for Sustainability USA, 2013; Intergovernmental Panel on Climate Change, 2006; Ministry of Environment, 2009; The Covenant of Mayors Initiative, 2010; UNEP, UN-Habitat, & World Bank, 2010), the two protocols used to compile this report were the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (GPC) and the *Local Government Operations Protocol* (LGO Protocol). These standardized protocols have been widely adopted and represent international best practices for calculating GHG emissions for two types of inventories – community-wide (or city-wide) inventories and local government operations inventories, respectively. The following sections of this chapter briefly describe the GPC and LGO Protocols and why they were used to complete each inventory included in this report.

2.1 The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC)

The GPC offers local governments and communities a robust, transparent, and globally-accepted framework for consistently identifying, calculating, and reporting community-scale GHG emissions. This includes GHG emissions released within city boundaries, known as geographically-defined emissions, as well as city-induced emissions that occur outside the city boundary as a result of activities taking place within the boundary. Ultimately, credible emissions accounting and reporting practices like the GPC can help communities and local governments set energy and emissions targets, track progress over time, and ensure transparent and consistent measurement and reporting of GHG emissions.

2.1.1 Why Use the GPC?

To date, the GHG emissions inventory protocols that communities, including the City of Spokane, have used to account for city-wide GHG emissions have varied (Fong et al., 2014; ICLEI - Local Governments for Sustainability USA, 2013; The Covenant of Mayors Initiative, 2010; UNEP et al., 2010). Inconsistency in reporting protocols can make comparisons between cities difficult (especially those of similar size and characteristics), raises questions around data quality, and limits the ability to aggregate GHG emissions data on a local, subnational, and national level. The GPC was created as a response to these challenges by producing a robust and clear framework, which allows for more credible and meaningful reporting, and greater consistency in GHG accounting.

Building off existing methodologies for calculating and reporting city-wide GHG emissions, the GPC was started as a collaborative effort in 2011 between ICLEI-Local Government for Sustainability (ICLEI), the C40 Cities Climate Leadership Group (C40), the World Resources Institute (WRI), and the Joint Work Programme of the Cities Alliance (including the World Bank, United Nations Environment Programme, and United Nations Human Settlements Programme). After several versions and pilot testing, the GPC was launched in December 2014. Upon its publication, the GPC superseded the provisions from other, previously-developed standards as the international best practice standard for community-wide GHG emissions inventories (World Resources Institute & World Business Council for Sustainable Development, 2014), allowing communities to report to international registries such as carbon*n* Climate Registry and the CDP (formerly the Carbon Disclosure Project).

2.1.2 The GPC and Local Government Operations (LGO) GHG Emissions Inventories

In addition to compiling a community-wide GHG inventory, local governments may also want to account for GHG emissions from their own municipal operations using a local government operations (LGO) inventory. An LGO inventory allows local governments to identify GHG reduction opportunities across their jurisdiction, while also demonstrating leadership in the community by taking action to increase efficiency and curb emissions. While this is not a requirement of community-wide GHG emissions inventories, data from an LGO inventory may also be helpful in compiling information for a community-wide inventory, as some of the activity data may overlap. In that way, LGO inventories can serve as a complement to community-wide GHG inventories, allowing for more precise estimates to be made at the community scale.

2.2 The Local Government Operations Protocol (LGO Protocol)

Similar to community-scale inventories, local governments can inventory the emissions from their operations to identify opportunities, monitor progress, and create strategies and actions to curb GHG emissions in a quantifiable and transparent way. The Local Government Operations Protocol (LGO Protocol) was designed to provide local governments with complete, consistent, and accurate accounting guidelines to quantify and report GHG emissions associated with their government operations.

2.2.1 Why Use the LGO Protocol?

Apart from the LGO Protocol being a tool for accounting and reporting GHG emissions across a government's local operations, the LGO Protocol also benefits local governments and communities by:

- Addressing inefficiencies related to energy resource consumption and waste, which allows local governments to consider improvements to business operations and processes, the implementation of new technology, and ultimately how to save money and resources
- Helping local governments prepare for and respond to the potential impact of new energy and GHG emissions regulations

- Providing local governments with a pathway to recognize, publicize, and promote their environmental stewardship
- Informing city staff, constituents, employees, and the public about a local government's GHG emissions profile

The LGO Protocol was developed in partnership by the California Air Resources Board (ARB), California Climate Action Registry (CCAR), ICLEI, and The Climate Registry. The LGO Protocol was designed to bring together GHG inventory guidance from a number of existing programs, including the guidance provided by ICLEI to its Cities for Climate Protection campaign members, the guidance provided by CCAR and The Climate Registry through their General Reporting Protocols, and the guidance from ARB's mandatory GHG reporting regulation under AB 32. Overall, the LGO Protocol was intended to reflect best practices associated with GHG accounting and has continued to evolve as new science and tools become available. Version 1.0 of the LGO Protocol was first adopted by ARB, CCAR and ICLEI in 2008, and by The Climate Registry in 2009. The most recent version of the LGO Protocol – Version 1.1 – was released in May 2010 and has been maintain by the partner organizations mentioned above.

3 INVENTORY BOUNDARIES

The first step in conducting a GHG emissions inventory is to establish the inventory boundary, which identifies the GHGs, emissions sources, physical boundaries, and the time span the inventory covers. The following sections of this chapter describe each of these components as they were applied to the community-scale and local government operations inventories. While many of these parameters where shared between the two inventories (e.g., the GHGs included and 2016 inventory year), there are also important differences between the boundaries of the two inventories given the differences in scale, namely in the sources and sectors included.

3.1 Geographic and Organizational Boundaries

Geographic and organizational boundaries are the spatial dimensions that define the physical perimeters of an inventory boundary. Depending on the purpose of the inventory, the geographic or organizational boundary can align with the administrative boundary of a local government, a ward or borough within a city, a combination of administrative divisions, or another geographically identifiable entity.

The geographic boundary used for the 2016 community-wide inventory in this report was the municipal boundary of the City of Spokane (see Figure 5).

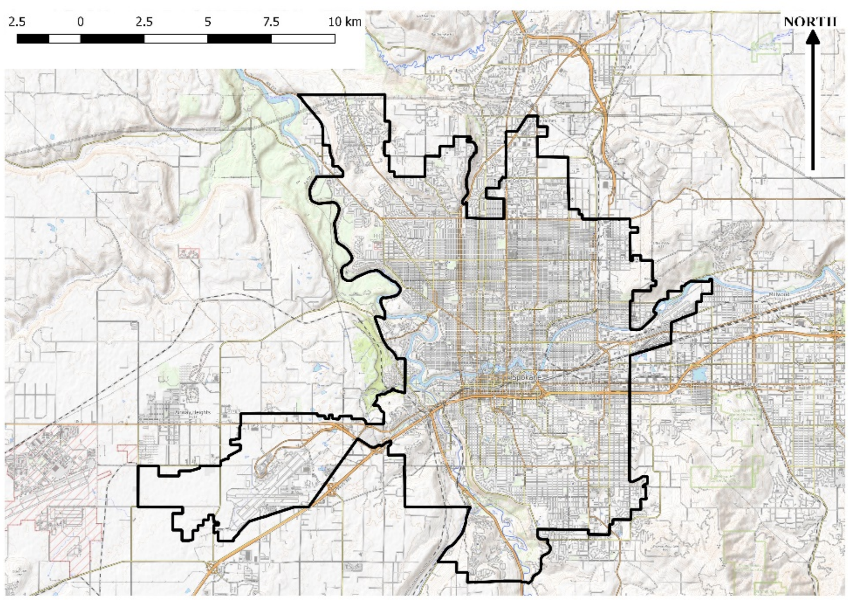

Figure 5 – City of Spokane Municipal Boundary

The municipal boundary of Spokane covers an area of approximately 69.5 square miles (outlined in black in Figure 5). Maintaining this geographic boundary over time allows for consistent comparisons to be made across inventory years. However, when structural changes to the geographical boundary occur, recalculations may also be made to account for such changes

(Fong et al., 2014, sec. 11.3). Such changes have occurred in the past, as was noted in the *City of Spokane Greenhouse Gas Inventory Report for 2010-2012* (City of Spokane, 2016d, p. 18).

Unlike the community-wide GHG emissions inventory, the LGO inventory boundary was limited to only operations over which the local government of the City of Spokane had control (e.g., City Hall, City fire and police stations, City fleet vehicles, etc.). This is referred to in the LGO Protocol as "operational control" and is the recommended approach for defining inventory boundaries in LGO emissions inventories (California Air Resources Board, 2010, sec. 3.1). A local government has operational control over a local government operation if the local government has the full authority to introduce and implement its operating policies at the operation. As noted in the LGO Protocol, the operational control approach is "consistent with the current accounting and reporting practice of many organizations that report on emissions from facilities [that] they operate" (California Air Resources Board, 2010, p. 14).

3.2 Reporting Year

The GPC and LGO Protocol are designed to account for emissions from a single reporting year (i.e., 12 continuous months), ideally aligning with a calendar year. Reporting emissions on a calendar year is considered an international standard, as the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, and The Climate Registry all require GHG inventories to be tracked and reported on the basis of a calendar year.

Prior to beginning data collection for this report, the principal investigator, in partnership with the City of Spokane Environmental Programs, examined the range of data sources available and selected the 2016 calendar year as the inventory year for use in both the community-wide and LGO inventories. 2016 was selected because it was the calendar year for which the most comprehensive and up-to-date records for key emissions sources were available. Therefore, all emissions reported in each inventory of this report are from the 2016 calendar year.

3.3 Greenhouse Gases (GHGs)

The GHGs accounted for using the GPC and LGO Protocol included all those recognized and regulated under the Kyoto Protocol (UNFCCC, 1997), including: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions from each gas were accounted for separately wherever possible and reported as emissions in metric tons (MT) and eventually converted to units of CO_2 equivalent (CO_2e) to allow for the aggregation of emissions and for comparisons to be made using a functional, equivalent concentration.

3.4 GHG Emissions Sectors and Sources

GHG emissions from community-wide activities were classified into five main sectors in accordance with the GPC (Fong et al., 2014, sec. 3.4). These sectors included:

- *Stationary Energy* – this sector accounts for GHG emissions produced from fuel combustion, as well as fugitive emissions released in the process of generating, delivering, and consuming useful forms of energy (e.g., electricity or heat)
- *Transportation* – this sector accounts for GHG emissions produced from transport vehicles and mobile equipment or machinery through the direct combustion of fuel or indirectly through the consumption of grid-supplied electricity
- *Waste* – this sector accounts for GHG emissions from waste disposal and treatment processes through aerobic and anaerobic decomposition, or incineration
- *Industrial Processes and Product Use (IPPU)* – this sector accounts for GHG emissions from non-energy related industrial activities and product use
- *Agriculture, Forestry, and Other Land Use (AFOLU)* – this sector accounts for GHG emissions produced through a variety of pathways, including land-use changes, methane emissions from livestock digestive processes, and nutrient management for agricultural purposes

Emissions from these community-scale sectors were further subdivided into related sub-sectors (e.g., residential buildings, on-road transportation, and wastewater treatment and discharge) to provide opportunities to use disaggregated data and improve the detail of the inventory. Additionally, in keeping with the guidance from the GPC (Fong et al., 2014, p. 12), emissions included in the community-wide inventory were reported according to the BASIC+ reporting requirements. Unlike BASIC level reporting requirements, which cover scope 1 and 2 emissions from the Stationary Energy and Transportation sectors and scope 1 and 3 emissions from the Waste sector, BASIC+ requires additional data collection and calculation processes to estimate emissions from the IPPU and AFOLU sectors and transboundary transportation. The sources covered in BASIC+ also align with sources required for national reporting in IPCC guidelines.

GHG emission from local government operations were categorized into local government sectors in accordance with the LGO Protocol (California Air Resources Board, 2010, sec. 4.2). These sectors included:

- Buildings and Other Facilities
- Streetlights and Traffic Signals
- Water Delivery Facilities
- Wastewater Facilities
- Vehicle Fleet
- Power Generation Facilities
- Solid Waste Facilities

Emissions from these local government sectors were further subdivided into related emission scopes (e.g., scope 1, 2, and 3) and sources (e.g., stationary combustion, mobile combustion, fugitive and indirect emissions) to allow for easier reporting of this information to The Climate

Registry reporting program using the LGO Standard Inventory Report Template (California Air Resources Board, 2010, Chapter 13). More information on the categorization of GHG emissions by scope is included in the next section of this chapter.

3.5 Categorizing GHG Emissions by Scope

The GPC and LGO protocols also group emissions into three categories – or *scopes* – based on where they occur relative to the community-wide and LGO inventory boundaries. This is important, as activities taking place within a community or local government operations can generate GHG emissions that occur inside the inventory boundary as well as outside the boundary. Definitions of each scope are provided in Table 1 below and are adapted from *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard* (World Business Council for Sustainable Development & World Resources Institute, 2004, p. 25).

Table 1 – Scope definitions for community- or city-wide GHG emissions inventories

Scope	**Definition**
Scope 1	Direct GHG emission from activity sources located within the community or local government operations boundaries
Scope 2	Indirect GHG emissions occurring as a result of the use of grid-supplied electricity, heat, steam, and/or cooling within the community or local government operations boundaries
Scope 3	All other indirect GHG emissions that occur outside the community or local government operations boundaries as a result of activities taking place within the community or local government boundaries

Figure 6 illustrates the scopes, sources, and boundaries that may be used to account for emissions in GHG emissions inventories.

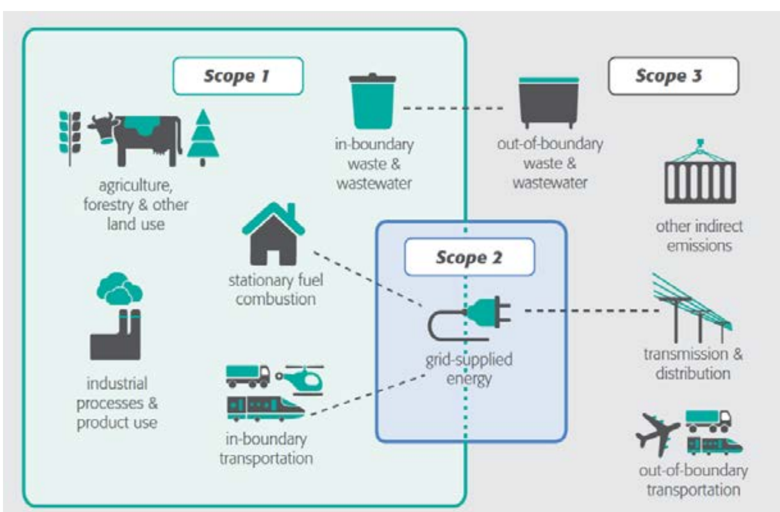

Figure 6 – Scopes, sources, and boundaries of a GHG emissions inventory (Source: © C40 Cities et al., 2014, fig. 3.1/WRI/CC-BY-SA-3.0)

4 METHODOLOGY FOR CALCULATING COMMUNITY-WIDE GHG EMISSIONS BY SOURCE USING THE GPC

The following subsections describe the GPC methodologies used to quantify GHG emissions by sector for the community-wide GHG emissions inventory. These subsections are a summary of the scopes and sources in each sector and provide the specific activity data, emissions factors, and calculation methodologies that were used in this GHG inventory. The organizational structure of this chapter is designed to make it easier for external review, future community-wide inventory efforts, and reporting of results to reporting platforms like carbon*n* Climate Registry and the CDP (formerly the Carbon Disclosure Project) using the Excel-based City Inventory Reporting and Information System (CIRIS). For more information on the step-by-step guidance for how to quantify GHG emissions from various community-wide sources using the GPC, see Part II of the GPC (Fong et al., 2014, pp. 45–134).

4.1 Stationary Energy

The Stationary Energy sector accounts for the emissions from fuel combustion and fugitive emissions released in the process of generating, delivering, and consuming energy (Fong et al., 2014, p. 55). Table 2 summarizes the scopes and sub-sectors used for calculating GHG emissions from the Stationary Energy sector.

Table 2 – Scopes and sub-sectors used for calculating GHG emissions from the Stationary Energy sector

Subsector	Scope 1	Scope 2	Scope 3
Residential Buildings	☒	☒	☒
Commercial and Institutional Buildings and Facilities	☒	☒	☒
Manufacturing Industries and Construction	☒	☒	☒
Energy Industries	☒	☒	☒
Agriculture, Forestry, and Fishing Activities	☒	☐	☐
Non-Specified Sources	☒	☐	☐
Fugitive Emissions from Mining, Processing, Storage, and Transportation of Coal	☐	-	-
Fugitive Emissions from Oil and Natural Gas Systems	☒	-	-

The scope 1 emissions in this sector include emissions generated by the combustion of fuels and fugitive emission in the City of Spokane. Scope 1 fugitive emissions from the Mining, Processing, Storing, and Transportation of Coal sub-sector were excluded from this inventory because there were not coal-related mining activities within the Spokane municipal boundary. The scope 2 emissions in this sector were generated by the consumption of grid-supplied energy.

The Waste to Energy (WTE) facility produces energy through the combustion of municipal solid waste (MSW), which the GPC categorizes as a scope 1 emission (Fong et al., 2014, p. 64). Scope 2 emissions from the Agricultural, Forestry & Fishing sub-sector and Non-specified Sources sub-sector were excluded from this sector of the inventory because the only activity from these sub-sectors in the City of Spokane were the use of off-road vehicles, which produce scope 1 emissions.

The scope 3 emissions in this sector include the emissions generated from the transmission and distribution losses (T&D) from the use of grid-supplied energy. Scope 3 emissions were excluded in this inventory for the Energy Industries sub-sector, Agricultural, Forestry & Fishing sub-sector, and Non-specified Sources sub-sector because there were no scope 3 activities to report in these three sub-sectors.

It is important to note that scope 1 emissions from the Agriculture, Forestry, and Fishing sub-sector, Non-specified Sources sub-sector, and Energy Industries sub-sector were new to this 2016 inventory and not reported in the previous *City of Spokane's Greenhouse Gas Inventory Report for 2010-2012* (City of Spokane, 2016d). Also, emissions from the WTE facility were previously included in the Waste section of the *City of Spokane's Greenhouse Gas Inventory Report for 2010-2012* (City of Spokane, 2016d, pp. 58–65), instead of in the Stationary Energy sector, as it was reported in this inventory.

The activity data for energy supplied by Avista Utilities (Avista) in the Stationary Energy sub-sectors was provided by Dr. John Lyons in a report titled *City of Spokane 2016.KBooth.5.15.18* (Avista Corporation, 2018). Electricity and natural gas consumption was (respectively) reported in kilowatt hours (kWh) and therms. Ian Swan provided the activity data for the Inland Power and Light (IPL) supplied electricity that was consumed in the Stationary Energy sub-sectors reported in megawatt hours (MWh). The most accurate data that IPL was able to provide was energy consumed in 2018. However, due to their service territory agreement with Avista, IPL's service area remained the same between 2016 and 2018. It was recommended by Ian Sawn and assumed as part of the calculation methodology that this data could reasonably be used in the calculations for the 2016 GHG inventory. Both utility providers organized the energy consumption into three categories: residential, commercial, and industrial. The activity data provided did not deviate from what is recommended for use by the GPC because it was real consumption data, disaggregated by sub-sector and obtained from the utility provider (Fong et al., 2014, p.57).

4.1.1 Residential Buildings

The Residential Buildings sub-sector accounted for the emissions generated from electricity and fuels used in households within the City of Spokane (Fong et al., 2014, p. 58).

4.1.1.1 Activity Data

Activity data for the Residential Buildings sub-sector was provided by Avista and IPL, and included data on fuel and electricity consumption used to power and heat homes in the City of Spokane. Table 3 lists the activity data used for calculating emissions in this sub-sector.

Table 3 – Residential Buildings sub-sector activity data

Utility Provider	Energy Consumed
2016 Avista Natural Gas Consumption (scope 1)	39,243,355 therms
2016 Avista Electricity Consumption (scope 2)	930,053,623 kWh
2018 IPL Electricity Consumption (scope 2)	4,325 MWh

IPL does not provide natural gas service within the City of Spokane; therefore, only scope 2 emissions were generated from using IPL supplied energy. To generate their grid-supplied energy, IPL uses a fuel mix consisting of biomass, coal, hydroelectric, natural gas, nuclear, non-biogenic, and petroleum fuel sources. The percentage of each fuel and the corresponding MWhs of electric power delivered for each fuel is listed in Table 4.

Table 4 – Percentage of each fuel in IPL's fuel mix (Brian, Furze, Greg, & Carolee, 2017)

Fuel / Energy Source	Percentage of total mixture (%)	MWh
Biomass	0.10	985
Coal	1.14	11,193
Hydroelectric	79.92	786,559
Natural gas	0.65	6,393
Nuclear	10.27	101,110
Non-biogenic	0.03	264
Petroleum	0.02	166
Solar	0.08	829
Wind	7.79	76,668

In addition to natural gas and grid-supplied electricity, a portion of homes in the City are heated using residential distillate fuel oils, propane, wood, and kerosene. The activity data for these energy sources were obtained from the U.S. Energy Information Administration State Statistics (EIA) and reported in trillion British thermal units (TBTU) (U.S. Energy Information Administration, 2016). This data was used to estimate emissions from fuel sources used to heat homes but not provided by Avista or IPL. Table 5 summarizes the activity data of these fuel sources.

Table 5 – The amount of energy consumed in Washington State using alternate fuels in the Residential Buildings sub-sector to heat homes (U.S. Energy Information Administration, 2016)

Type of fuel	TBTU
Distillate fuel oils	3.5
Propane	7.3
Wood	12.2
Kerosene	Less than 0.05

The data supplied by EIA provided the quantity of these fuels combusted for the entire state of Washington (U.S. Energy Information Administration, 2016). The previous 2010 and 2012 community-wide inventories used surveys from the American Community Census Data (ACC) and EIA data to calculate the emissions from these fuels in the Residential Buildings sub-sector. However, the ACC could not be used in the 2016 inventory because the required inputs for the actual quantity of fuel types consumed was not available. Therefore, this inventory scaled the emissions calculated using the EIA data to estimate emissions from the combustion of distillate fuel oils, propane, wood, and kerosene in the Residential Buildings sub-sector. Note, the GPC requires biogenic emissions from the combustion of biomass (i.e., firewood) to be accounted for informational purposes but reported separately from total CO_2e emissions (Fong et al., 2014, p. 153).

4.1.1.2 Emission Factors and Calculation Methodologies

The global warming potentials (GWP) used to calculate the emissions in terms of CO_2e for this inventory are listed in Table 6.

Table 6 – Global warming potentials for CO_2e calculations (Intergovernmental Panel on Climate Change (IPPC), 2013)

Greenhouse Gas	Global Warming Potential
CO_2	1
CH_4	28
N_2O	265

Emission factors were used to calculate the emissions for each GHG reported and are specific to the fuel source and grid-supplied energy consumed. Avista provided a utility-specific emission factor for the Avista grid-supplied electricity. The default emission factor from the U.S. Environmental Protection Agency (EPA) Center for Corporate Climate Leadership's *Emission Factors for Greenhouse Gas Inventories* report (EPA Center for Corportate Climate Leadership, 2018) for natural gas was used for the CO_2e calculations (Table 7).

Table 7 – 2016 emission factors for natural gas and Avista Utilities grid-supplied electricity

Energy Source	Emission	Emission Factor	Source
Natural Gas	CO_2	53.06 kg-CO_2 mmBtu^{-1}	U.S. EPA Center for Corporate Climate Leadership, 2018
	CH_4	1.0 g-CH_4 mmBtu^{-1}	
	N_2O	0.1 g-N_2O mmBtu^{-1}	
Grid-supplied electricity		294 kg CO_2e MWh^{-1}	Avista Corporation

IPL does not have utility-specific emission factors for their grid-supplied energy. Emission factors (Table 8) from the U.S. EPA eGRID 2016 data file NWPP sub-region (U.S. EPA, 2018a) were used to calculate the GHG emissions from IPL's fuel mix.

Table 8 – IPL fuel mix emission factors

Fuel from fuel mix	lbs CO_2 MWh^{-1}	lbs CH_4 MWh^{-1}	lbs N_2O MWh^{-1}	Source
Coal	2,252.397	0.236	0.037	eGRID NWPP sub-region U.S. EPA, 2018a
Oil	3.962	0.000	0.000	
Natural Gas	908.172	0.017	0.002	
Fossil fuel (non-biogenic)	1,706.11	0.147	0.023	
Biomass	93.80	7.20	3.60	EPA Center for Corportate Climate Leadership, 2018

The CO_2e emissions for the fuel mix were calculated by multiplying the MWhs of electric power delivered (shown in Table 4) for each fuel in the fuel mix by their corresponding emission factors listed in Table 8. Note, the associated emission factor for petroleum is listed in Table 8 as "oil." Emission factors for the renewable energy sources (e.g., hydro, solar, and wind) used in IPL's fuel mix were not available from the U.S. Environmental Protection Agency or alternate local sources. It was assumed that these energy sources did not generate GHGs because they were renewable energy sources. The calculated emission factor for IPL' fuel mix used was 0.015 CO_2e MWh^{-1}.

The emission factors from the eGRID 2016 NWPP sub-region data file are updated and more regionally-specific values than the eGRID 2010 version 9 values that were used in the previous 2012 GHG inventory (City of Spokane, 2016d, p. 44).

The emissions factors listed in Table 9 were used to calculate the GHGs associated with the alternate fuel sources (Table 5) used to heat homes.

Table 9 – U.S. EPA's emission factors for alternate fuel sources (U.S. EPA Center for Corporate Climate Leadership, 2018b)

Fuel source	kg CO_2 $mmBtu^{-1}$	g CH_4 $mmBtu^{-1}$	g N_20 $mmBtu^{-1}$
Distillate fuel oils	74.08	3.0	0.60
Propane	62.87	3.0	0.60
Wood	93.80	7.2	3.6
Kerosene	68.86	3.0	0.60

GHG emissions for energy supplied by Avista, IPL, and other fuel sources were calculated using Equation 1, and Equation 2 was used to calculate the total CO_2e emissions.

$$GHG\ emission = activiy\ data \times emission\ factor \times unit\ conversion \quad \textbf{(1)}$$

$$CO_2e = CO_{2_{emissions}} + \left(CH_{4_{emissions}} \times GWP_{CH_4}\right) + \left(N_2O_{emissions} \times GWP_{N_2O}\right) \quad \textbf{(2)}$$

The CO_2e emissions related to energy supplied by IPL were disaggregated to account for emissions from the services provided within the City of Spokane to Residential Buildings, Commercial and Institutional Buildings and Facilities, and the Manufacturing Industries and Construction sub-sectors as reported by Ian Swan.

Scope 3 emissions from T&D losses associated with grid-supplied energy were calculated for Avista and IPL by multiplying the MT of total CO_2e by the grid gross-loss percent value of 4.23 (U.S. EPA, 2018a). It was assumed the grid gross-loss rate for the western region of the United States was an accurate representation for the T&D losses from grid-supplied energy consumed in the City of Spokane. A similar assumption was made in the *City of Spokane's GHG Emissions Inventory for 2010-2012* (City of Spokane, 2016, p. 44), and the methodology for estimating grid gross-loss is detailed by the U.S. EPA eGRID in the *Emissions & Generation Resource Integrated Database Technical Support Document* (U.S. EPA, 2018b, p. 30).

4.1.2 Commercial and Institutional Buildings and Facilities

The Commercial and Institutional Building and Facilities sub-sector accounted for the emissions generated from energy used in buildings that provide public services for the needs of the community. These buildings can be public or government-owned and include facilities like commercial shopping complexes, office buildings, schools, and hospitals (Fong et al., 2014, pp. 58-59).

4.1.2.1 Activity Data

Activity data for the Commercial and Institutional Buildings and Facilities sub-sector is listed in Table 10.

Table 10 – Commercial and Institutional Buildings and Facilities sub-sector activity data for utility supplied energy

Utility Provider	Energy Consumed
2016 Avista Natural Gas Consumption (scope 1)	30,110,374 therms
2016 Avista Electricity Consumption (scope 2)	1,001,580,043 kWh
2018 IPL Electricity Consumption (scope 2)	1,222 MWh

IPL uses a mix of biomass, coal, hydroelectric, natural gas, nuclear, non-biogenic, and petroleum fuel sources for generating the electricity in their grid-supplied energy. The percentage of each fuel and the corresponding MWhs of electric power delivered for each fuel is listed in Table 4.

The latest versions of the U.S. EPA's Motor Vehicle Emission Simulator (MOVES) (U.S. EPA, 2018b) was used to calculate CO_2 and CH_4 emissions (in kg) from fuel used in off-road vehicles for commercial activities in Spokane County for 2016. The MOVES model provided county-level results, and to estimate off-road emissions in the Commercial and Institutional Facilities sub-sector, a household scaling factor was applied to scale the estimated county-level emissions to the city boundary. Scaling according to households is in keeping with the GPC (Fong et al., 2014, p. 49) when alternate data (e.g., roadway miles) is not available. This additional source of activity data was not included in the previous *City of Spokane's GHG Emissions Inventory Report for 2010-2012*. In keeping with the GPC, it was included in this 2016 inventory to be as comprehensive as possible in the reporting of emissions from this sub-sector.

In the previous *City of Spokane Greenhouse Gas Inventory Report for 2010 - 2012* emissions from agricultural, commercial, construction, industrial, and lawn and garden activities were all reported under the Off-road sub-sector (City of Spokane, 2016d, p. 51). However, in keeping with the GPC guidelines, emissions were reported under the Stationary Energy sector in this 2016 inventory (Fong et al., 2014, pp.82-83). The previous 2010 - 2012 inventory used the U.S. EPA NONROAD Model (U.S. EPA, 2019) to estimate all off-road transportation emissions. However, this model was incorporated into the MOVES model (U.S. EPA, 2018b) that was used to estimate the 2016 off-road emissions. Due to software issues with the NONROAD Model, the MOVES model was used to estimate the GHG emissions in this sub-sector of the 2016 inventory, as recommended by the U.S. EPA.

4.1.2.2 Emission Factors and Calculation Methodologies

The fuel specific emission factors (Table 7 and Table 8) and Equation 1 were used to calculate the emissions for each GHG reported. The GWPs for each GHG (Table 6) and Equation 2 were used to calculate the total CO_2e emissions.

Emission factors for off-road vehicles were not required because the MOVES model reported the GHGs in kg. Equation 2 and the GWPs in Table 6 were used to calculate the MT CO_2e, and the results were then scaled to the number of households of the City of Spokane relative to the number of households in Spokane County as reported in the U.S. Census Bureau American Community Survey (United States Census Bureau, n.d.).

The CO_2e emissions related to energy supplied by IPL were disaggregated to account for emissions from the services provided within the City of Spokane to Residential Buildings, Commercial and Institutional Buildings and Facilities, and the Manufacturing Industries and Construction sub-sectors as reported by Ian Swan.

Scope 3 emissions from T&D losses associated with grid-supplied energy were calculated for Avista and IPL by multiplying the MT of total CO_2e by the grid gross-loss percent value of 4.23 (U.S. EPA, 2018a). It was assumed the grid gross-loss rate for the western region of the United States was an accurate representation for the T&D losses from grid-supplied energy consumed in the City of Spokane. A similar assumption was made in the *City of Spokane's GHG Emissions Inventory for 2010-2012* (City of Spokane, 2016, p. 44), and the methodology for estimating grid gross-loss is detailed by the U.S. EPA eGRID in the *Emissions & Generation Resource Integrated Database Technical Support Document* (U.S. EPA, 2018b, p. 30).

4.1.3 Manufacturing Industries and Construction

The Manufacturing Industries and Construction sub-sector accounts for the emissions generated from energy consumption in activities related to manufacturing goods and the use of construction equipment and machinery (Fong et al., 2014, p. 60).

4.1.3.1 Activity Data

The activity data included in the Manufacturing Industries and Construction sub-sector is listed in Table 11.

Table 11 – Manufacturing Industries and Construction sub-sector activity data for utility supplied energy

Utility Provider	Energy Consumed
2016 Avista Natural Gas Consumption (scope 1)	2,365,238.69 therms
2016 Avista Electricity Consumption (scope 2)	65,710.59 kWh
2018 IPL Electricity Consumption (scope 2)	5,053 MWh

IPL uses a mix of biomass, coal, hydroelectric, natural gas, nuclear, non-biogenic, and petroleum fuel sources for generating the electricity in their grid-supplied energy. The percentage of each fuel and the corresponding MWhs of electric power delivered for each fuel is listed in Table 4.

The latest versions of the U.S. EPA's MOVES model (U.S. EPA, 2018b) was used to calculate CO_2 and CH_4 emissions (in kg) from fuel used in off-road vehicles for commercial activities in

Spokane County for 2016. It was assumed the results of the total CO_2e emissions calculated using this activity data could be scaled to the households of the City of Spokane to more accurately estimate off-road emissions in the Commercial and Institutional Facilities sub-sector. This additional source of activity data was not included in the previous *City of Spokane's GHG Emissions Inventory Report for 2010-2012*. In keeping with the GPC, it was included in this 2016 inventory to be as comprehensive as possible in the reporting of emissions from this sub-sector.

4.1.3.2 Emission Factors and Calculation Methodologies

The fuel specific emission factors (Table 7 and Table 8) and Equation 1 were used to calculate the emissions for each GHG reported. The GWPs for each GHG (Table 6) and Equation 2 were used to calculate the total CO_2e emissions.

The CO_2e emissions related to energy supplied by IPL were disaggregated to account for emissions from the services provided within the City of Spokane to Residential Buildings, Commercial and Institutional Buildings and Facilities, and the Manufacturing Industries and Construction sub-sectors as reported by Ian Swan.

Emission factors for off-road vehicles were not required because the MOVES model reported the GHGs in kg. Equation 2 and the GWPs in Table 6 were used to calculate the MT CO_2e, and the results were then scaled to the number of households of the City of Spokane relative to the number of households in Spokane County as reported in the U.S. Census Bureau American Community Survey (United States Census Bureau, n.d.).

Scope 3 emissions from T&D losses associated with grid-supplied energy were calculated for Avista and IPL by multiplying the MT of total CO_2e by the grid gross-loss percent value of 4.23 (U.S. EPA, 2018a). It was assumed the grid gross-loss rate for the western region of the United States was an accurate representation for the T&D losses from grid-supplied energy consumed in the City of Spokane. A similar assumption was made in the *City of Spokane's GHG Emissions Inventory for 2010-2012* (City of Spokane, 2016, p. 44), and the methodology for estimating grid gross-loss is detailed by the U.S. EPA eGRID in the *Emissions & Generation Resource Integrated Database Technical Support Document* (U.S. EPA, 2018b, p. 30).

Although the electricity and natural gas that Avista supplies to the Upriver Hydroelectric Dam (UHD) and the WTE facility were included in the activity data provided for the Manufacturing Industries and Construction sub-sector, the GPC requires emissions from the UHD and WTE facilities be accounted for in the Energy Industries sub-sector. The emissions for these two power generation facilities were subtracted from the overall MT of CO_2e emissions from the Manufacturing Industries and Construction sub-sector.

4.1.4 Energy Industries

The Energy Industries sub-sector accounts for the emissions generated by activities related to fuel production (e.g., coal mining, oil extraction), fuel processing and conversion of fuels (e.g., oil refineries), and electricity generation (Fong et al., 2014, p. 62).

4.1.4.1 Activity Data

The GHG emissions generated from the combustion of solid waste at the WTE facility (in terms of MT) for CO_2e, CO_2, CH_4, and N_2O were provided by the environmental manager for the WTE facility, Kelle Vigeland, in *AIR3281 2016 GHG Reporting Data* (City of Spokane, 2016c). The emissions were determined through the quarterly sampling and analysis of steam exiting the facility. Biogenic CO_2e (CO_2e(b)), was subtracted from the total MT of CO_2e, as required by the GPC (Fong et al., 2014, p.64) and reported for informational purposes. Additionally, the emissions from purchased electricity (energy that was supplied from Avista) for the WTE facility operations were calculated using 147.15 MWhs, as reported by Kelle Vigeland.

Activity data on the natural gas consumption for facility operations at the WTE facility and UHD was provided by Kelle Vigeland and collected by the City of Spokane in the *Facility Energy Report 2015 – 2017* (Simmons & Olsen, 2018), respectively.

4.1.4.2 Emission Factors and Calculation Methodologies

The calculation of scope 1 emissions generated by MSW combustion at the WTE facility did not require the use of emission factors. The calculation of scope 1 emissions generated by the combustion of natural gas for facility operations at the WTE facility and UHD were calculated using the recommended approach from the LGO Protocol (California Air Resources Board, 2010, sec. 6.1.1), which used Equation 1, the activity data, and the default emission factors (Table 7) for CO_2, CH_4, and N_2O to calculate the GHG emissions. Equation 2 and the corresponding GWPs (Table 6) for each GHG were used to calculate the total MT of CO_2e. Scope 2 emissions were calculated using the emission factors from Table 7, GWPs from Table 6, Equation 1, and Equation 2.

Note, the emissions resulting from the purchased electricity and combustion of natural gas purchased at the WTE facility (for use in the boilers and building heat), and the emissions resulting from the combustion of natural gas at the UHD (for use in facility operations), was subtracted from the total emissions reported in the Manufacturing Industries and Construction sub-sector to avoid double-counting.

4.1.5 Agriculture, Forestry, and Fishing Activities

The Agriculture, Forestry, and Fishing Activities sub-sector accounts for emissions from the combustion of fuel in agricultural activities, afforestation and reforestation activities, and fishery activities. Emissions in this sub-sector can be from the use of farm machinery, generators, and pumps (Fong et al., 2014, p. 64).

4.1.5.1 Activity Data

The MOVES model (U.S. EPA, 2018b) was used to calculate CO_2 and CH_4 emissions (in kg) from fuel used in off-road vehicles for commercial activities in Spokane County for 2016. It was assumed the results of the total CO_2e emissions calculated using this activity data could be scaled to the households of the City of Spokane to more accurately estimate off-road emissions in the Agriculture, Forestry, and Fishing Activities sub-sector. This additional source of activity data was not included in the previous *City of Spokane's GHG Emissions Inventory Report for 2010-2012*. In keeping with the GPC, it was included in this 2016 inventory to be as comprehensive as possible in the reporting of emissions from this sub-sector.

Fishing activities within the Spokane municipal boundary are limited, and it was assumed that GHG emissions due to these activities were negligible and not applicable to this inventory. This assumption was based on insufficient data to support commercialized fishing activity in the municipal boundary. While recreational fishing on the Spokane River is legal, following Washington Department of Fish and Wildlife regulations (Washington Department of Fish and Wildlife (WDFW), 2016), there was no off-road vehicle use identified using the MOVES model (U.S. EPA, 2018b) associated with these fishing activities.

4.1.5.2 Emission Factors and Calculation Methodologies

Emission factors for off-road vehicles in the Agriculture, Forestry, and Fishing Activities sub-sector were not required because the MOVES model reported the GHGs in kg.
Equation 2 and the GWPs in Table 6 were used to calculate the MT CO_2e, and the results were then scaled to the number of households of the City of Spokane relative to the number of households in Spokane County as reported in the U.S. Census Bureau American Community Survey (United States Census Bureau, n.d.).

4.1.6 Non-Specified Sources

The Non-specified Sources sub-sector accounts for all remaining emission in the Stationary Energy sector that have not been specified elsewhere (Fong et al., 2014, p. 65).

4.1.6.1 Activity Data

The MOVES model (U.S. EPA, 2018b) was used to calculate CO_2 and CH_4 emissions (in kg) from fuel used in off-road vehicles for non-specified activities in Spokane County for 2016. This data was scaled to the households of the City of Spokane and then used to estimate off-road emissions in the Non-specified Sources sub-sector, specifically from off-road vehicle emissions in lawn and garden activities within the municipal boundary.

4.1.6.2 Emission Factors and Calculation Methodologies

Emission factors for off-road vehicles in the Non-specified Sources sub-sector were not required because the MOVES model reported the GHGs in kg. Equation 2 and the GWPs in Table 6 were used to calculate the MT CO_2e, and the results were then scaled to the number of households of the City of Spokane relative to the number of households in Spokane County as reported in the U.S. Census Bureau American Community Survey (United States Census Bureau, n.d.). This additional source of activity data was not included in the previous *City of Spokane's GHG Emissions Inventory Report for 2010-2012*. In keeping with the GPC, it was included in this 2016 inventory to be as comprehensive as possible in the reporting of emissions from this sub-sector.

4.1.7 Fugitive Emissions from Oil and Natural Gas Systems

The Fugitive Emissions from Oil and Natural Gas Systems sub-sector accounts for the emissions in the Stationary Energy sector that are generated by the extraction, transformation and transportation of fossil fuels (Fong et al., 2014, p. 65).

4.1.7.1 Activity Data

Avista provided 2016 natural gas fugitive emissions and 2016 sulfur hexafluoride (SF_6) fugitive emissions in MT CO_2e for the services they provide in the City of Spokane. These fugitive emissions, reported by Avista, are a pro-rata share of the City of Spokane gas deliveries from Avista's total gas deliveries in Washington State.

4.1.7.2 Emission Factors and Calculation Methodologies

The fugitive emissions from oil and natural gas systems did not require additional emissions factors to calculate total CO_2e emissions, as the CO_2e values for this sub-sector were provided by Avista.

4.2 Transportation

Table 12 summarizes the scopes and sub-sectors used for calculating GHG emissions from the Transportation sector.

Table 12 – Scopes and sub-sectors used for calculating GHG emissions from the Transportation sector

Sub-sector	Scope 1	Scope 2	Scope 3
On-Road	☒	☐	☒
Railways	☒	☐	☒
Waterborne navigation	☐	☐	☒
Aviation	☒	☐	☒
Off-road	☒	☐	☐

The Transportation sector accounted for all GHG emissions generated from trips made in the On-road, Railway, Waterborne, Aviation, and Off-road Transportation sub-sectors. The GHG emissions are produced directly from the combustion of fuel or indirectly from the portion of transboundary journeys occurring outside the city. Scope 1 GHG emissions from the Waterborne Navigation sub-sector were not estimated due to the lack of available data on related activities occurring within the municipal boundary. Scope 2 GHG emissions, generated by the consumption of grid-supplied energy, from the On-road sub-sector were assumed to be included in the Stationary Energy sector. Scope 2 GHG emissions from the Railway, Waterborne Navigation, Aviation, and Off-road sub-sectors were not estimated due to the lack of available activity data. All GHG emissions from the Off-road sub-sector were, in accordance with the GPC, reported as scope 1 based on the assumption that airport support and railway equipment emissions were produced at the airports and railway stations that are located within the City boundary. Reporting off-road GHG emissions in scope 1 is also in accordance with the GPC (Fong et al., 2014, p. 82). The scope 3 GHG emissions reported in the On-road sub-sector were generated by Spokane Transit Authority (STA) fleet vehicles operating outside of the municipal boundary. These emissions were included in the 2016 inventory because STA is the public transit system based in the Spokane community. Detailed transboundary trip data was unavailable; therefore, other scope 3 GHG emissions from the On-road sub-sector were excluded from this inventory.

4.2.1 On-Road

The On-road sub-sector accounts for emissions generated by vehicles operating on public roadways designed for transporting people and goods (Fong et al., 2014, p. 73).

4.2.1.1 Activity Data

Ryan Stewart from the Spokane Regional Transportation Council (SRTC) provided the *2015 SRTC Model for VMT* that contained daily model volumes for Spokane County within a geographic information systems (GIS) shapefile. This shapefile contained road segment lengths and trips. This model was primarily composed of roads with a classification of principle arterial and higher, so it was assumed the model provided by SRTC was a reasonable representation of the vehicle miles traveled (VMT) within Spokane County.

To estimate the 2016 VMT data for this inventory, it was assumed the provided 2015 VMT data would increase by 3.5 %. This assumption was based on the 3.5 % increase in Spokane County's state highway annual VMT between 2015 and 2016, which was reported in the *Washington State Department of Transportation (WSDOT) Annual Traffic Reports* (Washington State Department of Transportation, 2016). The Washington State Department of Licensing (DOL) provided 2016 vehicle registration counts separated by vehicle class for each county in Washington State (Washington State Department of Licensing, 2019c, 2019a, 2019b, 2019d).

Charlie Phillips and Karl Otterstrom from the STA provided total fuel consumption in gallons, miles traveled for the bus fleet, and a shapefile of the transit system. The previous inventory also utilized an additional VMT model from the Washington State Department of Ecology (DOE) to estimate on-road transportation emissions and compared the results to the SRTC estimations. However, an update to the DOE model was not available for the 2016 inventory, so a comparison between the SRTC and DOE travel models was not conducted, and only the SRTC data was used to estimate the 2016 on-road GHG emissions.

4.2.1.2 Emission Factors and Calculation Methodologies

In accordance with the GPC, the geographic method was used to calculate the GHG emissions for scope 1 on-road transportation emissions and scope 3 STA emissions. The geographic method offers the simplest approach for estimating on-road GHG emissions and also aligns with the methodology used in the previous *City of Spokane Greenhouse Gas Emissions Inventory Report for 2010-2012*, making it easier for comparisons to be made. The geographic method estimates emissions from trips that occur within the municipal boundary, regardless of the origin or destination of the trip. The scope 1 emissions were calculated using the estimated 2016 VMT data and STA operations exclusive to the municipal boundary. The emissions from the operation of STA buses outside the municipal boundary were reported under scope 3. The other scope 3 emissions from the on-road transportation sector were not calculated since detailed activity data on the out-of-boundary trips resulting from residents' activities was unavailable. To be able to properly report scope 3 emissions, additional surveys are needed to account for the detailed travel activity of Spokane residents who may travel outside the municipal boundary. This aligns with the GPC, as the protocol describes scope 3 emissions as not applicable to the geographic method unless additional steps are taken (Fong et al., 2014, p. 78). In 2016, the municipal boundary contained an estimated 1,245.76 million VMT (MVMT).

The estimated VMT data was allocated to the appropriate vehicle type using vehicle registration data reported by the DOL. It should be noted that the registration data was separated by vehicle types that were not always consistent with the vehicle emission factors reported by the *International Panel on Climate Change (IPCC) Emission Factor Database* (2013). Some vehicle classes reported by the DOL were combined to better align with the passenger, light-duty, heavy-duty, and motorcycle emission factors used by the IPCC. The motorhome, combination, commercial, fixed load, and tow trucks reported by the DOL were assumed to be classified as heavy-duty, gas-powered vehicles. The non-gas-powered combination, commercial, fixed load, and tow trucks reported by the DOL were assumed to be classified as heavy-duty, diesel-powered vehicles. It was also assumed the truck classification in the DOL data could be classified as a light-duty vehicle, and the motorcycle and moped counts reported by the DOL were combined to use the gas-powered motorcycle emission factor. Table 13 lists the emission factors from the IPCC that were used to estimate the GHG emissions from the on-road transportation subsector.

Table 13 – On-road transportation vehicle types and emission factors (Intergovernmental Panel on Climate Change (IPPC), 2018)

Vehicle Type (Fuel Type)	Units	CO_2	CH_4	N_20
Passenger (gas)	g km^{-1}	285	0.039	0.026
Light-Duty (gas)	g km^{-1}	396	0.039	0.043
Heavy-Duty (gas)	g km^{-1}	1,017	0.121	0.088
Light-Duty (diesel)	g km^{-1}	331	0.001	0.001
Heavy-Duty (diesel)	g km^{-1}	1,011	0.004	0.003
Motorcycle (gas)	g km^{-1}	219	0.04	0.003

The default emission factors from *IPCC Emission Factor Database* (Intergovernmental Panel on Climate Change (IPPC), 2018) were used, as recommended by the GPC, because detailed vehicle information (i.e., make, model, and age) for each vehicle was unavailable (Fong et al., 2014, p. 50).

The STA bus fleet consumed a total of 1,133,866 gallons of fuel during 2016. This data was scaled using route miles in City of Spokane. The heavy-duty diesel vehicle emission factor from Table 13 was used to calculate the emissions within the municipal boundary and was reported under scope 1 emissions. Equation 1 was used to calculate the on-road GHG emissions, and Equation 2 was used to calculate the total CO_2e emissions.

4.2.2 Railways

The Railways sub-sector accounts for the emissions generated by locomotives used to transport people and goods (Fong et al., 2014, p. 78).

4.2.2.1 Activity Data

Amanda Maruffo from Burlington Northern Santa Fe Railway (BNSF) provided the *2017 Washington State Fuel Data* (Burlington Northern Santa Fe, 2017) that BNSF reported to the DOE. The file contained estimated 2017 fuel consumption, in gallons, for rail operations occurring in Spokane County. James Brannen from Union Pacific Railroad (UPRR) provided the *UPRR 2017 Estimated Fuel Consumption in Washington* report (Union Pacific Railroad, 2017) that contained the estimated 2017 fuel consumption in gallons and length in miles for track segments in Spokane. Nicole Farthing from Amtrak provided the Spokane County route map and 2016 Spokane County estimated fuel consumption in gallons. National freight-rail fuel usage from the *2016 / 2017 BNSF Annual Report* (Burlington Northern Santa Fe Railway, 2017) and the *UPRR 2017 Building America Repor*t (Union Pacific Railroad, 2017) was used to scale the 2017 fuel data to account for the 2016 fuel consumption. Due to the lack of transboundary railway fuel usage, scope 3 emissions were accounted for using Spokane County fuel consumption that occurs outside the municipal boundary. In the previous *City of Spokane Greenhouse Gas Inventory Report for 2010-2012*, national freight-rail reports were not used because relevant county-level data was available from each inventory year.

4.2.2.2 Emission Factors and Calculation Methodologies

The estimated 2017 Spokane County fuel consumption provided by BNSF and UPRR was scaled to 2016 values using the percent change in fuel consumption reported by each company's annual reports. The length of track owned by BNSF was used to estimate the in-boundary and out-of-boundary railway emissions. Since UPRR operations may require the use of BNSF-owned tracks, the Spokane subdivision track length provided by UPRR (Union Pacific Railroad, 2017) was used to scale the County fuel consumption to account for the emissions within the City boundary. To estimate the GHG emissions from Amtrak, the 2016 Spokane County fuel consumption was scaled based on the route-miles that were within the municipal boundary. The emission factors were provided from the *Emission Factors for Greenhouse Gas Inventories* (EPA Center for Corportate Climate Leadership, 2018). The locomotive diesel fuel emission factors for CO_2, CH_4, and N_2O were 10.21 kg $gallon^{-1}$, 0.0008 kg $gallon^{-1}$, and 0.0003 kg $gallon^{-1}$, respectively. Equation 1 was used to calculate the railway emissions using fuel consumption data and the U.S. EPA locomotive diesel fuel emission factors, and Equation 2 was used to calculate the total CO_2e emissions.

4.2.3 Waterborne Navigation

The Waterborne Navigation sub-sector accounts for emissions generated by the use of motorized boats used for recreation and transporting goods and people (Fong et al., 2014, p. 80).

4.2.3.1 Activity Data

Waterborne navigation GHG emissions were accounted for using the EPA MOVES model (U.S. EPA, 2018b), which provided the estimated emissions from recreational marine vessels. *City of Spokane Municipal Code Section 16A.60.020* prohibits the use of motorboats and other personal motorized watercrafts on the Spokane River within the City of Spokane, unless the operations occur east of the UHD (2018). Approximately 0.9 miles of the Spokane River extends east of the UHD, while remaining within the municipal boundary. It was assumed that the U.S. EPA MOVES model produced a reasonable estimation of the waterborne GHG emissions that were reported under scope 3 due to the lack of origin or destination information regarding marine vessel activities along the Spokane River. Additional GHG emissions may result from the use of a jet boat owned by the Spokane Fire Department for water rescue operations. However, detailed activity data was unavailable; therefore, the emissions from the water rescue operations were not included in the inventory. The previous *City of Spokane's Greenhouse Gas Inventory Report for 2010-2012* did not include an estimation of waterborne navigation GHG emissions. In keeping with the GPC, it was included in this 2016 inventory to be as comprehensive as possible in the reporting of emissions from this sub-sector.

4.2.3.2 Emission Factors and Calculation Methodologies

Waterborne navigation GHG emissions from marine vessels were estimated using the U.S. EPA MOVES model (U.S. EPA, 2018b). The model estimated total GHG emissions in kg of CO_2 and CH_4 for recreational marine vessels in Spokane County. The results were scaled using the proportion of households in the City of Spokane relative to the number of households in Spokane County as reported in the U.S. Census Bureau American Community Survey (United States Census Bureau, n.d.). Equation 1 was used to calculate the waterborne GHG emissions, and Equation 2 was used to calculate total CO_2e emissions.

4.2.4 Aviation

The Aviation sub-sector accounts for emissions generated by flights occurring in the geographic boundary and flights departing from the airports that serve the City (Fong et al., 2014, p. 81).

4.2.4.1 Activity Data

Matt Breen from Spokane International Airport (SIA) provided the total number of flight operations, which included incoming and departing flights, and estimated fuel consumption (in gallons) for fuel purchased at SIA and Spokane Felts Field (SFF). Both airports are located within the municipal boundary of the City. Scope 1 aviation GHG emissions were estimated based on the total fuel consumed for local flights from SIA and SFF. Scope 3 emissions were estimated based on the total fuel consumed for itinerant flights from both airports.

Aviation emissions were not estimated for each aircraft type due to the lack of available data. Occasional international private flights arrive at SIA and these flights are included in the operations count; however, SIA does not track the international flights and was unable to provide an accurate number. Therefore, all flights were assumed to be domestic.

In 2016, SIA consumed 15,336,814 gallons of Jet-A fuel and 26,825 gallons of aviation gasoline. It was estimated that SFF used 493,000 gallons of total fuel. Based on the information provided by Matt Breen, it was assumed the fuel consumed for flights occurring at SFF was 50% jet fuel and 50% aviation gasoline. The activity data used for the Aviation sector follows guidance given in the GPC where the protocol requires the emissions from the direct combustion of fuel from aviation trips that depart and land within the city boundary to be reported as scope 1 emissions (Fong et al., 2014, pp. 80-81). These aviation trips were identified as local flights in the data that was provided. The GPC also requires emissions from departing flights to be reported under scope 3 (Fong et al., 2014, p.82) .These flights were identified as itinerant flights in the data that was provided.

The *City of Spokane's Greenhouse Gas Inventory report for 2010-2012* did not report SFF emissions due to the lack of available data. The previous inventory also incorporated annual passenger data and cargo tonnage to scale the activity data. The 2016 inventory did not scale the activity data based on passenger data because the GPC describes the use of passenger data as optional. Not scaling the emissions using passenger data generates a more conservative estimate of the aviation GHG emissions (Fong et al., 2014, p.82). Airport fleet vehicle emissions were also reported under the Aviation sub-sector in the previous *City of Spokane's Greenhouse Gas Inventory Report for 2010-2012*. Following the guidance given by the GPC (Fong et al., 2014, p.82) this inventory reported the GHG emissions from airport support vehicles under the Off-road sub-sector.

4.2.4.2 Emission Factors and Calculation Methodologies

The reported fuel data was divided between local and itinerant flights based on their proportion to the total flight counts. To calculate the total aviation GHG emissions, an aviation gasoline emission factor from the IPCC (Intergovernmental Panel on Climate Change (IPPC), 2013) and a jet fuel emission factor from the U.S. EPA's *GHG Emission Factors Hub* (EPA Center for Corportate Climate Leadership, 2018) were used. The aviation gasoline emission factors used for CO_2, CH_4, and N_2O were 72,000 kg terajoule^{-1} (TJ), 0.50 kg TJ^{-1}, and 2.00 kg TJ^{-1} respectively. The jet fuel emission factor for CO_2, CH_4, and N_2O was 9.75 kg gallon^{-1}, 0.0 kg gallon^{-1}, and 0.0003 kg gallon^{-1}, respectively. Equation 1 was used to calculate the aviation GHG emissions given the fuel consumption data from SIA and SFF, Equation 2 was used to calculate total CO_2e emissions.

The *City of Spokane's Greenhouse Gas Inventory Report for 2010-2012* scaled down the aviation GHG emissions due to the joint ownership of SIA between the City of Spokane and Spokane County. The emissions were also scaled based on the amount of deplaning and enplaning passengers. The data provided for the 2016 inventory was not scaled. For this inventory the GHG emissions were allocated based on the geographic location since both airports were located within the boundary. This is in accordance with the GPC (Fong et al., 2014, p.82) and may have resulted in a more conservative estimate of the aviation GHG emissions than was reported in past community-scale inventories.

4.2.5 Off-Road

The Off-road sub-sector accounts for emissions from vehicles designed to travel on unpaved terrain (Fong et al., 2014, p. 82).

4.2.5.1 Activity Data

The MOVES model (U.S. EPA, 2018b) provided the total amount of CO_2 and CH_4 emissions in kg and was used to estimate the off-road transportation emissions from recreational, airport support, and railway activities. The results of the MOVES model were assumed to be a reasonable representation for the off-road emissions in Spokane County. Since both airports and railyards are located within the municipal boundary, the results of the model were reported as scope 1 emissions.

In the previous *City of Spokane Greenhouse Gas Inventory Report for 2010-2012* emissions from agricultural, commercial, construction, industrial, and lawn and garden activities were all reported under the Off-road sub-sector (City of Spokane, 2016d, p. 51). However, in keeping with the GPC guidelines, for this 2016 inventory, these emissions were reported under the Stationary Energy sector (Fong et al., 2014, pp.82-83).

4.2.5.2 Emission Factors and Calculation Methodologies

Emission factors for off-road vehicles and equipment in the Off-road sub-sector were not required because the MOVES model reported the GHGs in kg. Equation 2 and the GWPs in Table 6 were used to calculate the MT CO_2e, and the results were then scaled to the number of households of the City of Spokane relative to the number of households in Spokane County as reported in the U.S. Census Bureau American Community Survey (United States Census Bureau, n.d.). The recreational, airport support, and railway off-road GHG emissions were reported as scope 1 emissions. The recreational marine vessel emissions were reported as scope 3 emissions in the Waterborne Navigation sub-sector. The GHG emissions from the construction, industrial, lawn and garden, commercial, logging, and agriculture sectors were reported under the Stationary Energy sector following the framework given in the GPC. The *City of Spokane's Greenhouse Gas Inventory Report for 2010-2012* also scaled the off-road GHG emissions using the percentage of households in Spokane (City of Spokane, 2016d, p. 55)

4.3 Waste

The Waste sector accounts for emissions generated by the disposal and treatment of solid waste and wastewater (Fong et al., 2014, p. 85). Table 14 summarizes the scopes and sub-sectors used for calculating GHG emissions from the Waste sector.

Table 14 – Scopes and sub-sectors used for calculating GHG emissions from the Waste sector

Sub-sector	Scope 1	Scope 2	Scope 3
Disposal of Solid Waste Generated in the City	☒	-	☒
Biological Treatment of Waste Generated in the City	☐	-	☒
Incineration and Open Burning of Waste Generated in the City	☐	-	☐
Wastewater Generated in the City	☒	-	☐

Emissions were included in the Waste sector if they were generated by the disposal of waste, including wastewater, solid waste, and organic waste, within the municipal boundary.

Incineration and open burning of waste, as defined in the GPC, was not included in this inventory due to the lack of activity data for the small-scale incineration of waste.

Disposal of solid waste generated by the community included any waste sent to a landfill or disposed of without biological treatment or incineration. Biological treatment of waste is the composting and anaerobic digestion of organic waste. Incineration is the controlled burning of solid waste. Wastewater emissions are the fugitive methane emissions generated in the aerobic or anaerobic process of wastewater treatment.

The previous *City of Spokane Greenhouse Gas Inventory Report for 2010-2012* divided waste emissions into six sub-sectors for solid waste and four sub-sectors related to wastewater. In the previous inventory, the Waste sector included community-generated emission from the following sub-sectors: Methane Emissions from Landfills, Waste Combustion Facilities, Waste to Landfills, Process Emissions, Waste Transportation Emissions, and Waste to Combustion Facility. Methane emissions from landfills and treatment processes were included in the Waste sector for this 2016 community-wide inventory. In keeping with the GPC the emissions from waste transportation were kept separate (Fong et al., 2014, pp. 85-86), and the WTE facility emissions were accounted for in the Stationary Energy sector of this 2016 inventory (Fong et al., 2014, p. 63). In the previous *City of Spokane Greenhouse Gas Inventory Report for 2010-2012*, the emission from the biological treatment of waste emissions were excluded because it was assumed Royal City Organics (in 2010) and Barr-Tech (in 2012), the contractors used for processing organic wastes in each inventory year, used properly aerated compost piles resulting in emissions of almost entirely biogenic CO_2 (City of Spokane, 2016d, p. 61). In keeping with the GPC guidelines, this 2016 inventory accounted for the emissions resulting from organic waste processed by Barr-Tech were included as scope 3 emissions.

Lastly, it is also important to note that the previous *City of Spokane Greenhouse Gas Inventory Report for 2010-2012* separated emissions from wastewater and solid waste into two separate sectors. In keeping with the GPC guidelines for this 2016 inventory, these emissions were accounted for under the Waste sector as separate sub-sectors.

4.3.1 Disposal of Solid Waste Generated in the City

The Disposal of Solid Waste Generated in the City sub-sector accounts for emissions from solid waste at the two managed disposal sites operated by the City – the Northside Landfill (NSLF) and the Southside Landfill (SSLF). The SSLF is not located in the municipal boundary but received, prior to closing, refuse generated within the boundary; therefore, the emissions from the SSLF were reported as scope 3.

4.3.1.1 Activity Data

The City of Spokane Solid Waste Disposal Department provided the annual CH_4 emissions generated at both landfills (Vigeland, 2018c, 2018b). The NSLF operates two types of cells, open and closed. The emissions for the closed cell were calculated using Equation 3, which used the actual amount of CH_4 recovered, a 95% collection efficiency, a 99% destruction efficiency, and a 10% oxidation factor. The modeled CH_4 generation rate and the oxidation factor was used to calculate the CH_4 emissions from the open cell. Both equations incorporate a modeled CH_4 generation rate using a first-order decay calculation to account for cumulative annual emissions starting in the first year of operation. Emissions from the SSLF was calculated using flare station data from the *Southside Landfill Flare Station YEAR 2016* (City of Spokane Solid Waste Disposal Department, 2016b, 2016a).

Table 15 – Activity data for the SSLF flare stations (City of Spokane Solid Waste Disposal Department, 2016b, 2016a)

Facility	Total Flow Flares (scf)	Average CH_4 Percentage	Collection Efficiency
Southside Landfill	85,981,587.12	26.46%	95%

4.3.1.2 Emission Factors and Calculation Methodologies

Methane emissions were calculated using guidelines from the LGO Protocol (California Air Resources Board, 2010, sec. 9.3.2). The total CH_4 emitted in MT of CO_2e was calculated using Equation 3.

$$\text{CH}_4 \text{ emitted } CO_2e\ (MT) = LFG_{collected} \times \%CH_4 \times \left\{(1-DE) + \left[\left(\frac{1-CE}{CE}\right) \times (1-OX)\right]\right\} \times unit\ conversion \times GWP \quad \textbf{(3)}$$

Where:

$LFG_{collected}$	=	Annual LFG collected by the collection system [million standard cubic feet (MMSCF)]
% CH_4	=	0.2646 – fraction of CH_4 in LFG
DE	=	0.99 – CH_4 destruction efficiency, based on the type of combustion/flare system
CE	=	0.95 – collection efficiency
OX	=	0.10 – oxidation factor
Unit conversion	=	19.125 – applies when converting MMSCF of CH_4 to MT of CH_4
GWP	=	28 – global warming potential

4.3.2 Biological Treatment of Waste Generated in the City

The Biological Treatment of Waste Generated in the City sub-sector accounts for the emissions generated by the composting and anaerobic digestion of organic waste (Fong et al., 2014, p. 94).

4.3.2.1 Activity Data

The activity data for Biological Treatment of Waste Generated in the City came from the amount of clean green material sent to the sub-contractor Barr-Tech, who biologically treats organic waste. The *Annual Report: Energy Recover/Incineration* (Washington State Deparment of Ecology, 2016), provided by Rhonda Albin, reported a quantity of 9,650.64 tons of organic waste sent to Barr-Tech. The *City of Spokane Greenhouse Gas Inventory Report for 2010-2012* (2016, p.61) excluded the Biological Treatment of Waste Generated in the City because it was assumed the compost piles were properly aerated, resulting in emissions of almost entirely biogenic CO_2 with trace amounts of CH_4 and N_2O. In keeping with the GPC, this 2016 inventory included these emissions from the biological treatment of organic waste.

4.3.2.2 Emission Factors and Calculation Methodologies

The emission factors for CH_4 and N_2O used to calculate the emissions from the organic waste were provided in the GPC, 4 g CH_4 kg^{-1} waste and 0.3 g N_2O kg^{-1} waste, respectively (Fong et al., 2014, p.95) Equation 4 and Equation 5 (Fong et al., 2014, p. 95) were used to calculate the CH_4 and N_2O emissions and Equation 2 was used to calculate the CO_2e.

$$CH_4\ Emissions = (\Sigma_i(\mathrm{m}_i \times EF_{CH_{4_i}}) \times 10^{-3} - R) \quad \textbf{(4)}$$

$$N_2O\ Emissions = (\Sigma_i\left(m_i \times EF_{N_2O_i}\right) \times 10^{-3}) \quad \textbf{(5)}$$

Where:

CH_4 Emissions	=	Total CH_4 emissions (MT)
N_2O Emissions	=	Total N_2O emissions in (MT)
m	=	Mass of organic waste treated by biological treatment type, i (kg)
EF_{CH4}	=	CH_4 emission factor based upon treatment type, i
EF_{N2O}	=	N_2O emission factor based upon treatment type, I
i	=	Treatment type: composting or anaerobic digestion
R	=	Total MT CH_4 recovered in the inventory year, if gas recovery system is in place

4.3.3 Wastewater Generated in the City

The Wastewater Generated in the City sub-sector accounts for the emissions generated by the wastewater treatment process (Fong et al., 2014, p. 99).

4.3.3.1 Activity Data

Stationary combustion data for the incomplete combustion of biogas was provided by Deborah Bisenius in the *2016 Biogas Usage.4.24.17* report (City of Spokane, 2016b). This document reported: the volume of biogas (in cubic feet per day, $ft^3\ day^{-1}$) that was produced by the anaerobic digesters, the percent of CH_4 in the biogas, the population that was served by this treatment facility, and the biological oxygen demand (BOD).

The process scope 1 emissions also included the emissions from the generation of N_2O as a result of treatment plant and effluent processes. The treatment of domestic wastewater generates N_2O emissions during the nitrification and denitrification processes. Additionally, the discharge of effluent to receiving waters (e.g., the Spokane River) may also generate N_2O emissions. Process emissions data was provided by RPWRF in the *2016 Annual Assessment: City of Spokane Riverside Park Water Reclamation Facilit*y (City of Spokane, 2016a).

4.3.3.2 Emission Factors and Calculation Methodologies

Stationary combustion emissions from the incomplete combustion of biogas were calculated following the guidelines from the LGO Protocol (California Air Resources Board, 2010, p. 109). Using Equation 6, the annual CH_4 emissions from incomplete combustion of biogas in MT CO_2e was calculated.

$$CO_2e\ (MT) = Digester\ Gas \times F_{CH_4} \times \rho(CH_4) \times (1 - DE) \times 0.0283 \times 365.25 \times 10^{-6} \times GWP \qquad \textbf{(6)}$$

Where:

Digester Gas	=	cubic feet of biogas produced per day (ft^3/day)
F CH_4	=	fraction of CH_4 in biogas (58.64%)
$\rho(CH_4)$	=	662.00 (g/m^3) – density of methane at standard conditions
DE	=	0.99 – destruction efficiency
0.0283	=	conversion factor for ft^3 to m^3
365.25	=	conversion factor for days to year
10^{-6}	=	conversion from grams (g) to MT
GWP	=	28 – global warming potential for methane

Process emissions from the RPWRF nitrification and denitrification processes were calculated following the guidelines from the LGO Protocol (LGO) (California Air Resources Board, 2010, sec. 10.3.1.1). Using Equation 7, the annual N_2O emissions in MT of CO_2e were calculated.

$$CO_2e\ (MT) = \left((P_{total} \times F_{ind-com}) \times EF\ nit/denit \times 10^{-6}\right) \times GWP \qquad \textbf{(7)}$$

Where:

P_{total}	=	Total population that is served by the wastewater treatment plant (WWTP) adjusted for industrial discharge, if applicable (person)
$F_{ind-com}$	=	1.25 – Factor for industrial and commercial co-discharge waste into the sewer system
EF $nit/denit$	=	7 – Emission factor for a WWTP with nitrification/denitrification [g N_2O person^{-1} year^{-1}]
10^{-6}	=	conversion from grams (g) to MT
GWP	=	265 – global warming potential for N_2O

Process emissions from the RPWRF's effluent discharges to the Spokane River were calculated following the guidelines from the LGO Protocol (California Air Resources Board, 2010, sec. 10.3.2.3). Using Equation 8, the annual N_2O emissions in MT CO_2e from effluent discharge were calculated.

$$CO_2e\ (MT) = N\ load \times EF\ effluent \times 365.25 \times 10^{-3} \times \frac{44}{28} \times GWP \quad \textbf{(8)}$$

Where:

N load	=	Measured average total nitrogen (N) discharged (kg N day^{-1})
$EF_{effluent}$	=	0.005 – emission factor (kg N_2O-N kg sewage-N produced^{-1})
365.25	=	conversion factor for days to year
10^{-3}	=	conversion from kg to MT
44/28	=	Molecular weight ratio of N_2O to N_2
GWP	=	265 – global warming potential for N_2O

4.4 Industrial Processes and Product Use (IPPU)

The IPPU sector accounts for the emissions generated from non-energy related industrial activities. This includes industrial uses of fossil fuels (Fong et al., 2014, p. 105). Table 16 summarizes the scopes and sub-sectors used for calculating GHG emissions from the IPPU sector.

Table 16 – Scopes and sub-sectors used for calculating GHG emissions from the Industrial Processes and Product Use (IPPU) sector

Sub-sector	Scope 1	Scope 2	Scope 3
Industrial Processes	☐	-	-
Product Use	☐	-	-

Facilities that produce more than 10,000 MT of total CO_2e are required to report GHG emissions to the DOE as mandatory reporters. However, all of these facilities were located outside of the community-wide inventory boundary and were not included in this inventory. To locate possible IPPU GHG emissions sources that do not report to the U.S. EPA, research was conducted on industrial process facilities within the City. Six facilities: Pacific Steel and Recycling, Pyrotek, Coeur d'Alene Window, Haskin Steel Co., Metal Sales Manufacturing, and Melcher Manufacturing Company, Inc. were located within the municipal boundary. While these facilities were contacted for production data (e.g., kg of ore, square feet of glass), all six facilities declined to share their production data; however, it is likely a significant portion of their emissions are included in the energy consumption data provided by Avista and IPL. Without production and energy consumption data for these facilities, the GHG emissions from the IPPU sector could not be estimated. Further research and data sharing will be needed in the future to estimate emissions from the IPPU sector.

In the *City of Spokane's Greenhouse Gas Inventory Report for 2010-2012* (City of Spokane, 2016d), the City reported emissions from four industrial process facilities. These four facilities are mandatory reporters to the U.S. EPA; however, they lie outside the municipal boundary and were not included in the 2016 GHG emissions inventory. Also reported as industrial process emissions in the previous inventory was a portion of natural gas leaks from Avista. However, activity data for natural gas leaks during the 2016 inventory year was not available.

4.5 Agriculture, Forestry and Other Land Use (AFOLU)

The AFOLU sector accounted for emissions that are generated by land-use changes, livestock, and the use of agriculture fertilizers (Fong et al., 2014, p.117). Table 17 summarizes the scopes and sub-sectors used for calculating GHG emissions from the AFOLU sector.

Table 17 – Scopes and sub-sectors used for calculating GHG emissions from the Agriculture, Forestry and Other Land Use (AFOLU) sector

Sub-sector	Scope 1	Scope 2	Scope 3
Livestock	☐	-	-
Land	☒	-	-
Aggregate Sources and Non-CO_2 Emission Sources on Land	☒	-	-

The AFOLU sector of this report included emissions from land and non-CO_2 emission sources on land within the City boundary. Emissions from land-use were modeled through remote sensing imagery and excluded forestland due to lack of available activity data (discussed further in Section 4.5.1). The inclusion of forestland in land emissions will change the overall amount of GHG emissions estimated in the AFOLU sector. No GHG emissions from urea application, rice cultivation, liming, or harvested wood products were estimated because of the lack of available activity data.

The contribution of emissions from livestock were also considered negligible (< 5 MT of CO_2e) in relation to the community-wide inventory emissions. For this reason, they were not estimated. The *City of Spokane Ordinance 17C.310.115* restricts the keeping of small livestock within the city limits to one small livestock (i.e. goat, pig, donkey, less than 24 inches shoulder height and 150 pounds) per 2,500 square feet (2014b). This ordinance was passed in 2014, and since then records of the total number of animals within the City have not been kept. The keeping of large livestock is outlined in *Spokane Ordinance Section 17C.310.100* (2014a) and restricts larger livestock (such as bovine and equine) to residential agriculture (RA) zones. There are two RA zones, within the municipal boundary, both located in Hangman Valley (southern Spokane) that are less than 200 total acres. This restrictive ordinance also limits the keeping of large livestock to a maximum of three animals per irrigated acre, meaning no more than 600 total large livestock are permitted within the boundary. The information from this ordinance was used with the default IPCC emission factors for enteric fermentation and manure management (Intergovernmental Panel on Climate Change (IPPC), 2018; U.S. EPA, 2018c), 5 kg CO_2 animal^{-1} year^{-1} and < 1 kg CO_2 animal^{-1} year^{-1}, respectively, to calculate < 5 MT of CO_2e emissions, which is less than 0.001% of total 2016 community-wide GHG emissions.

It is also important to note that emissions from the AFOLU sector were not included in the *City of Spokane's Greenhouse Gas Inventory Report for 2010-2012*, and therefore no longitudinal comparison can be made.

4.5.1 Land

Changes in soil composition, caused by land-use changes, can generate GHG emissions (Fong et al., 2014, p.117).

4.5.1.1 Activity Data

Remotely sensed GIS imagery data from the Washington State Department of Agriculture (WSDA) and the City of Spokane was used as the primary sources of activity data in this sub-sector. WSDA crop data, in the form of crop type and corresponding area, for the years 2011 and 2016 was supplied by Perry Beale at the WSDA Natural Resources Assessment Section. Building, pavement, land use, and wetland spatial data layers were supplied by the GIS manager, Bill Myers, at the City of Spokane. The Multi-Resolution Land Characteristics Consortium produces the National Land Cover Database every 5 years; however, due to the government shutdown, publications were postponed, and 2016 forestland data was unavailable. To collect forestland spatial data, the *United States Geological Survey*, the *National Oceanic and Atmospheric Administration*, and the *Washington Geospatial Open Data* databases were all consulted as possible additional sources of forestland activity data. However, these databases were not able to provide forestland spatial data for the 2016 reporting period which led to the exclusion of forestland data in the modeling process.

4.5.1.2 Emission Factors and Calculation Methodologies

Land emissions analysis required the use of GIS data that represents land cover for the years 2011 and 2016 only. The GPC (Fong et al., 2014, sec. 10.4) recommends using 20-year data to get an average annual land change. However, five years prior was the best available data on land use for the 2016 inventory. Each spatial dataset layer contained feature classes, or land cover types, which were categorized by the applicable IPCC land cover categories in Table 18.

Table 18 – Land cover classification by land cover types and corresponding equivalent IPCC land use category

City of Spokane and WSDA Data		IPCC
Layers	Type	GHG Land Use Category
Buildings	Residential: Single/multi-family dwelling	Settlement
	Outbuilding: garage, shop etc.	Settlement
	Carport	Settlement
	Mobile Home	Settlement
	Sky Walk	Settlement
	Tank or Silo	Settlement
	Under Construction	Settlement
	Commercial	Settlement
Wetlands	Permanent Lake	Wetland
	Permanent Marsh	Wetland
	Permanent River	Wetland
	Seasonal Lake	Wetland
	Seasonal Marsh	Wetland
Pavement	Asphalt	Settlement
	Brick paver	Settlement
	Composite	Settlement
	Concrete	Settlement
	Gravel	Settlement
	Oiled	Settlement
	Unimproved	Settlement
	Wood	Settlement
	Dirt	Settlement
	Brick	Settlement
Cropland	Hay/Silage	Cropland
	Berry	Cropland
	Cereal Grain	Cropland
	Nursery	Cropland
	Other	Grassland
	Turfgrass	Grassland
Land use	Open Space	Grassland
	Conservation Open Space	Grassland
	Potential Open Space	Forestland/Grassland
	Agriculture	Grassland

The initial dataset layers overlapped, causing the total coverage area to be greater than what exists. To address this issue, each layer from the 2016 and 2011 datasets were clipped to eliminate all intersections that would result in the double counting of land. Historical satellite imagery was used to determine actual land use cover from the land use types (e.g. potential open space = forestland, open space = grassland). Each layer was then isolated and separated in accordance with the assigned IPCC land use category. Each land use layer was then merged to create six separate spatial data layers highlighting the IPCC land use categories. The result was twelve individual shapefiles illustrating the six land use categories for both 2011 and 2016. Figure 5 illustrates the clipped and isolated 2011 land cover categories.

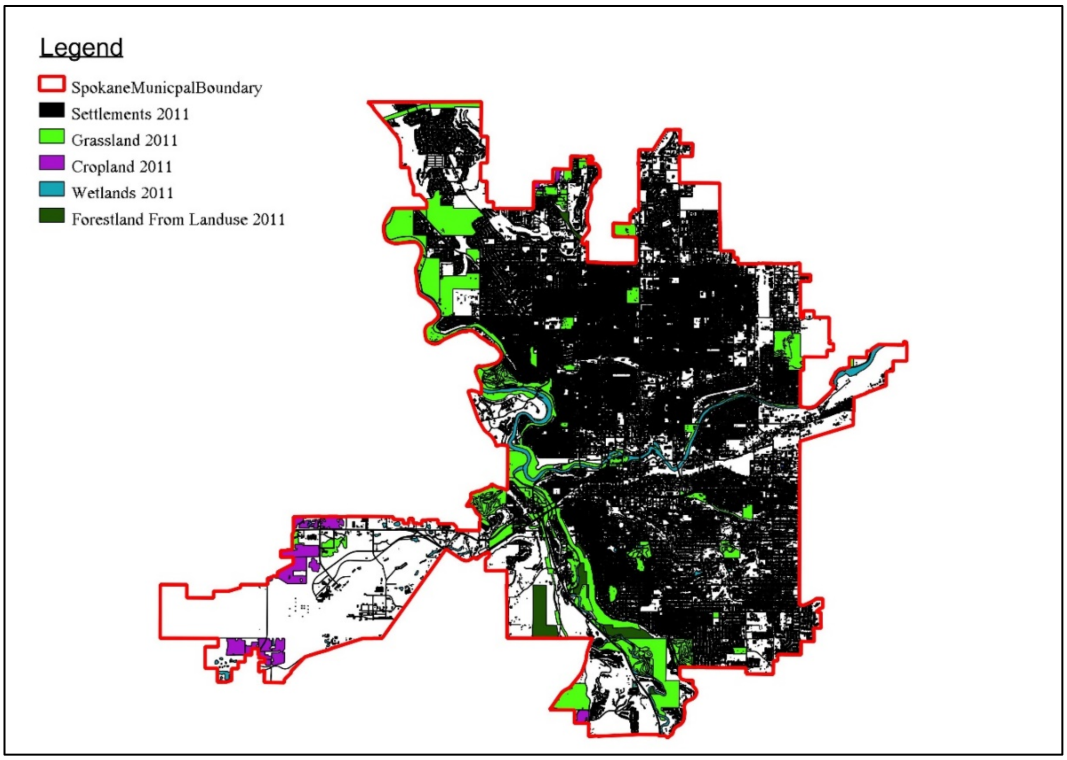

Figure 7 – 2011 land cover categories within the City of Spokane municipal boundary

Once completed, each 2011 layer was intersected with a corresponding 2016 layer. The change in each land use category was then calculated between the reporting years 2011 and 2016. The tabular data was compiled into a land use change matrix, shown in Table 19, where the data was then manipulated to calculate GHG emissions for each land use change category for the 2016 reporting year.

Table 19 – 2011 - 2016 land use change matrix in hectares (ha)

		2011						**2016 Land Totals**
		Forestland	Cropland	Grassland	Wetland	Settlements	Other	
2016	Forestland	-	-	-	-		-	**-**
	Cropland	-	278.63	0.55	0.00	0.01	-	**279.19**
	Grassland	-	13.01	2726.27	0.05	1.58	-	**2740.91**
	Wetland	-	0.00	0.11	314.46	2.85	-	**317.42**
	Settlements		0.00	2.63	0.00	4698.23	-	**4700.86**
	Other	-	-	-	-	-	-	**-**
2011 Land Totals		**-**	**291.64**	**2729.56**	**314.50**	**4702.67**	**-**	

The underlined values are the area for each land category that did not change between 2011 and 2016. Due to the lack of data, forestland and other land was not estimated nor included in the inventory. Table 20 lists the total change in area for each land category.

Table 20 –Total land use change by land type in hectares (ha)

Category	Forestland	Cropland	Grassland	Wetland	Settlements	Other	**Total**
Forestland	-	-	-	-	-	-	-
Cropland	-	-2.17	0.09	-	-	-	**-2.08**
Grassland	-	2.17	-0.55	0.01	0.26	-	**1.89**
Wetland	-	-	0.02	-0.01	0.48	-	**0.49**
Settlements	-	-	0.44	-	-0.74	-	**-0.30**
Other	-	-	-	-	-	-	-

Approximately 1.89 hectares of grassland was added between the 2011 and 2016 GHG inventories. The land use emission factors are categorized in Table 21 by sector.

Table 21 – Emissions factors for land use change (United Nations Climate Change, 2017)

Land Use Change Category	Emission Factor (MT CO_2e ha^{-1})
Land Converted to Settlements	9.40
Land Converted to Other	9.40
Land Converted to Cropland	1.70
Land Converted to Grasslands	0.94
Land Converted to Wetlands	-4.47
Land Converted to Forestland	-76.27
Settlements Remaining Settlements	-2.85
Other Land Remaining Other Land	-2.85
Cropland Remaining Cropland	-0.06
Grassland Remaining Grassland	-92.55
Wetlands Remaining Wetlands	-2.90
Forestland Remaining Forestland	-2.28

To convert land use data to GHG emissions the following procedure was used:

1. Using the data in Table 19, land use categories that were not converted (i.e., underlined values in Table 19), the 2011 total was deducted from the corresponding change and divided by the analysis period (6 years) to result in a final average annual land change (Table 20).
2. Each land use category in Table 19 that was converted over the analysis period was also divided by the number of years in the analysis period to result in an average annual land change (Table 20).
3. Emissions factors (in CO_2e hectare^{-1}) were applied to each land use category to calculate the respective emissions and sinks from each land use change between the years 2011 and 2016. These emissions factors can be found in Table 21 and were obtained from the 2017 U.S. National Inventory Report (United Nations Climate Change, 2017).

Equation 9 and Equation 10 were used to calculate GHG emissions.

$$CO_2e\ \text{emissions}_{lands\ not\ converted} = land\ type_{ha} \times EF_{land\ remaining\ as\ land} \quad \textbf{(9)}$$

$$CO_2e\ \text{emissions}_{lands\ converted} = land\ type_{ha} \times EF_{land\ converted\ to\ land} \quad \textbf{(10)}$$

4.5.2 Aggregate Sources and Non- CO_2 Emission Sources on Land

The Aggregate Sources and Non-CO_2 Emission Sources on Land sub-sector accounts for the emissions generated by the burning of biomass without energy recovery (Fong et al., 2014, p. 124).

4.5.2.1 Activity Data

The Washington Department of Natural Resources (DNR) spatial data was used to estimate GHG emissions from the burning of biomass. Spatial data from large fires was extrapolated from the *Washington Large Fires 1973-2017* file (Washington Department of Natural Resources, 2018b). Geolocated point data was found in the *DNR Fire Statistics 2008 – Present* file (Washington Department of Natural Resources, 2018a) and was used to determine smaller fires. This data listed all recorded fires within the inventory boundary for the 2016 year and the associated area burned. This data can be found on the *Washington Department of Natural Resources GIS Open Data* database (Washington State Department of Natural Resources, 2019). This subsector was not included in the previous *City of Spokane's Greenhouse Gas Inventory Report for 2010-2012*; therefore, no longitudinal comparisons can be made with previous inventories.

4.5.2.2 Emission Factors and Calculation Methodologies

To determine GHG emissions from the burning of biomass, a GIS spatial data analysis was completed. The two spatial files were clipped to the Spokane municipal boundary and fires from the 2016 reporting year were isolated. There were no large fires which occurred within the municipal boundary for the 2016 year, which resulted in no scope 1 emissions from wildfires. Fires within the clipped and isolated *DNR Fire Statistics 2008 – Present* file (Washington Department of Natural Resources, 2018a, 2018b) were highlighted, and the total amount of area consumed was calculated. The result was 1.76 total hectares consumed. The emission factors for burning biomass and the total emissions from the non-CO_2 emission sources on land subsector (Table 22) are listed below. This data, Equation 1, and Equation 2 were used to calculate GHG emissions from the area burned.

Table 22 – Emissions factors for the burning of biomass (Washington Department of Natural Resources, 2018a, 2018b)

MT CH_4 hectare^{-1} consumed	MT N_2O hectare^{-1} consumed
0.2879	0.0159

5 METHODOLOGY FOR CALCULATING LOCAL GOVERNMENT OPERATIONS GHG EMISSIONS BY SOURCE USING THE LGO PROTOCOL

The following subsections describe the LGO Protocol methodologies used to quantify GHG emissions for the local government operations inventory by local government sectors and sources. These subsections are a summary of the scopes and sources of emissions from each sector, including details on specific activity data, emissions factors, and calculation methodologies. The organizational structure of this chapter is designed to make it easier for external review, future LGO inventory efforts, and reporting of results to The Climate Registry reporting program using the Local Government Operations Standard Inventory Report Template (California Air Resources Board, 2010, Chapter 13). For more information on step-by-step guidance for quantifying GHG emissions from various local government sources using the LGO Protocol, see Part III of the LGO Protocol (California Air Resources Board, 2010, pp. 27–125).

5.1 Buildings and Other Facilities

Table 23 summarizes the scopes and sources used for calculating GHG emissions from the Buildings and Other Facilities sector. This sector analyzes emissions from all buildings and facilities that are not included in other sectors of the inventory, such as the Water Delivery Facilities and Power Generation Facilities sub-sectors.

Table 23 – Scopes and sub-sectors used for calculating GHG emissions from the –Buildings and Other Facilities sector

Source	Scope 1	Scope 2	Scope 3
Stationary Combustion	☒	-	-
Fugitive Emissions	☐	-	-
Purchased Electricity	-	☒	-
Purchased Steam	-	☐	-
Purchased District Heating and Cooling	-	☐	-
Scope 3	-	-	☐

Purchased steam was not included in the 2016 inventory due to the lack of available activity data from potential sources in the spaces rented by the City in the Spokane County Courthouse.

5.1.1 Scope 1 Stationary Combustion

5.1.1.1 Activity Data

Stationary combustion data was collected by the City of Spokane in the *Facility Energy Report 2015 – 2017* (Simmons & Olsen, 2018). This document reported the activity data for each source of emissions within the City of Spokane LGO boundary categorized by facility location and type.

The amount of energy purchased in 2016 was reported in terms of kWh and therms of natural gas.

5.1.1.2 Emission Factors and Calculation Methodologies

Stationary combustion emissions were calculated using the recommended approach from the LGO Protocol (California Air Resources Board, 2010, sec. 6.1.1), which used Equation 1, the activity data, and the default emission factors (Table 7) for CO_2, CH_4, and N_2O to calculate the GHG emissions. Equation 2 and the corresponding GWPs (Table 6) for each GHG were used to calculate the total MT of CO_2e.

5.1.2 Scope 2 Purchased Electricity

5.1.2.1 Activity Data

Purchased electricity data was collected by the City of Spokane in the *Facility Energy Report 2015 – 2017* (Simmons & Olsen, 2018). This document reported the activity data for each source within the City of Spokane LGO boundary categorized by facility location and type. The amount of power purchased in 2016 was reported in terms of kWh.

5.1.2.2 Emission Factors and Calculation Methodologies

Emissions for purchased electricity were calculated using the recommended approach from the LGO Protocol (California Air Resources Board, 2010, sec. 6.2.1). Using Equation 1, the activity data was multiplied by the associated emission factor (Table 7) to calculate the GHG emissions that were generated by using purchased electricity (in units of MT).

5.2 Street Lighting and Traffic Signals

Table 24 summarizes the scopes and sources used for calculating GHG emissions from the Street Lighting and Traffic Signals sector, which includes all City-owned and operated street lighting and traffic signal facilities, as well as Avista-contracted streetlights.

Table 24 – Scopes and sub-sectors used for calculating GHG emissions from the Street Lighting and Traffic Signals sector

Source	Scope 1	Scope 2	Scope 3
Purchased Electricity	-	☒	-
Scope 3	-	-	☒

5.2.1 Scope 2 Purchased Electricity

5.2.1.1 Activity Data

Purchased electricity data for City-owned and operated street lighting and traffic signals was collected by the City of Spokane in the *Facility Energy Report 2015 – 2017* and *2016SummariesDeptRank* (City of Spokane, 2018b; Simmons & Olsen, 2018). This document reports the activity data for each source within the City of Spokane LGO boundary categorized by facility location and type. The amount of power purchased in 2016 was reported in terms of kWh.

5.2.1.2 Emission Factors and Calculation Methodologies

Emissions for purchased electricity were calculated using the recommended approach from the LGO Protocol (California Air Resources Board, 2010, sec. 6.2.1). Using Equation 1, the utility specific emission factor (294 kg-CO_2e MWh^{-1}) provided by Avista was multiplied by the activity data to calculate the MT CO_2e generated from the use of purchased electricity. Equation 2 was used to calculated the MT CO_2e using the GWPs in Table 6.

5.2.2 Scope 3 Contracted Street Lighting

5.2.2.1 Activity Data

A portion of the City's street lights are owned and operated by Avista. The emissions generated from the use of grid-supplied energy for these contracted street lights are reported as scope 3 emissions. In 2016, there were 5,062.507 MWh consumed by Avista owned street lights (City of Spokane, 2018c).

5.3 Water Delivery Facilities

Table 25 summarizes the scopes and sources used for calculating GHG emissions from the Water Delivery Facilities sector, which includes the pumps and facilities required to transport water across the City.

Table 25 – Scopes and sub-sectors used for calculating GHG emissions from the Water Delivery Facilities sector

Source	Scope 1	Scope 2	Scope 3
Stationary Combustion	☒	-	-
Purchased Electricity	-	☒	-
Purchased Steam	-	☐	-
Purchased District Heating and Cooling	-	☐	-
Scope 3	-	-	☐

These facilities consume both natural gas and electricity to power the facility operations. Activity data supplied by the City of Spokane and emission factors (Table 7) were used to calculate emissions associated with these facilities.

It is important to note that the City of Spokane's 2012 LGO inventory reported emissions from the Water Delivery Facilities sector in a combined "Wastewater and Water" chapter. In keeping with the reporting structure of the LGO Protocol, 2016 emissions from the Water Delivery

Facilities and Wastewater Facilities sectors were reported in two separate sections of this chapter.

5.3.1 Scope 1 Stationary Combustion

5.3.1.1 Activity Data

The activity data for water delivery facilities was provided by the *Facility Energy Report 2015 – 2017* (Simmons & Olsen, 2018). This report provided the natural gas used (in therms) and purchased electricity (in kWhs) for each water delivery facility owned and operated by the City of Spokane, categorized by location and grouped by sector.

5.3.1.2 Emission Factors and Calculation Methodologies

Stationary combustion emissions were calculated using the recommended approach from the LGO Protocol (California Air Resources Board, 2010, sec. 6.1.1). Using this approach, the fuel use activity data was multiplied by the default emission factors (Table 7) for CO_2, CH_4, and N_2O and converted to units of MT using Equation 1. The calculated GHG emissions were then converted to CO_2e using the GWPs in Table 6 for each gas (Equation 2).

5.3.2 Scope 2 Purchased Electricity

5.3.2.1 Activity Data

Purchased electricity data was provided by the City of Spokane in the *Facility Energy Report 2015 – 2017* (Simmons & Olsen, 2018). This document reported the activity data for each source within the City of Spokane LGO boundary categorized by facility location and type. The amount of power purchased in 2016 was reported in terms of kWh.

5.3.2.2 Emission Factors and Calculation Methodologies

Emissions for purchased electricity were calculated using the recommended approach from the LGO Protocol (California Air Resources Board, 2010, sec. 6.2.1). Using Equation 1, the utility specific emission factor (294 kg-CO_2e MWh^{-1}) provided by Avista was multiplied by the activity data to calculate the MT CO_2e generated from the use of purchased electricity. Equation 2 was used to calculated the MT CO_2e using the GWPs in Table 6.

5.4 Wastewater Facilities

Table 26 summarizes the scopes and sources used for calculating GHG emissions from the Wastewater Facilities sector, which includes the emissions from treatment plants owned and operated by the City of Spokane. The RPWRF is the wastewater facility that serves the City of Spokane. It has a capacity of 150 million gallons per day and treats an average of approximately 34 million gallons per day (City of Spokane, 2016a).

Table 26 – Scopes and sub-sectors used for calculating GHG emissions from the Wastewater sector

Source	Scope 1	Scope 2	Scope 3
Stationary Combustion	☒	-	-
Fugitive Emissions	☐	-	-
Purchased Electricity	-	☒	-
Process Emissions	☒	-	-
Purchased Steam	-	☐	-
Purchased District Heating and Cooling	-	☐	-
Scope 3	-	-	☐

Stationary combustion emissions were generated by the incomplete combustion of digester gas and the combustion of natural gas as an energy source for plant operations. Purchased electricity was used for plant operations, while other treatment plant and effluent processes generated process N_2O emissions. The amount of purchased electricity and natural gas consumed in 2016 was reported in terms of kWh and therms, respectively. Scope 2 emissions for purchased steam and district heating & cooling were not included in this inventory, as they are not used or produced by the City of Spokane in the wastewater facilities included in this sector. The City of Spokane does not own or operate septic tank systems; therefore, scope 1 fugitive emissions from this source were also excluded from this inventory.

5.4.1 Scope 1 Stationary Combustion

5.4.1.1 Activity Data

Stationary combustion data for the incomplete combustion of biogas was provided by Deborah Bisenius in the *2016 Biogas Usage.4.24.17* report (City of Spokane, 2016b). This document reported: the volume of biogas (in cubic feet per day, $ft^3\ day^{-1}$) that was produced by the anaerobic digesters, the percent of CH_4 in the biogas, the population that was served by this treatment facility, and the BOD.

Stationary combustion data from the combustion of natural gas for use as an energy source was collected by the City of Spokane in the *Facility Energy Report 2015 – 2017* (Simmons & Olsen, 2018). CO_2 emissions resulting from flaring CH_4 produced by wastewater anaerobic digesters were excluded from this inventory. Similar to the previous City inventories, it was assumed in this inventory that the amount of CO_2 generated by the flaring process is less than or equal to the amount of CO_2 that would have been emitted had the source organic material decomposed in aerobic conditions (City of Spokane, 2016d, p. 119).

5.4.1.2 Emission Factors and Calculation Methodologies

Stationary combustion emissions from the incomplete combustion of biogas were calculated following the guidelines from the LGO Protocol (California Air Resources Board, 2010, p. 109). Using Equation 6, the annual CH_4 emissions from incomplete combustion of biogas in MT CO_2e was calculated.

Stationary combustion emissions, from the burning of natural gas, were calculated using the recommended approach from the LGO Protocol (California Air Resources Board, 2010, sec. 6.1.1). Using this approach, the fuel use activity data was multiplied by the default emission factors (Table 7) for CO_2, CH_4, and N_2O and converted to units of MT using Equation 1. The calculated GHG emissions were then converted to CO_2e using the GWPs in Table 6 for each gas (Equation 2).

5.4.2 Scope 1 Process Emissions

5.4.2.1 Activity Data

Process emissions included the emissions from the generation of N_2O as a result of treatment plant and effluent processes. The treatment of domestic wastewater generates N_2O emissions during the nitrification and denitrification processes. Additionally, the discharge of effluent to receiving waters (e.g., the Spokane River) may also generate N_2O emission. Process emissions data was provided by RPWRF in the *2016 Annual Assessment: City of Spokane Riverside Park Water Reclamation Facilit*y (City of Spokane, 2016a).

5.4.2.2 Emission Factors and Calculation Methodologies

Process emissions from the RPWRF nitrification and denitrification processes were calculated following the guidelines from the LGO Protocol (California Air Resources Board, 2010, sec. 10.3.1.1). Using Equation 7, the annual N_2O emissions in metric tons of CO_2e were calculated.

Process emissions from the RPWRF effluent discharges to the Spokane River were calculated following the guidelines from the LGO Protocol (California Air Resources Board, 2010, sec. 10.3.2.3). Using Equation 8, the annual N_2O emissions in MT CO_2e from effluent discharge were calculated.

5.4.3 Scope 2 Purchased Electricity

5.4.3.1 Activity Data

Purchased electricity data was collected by the City of Spokane in the *Facility Energy Report 2015 – 2017* (Simmons & Olsen, 2018). This document reported the activity data for each source within the City of Spokane LGO boundary categorized by facility location and type. The amount of power purchased in 2016 was reported in terms of kWh.

5.4.3.2 Emission Factors and Calculation Methodologies

Emissions for purchased electricity were calculated using the recommended approach from the LGO Protocol (California Air Resources Board, 2010, sec. 6.2.1). Using Equation 1, the utility specific emission factor (294 kg-CO_2e MWh^{-1}) provided by Avista was multiplied by the activity data to calculate the MT CO_2e generated from the use of purchased electricity. Equation 2 was used to calculated the MT CO_2e using the GWPs in Table 6. Total wastewater emissions were calculated using Equation 11.

$$\begin{aligned} Total\ wastewater\ CO_2e \\ &= stationary\ CH_{4\ incomplete\ combustion} + stationary\ CH_{4\ natural\ gas} \\ &+ process\ N_2O_{nitrification/denitrification} + process\ N_2O_{effluent} \end{aligned} \quad \textbf{(11)}$$

5.5 Airport Facilities

Table 27 summarizes the scopes and sources used for calculating GHG emissions from the Airport Facilities sector. The City of Spokane maintains partial (50%) ownership of the Spokane International Airport (SIA) in partnership with Spokane County. Therefore, half of the emissions generated from SIA should be accounted for in this sector of the inventory. These emissions are generated by airport operations and do not include tenant operations, such as planes or vehicles owned by airport tenants.

Table 27 – Scopes and sub-sectors used for calculating GHG emissions from the Airport Facilities sector

Source	Scope 1	Scope 2	Scope 3
Stationary Combustion	☐	-	-
Fugitive Emissions	☐	-	-
Purchased Electricity	-	☐	-
Purchased Steam	-	☐	-
Purchase District Heating and Cooling	-	☐	-
Scope 3	-	-	☐

For 2016, there was not sufficient data provided to calculate an accurate estimate of the emissions from SIA. However, airport usage data was provided, such as flight numbers and gallons of fuel consumed. Since this data does not pertain to the facilities and operations of SIA, it is not attributed to the City of Spokane local government operations and was excluded from this inventory.

In future inventories, facilities data (e.g., electricity and natural gas usage) can be utilized to calculate emissions from SIA with 50% of the emissions attributed to the City of Spokane. For airport vehicles, fuel use data and VMT can be used to calculate emissions and attribute 50% of emissions to the City of Spokane.

It is important to note that the Airport Facilities sector was not included in the previous 2010 LGO inventory. The City annexed and took partial control of SIA between the 2010 and 2012 LGO inventories. In the 2012 inventory, the City attributed two-thirds of the Airport's emissions to the LGO, instead of 50% as recommended here to accurately reflect the emissions based on ownership.

5.6 Vehicle Fleet

Table 28 summarizes the scopes and sources used for calculating GHG emissions from the Vehicle Fleet sector. The City of Spokane owns and operates a fleet of on-road and off-road vehicles that produce emissions and must be accounted for in the GHG inventory.

Table 28 – Scopes and sub-sectors used for calculating GHG emissions from the Vehicle Fleet sector

Source	Scope 1	Scope 2	Scope 3
Mobile Combustion	☒	-	-
Fugitive Emissions	☒	-	-
Purchased Electricity for Electric Vehicles	-	☒	-
Scope 3	-	-	☒

Scope 1 emissions were generated by the combustion of fuels used to power vehicles and fugitive emissions from mobile air conditioning. Scope 2 emissions were generated from electricity used to power electric vehicles.

It is important to note that the 2010 and 2012 City of Spokane inventories (City of Spokane, 2016d) did not account for emissions from natural gas vehicles or electric vehicles in the Vehicle Fleet sector. Instead, these emissions were accounted for in the Buildings and Other Facilities sector because the natural gas and purchased electricity for these vehicles was supplied and metered at City-owned facilities. In keeping with the LGO Protocol, this 2016 inventory accounted for the natural gas and electric vehicle types in the Vehicle Fleet sector.

5.6.1 Scope 1 Mobile Combustion

5.6.1.1 Activity Data

Direct emissions from fuel combustion included CO_2, N_2O, and CH_4 emissions. Activity data for CO_2 emissions was provided by the City of Spokane in the *2016 City of Spokane Vehicle Fleet Summary* (City of Spokane, 2018a). This document reported total fuel consumption for the City of Spokane vehicles, including gasoline, diesel, propane, and natural gas from both highway and non-highway vehicles. The previous inventories in 2010 and 2012 included emissions for vehicles powered by biofuels (City of Spokane, 2016d). This inventory does not include biofuel related emissions because the City no longer has biofuel vehicles in their fleet.

Vehicle type and VMT were used to calculate CH_4 and N_2O emissions generated by the vehicle fleet. The activity data used was reported in the *2016 City of Spokane Vehicle Fleet Summary* (City of Spokane, 2018a). This report categorized the year, make, model, and mileage by each vehicle owned and operated by the City of Spokane. Vehicle mileage was recorded during regular vehicle maintenance, as it was not feasible to gather annual vehicle mileage at the end of each year for all vehicles in the fleet. Aproximations were made to estimate the annual VMT based on the vehicle, partial mileage data, and the date the mileage data was recorded (City of Spokane, 2016d). It should be noted that VMT data can be inaccurate due to ineffective record keeping procedures across the vehicle fleet. However, the quality of calculated total emissions was preserved because N_2O and CH_4 emissions from VMT account for less than one percent of the overall vehicle fleet emissions.

5.6.1.2 Emission Factors and Calculation Methodologies

Mobile combustion CO_2 emissions, for highway and non-highway vehicles, were calculated using the recommended approach in the LGO Protocol (California Air Resources Board, 2010, sec. 7.1.1.1). Using this approach, the annual volume of each fuel consumed was multiplied by the associated emission factor in Table 29 and then converted to MT using Equation 1. Equation 12 was used to calculate total CO_2 emissions from mobile combustion for non-highway vehicles.

$$\begin{aligned} &Total\ CO_2\ emissions\ for\ mobile\ combustion\ (MT) \\ &\quad = CO_{2_{diesel}} + CO_{2_{gasoline}} + CO_{2_{natural\ gas}} + CO_{2_{propane}} \end{aligned} \qquad \textbf{(12)}$$

Table 29 – CO_2 emission factors by fuel source

Fuel	Emission Factor	Source
Aviation gasoline	8.31 kg-CO_2 gallon^{-1}	U.S. EPA Center for Corporate Climate Leadership, 2018, p. 2
Diesel	10.21 kg-CO_2 gallon^{-1}	U.S. EPA Center for Corporate Climate Leadership, 2018, p. 2
Gasoline	8.78 kg-CO_2 gallon^{-1}	U.S. EPA Center for Corporate Climate Leadership, 2018, p. 2
Natural Gas	0.0545 kg CO_2 ft^{-3}	U.S. EPA Center for Corporate Climate Leadership, 2018, p. 2
Propane	5.59 kg-CO_2 gallon^{-1}	California Air Resources Board, 2010, p. 215

Mobile combustion CH_4 and N_2O emissions for highway vehicles were calculated using the recommended approach from the LGO protocol (California Air Resources Board, 2010, sec. 7.1.3.1). Using this approach, the annual VMT for each vehicle type was multiplied by the associated emission factor (see Appendix C) and converted to units of MT using Equation 1.

Mobile combustion CH_4 and N_2O emissions for non-highway vehicles were calculated using the recommended approach from the LGO protocol (California Air Resources Board, 2010, sec. 7.1.1.1). Using this approach, the volume of fuel consumed was multiplied by the associated emission factor and converted to units of MT using Equation 1. The emission factors for non-highway vehicles are listed in Appendix C based on vehicle type. The calculated GHG emissions were then converted to CO_2e using the GWPs in Table 6 for each gas (Equation 2).

5.6.2 Scope 1 Fugitive Emissions

5.6.2.1 Activity Data

Data for the scope 1 fugitive emissions (generated by leaked refrigerants) was provided by the City of Spokane in the *R134A City of Spokane Vehicle Fleet Refrigerant 2016* (City of Spokane, 2016e). The amount of R-134a refrigerant was reported in terms of kg. In the previous 2010 and 2012 inventories, because limited data was available, only refrigerant amounts for new and retired vehicles was included in the calculations (City of Spokane, 2016d). For this inventory, data on refrigerant use and purchases was used for the fugitive emissions calculations.

5.6.2.2 Emission Factors and Calculation Methodologies

Fugitive emissions were calculated using the recommended approach from the LGO Protocol (California Air Resources Board, 2010, sec. 7.4.1). This mass balance approach uses Equation 13 to calculate the amount of refrigerant that was released into the atmosphere in a calendar year, which is the total annual emissions for each hydrofluorocarbon (HFC), and converts the result to kg MT^{-1}. The total HFC emissions were then multiplied by 1,300, the GWP for R-134a (California Air Resources Board, 2010, p. 198), to convert the emissions to CO_2e. It should be noted this GWP is listed as HCF-134a, which is the same HFC as R-134a.

$$\begin{aligned} Total\ annual\ emissions &= (inital\ inventory\ of\ R134a - final\ inventory\ of\ R13a \\ &+ additions\ to\ inventory - sutractions\ from\ inventory \\ &- change\ to\ nameplate\ capacity) \div 1{,}000 \end{aligned} \quad \textbf{(13)}$$

5.6.3 Scope 2 Purchased Electricity for Electric Vehicles

5.6.3.1 Activity Data

Vehicle type and VMT was used to calculate CH_4 and N_2O emissions generated by the electric vehicle. The activity data used was reported in *2016 City of Spokane Vehicle Fleet Summary* (City of Spokane, 2018a). This report categorized the year, make, model, and mileage by each vehicle owned and operated by the City of Spokane. In the 2010 and 2012 inventories, the City of Spokane's electric vehicle was accounted for under building emissions because it used electricity from City Hall (City of Spokane, 2016d). In keeping with the LGO Protocol, the electric vehicle was accounted for in the Vehicle Fleet sector in this inventory.

5.6.3.2 Emission Factors and Calculation Methodologies

Emissions from purchased electricity were calculated using the recommended approach from the LGO Protocol (California Air Resources Board, 2010, sec. 6.2.1). The total miles traveled were converted to MWh using conversion factors from the United States Department of Energy's website (U.S. Department of Energy, n.d.). A utility specific emission factor (294 kg-CO_2e MWh^{-1}) provided by Avista was used to calculate the total CO_2e in MT for the City's electric vehicle using Equation 1.

5.6.4 Scope 3 Emissions from Employee Commute and Business Travel

5.6.4.1 Activity Data

Activity data for scope 3 emissions from employee commuting and business travel was supplied by the City of Spokane's *Data Entered from Paper Voucers.12.16.2016* report (Bisenius, 2016), which detailed employee business travel and survey responses from City employees that commute to work. Emissions associated with government employees commuting to work in vehicles not owned or operated by the local government are considered scope 3 emissions. This includes travel in personal and rented vehicles, mass transit, marine, and air travel (California Air Resources Board, 2010, sec. 12.2.1). Employee business travel records for each year were maintained and reported by roundtrip mileage and mode of transportation to the destination. Transportation while at the destination of travel were not accounted for and were not included in this inventory.

5.6.4.2 Emission Factors and Calculation Methodologies

The alternate approach from Section 7.1.1.2 in the LGO Protocol (California Air Resources Board, 2010, pp. 66-67) was used to calculate the CO_2 emissions associated with employee travel using VMT, fuel economy for the associated vehicles, emission factors (Table 29) and Equation 1. The CH_4 and N_2O emissions from employee commute and business travel were calculated using the recommended approach from the LGO Protocol (California Air Resources Board, 2010, sec. 7.1.3.1). Using this approach, the annual VMT for each vehicle type was multiplied by the associated emission factor from the LGO Protocol (see Appendix C), and converted to units of MT using Equation 1.

To calculate emissions for employee travel, the data was first categorized by vehicle type: a passenger vehicle, bus, or air travel. City employees did not use any other forms of transportation for business trips during this year. For passenger vehicle, VMT was used with an associated emissions factor (Table 29) to calculate CO_2, CH_4, and N_2O emissions. For bus and air travel, the total roundtrip passenger mileage was used instead of VMT because there were more passengers than just the city employees on each vehicle, so not all vehicle emissions can be attributed to the City of Spokane. For bus travel, short air travel (less than 300 miles), medium air travel (200-2300 miles), and long air travel (more than 2300 miles), there are unique emission factors for each gas to attribute a portion of total vehicle emissions to each passenger (EPA Center for

Corportate Climate Leadership, 2018). These emission factors were multiplied by passenger mileage to calculate total emissions from bus and air travel.

Additionally, for a more comprehensive accounting of scope 3 emissions from employee commute and business travel, it is recommended that the approach from Section 7.1.1.1 in the LGO Protocol be used (California Air Resources Board, 2010, pp. 65-66). This approach multiplies the annual volume of each fuel consumed by the associated emission factor (Table 29) and is then converted to MT per kg using Equation 1.

5.7 Power Generation Facilities

The Power Generation Facilities sector accounts for emissions at the City's power generation facilities. The City of Spokane operates two power generation facilities, the WTE facility and UHD. However, the scope 1 and scope 2 emissions from UHD are excluded from this inventory because the natural gas and purchased electricity consumed cannot be distinguished from the Water Delivery Facilities sector. Table 30 summarizes the scopes and sources used for calculating GHG emissions from the Power Generation Facilities sector.

Table 30 – Scopes and sub-sectors used for calculating GHG emissions from the Power Generation Facilities sector

Source	Scope 1	Scope 2	Scope 3
Stationary Combustion	☒	-	-
Process Emissions	☐	-	-
Fugitive Emissions	☐	-	-
Purchased Electricity	-	☒	-
Purchased Steam	-	☐	-
Purchase District Heating and Cooling	-	☐	-

The WTE facility incinerates MSW, converting the waste to electrical power. The facility generates scope 1 emissions from burning MSW and the consumption of natural gas for facility operations. This facility also used purchased electricity, which generated scope 2 emissions. In the 2010 LGO inventory, the emissions from WTE facility were excluded because the facility was located outside of the LGO boundary. Between the 2010 inventory and the subsequent 2012 inventory the facility location was annexed into the City and emissions from WTE were included in the 2012 inventory (City of Spokane, 2016d).

5.7.1 Scope 1 Stationary Combustion

5.7.1.1 Activity Data

The GHG emissions at the WTE facility are calculated using emissions data from the continuously monitored steam emitted from the stack at the facility. Activity data for the emissions generated by the incineration of MSW and natural gas used for facility operations was provided by Kelle Vigeland in the *2016 WTE GHG Calculations* document (Vigeland, 2018a).

5.7.1.2 Emission Factors and Calculation Methodologies

The calculation of scope 1 emissions generated by MSW combustion at the WTE facility did not require the use of emission factors. Scope 2 emissions were calculated using the emission factors from Table 7, GWPs from Table 6, Equation 1, and Equation 2.

5.7.2 Scope 2 Purchased Electricity

5.7.2.1 Activity Data

The emissions from purchased electricity (energy that was supplied from Avista) for the WTE facility operations were calculated using 147.15 MWhs as reported by Kelle Vigeland.

5.7.2.2 Emission Factors and Calculation Methodologies

Emissions for purchased electricity were calculated using the recommended approach from the LGO Protocol (California Air Resources Board, 2010, sec. 6.2.1). Using Equation 1, the utility specific emission factor (294 kg-CO_2e MWh^{-1}) provided by Avista was multiplied by the activity data to calculate the MT CO_2e generated from the use of purchased electricity. Equation 2 was used to calculated the MT CO_2e using the GWPs in Table 6.

5.8 Solid Waste Facilities

Table 31 summarizes the scopes and sources used for calculating GHG emissions from the Solid Waste Facilities sector.

Table 31 – Scopes and sub-sectors used for calculating GHG emissions from the Solid Waste Facilities sector

Source	Scope 1	Scope 2	Scope 3
Stationary Combustion	☐	-	-
Process Emissions	☐	-	-
Fugitive Emissions	☒	-	-
Purchased Electricity	-	☒	-
Purchased Steam	-	☐	-
Purchase District Heating and Cooling	-	☐	-
Scope 3	-	-	☐

5.8.1 Scope 1 Fugitive Emissions

5.8.1.1 Activity Data

The City of Spokane Solid Waste Disposal Department provided the annual CH_4 emissions generated at both landfills (Vigeland, 2018c, 2018b). The NSLF operates two cells, open and closed. The emissions for the closed cell were calculated using Equation 3 which used the actual amount of CH_4 recovered, a 95% collection efficiency, a 99% destruction efficiency, and a 10% oxidation factor. The modeled CH_4 generation rate and the oxidation factor was used to calculate the CH_4 emissions from the open cell. Both equations incorporate a modeled CH_4 generation rate using a first-order decay calculation to account for cumulative annual emissions starting in the first year of operation. Emissions from the SSLF were calculated using flare station data from the *Southside Landfill Flare Station YEAR 2016* (City of Spokane Solid Waste Disposal Department, 2016b, 2016a).

Table 32 – Activity data for the SSLF flare stations (City of Spokane Solid Waste Disposal Department, 2016b, 2016a)

Facility	Total Flow Flares (scf)	Average CH_4 Percentage	Collection Efficiency
Southside Landfill	85,981,587.12	26.46%	95%

5.8.1.2 Emission Factors and Calculation Methodologies

Fugitive methane emissions were calculated using guidelines from the LGO Protocol (California Air Resources Board, 2010, sec. 9.3.2). The total CH_4 emitted in MT of CO_2e was calculated using Equation 14.

$$\mathrm{CH_4}\ \text{emitted}\ CO_2e\ (MT) = LFG_{collected} \times \%CH_4 \times \left\{(1-DE) + \left[\left(\frac{1-CE}{CE}\right) \times (1-OX)\right]\right\} \times unit\ conversion \times GWP \tag{14}$$

Where:

$LFG_{collected}$	=	Annual LFG collected by the collection system [million standard cubic feet (MMSCF)]
% CH_4	=	0.2646 – fraction of CH_4 in LFG
DE	=	0.99 – CH_4 destruction efficiency, based on the type of combustion/flare system
CE	=	0.95 – collection efficiency
OX	=	0.10 – oxidation factor
Unit conversion	=	19.125 – applies when converting MMSCF of CH_4 to MT of CH_4
GWP	=	28 – global warming potential

5.8.2 Scope 2 Purchased Electricity

5.8.2.1 Activity Data

The *Facility Energy Report 2015 – 2017* (Simmons & Olsen, 2018) provided the purchased electricity activity data for the two solid waste facilities.

5.8.2.2 Emission Factors and Calculation Methodologies

Emissions for purchased electricity were calculated using the recommended approach from the LGO Protocol (California Air Resources Board, 2010, sec. 6.2.1). Using Equation 1, the utility specific emission factor (294 kg-CO_2e MWh^{-1}) provided by Avista was multiplied by the activity data to calculate the MT CO_2e generated from the use of purchased electricity. Equation 2 was used to calculated the MT CO_2e using the GWPs in Table 6.

6 RESULTS AND ANALYSIS OF 2016 COMMUNITY-WIDE GHG EMISSIONS INVENTORY BY SOURCE

The following subsections describe the results from applying the GPC methodologies to quantify GHG emissions for the community-wide GHG emissions inventory by sector. These subsections comprise a tabular summary of calculated GHG emissions that is intended to align with the tables required by CIRIS reporting tool (C40 Cities, 2018). Alignment with CIRIS allows for easier reporting to the carbon*n* and CDP reporting platforms (Carbonn Climate Registry, 2017; CDP, 2019). These subsections also include a brief analysis of the results, highlighting (where possible) how these results compare to results from past City of Spokane community-scale GHG emissions inventories. However, it is important to note that this 2016 community-wide inventory used updated protocols, emission factors, and global warming potentials to account for many of the emissions included in this results chapter. Therefore, more accurate comparisons between this inventory and previous City of Spokane community-scale inventories may require the re-estimation of previous emissions.

6.1 Stationary Energy

The Stationary Energy sector accounts for the emissions from fuel combustion and fugitive emissions released in the process of generating, delivering, and consuming energy (Fong et al., 2014, p. 55). Table 33 summarizes the calculated 2016 community-wide GHG emissions from the Stationary Energy sector.

Table 33 – 2016 Stationary Energy GHG Emissions (MT CO_2e)

GHG Emission Sub-sectors	MT CO_2e								
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*	*$CO_2(b)$*
Residential Buildings	231,209.31	139.02	159.10	-	-	-	-	516,512.21	36,798.67
Commercial and Institutional Buildings and Facilities	160,475.59	99.26	79.84	-	-	-	-	467,575.83	-
Manufacturing Industries and Construction	14,752.59	15.87	6.54	-	-	-	-	34,914.25	-
Energy Industries	95,355.45	2,289.26	2,843.63	-	-	-	-	100,533.43	136,713.40
Agriculture, Forestry and Fishing Activities	1,671.18	2.66	-	-	-	-	-	1,673.84	-
Non-specified sources	868.30	20.72	-	-	-	-	-	889.02	-
Fugitive Emissions from Mining, Processing, Storage, and Transportation of Coal	-	-	-	-	-	-	-	-	-
Fugitive Emissions from Oil and Natural Gas Systems	-	-	-	-	-	1,569	-	6,226	-
TOTALS	**504,332.42**	**2,566.79**	**3,089.11**	**-**	**-**	**1,569.00**	**-**	**1,128,324.58**	**173,512.07**

The Stationary Energy sector was the largest contributor of the total community-wide GHG emissions in 2016. Not listed in the table above are the natural gas fugitive emissions (4,657 MT CO_2e), but they are included as part of the total CO_2e emissions for the Fugitive Emissions from Oil and Natural Gas Systems sub-sector. In the previous City of Spokane community-wide GHG inventories, similar emissions were accounted for in the Built Environment sector; however, these previous inventories did not include the Energy Industries sub-sector, Agriculture, Forestry, and Fishing sub-sector, and the Non-specified sub-sector. With the addition of these sub-sectors in the 2016 inventory, a comparison cannot be made between inventories. Table 34 summarizes the GHG emissions from the Stationary Energy sector by sub-sector and scope.

Table 34 – 2016 Stationary Energy GHG emissions by sub-sector and scope (MT CO_2e)

Sub-sectors	Scope 1	Scope 2	Scope 3	Total CO_2e	CO_2(b)
Residential Buildings	231,443.90	273,499.29	11,569.02	516,512.21	36,798.67
Commercial and Institutional Facilities	160,636.74	294,482.48	12,456.61	467,575.83	-
Manufacturing Industries and Construction	14,700.79	19,393.13	820.33	34,914.25	-
Energy generation Supplied to the Grid	100,488.34	43.26	1.83	100,533.43	136,713.40
Agricultural, Forestry, and Fishing Activities	1,673.84	-	-	1,673.84	-
Non-Specified Sources	889.02	-	-	889.02	-
Fugitive Emissions from Oil and Natural Gas Systems	6,226	-	-	6,226	-
Total CO_2e	**516,058.63**	**587,418.16**	**24,847.79**	**1,128,324.58**	**173,512.07**

Residential Buildings, Commercial and Institutional Buildings and Facilities, and Energy Industries are the sub-sectors that generated the most GHG emissions in the Stationary Energy sector. The following sections detail each sub-sector of the Stationary Energy sector.

6.1.1 Residential Buildings

The Residential Buildings sub-sector accounted for the emissions generated from electricity and fuels used in households within the City of Spokane (Fong et al., 2014, p. 58). Table 35 categorizes the sources and amounts of the GHG emissions that contributed to the total CO_2e in the Residential Buildings sub-sector.

Table 35 – 2016 Residential Buildings GHG emissions by source

GHG Emission Sources	GHGs (MT CO_2e)								
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*	CO_2(b)
Avista natural gas supplied to homes	208,183.60	109.86	103.97		-	-	-	208,397.43	-
Avista electricity supplied to homes	-	-	-	-	-	-	-	273,435.77	-
Inland Power and Light electricity supplied to homes	63.13	0.157	0.233	-	-	-	-	63.52	-
Other fuels burned, not supplied by utility providers, to heat homes	22,962.58	29.00	54.89	-	-	-	-	23,046.4	36,798.67
Avista transmission and distribution losses	-	-	-	-	-	-	-	11,566.33	-
Inland Power and Light transmission and distribution losses	-	-	-	-	-	-	-	2.69	-
TOTALS	**231,209.31**	**139.02**	**159.10**	**-**	**-**	**-**	**-**	**516,512.21**	**36,798.67**

The utility-specific emissions factors provided by Avista were used to convert activity data directly from MWh to total CO_2e. Activity data from natural gas was multiplied by the default emission factors from the U.S. Environmental Protection Agency (EPA) Center for Corporate Climate Leadership's *Emission Factors for Greenhouse Gas Inventories* report (EPA Center for Corportate Climate Leadership, 2018). Emission factors from EPA's eGRID sub-region NWPP were used with IPL's activity data, which allowed for MT of CO_2e from each GHG to be calculated. The total CO_2e emissions from scope 2 sources for the Residential Buildings sub-sector was 273,498.92. Table 36 categorizes the emissions from the Residential Buildings sub-sector by scope.

Table 36 – 2016 Residential Buildings GHG emissions by scope (MT)

Sub-sectors	Scope 1	Scope 2	Scope 3	Total CO_2e	CO_2(b)
Residential Buildings	231,443.90	273,499.29	11,569.02	516,512.21	36,798.67

Scope 1 emissions, generated by the combustion of fuels, account for 45% of the total CO_2e for the Residential Buildings sub-sector. This fuel combustion included the consumption of natural gas and the burning of other fuels (e.g., propane, kerosene) except wood. The biogenic emissions from burning wood as source for heat is reported in the CO_2(b) column.

6.1.2 Commercial and Institutional Buildings and Facilities

The Commercial and Institutional Building and Facilities sub-sector accounted for the emissions generated from energy used in buildings that provide public services for the needs of the community. These buildings can be public or government-owned and include facilities like commercial shopping complexes, office buildings, schools, and hospitals (Fong et al., 2014, pp. 58-59). Table 37 categorizes the sources and amounts of the GHG emissions that contributed to the total CO_2e in the commercial and institutional facilities sub-sector.

Table 37 – 2016 Commercial and Institutional Facilities GHG emissions by sources

GHG Emission Sources	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Avista natural gas provided to commercial and institutional facilities.	159,733.69	84.29	79.78	-	-	-	-	159,897.76
Avista electricity provided to commercial and institutional facilities.	-	-	-	-	-	-	-	294,464.53
Inland Power and Light electricity provided to commercial and institutional facilities.	17.84	0.044	0.066	-	-	-	-	17.95
Avista transmission and distribution losses.	-	-	-	-	-	-	-	12,455.85
Inland Power and Light transmission and distribution losses.	-	-	-	-	-	-	-	0.76
Fuel combustion in off-road commercial vehicle use.	724.06	14.92	-	-	-	-	-	738.98
TOTALS	**160,475.59**	**99.26**	**79.84**	-	-	-	-	**467,575.83**

The utility-specific emissions factors provided by Avista were used to convert activity data directly from MWh to total CO_2e. Activity data from natural gas was multiplied by the default emission factors from the U.S. Environmental Protection Agency (EPA) Center for Corporate Climate Leadership's *Emission Factors for Greenhouse Gas Inventories* report (EPA Center for Corportate Climate Leadership, 2018). Emission factors from EPA's eGRID sub-region NWPP were used with IPL's activity data, which allowed for MT of CO_2e from each GHG to be calculated. For emissions from IPL in the Commercial and Institutional Facilities sub-sector, there were 17.84 MT of CO_2, 0.00257 MT of N_20, and 0.00398 MT of CH_4. Table 38 categorizes the total CO_2e by each scope for the Commercial and Institutional Facilities.

Table 38 – 2016 Commercial and Institutional Facilities GHG emissions by scope (MT)

Sub-sector	Scope 1	Scope 2	Scope 3	Total CO_2e
Commercial and Institutional Facilities	160,636.74	294,482.48	12,456.61	467,575.83

In 2016, the emissions generated by the community-wide commercial electricity use were 294,482 MT of CO_2e. For comparison, in 2010 and 2012 the CO_2e emissions resulting from the community-wide commercial electricity use were 394,802 MT and 357,972 MT, respectively (City of Spokane, 2016, p. 38). However, it is important to note that this 2016 inventory used updated protocols, emission factors, and global warming potentials to account for many of the emissions in this sub-sector. Therefore, more accurate comparisons between this inventory and previous community-scale inventories will likely require the re-estimation of previous emissions.

Scope 2 emissions were the largest contributors to total CO_2e of the three scopes for the Commercial and Institutional Facilities sub-sector.

6.1.3 Manufacturing Industries and Construction

The Manufacturing Industries and Construction activities sub-sector accounts for the emissions generated from energy consumption in activities related to manufacturing goods and the use of construction equipment and machinery (Fong et al., 2014, p. 60). Table 39 categorizes the sources and amounts of the GHG emissions that contributed to the total CO_2e in the Manufacturing Industries and Construction sub-sector.

Table 39 – 2016 Manufacturing Industries and Construction GHG emissions by source

GHG Emission Sources	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Avista supplied industrial natural gas.	12,547.45	6.62	6.27	-	-	-	-	12,560.33
Avista supplied industrial electricity.	-	-	-	-	-	-	-	19,318.91
Inland Power and Light supplied industrial electricity.	73.76	0.183	0.272	-	-	-	-	74.22
Avista industrial transmission and distribution losses.	-	-	-	-	-	-	-	817.19
Inland Power and Light industrial transmission and distribution losses.	-	-	-	-	-	-	-	3.14
Fuel combustion for off-road industrial and construction vehicles.	2,131.39	9.07		-	-	-	-	2,140.45
TOTALS	**14,752.59**	**15.87**	**6.54**	**-**	**-**	**-**	**-**	**34,914.25**

The utility-specific emissions factors provided by Avista were used convert activity data directly from MWh to total CO_2e. Activity data from natural gas was multiplied by the default emission factors from the U.S. Environmental Protection Agency (EPA) Center for Corporate Climate Leadership's *Emission Factors for Greenhouse Gas Inventories* report (EPA Center for Corportate Climate Leadership, 2018). Emission factors from EPA's eGRID sub-region NWPP were used with IPL's activity data, which allowed for MT of CO_2e from each GHG to be calculated. The specific GHG gas emissions generated by the use of grid-supplied electricity provided by IPL for the manufacturing industries and construction sub-sector were 74 MT of CO_2, 0.011 MT of N_2O, and 0.016 MT of CH_4.

In 2016, the emissions generated by the community-wide industrial electricity use were 14,753 MT of CO_2e. For comparison, in 2010 and 2012 the CO_2e emissions resulting from the community-wide industrial electricity use were 15,639 MT and 21,581 MT, respectively (City of Spokane, 2016 p. 38). However, it is important to note that this 2016 inventory used updated protocols, emission factors, and global warming potentials to account for many of the emissions in this sub-sector. Therefore, more accurate comparisons between this inventory and previous community-scale inventories will likely require the re-estimation of previous emissions.

Table 40 categorizes the total CO_2e by scope for the Manufacturing Industries and Construction sub-sector.

Table 40 – 2016 Manufacturing Industries and Construction GHG emissions by scope (MT CO_2e)

Sub-sectors	Scope 1	Scope 2	Scope 3	Total CO_2e
Manufacturing Industries and Construction	14,700.79	19,393.13	820.33	34,914.25

Scope 1 emissions, generated by fuel combustion, were the largest contributor to the total CO_2e for the Manufacturing Industries and Construction sub-sector.

6.1.4 Energy Industries

The Energy Industries sub-sector accounts for the emissions generated by activities related to fuel production (e.g., coal mining, oil extraction), fuel processing and conversion of fuels (e.g., oil refineries), and electricity generation (Fong et al., 2014, p. 62). Table 41 categorizes the sources and amounts of the GHG emissions that contributed to the total CO_2e in the Energy Industries sub-sector.

Table 41 – 2016 Energy Industries GHG emissions by source

GHG Emission Sources	GHGs (MT CO_2e)								
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*	*CO_2e(b)*
WTE Facility MSW combustion	95,004.22	2,289.07	2,843.46	-	-	-	-	100,136.76	136,713.40
WTE Facility Natural Gas used to heat buildings	300.55	0.16	0.15					300.86	
Upriver Dam consumption natural gas	50.68	2.67E-02	2.53E-02					50.73	
WTE Facility consumption of purchased electricity	-	-	-	-	-	-	-	43.26	-
Transmission and distribution loss	-	-	-	-	-	-	-	1.83	-
TOTALS	**95,355.45**	**2,289.26**	**2,843.63**	**-**	**-**	**-**	**-**	**100,533.43**	**136,713.40**

In previous community-wide inventories, emissions from the WTE facility were included in the Community Solid Waste sector. However, following the GPC guidelines, emissions generated by WTE were accounted for in the Stationary Energy sector (Fong et al., 2014, p. 58). For the 2016 inventory, the WTE facility scope 1 emissions contributed 100,488 MT CO_2e. For comparison, in the previous 2010 and 2012 inventories, the WTE contributed 101,893 MT CO_2e and 102,963 MT CO_2e, respectively (City of Spokane, 2016, p.58). Table 42 categorizes the total CO_2e by scope for the energy industries sub-sector.

Table 42 – 2016 Energy Industries GHG emissions by scope (MT CO_2e)

Sub-sector	Scope 1	Scope 2	Scope 3	Total CO_2e
Energy Industries	100,488.34	43.26	1.83	100,533.43

The scope 1 emissions in this sub-sector were generated by the incineration of municipal solid waste at WTE for the generation of electricity.

6.1.5 Agriculture, Forestry, and Fishing Activities

The Agriculture, Forestry, and Fishing Activities sub-sector accounts for emissions from the combustion of fuel in agricultural activities, afforestation and reforestation activities, and fishery activities. Emissions in this sub-sector can be from the use of farm machinery, generators, and pumps (Fong et al., 2014, p. 64). Table 43 categorizes the sources and amounts of the GHG emissions that contributed to the total CO_2e in the Agriculture, Forestry, and Fishing Activities sub-sector.

Table 43 – 2016 Agriculture, Forestry, and Fishing Activities GHG emissions by sources

GHG Emission Source	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Agricultural off-road vehicle use	1,671.18	2.66	-	-	-	-	-	1,673.84
TOTAL	**1,671.18**	**2.66**	**-**	**-**	**-**	**-**	**-**	**1,673.84**

Table 44 categorizes the total CO_2e by scope for the Agriculture, Forestry, and Fishing Activities Sub-sector.

Table 44 – 2016 Agricultural, Forestry, and Fishing Activities GHG Emissions by scope (MT)

Sub-sector	Scope 1	Scope 2	Scope 3	Total CO_2e
Agricultural, Forestry, and Fishing Activities	1,673.84	-	-	1,673.84

The scope 1 emissions in this sub-sector were generated by the use off-road vehicles (e.g., farm vehicles, generators, pumps, etc.) used for activities related to this sub-sector. The GPC requires all emissions from off-road vehicles and machinery be reported as a Stationary Energy source (Fong et al., 2014, p. 65). Activity data for scope 2 and scope 3 emissions from this sub-sector were not available, and these emissions could not be calculated.

6.1.6 Non-Specified Sources

The Non-specified Sources sub-sector accounts for all remaining emission in the Stationary Energy sector that have not been specified elsewhere (Fong et al., 2014, p. 65). Table 45 categorizes the sources and amounts of the GHG emissions that contributed to the total CO_2e in the Non-specified Sources sub-sector.

Table 45 – 2016 Non-specified Sources GHG emissions by source

GHG Emission Sources	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Fuel combustion from off-road lawn and garden vehicles.	868.30	20.72	-	-	-	-	-	889.02
TOTALS	**868.30**	**20.72**	**-**	**-**	**-**	**-**	**-**	**889.02**

The GPC was not used for the *City of Spokane Greenhouse Gas Inventory Report for 2010-2012* and the *City of Spokane 1990 & 2005 Greenhouse Gas Inventory.* Since these inventories did not include the Non-specified Sources sub-sector, comparisons could not be made between this 2016 inventory and the previous community-wide inventories. Table 46 categorizes the total CO_2e by scope for the Non-specified Sources sub-sector.

Table 46 – 2016 Non-Specified Sources GHG emissions by scope (MT CO_2e)

Sub-sector	Scope 1	Scope 2	Scope 3	Total CO_2e
Non-Specified Sources	889.02	-	-	889.02

The scope 1 emissions were generated by the use off-road vehicles for lawn and garden maintenance (e.g., lawn mowers, leaf blowers, tractors, etc.). Activity data for scope 2 and scope 3 emissions from this sub-sector were not available and therefore could not be calculated.

6.1.7 Fugitive Emissions from Oil and Natural Gas Systems

The Fugitive Emissions from Oil and Natural Gas Systems sub-sector accounts for the emissions generated from the Stationary Energy sector that arise as fugitive emissions occurring from the extraction, transformation and transportation of fossil fuels. Table 47 categorizes the sources and amounts of the GHG emissions that contributed to the total CO_2e in the fugitive emissions from oil and natural gas systems sub-sector.

Table 47 – 2016 Fugitive Emissions from Oil and Natural Gas Systems GHG emissions

GHG Emission Sources	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Avista natural gas fugitives	-	-	-	-	-	-	-	4,657
Avista SF_6 fugitives	-	-	-	-	-	1,569	-	1,569
TOTALS	-	-	-	-	-	-	-	**6,226**

Table 48 categorizes the total CO_2e by scope for the non-specified sources sub-sector.

Table 48 – 2016 Fugitive Emissions from Oil and Natural Gas Systems by scope (MT CO_2e *)*

Sub-sector	Scope 1	Scope 2	Scope 3	Total CO_2e
Fugitive Emissions from Oil and Natural Gas Systems	6,226	-	-	6,226

This sub-sector contributed less than 0.5% to the total CO_2e for the Stationary Combustion sector.

6.2 Transportation

The Transportation sector accounts for the direct emissions from fuel combustion and the indirect emissions from the consumption of grid-supplied electricity generated by transport vehicles, mobile equipment, and machinery (Fong et al., 2014, p. 71). Table 49 summarizes the calculated 2016 community-wide GHG emissions from the transportation sector.

Table 49 – 2016 Transportation sector GHG emissions by sub-sector

GHG Emission Sub-sector	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
On-road	690,452	2,277	15,737	-	-	-	-	708,465
Railways	102,219	224	690	-	-	-	-	103,134
Waterborne Navigation	97.4	2.60	-	-	-	-	-	100
Aviation	154,430	0	1,257	-	-	-	-	155,687
Off-road	205	3.81	-	-	-	-	-	209
TOTALS	**947,403**	**2,507**	**17,684**					**967,595**

The Transportation sector covers the GHG emissions from the direct combustion of fuel or the indirect use of grid-supplied electricity during trips in the following sub-sectors: On-road Transportation, Railways, Waterborne Navigation, Aviation, and Off-road. In 2016, the Transportation sector generated 967,595 MT of total CO_2e.

The On-road sub-sector accounted for approximately 73% of the total GHG emissions in the Transportation sector. There are no scope 2 emissions for the Transportation sector. For comparison, the *City of Spokane Greenhouse Gas Inventory Report for 2010-2012* reported an estimated 856,841 MT CO_2e in 2010 and 914,370 MT CO_2e in 2012 from direct GHG emissions in the Transportation sector (City of Spokane, 2016d, p. 15).

6.2.1 On-Road

The On-road sub-sector accounts for emissions generated by vehicles operating on public roadways designed for transporting people and goods (Fong et al., 2014, p. 73). Table 50 categorizes the source of GHG emissions and the corresponding quantities that contributed to the total CO_2e in the On-road sub-sector.

Table 50 – 2016 On-Road GHG emissions

GHG Emission Source	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Passenger Vehicle (gas)	399,788	1,532	9,665	-	-	-	-	410,985
Light-Duty Trucks (gas)	150,515	415	4,331	-	-	-	-	155,261
Heavy-Duty Vehicles (gas)	71,435	238	1,638	-	-	-	-	73,311
Light-Duty Trucks (diesel)	16,935	1	14	-	-	-	-	16,950
Heavy-Duty Vehicles (diesel)	24,975	3	20	-	-	-	-	24,998
Motorcycles (gas)	16,884	86	61	-	-	-	-	17,031
Public Transit/STA (diesel)	9,920	2	8	-	-	-	-	9,930
TOTALS	**690,452**	**2,277**	**15,737**					**708,465**

In 2016, the Spokane community emitted an estimated 708,465 MT of CO_2e in the On-road sub-sector. Approximately 58% of the on-road transportation GHG emissions were attributed to passenger vehicles. For comparison, the *City of Spokane Greenhouse Gas Inventory Report for 2010-2012* reported 715,450 MT of CO_2e and 732,188 MT of CO_2e on Spokane streets and highways for the inventory years of 2010 and 2012 respectively (City of Spokane, 2016, p.49).

6.2.2 Railways

The Railways sub-sector accounts for the emissions generated by locomotives used to transport people and goods (Fong et al., 2014, p. 78). Table 51 categorizes the source of GHG emissions and the corresponding quantities of total CO_2e from the railway sub-sector.

Table 51 – 2016 Railways GHG emissions

GHG Emission Sources	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
BNSF (freight)	88,906	195	600	-	-	-	-	89,701
UP (freight)	12,118	27	82	-	-	-	-	12,227
Amtrak (passenger)	1,195	2	8	-	-	-	-	1,206
TOTALS	**102,219**	**224**	**690**	-	-	-	-	**103,134**

In 2016, the railways operating throughout the community emitted an estimated 103,134 MT of CO_2e. These emissions are a result of yard-switching and line-haul activities. For comparison, the *City of Spokane Greenhouse Gas Inventory Report for 2010-2012* reported 20,054 MT of CO_2e, 21,290 MT of CO_2e, and 21,173 MT of CO_2e, for railway emissions in the 2012, 2010, and 2005 inventory years, respectively (City of Spokane, 2009, p. 17, 2016d, p. 50). The difference in estimated emissions between the previous inventory and the 2016 inventory can be linked to the lack of transparency in the 2010-2012 inventory. It was not indicated if the reported emissions included the emissions from pass-through rail operations. The 2016 inventory estimated emissions assuming the total fuel usage included the fuel used during pass-through trips. A more transparent explanation of the adopted approach used for the 2010-2012 is necessary before accurate comparisons can be made.

6.2.3 Waterborne Navigation

The Waterborne Navigation sub-sector accounts for emissions generated by the use of motorized boats used for recreation and transporting goods and people (Fong et al., 2014, p. 80). Table 52 categorizes the source of GHG emissions and the corresponding quantities of total CO_2e from the Waterborne Navigation sub-sector.

Table 52 – 2016 Waterborne Navigation GHG emissions

GHG Emission Sources/Types	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Recreational Marine Vessels	97.4	2.60	-	-	-	-	-	100
TOTALS	**97.4**	**2.60**						**100**

In 2016, the Spokane community emitted an estimated 100 MT of CO_2e in the Waterborne Navigation sub-sector. The EPA MOVES model estimated the amount CO_2 and CH_4 emissions in kg. The N_2O emissions were not estimated since the model only included an input parameter for the general category of nitrogen oxides and did not include a specific input parameter for N_2O. The waterborne emissions were estimated as the product of recreational marine vessels used on the Spokane River. The estimation was done under the assumption that the recreational marine vessels were only used on the section of the Spokane River east of Upriver Dam to be in compliance with city of Spokane Municipal code Section 16A.60.020 (2018). Note, the previous *City of Spokane Greenhouse Gas Inventory Report for 2010-2012* and *2005 Greenhouse Gas Inventory* did not include GHG emissions from the Waterborne Navigation sub-sector, and therefore longitudinal comparisons cannot be made without additional activity data and estimations.

6.2.4 Aviation

The Aviation sub-sector accounts for emissions generated by flights occurring in the geographic boundary and flights departing from the airports that serve the City (Fong et al., 2014, p. 81). Table 53 categorizes the source of GHG emissions and the corresponding quantities of total CO_2e from the Aviation sub-sector.

Table 53 – 2016 Aviation GHG emissions

GHG Emission Sources	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Spokane International Airport	149,779	-	1,221	-	-	-	-	151,000
Spokane Felts Field	4,651	-	36	-	-	-	-	4,687
TOTALS	**154,430**	**-**	**1,257**	-	-	-	-	**155,687**

During the 2016 inventory year, the flight operations at airports in Spokane emitted an estimated 155,687 MT of CO_2e. Scope 2 aviation emissions were not estimated due to the lack of available activity data on aircraft charging at the airports. For comparison, the *City of Spokane Greenhouse Gas Inventory Report for 2010-2012* estimated the aviation emissions from SIA were 146,726 MT of CO_2e and 151,249 MT of CO_2e for 2010 and 2012, respectively (City of Spokane, 2016 p.51).

6.2.5 Off-Road

The Off-road sub-sector accounts for emissions from vehicles designed to travel on unpaved terrain (Fong et al., 2014, p. 82). Table 54 categorizes the source of GHG emissions and the corresponding quantities of total CO_2e from the Off-road sub-sector.

Table 54 – 2016 Off-Road GHG emissions

GHG Emission Sources	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Recreational Vehicles	104	3.70	-	-	-	-	-	108
Airport Support	90.9	0.08	-	-	-	-	-	91.0
Railroad Equipment	9.95	0.03	-	-	-	-	-	10.0
TOTALS	**205**	**3.81**						**209**

In 2016, the Spokane community emitted an estimated 209 MT of CO_2e in the Off-road sub-sector. The EPA MOVES model estimated the amount CO_2 and CH_4 emissions in kg. The N_2O emissions were not estimated since the model only included an input parameter for the general nitrogen oxides and did not include a specific input parameter for N_2O. The emissions reported under the Off-road sub-sector were produced by the operations of recreational vehicles, airport support vehicles, and railroad equipment. Following the GPC guidelines, the GHG emissions from airport support vehicles and railroad equipment were not reported under the Aviation sub-sector and Railways sub-sector, since the protocol recommends reporting the GHG emissions from off-road transportation activities that occur within transportation premises under the Off-road sub-sector (Fong et al., 2014, p. 82). A direct comparison with the *City of Spokane Greenhouse Gas Inventory Report for 2010-2012* was not possible because the previous inventory report included additional sub-sectors in the estimation of off-road GHG emissions.

6.3 Waste

The Waste sector accounts for emissions generated by the disposal and treatment of solid waste and wastewater (Fong et al., 2014, p. 85). Table 55 summarizes the calculated 2016 community-wide GHG emissions from the Waste sector.

Table 55 – 2016 Waste GHG emissions

GHG Emission Sub-sectors	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Solid Waste Disposal	-	7,879.5		-	-	-	-	7,879.5
Biological Treatment of Waste	-	981	696	-	-	-	-	1,677
Incineration and Open Burning	-	-	-	-	-	-	-	-
Wastewater Treatment and Discharge	-	558	2,684	-	-	-	-	3,242
TOTALS	-	**9,418.5**	**3,380**	-	-	-	-	**12,799**

The 2016 community-scale GHG emissions inventory calculated 12,799 MT of total CO_2e from the Waste sector. Eighty-four percent of the emissions from the Waste sector were generated by the fugitive CH_4 emissions produced the NSLF and SSLF from the disposal of solid waste.

6.3.1 Disposal of Solid Waste Generated in the City

The Disposal of Solid Waste Generated in the City sub-sector accounts for emissions from solid waste that is disposed of at the two managed disposal sites – the City the NSLF and the SSLF (Fong et al., 2014, p. 90). Greenhouse gas emissions from the NSLF and SSLF were generated by fugitive CH_4 emissions from the landfill gas capture systems. Table 56 lists the reported totals of scope 1 fugitive emissions from the NSLF and SSLF.

Table 56 – Total CO_2e from Northside Landfill and Southside Landfill

GHG Emission Sources	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
NSLF Open Cell	-	5,034.66	-	-	-	-	-	5,034.66
NSLF Closed Cell		2,139.80						2,139.80
SSLF	-	705.04	-	-	-	-	-	705.04
TOTAL	-	**7,879.5**	-	-	-	-	-	**7,879.5**

Both landfills generated a combined total of 7,880 MT CO_2e in 2016. For comparison, the 2012 inventory reported a combined total of 12,367 MT CO_2e (City of Spokane, 2016, p. 102).

6.3.2 Biological Treatment of Waste Generated in the City

The Biological Treatment of Waste Generated in the City sub-sector accounts for the emissions generated by the composting and anaerobic digestion of organic waste (Fong et al., 2014, p. 94).

Table 57 categorizes the source of GHG emissions and the corresponding quantities of total CO_2e in the Biological Treatment of Waste Generated in the City sub-sector.

Table 57 – 2016 Biological Treatment of Waste Generated in the City GHG emissions

GHG Emission Sources	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Organic waste sent to Barr-Tech	-	981	696	-	-	-	-	1,677
TOTALS	-	**981**	**696**	-	-	-	-	**1,677**

The previous *City of Spokane Greenhouse Gas Inventory Report for 2010-2012* did not include the biological treatment of waste in a similar sub-sector. However, it did report the amount of clean green material sent to the contracted composting facilities for processing. In 2010, 19,632 short tons of clean green material was sent to Royal City Organics, and 8,953 short tons of clean green material was sent to Barr-Tech in 2012 (City of Spokane, 2016, p.61). For the 2016 inventory, 9,651 short tons (an eight percent increase from 2012) of clean green material was sent to Barr-Tech (Washington State Deparment of Ecology, 2016). The GHG emissions for the biological treatment of waste are directly related to the mass of the waste processed. Therefore, the eight percent increase in the amount of green material sent to Barr-Tech correlated to an eight percent increase in the total CO_2e generated in the Biological Treatment of Waste Generated in the City sub-sector between 2012 and 2016.

6.3.3 Wastewater Generated in the City

The Wastewater Generated in the City sub-sector accounts for the emissions generated by the treatment of wastewater treatment process (Fong et al., 2014, p. 99). Table 58 categorizes the source of GHG emissions and the corresponding quantities of total CO_2e in the Wastewater sub-sector.

Table 58 – 2016 Wastewater Generated in the City GHG emissions

GHG Emission Sources	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Incomplete Combustion of Digester Gas	-	558	-	-	-	-	-	558
Nitrification / Denitrification	-	-	538	-	-	-	-	538
Effluent Processes	-	-	2,146	-	-	-	-	2,146
TOTALS	-	**558**	**2,684**	-	-	-	-	**3,242**

Total CO_2e emissions in the Wastewater Generated in the City sub-sector was 3,242 MT of CO_2e in 2016, with over 66% coming from effluent process emissions.

6.4 Agriculture, Forestry and Other Land Use (AFOLU)

The AFOLU sector accounted for emissions generated by land-use changes, livestock, and the use of agriculture fertilizers (Fong et al., 2014, p.117). Table 59 summarizes the calculated 2016 community-wide GHG emissions from the AFOLU sector.

Table 59 – 2016 Agriculture, Forestry and Other Land Use (AFOLU) GHG Emissions

GHG Emission Sub-sector	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Livestock	-	-	-	-	-	-	-	-
Land	57.39	-	-	-	-	-	-	57.39
Aggregate sources	-	14.22	7.44	-	-	-	-	21.66
TOTALS	**57.39**	**14.22**	**7.44**	**-**	**-**	**-**	**-**	**79.05**

The AFOLU emissions sector is only required for expanded GHG reporting, otherwise known as the BASIC+ framework, under the GPC. This sector includes emissions from livestock, land-use, and aggregate sources from non-CO_2 emission sources on land. Spokane has limited activities within this sector, and only emissions from the Land sub-sector and Aggregate Sources sub-sector were calculated. A similar sector was not included in previous inventories; therefore, no comparison can be made between this inventory and the previous inventories from 2010 and 2012. GHG emissions were calculated using 2017 National Inventory Report emissions factors and remotely-sensed, geospatial data from WSDA, City of Spokane, and DNR. Although emissions from the AFOLU sector account for only 0.00375% of total emissions in the community-scale inventory, the methodology provided in Chapter 4 allows for future inventories to build upon these initial calculations.

6.4.1 Land

Changes in soil composition, caused by land-use changes, can generate GHG emissions (Fong et al., 2014, p.117). Table 60 lists the estimated total CO_2e emissions from each land change category.

Table 60 – 2016 Land use change GHG emissions

GHG Emission Sources	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Cropland remaining Cropland	*0.13*							*0.13*
Cropland to Wetland	*0.00*							*0.00*
Grassland remaining Grassland	*50.77*							*50.77*
Grassland to Cropland	*0.16*							*0.16*
Grassland to Wetland	*-0.09*							*-0.09*
Grassland to Settlement	*4.12*							*4.12*
Wetland remaining Wetland	*0.02*							*0.02*
Wetland to Grassland	*0.01*							*0.01*
Settlement remaining Settlement	*2.11*							*2.11*
Settlement to Grassland	*0.25*							*0.25*
Settlement to Wetland	*-2.13*							*-2.13*
TOTALS	***57.39***							**57.39**

Emissions from the Land sub-sector were calculated between the years 2011 and 2016. Land use change categories that show negative values are GHG emissions sinks, meaning the soil has absorbed GHG emissions from 2011 to 2016. Due to the 2018-2019 government shutdown, spatial data for 2016 forest cover was unavailable at the time of the analysis. The data will be tentatively available in April 2019; therefore, the emissions from land use changes related to forest cover are not reflected in these results.

6.4.2 Aggregate Sources and Non-CO_2 Emission Sources on Land

The Aggregate Sources and Non-CO_2 Emission Sources on Land sub-sector accounts for the emissions generated by the burning of biomass without the energy being recovered (Fong et al., 2014, p. 124). Table 61 lists the estimated total CO_2e emissions associated with the burning of biomass.

Table 61 – 2016 Aggregate Sources and Non-CO_2 GHG emissions

GHG Emission Sources/Types	GHGs (MT CO_2e)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Biomass Burning without Energy Recovery		14.22	7.44	-	-	-	-	21.66
TOTALS		**14.22**	**7.44**	-	-	-	-	**21.66**

The emissions from the burning of biomass are an underestimate because only the fires recorded by DNR are included in this inventory. Undocumented fires that occur for recreational use (i.e. campfires) or residential waste incineration are not accounted for in this section. Other sources of emissions such as liming, soil management, and urea fertilization were not accounted for due to the lack of available data.

7 RESULTS AND ANLYSIS OF 2016 LOCAL GOVERNMENT OPERATIONS GHG EMISSIONS INVENTORY BY SOURCE

The following subsections describe the results of applying the LGO Protocol to quantify GHG emissions from local government operations by sector. These subsections comprise a tabular summary of calculated GHG emissions that is intended to align with the tables required by The Climate Registry's *Local Government Operations Standard Inventory Report* (The Climate Registry, 2016). These subsections also include a brief analysis of the results, highlighting (where possible) how these results compare to similar results from past City of Spokane LGO GHG inventories. However, it is important to note that this 2016 LGO inventory used updated emission factors, activity data sources, and global warming potentials to account for many of the emissions included in this results chapter. Therefore, more accurate comparisons between this inventory and previous City of Spokane LGO inventories may require the re-estimation of previous emissions.

7.1 Buildings and Other Facilities

The Buildings and Other Facilities sector accounts for emissions from all buildings and facilities owned, operated, or occupied by the City that are not included in other sectors of the inventory. Table 62 summarizes the calculated 2016 LGO GHG emissions from the Buildings and Other Facilities sector.

Table 62 – 2016 Buildings and Other Facilities GHG emissions

GHG Emission Scopes & Sources	GHGs (MT)							
SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
Stationary Combustion	2,661.82	2,661.77	0.05	2.66E-03	-	-	-	-
Fugitive Emissions	-	-	-	-	-	-	-	-
Total Direct Emissions from Buildings & Other Facilities	**2,661.82**	**2,661.77**	**0.05**	**2.66E-03**	-	-	-	-
SCOPE 2	CO_2e	CO_2	CH_4	N_2O	-	-	-	-
Purchased Electricity	11,475.41	-	-	-	-	-	-	-
Purchased Steam	-	-	-	-	-	-	-	-
Purchased District Heating and Cooling Heating	-	-	-	-	-	-	-	-
Total Indirect Emissions from Buildings & Facilities	**11,475.41**	-	-	-	-	-	-	-

Purchased steam was not included in this inventory because activity data was not available for the 2016 year, and the only local government facilities that potentially still used purchased steam in 2016 were leased spaces in County-owned buildings that were not under the operational control of the City of Spokane. For these reasons, the emissions were excluded from this LGO inventory.

7.1.1 Scope 1 Stationary Combustion

Scope 1 stationary combustion emissions from City of Spokane buildings and other facilities were generated by the combustion of natural gas used to power furnaces, burners, and boilers. The scope 1 emissions from the combustion of natural gas are categorized in Table 63 by the sources and amounts of the GHG emissions that contributed to the total CO_2e.

Table 63 – 2016 Buildings and Other Facilities scope 1 stationary combustion GHG emissions by facility

GHG Emission Source	GHGs (MT)			
	CO_2	*CH_4*	*N_2O*	*CO_2e*
City Hall	120.40	2.27E-03	1.20E-04	120.40
Main Library	175.37	3.31E-03	1.75E-04	175.37
Riverfront Park	205.96	3.88E-03	2.06E-04	206.97
Manito Greenhouse	238.34	4.49E-03	2.38E-04	238.35
Intermodal Center	82.45	1.55E-03	8.24E-05	82.45
Spokane Central Service Center	76.33	1.44E-03	7.63E-05	76.33
Fire -EMS Combined Command Center	47.99	9.04E-04	4.80E-05	47.99
Police Evidence	159.77	3.01E-03	1.60E-04	159.77
Broadway Fuel-Wash	69.59	1.31E-03	6.96E-05	69.59
Park Operations	51.75	9.75E-04	5.17E-05	51.75
Nelson Street Operations Center	31.86	6.00E-04	3.19E-05	31.86
Fire-EMS/Training Center	42.40	7.99E-04	4.24E-05	42.40
Police Academy	29.15	5.49E-04	2.92E-05	29.15
Public Defender/Public Prosecutor	22.86	4.31E-04	2.29E-05	22.86
Police Detectives/Gardner	11.91	2.25E-04	1.19E-05	11.92
Remaining Facilities	1,295.64	2.44E-02	1.30E-03	1296.67
Total	**2,661.77**	**0.05**	**2.66E-03**	**2,661.82**

7.1.2 Scope 2 Purchased Electricity

Scope 2 purchased electricity emissions from the Buildings and Other Facilities sector were generated by the consumption of electricity in all City-operated buildings and other facilities during the 2016 inventory year. Emissions from the consumption of electricity in unique LGO facilities, such as the water delivery facilities, wastewater and solid waste facilities, are covered in their respective sectors within this LGO inventory and can be found in the following sections of this chapter. The scope 2 emissions from purchased electricity in the Buildings and Other Facilities sector are categorized in Table 64 by the sources and amounts of the GHG emissions that contributed to the total CO_2e.

Table 64 – 2016 Buildings and Other Facilities scope 2 purchased electricity GHG emissions by location

GHG Emission Sources	MT CO_2e
City Hall	736.47
Main Library	543.90
Riverfront Park	730.88
Manito Greenhouse	37.04
Intermodal Center	275.18
Spokane Central Service Center	189.63
Fire -EMS Combined Command Center	302.53
Police Evidence	69.09
Broadway Fuel-Wash	73.50
Park Operations	53.21
Nelson Street Operations Center	95.26
Fire-EMS/Training Center	66.44
Police Academy	48.22
Public Defender/Public Prosecutor	49.98
Police Detectives/Gardner	56.15
Remaining Facilities	8,147.92
Total	**11,475.41**

7.2 Street Lighting and Traffic Signals

Emissions from the Streetlights and Traffic Signals sector incorporates emissions from electricity consumed in street lighting and traffic signals, including crosswalk signals and amber flashers. Other outdoor lighting that can be segregated from the facility that it serves can also be included in this sector; however, where this is not possible (e.g., when outdoor lighting at a given building is provided for by the same meter as the rest of the facility) these emissions were included in the Buildings and Other Facilities sector. Table 65 summarizes the calculated 2016 GHG emissions from the Street Lighting and Traffic Signals sector.

Table 65 – 2016 Street Lighting and Traffic Signals sub-sector GHG emissions

GHG Emission Scopes & Sources	GHGs (MT)							
SCOPE 2	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
Street Lighting	934.77				-			
Traffic signals	452.75							
Total Indirect Emissions from Streetlights and Traffic Signals	**1,387.52**		**-**	**-**	**-**	**-**	**-**	**-**
SCOPE 3	CO_2e	CO_2	CH_4	N_2O				
Avista Contracted Street Lighting	1,488.38	-	-	-				
Total Indirect Emissions from Streetlights and Traffic Signals	**1,488.38**	**-**	**-**	**-**				

The emissions from this sector do not include any additional scope 1 or scope 3 emissions, and therefore, only scope 2 emissions are reported in the sub-section below.

7.2.1 Scope 2 Purchased Electricity

The scope 2 emissions from purchased electricity are categorized in Table 66 by the sources and amounts of the GHG emissions that contributed to the total CO_2e from street lights and traffic signals.

Table 66 – 2016 Street Lighting and Traffic Signals scope 2 purchased electricity GHG emissions

GHG Emission Source	MT CO_2e
Street lighting	934.77
Traffic signals	452.75
TOTAL	**1,387.52**

For comparison, the emissions generated in the Street Lighting and Traffic Signals sector in the 2012 inventory were 1,284 MT CO_2e (City of Spokane, 2016, p.80).

7.2.2 Scope 3 Contracted Street Lighting

Street lighting emissions from energy contracted by Avista are categorized as scope 3 emissions. These emissions (1,488.38 MT CO_2e) account for six percent of the emissions from the Street Lighting and Traffic Signals sub-sector.

7.3 Water Delivery Facilities

Emissions from the Water Delivery Facilities sector includes scope 1 and scope 2 emissions related to any facilities used for the transportation, treatment and distribution, of drinking water. Typically this includes treatment facilities, booster stations, lift stations, in-line pumps, storage facilities reservoirs, and administrative facilities. Table 67 summarizes the calculated 2016 LGO GHG emissions from the Water Delivery Facilities sector.

Table 67 – 2016 Water Delivery Facilities GHG emissions

GHG Emission Scopes & Sources	GHGs (MT)							
SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
Stationary Combustion	208.99	208.82	3.94E-03	2.09E-04	-			
Total Direct Emissions from Water Delivery Facilities	**208.99**	**208.82**	**3.94E-03**	**2.09E-04**	**-**	**-**	**-**	**-**
SCOPE 2	CO_2e	CO_2	CH_4	N_2O				
Purchased Electricity	6,846.49	-	-	-				
Purchased Steam	-	-	-	-				
Purchased District Heating and Cooling	-	-	-	-				
Total Indirect Emissions from Water Delivery Facilities	**6,846.49**	**-**	**-**	**-**				

For comparison, the GHG emissions from this sector were 8,991 MT CO_2e in 2012 (City of Spokane, 2016d, p. 115).

7.3.1 Scope 1 Stationary Combustion

Scope 1 emissions in the Water Delivery Facilities sector were primarily generated by the stationary combustion of natural gas used to heat buildings related to City of Spokane's water delivery services (City of Spokane, 2016d, p. 117). The scope 1 emissions from the combustion of natural gas are categorized in Table 68 by the sources and amounts of the GHG emissions that contributed to the total CO_2e from water delivery facilities.

Table 68 – 2016 Water Delivery Facilities scope 1 GHG emissions

GHG Emission Sources	GHGs (MT)			
	CO_2	*CH_4*	*N_2O*	*Total CO_2e*
Upriver Operations Support Facility	50.68	2.67E-02	1.34E-02	50.72
North Foothills Support Facility	152.81	8.06E-02	4.05E-02	152.93
Wolverton Court Support Facility	5.34	2.82E-03	1.41E-03	5.34
TOTALS	208.82	1.10E-01	5.53E-02	208.99

There are only three water delivery facilities operated by the City of Spokane that use natural gas, Upriver Operations Support Facility, North Foothills Support Facility, and the Wolverton Court Support Facility. For comparison, the scope 1 emissions from stationary combustion in the Water Delivery Facilities sector were 337.6 MT CO_2e during the 2012 inventory year and 299 MT CO_2e during the 2010 inventory year (City of Spokane, 2016d, p. 115).

7.3.2 Scope 2 Purchased Electricity

Scope 2 emissions in the Water Delivery Facilities sector accounted for the GHG emissions generated by the electricity purchased at City-operated water delivery facilities. These facilities use electrical power to run equipment for facility operations such as water pumps, computers, and lights. The scope 2 emissions from the use of purchased electricity are categorized in Table 69 by source. Water delivery facilities that did not consume electricity were excluded from Table 69.

Table 69 – 2016 Water Delivery Facilities sub-sector scope 2 purchased electricity GHG emissions

GHG Emission Sources	MT CO_2e
PUMP: Nevada Grace Ave Stations	1,442.66
BOOSTER: Lincoln Heights Booster	1,115.35
Upriver Operations Support Facility	801.55
613 S Ray St	874.20
PUMP: Central Avenue Pump Station	703.70
PUMP: 3609 W West Dr Pump Station	397.06
North Foothills Support Facility	129.52
6806 N Belt St	261.89
Thorpe Road Valve Vault	232.01
PUMP: Hoffman Pump Station	162.99
PUMP: 204 W Eagle Ridge Ln Pump City	98.11
PUMP: 2722 W 15th Ave Pump Station	79.64
Thorpe & Spotted Rd	78.33
13th & Chestnut	75.60
BOOSTER: Division & Manito Booster	54.29
Glenrose & 57th	52.97
BOOSTER: Ray Booster Station	52.81
PUMP: 1202 W Eagle Ridge Blvd Pump	38.70
BOOSTER: Belt Street Booster Station	24.03
BOOSTER: 14th Grand Booster Station	19.42
PUMP: 24 E 9th Ave Pump	17.70
BOOSTER: New Five Mile Prairie	14.95
Wolverton Court Support Facility	4.05
Cedar Run System	11.82
4400 W Shawnee Ave Apt 410	9.56
5903 N Normandie St Apt 410	8.75
Shawnee Tank #2	8.24
2312 S Ray St	6.38
2216 1/2 W Strong Rd	6.22
PUMP: 57th & Glennaire Dr-Pumphous	5.78
24 E 9th Ave Tank	5.65
1015 W Bishop Ct	5.28
624 E 10th Ave	4.74

PUMP: Parkridge Blvd & Copper Ridge	3.98
Little & Swab SIA	3.78
3702 W Hawthorne	3.78
Glennaire Dr Apt 410	3.38
Thomas Mallon Water	2.84
Qualchan Water Tank	2.14
Abbot Rd	2.12
Cedar Run Tank	2.10
3800 S Little St Bldg Wtr 68	2.06
PUMP: No. Hill Valve Vault	1.89
Indian Trail Tank Vault	1.60
307 E 33rd Ave Apt 410	1.57
10300 N Wieber Dr	1.56
Indian Hill Tank Vault	1.54
Shadle Vault	1.39
Five Mile tank 410	1.30
4001 W Canyon Dr	1.18
BOOSTER: Garden Park Booster Stn	1.00
3103 W 21st Ave Apt 410	0.90
BOOSTER: Indian Hills Booster	0.90
MidBank Tank Vault	0.82
Garden Park Vault	0.62
Upriver Dr & Frederick Came	0.08
TOTAL	**6,846.49**

Additionally, Table 70 lists the electricity use by source (e.g., pumps, boosters, and support facilities) in the Water Delivery Facilities sector.

Table 70 – Water Deliver Facilities electricity consumed by source

Source	Electricity Used (MWH)	CO_2e from Electricity (MT CO_2e)
Pumps	10,041.55	2,949.60
Boosters	4,363.06	1,282.42
Support Facilities	8,882.76	2,612.98
TOTALS	**23,287.37**	**6,846.49**

Water delivery pumps are used to increase the pressure in a water pipe, allowing the fluid to travel uphill above its energy grade line. These pumps are often energy intensive due to the large scale of the operations, these pumps account for 43.1% of the electricity used in this sector. Boosters, used in conjunction with pumps, are a smaller scale pump that moves water to small subsections of the network adding additional energy. Boosters accounted for 18.7% of electricity use in this sector. Lastly, support facilities consumed a 38.1% of water delivery electricity use.

7.4 Wastewater Facilities

Emissions from the Wastewater Facilities sector includes scope 1 and scope 2 emissions related to any facilities used for the transportation, collection, or treatment of wastewater. Typically, this includes treatment facilities, booster stations, in-line pumps, lift stations, and administrative facilities. Table 71 summarizes the calculated 2016 GHG emissions from the Wastewater Facilities sector.

Table 71 – 2016 Wastewater Facilities GHG emissions

GHG Emission Scopes & Sources	GHGs (MT)							
SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFC	PFC	SF_6	NF_3
Stationary Combustion	471.98	471.51	0.249	0.125	-	-	-	-
Process Emissions	2,683.50	-	-	-	-	-	-	-
Fugitive Emissions	558.00	-	-	-	-	-	-	-
Total Direct Emissions from Wastewater Facilities	**3,713.48**	**471.51**	**0.249**	**0.125**	-	-	-	-
SCOPE 2	CO_2e	CO_2	CH_4	N_2O				
Purchased Electricity	5,020.64	-	-	-				
Purchased Steam	-	-	-	-				
Purchased District Heating and Cooling	-	-	-	-				
Total Indirect Emissions from Wastewater Facilities	**5,020.64**	-	-	-				

The total CO_2e emissions from the Wastewater Facilities sector was 8,734 MT of CO_2e in 2016. Fifty-seven percent (5,020.64 MT CO_2e) of the emissions from the Wastewater Facilities sector were scope 2 emissions from the use of purchased electricity, while process emissions accounted for 31% of the emissions from the Wastewater Facilities sector. For comparison, total CO_2e emissions from the Wastewater Facilities sector were 14,428 MT of CO_2e and 11,780 MT of CO_2e in the 2010 and 2012 inventory years, respectively (City of Spokane, 2016d, p. 115).

7.4.1 Scope 1 Stationary Combustion

Scope 1 stationary combustion emissions in the Wastewater Facilities sector were generated by the combustion of a natural gas used in the administrative and maintenance buildings associated with wastewater treatment. The total scope 1 emissions from the combustion of natural gas are reported in Table 72.

Table 72 – 2016 Wastewater Facilities scope 1 stationary combustion GHG emissions

Stationary Combustion Sources	GHGs (MT)			
	CO_2e	CO_2	CH_4	N_2O
Natural Gas used at RPWRF	414.27	413.85	7.80E-03	7.80E-04
Natural gas used for Wastewater Maintenance	57.71	57.66	0.03	0.01

The total CO_2e emissions from scope 1 stationary combustion sources in the Wastewater Facilities sector was 472 MT of CO_2e in 2016. For comparison, scope 1 stationary combustion emissions from the Wastewater Facilities sector were 391MT of CO_2e and 548 MT of CO_2e in the 2010 and 2012 inventory years, respectively (City of Spokane, 2016d, p. 115).

7.4.2 Scope 1 Process Emissions

Scope 1 process emissions in the Wastewater Facilities sector were from the generation of N_2O as a result of treatment plant and effluent processes. The treatment of domestic wastewater generates N_2O emissions during the nitrification and denitrification processes. Additionally, the discharge of effluent to receiving waters (e.g., the Spokane River) also generated N_2O emission. The scope 1 process emissions generated by these two sources are reported in Table 73.

Table 73 – 2016 Wastewater Facilities scope 1 process emissions GHG emissions

Process Emissions Sources	GHGs (MT)			
	CO_2e	CO_2	CH_4	N_2O
Nitrification / Denitrification	537.50	-	-	-
Effluent Processes	2,146.00	-	-	-

The total CO_2e emissions from scope 1 process emissions sources in the Wastewater Facilities sector was 2,684 MT of CO_2e in 2016. For comparison, scope 1 stationary combustion emissions from the Wastewater Facilities sector were 4,198 MT of CO_2e and 3,515 MT of CO_2e in the 2010 and 2012 inventory years, respectively (City of Spokane, 2016d, p. 115).

7.4.3 Scope 1 Fugitive Emissions

Scope 1 fugitive emissions in the Wastewater Facilities sector were generated by the incomplete combustion of anaerobic digester gas. The total scope 1 emissions from the incomplete combustion of digester gas and the combustion of natural gas are reported in Table 74.

Table 74 – 2016 Wastewater Facilities scope 1 fugitive emissions GHG emissions

Stationary Combustion Sources	GHGs (MT)			
	CO_2e	CO_2	CH_4	N_2O
Incomplete Combustion of Digester Gas	558.00	-	-	-

The total CO_2e emissions from scope 1 fugitive emissions sources in the Wastewater Facilities sector was 558 MT of CO_2e in 2016. For comparison, scope 1 fugitive emissions from the Wastewater Facilities sector was 557 MT of CO_2e and 528 MT of CO_2e in the 2010 and 2012 inventory years, respectively (City of Spokane, 2016d, p. 115).

7.4.4 Scope 2 Purchased Electricity

Scope 2 emissions in the Wastewater Facilities sector were generated by the consumption of electricity used to collect and treat the wastewater from the City of Spokane service area. The scope 2 emissions generated by these sources are reported in Table 75.

Table 75 – 2016 Wastewater Facilities scope 2 purchased electricity GHG emissions

Electricity Used (MWh)	CO_2e from Electricity Use (MT)
17,264	5,075.62

The total CO_2e emissions from scope 2 purchased electricity in the Wastewater Facilities sector amounted to 5,076 MT of CO_2e in 2016. For comparison, scope 1 stationary combustion emissions from the Wastewater Facilities sector were 9,282 MT of CO_2e and 7,189 MT of CO_2e in the 2010 and 2012 inventory years, respectively (City of Spokane, 2016d, p. 115).

7.5 Vehicle Fleet

The Vehicle Fleet sector accounts for the vehicles and employee travel related to local government operations and includes GHG emissions from both on-road and off-road vehicles owned by the City of Spokane. The City's 2016 fleet comprised a variety of vehicles including cars, trucks, busses, maintenance vehicles, and construction equipment. All of these vehicles ran on either gasoline, diesel, compressed natural gas (CNG), propane, or electricity. GHG emissions from these vehicles were classified as scope 1 direct emissions and scope 2 indirect emissions from the use of purchased of electricity.

Most (10,070 MT CO_2e) GHG emissions were direct scope 1 emissions from the combustion of fossil fuels used to power vehicles. Indirect emissions from the loss of refrigerants were also included as scope 1 fugitive emissions. Scope 2 emissions were generated by the City's single electric vehicle, a 2011 Nissan Leaf. In previous inventory years, emissions from the Leaf were included under the Buildings and Other Facilities sector, as the charging unit for this vehicle was included in the electricity consumption at City Hall (City of Spokane, 2016d, p. 85). Table 76 summarizes the calculated 2016 LGO emissions from the Vehicle Fleet sector.

Table 76 – 2016 Vehicle Fleet GHG emissions

GHG Emission Scopes & Sources	GHGs (MT)							
SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
Mobile Combustion	9,990.4	9,941	0.78	0.104	-	-	-	-
Fugitive Emissions	80	-	-	-	0.62	-	-	-
Total Direct Emissions from Vehicle Fleet	**10,070.4**	**9,941**	**0.78**	**0.104**	**0.62**	-	-	-
SCOPE 2	CO_2e	CO_2	CH_4	N_2O				
Purchased Electricity for Electric Vehicles	0.28	-	-	-				
Total Indirect Emissions from Vehicle Fleet	**0.28**	-	-	-				
SCOPE 3	CO_2e	CO_2	CH_4	N_2O				
Employee Commuting and Business Travel	105.10	-	-	-				
Total Indirect Emissions from Vehicle Fleet	**105.10**	-	-	-				

For the 2016 inventory, the scope 1 and 2 vehicle fleet emissions totaled 10,070 MT total CO_2e. For comparison, the vehicle fleet emissions reported in the 2010 and 2012 were 11,140 CO_2e and 11,273 CO_2e, respectively (City of Spokane, 2016, p. 84-85).

7.5.1 Scope 1 Mobile Combustion

The scope 1 emissions from the combustion of fossil fuels in City-operated vehicles are categorized in Table 77. The table separates emissions into highway vehicles, non-highway vehicles, and vehicles running on alternate fuel sources.

Table 77 – 2016 City of Spokane Vehicle Fleet emissions (MT)

GHG source	CO_2	N_2O	CH_4	Total CO_2e
Highway Vehicles	7,533	0.08	0.59	7,571.59
Non-Highway Vehicle	1,067	0.01	0.1	1,072.48
Alternate fuel vehicles	1,341	0.01	0.09	1,346.23
Mobile Combustion total	9,941	0.10	0.78	9,990.3
Fugitive emissions total	-	-	-	80
Totals	**9,941**	**0.104**	**0.78**	**10,070.4**

The City's vehicle fleet emitted 10,070 MT CO_2e in 2016. Approximately 85% of the emissions came from gasoline and diesel-powered highway vehicles. Alternate fuel vehicles used propane and CNG. Carbon dioxide emissions are directly proportional to the amount of fuel burned by a vehicle, while N_2O and CH_4 are related to the emissions control technology within each vehicle. Table 78 provides a summary of the total CO_2e emissions by fuel type.

Table 78 – Summary of CO_2e vehicle fleet emissions by fuel type

Fuel Type	**Total MT CO_2e**
Gasoline	2,771
Diesel	4,796
Propane	3
Natural Gas	1,071
Off Road Use (Diesel)	1,347
Total	**9,990**

The quantity of CH_4 and N_2O emissions generated depended on the type of vehicle, model year, how it was used, and total VMT. The City has comprehensive data on vehicle type; however, VMT data is more challenging to apply to emissions calculations due to record keeping procedures throughout the fleet. Vehicle odometers are not recorded at the beginning and end of each year because year-end recording of all fleet vehicles is not feasible. Therefore, some approximations were made based on similar vehicles and partial mileage data. After all approximations were complete, total VMT for 2016 totaled 5,094,175 miles.

Table 79 categorizes the City of Spokane's vehicle fleet by the number of cars in each fuel type. Note, the City's vehicle fleet decreased from 1,249 vehicles in 2012 to 1,207 in 2016.

Table 79 – Number of 2016 City of Spokane fleet vehicles by fuel type (City of Spokane, 2018a)

Fuel Type	Diesel	Gasoline	Propane	Hybrid	Electric	CNG	Total
Number of Vehicles	461	686	13	12	1	34	1,207

Gasoline powered vehicles are the largest fuel type (686 vehicles) in the fleet, while the 461 diesel-powered vehicles consumed the most volume of fuel in 2016. Additionally, the number of CNG vehicles has increased since 2012 from 2 to 34. This has decreased the fuel consumption of other vehicles, mainly the diesel-powered vehicles. In 2012, the City included ethanol in the fuel mix for its vehicles, as many diesel-powered vehicles ran on this biofuel. For 2016, all ethanol and biofuel used by the City had been phased-out by retiring or converting vehicles to diesel power. Table 80 is a comparison of fuel consumption, categorized by fuel type, for the 2010, 2012, and 2016 inventories.

Table 80 – 2016 fuel use by City of Spokane vehicle fleet in Gallons

Inventory Year	Gasoline	Diesel	Propane	Ethanol	CNG (therms)	Total Fuel Use
2010	364,558	755,406	2,288	40,652	-	1,162,905
2012	360,704	768,314	3,778	40,050	-	1,172,846
2016	314,341	601,700	614	-	19,1751	916,655

Total CNG usage was reported in units of therms, not gallons. The previous inventories included CNG as part of the Buildings and Other Facilities sector emissions because separate metering for these vehicles was unavailable. For 2016, metered data was made available, and CNG vehicles were accounted for under the Vehicle Fleet sector. Except for natural gas, the total volume of fuel consumed decreased from 1,172,846 gallons in the 2012 inventory (City of Spokane, 2016d) to 916,655 gallons consumed in 2016. While fuel usage has decreased by 21.84%, the total emissions from vehicles has only decreased by 10.65%. These changes in fuel consumption and GHG emissions may potentially be caused by the increased use of CNG vehicles because natural gas is reported in therms and not gallons. Other factors that can be attributed to the changes in fuel consumption and GHG emissions include retiring old vehicles and the addition of vehicles as fuel efficiencies change with vehicle model and year.

7.5.2 Scope 1 Fugitive Emissions

The Scope 1 Fugitive Emissions sub-sector accounted for the emissions from lost refrigerants from air conditioning systems in fleet vehicles. Most City of Spokane vehicles contain air conditioning systems that utilize chemicals that must be reported under the LGO Protocol. These refrigerants, through maintenance and normal use, can leak from the systems. If averaged throughout the whole fleet, each vehicle only lost 50 grams, about a tenth of one pound. However, these chemicals have proportionally high GWPs and contribute to GHGs in the atmosphere. The most common refrigerant used in vehicles (R-134a) has a GWP of 1,300 (Intergovernmental Panel on Climate Change (IPPC), 2013). Table 81 summarizes the total fugitive emissions from refrigerants in the City of Spokane vehicle fleet for 2016.

Table 81 – 2016 City of Spokane Vehicle Fleet refrigerant use and emissions

Refrigerant	Starting Inventory (kg)	Amount Purchased (kg)	Ending Inventory (kg)	Total Used (kg)	GWP	CO_2e (MT)
R-134a	27	68	34	62	1,300	81

Total fugitive emissions for this sector in 2016 was 81 MT CO_2e. For comparison, the scope 1 fugitive emissions reported in the 2010 and 2012 inventories were 152 MT CO_2e and 200 MT CO_2e, respectively (City of Spokane, 2016, p.81).

7.5.3 Scope 2 Purchased Electricity for Electric Vehicles

The City of Spokane owns and operates one electric vehicle, a 2011 Nissan leaf. Using vehicle specific efficiency information, the emissions were calculated using VMT. This vehicle is charged using purchased grid-supplied electricity; therefore, the emissions are considered scope 2. Table 82 summarizes the emissions generated by the City's one electric vehicle.

Table 82 – 2016 City of Spokane electric vehicle use emissions

Vehicle	Miles Traveled	kWh per 100 miles	Total MWh consumed	Emission Factor for CO_2	Total Emissions (MT CO_2e)
2011 Nissan Leaf	2,544	34	0.864	294 kg CO_2e MWh^{-1}	0.28

A comparison to the previous 2012 inventory cannot be made because the emissions were not included in the Vehicle Fleets sector, rather the emissions were accounted for in the Buildings and Other Facilities sector because the vehicle was charged at City Hall.

7.5.4 Scope 3 Emission from Employee Commuting and Business Travel

While not considered direct emissions from City-owned and operated vehicles, emissions from business travel should still be reported as scope 3 emissions in LGO inventories because they represent emissions from vehicles used for operations related to the City of Spokane's local government. Data for this sector is collected by the City on odd numbered calendar years, so data used in this inventory was from August 2014 through July 2015. For this reporting period, 426 employees took 267 business trips. This was approximately a 55% decrease from the 2012 inventory for employees who traveled, decreasing from 929 to 426. Total business trips by car decreased by 77%, from 396 to 92 (City of Spokane, 2016, p. 92). This means that overall, city employees were traveling less and for shorter distances.

City employees traveled by means of passenger car, bus, and air during the reporting period. The City of Spokane employee business travel is categorized in Table 83 by the type of vehicle, number of trips, and total VMT.

Table 83 – 2016 City of Spokane employee business travel

Vehicle	Number of trips	Total VMT traveled per trip
Car	92	47,612
Air	174	386,354
Bus	1	587

Airline and bus travel involve other passengers. Therefore, emissions were calculated using passenger mile as to not attribute total miles traveled to just the City employees. Passenger vehicle travel was calculated using VMT. Short air trips were trips involving less than 300 miles of travel, medium air travel was between 300 and 2,300 miles, and long air travel are trips over 2,300 miles. Table 84 below summarizes the emissions from City of Spokane employee travel.

Table 84 – 2016 Scope 3 employee travel emissions

Travel Method	Mileage	CO_2 Factor (kg/unit)	CH_4 Factor (g/unit)	N_2O Factor (g/unit)	Units	Total MT CO_2e
Passenger Car	47612	0.34	0.019	0.011	Vehicle-mile	16.33
Bus	587	0.06	0.0013	0.0009	Passenger-mile	0.033
Air (short)	531.4	0.23	0	0.007	Passenger-mile	0.120
Air (med)	143516	0.14	0.0006	0.004	Passenger-mile	19.50
Air (long)	416239	0.17	0.0006	0.0053	Passenger-mile	69.10
Total						**105.10**

Approximately, 85% of the emissions were generated by air travel. Interestingly, about 92% of employee travel miles were by air. Air travel is still the most carbon intensive form of business travel, but because the units were in miles traveled per passenger instead of vehicle mile, the overall emissions attributed to the City are less.

7.6 Power Generation Facilities

The Power Generation Facilities sector accounts for emissions at the City's power generation facilities. The City of Spokane operates two power generation facilities, the WTE facility and UHD. However, the scope 1 and scope 2 emissions from UHD are accounted for in the Water Delivery sector because the natural gas and purchased electricity consumed cannot be distinguished from the Water Delivery Facilities sector. Table 85 summarizes the calculated 2016 local government operations GHG emissions from the power generation facilities sector.

Table 85 – 2016 Power Generation Facilities GHG emissions

GHG Emission Scopes & Sources	GHGs (MT)							
SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFC	PFC	SF_6	NF_3
WTE Facility MSW Stationary Combustion	100,136.76	95,004.22	81.75	10.73	-	-	-	-
WTE Facility Natural Gas Stationary Combustion	300.86	300.55	5.66E-03	5.66E-04	-	-	-	-
Process Emissions	-	-	-	-	-	-	-	-
Fugitive Emissions	-	-	-	-	-	-	-	-
Total Direct Emissions from Power Generation Facilities	**100,437.62**	**95,304.77**	**81.76**	**10.73**	-	-	-	-
SCOPE 2	CO_2e	CO_2	CH_4	N_2O				
Purchased Electricity	43.26	-	-	-				
Purchased Steam	-	-	-	-				
Purchased District Heating and Cooling	-	-	-	-				
Total Indirect Emissions from Power Generation Facilities	**43.26**	-	-	-				

The total scope 1 emissions from the WTE facility included the direct incineration of MSW and the emissions from the consumption of natural gas for facility operations. Scope 2 emissions are also generated at the WTE facility from the use of purchased electricity for facility operations. In keeping with GPC guidelines, biogenic emissions generated by the combustion of MSW are not included in the reported totals. However, for informational purposes, there was 136,713 MT of $CO_2e(b)$ generated at the WTE facility in 2016.

7.6.1 Scope 1 Stationary Combustion

Stationary combustion emissions were generated from the use of natural gas and the incineration process at the WTE facility. Table 86 categorizes the sources and the amounts of the specific GHG emissions that contributed to the total CO_2e in the Power Generation Facilities sector.

Table 86 – 2016 Power Generation Facilities scope 1 GHG emissions

GHG Emission Sources	GHG's (MT)			
	CO_2	*CH_4*	*N_2O*	*Total CO_2e*
WTE Incineration	95,004.22	81.75	10.73	100,136.76
WTE Natural Gas Used to Heat Buildings	300.55	5.66E-03	5.66E-04	300.86
Total	**95,304.77**	**81.76**	**10.73**	**100,437.62**

The WTE facility emitted 100,137 MT CO_2e through direct MSW incineration emissions, which is 98% of the total stationary combustion emissions.

7.6.2 Scope 2 Purchased Electricity

The WTE facility generated indirect scope 2 emissions from the use of purchased electricity for facility operations. Table 87 lists the total scope 2 emissions generated by the WTE facility.

Table 87 – 2016 Power Generation Facilities scope 2 GHG emissions

GHG Emission Sources	MT CO_2e
WTE Electricity	43.26
TOTALS	**43.26**

The WTE facility generated 43 MT CO_2e from the consumption of purchased electricity used for facility operations. For comparison, the *Greenhouse Gas Inventory Report for 2010 – 2012* reported 24 MT CO_2e (City of Spokane, 2016d, p. 99). The annual total the facility purchased from Avista was 147.15 MWh.

7.7 Solid Waste Facilities

The Solid Waste Facilities sector accounted for fugitive emissions from the NSLF and SSLF. The NSLF and SSLF generate methane, which is extracted and combusted through a flaring process. Table 88 summarizes the calculated 2016 emissions from the solid waste facilities sector.

Table 88 – 2016 Solid Waste Facilities GHG emissions

GHG Emission Scopes & Sources	GHGs (MT)							
SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
Stationary Combustion	-	-	-	-	-	-	-	-
Process Emissions	-	-	-	-	-	-	-	-
Fugitive Emissions	7,879.5	-	281.41	-	-	-	-	-
Total Direct Emissions from Solid Waste Facilities	**7,879.5**	-	**281.41**	-	-	-	-	-
SCOPE 2	CO_2e	CO_2	CH_4	N_2O				
Purchased Electricity	52	-	-	-				
Purchased Steam	-	-	-	-				
Purchased District Heating and Cooling	-	-	-	-				
Total Indirect Emissions from Solid Waste Facilities	**52**	-	-	-				

The total CO_2e emissions from the Solid Waste Facilities sector amounted to 7,932 MT of CO_2e in 2016. For comparison, total CO_2e emissions from the Solid Waste Facilities sector were 12,239 MT of CO_2e and 12,493 MT of CO_2e in the 2010 and 2012 inventory years, respectively (City of Spokane, 2016d, p. 102).

7.7.1 Scope 1 Fugitive Emissions

Greenhouse gas emissions from the NSLF and SSLF were generated by fugitive CH_4 emissions from the landfill gas capture systems. Table 89 lists the reported totals of scope 1 fugitive emissions from the Northside and Southside Landfills.

Table 89 – 2016 Solid Waste Facilities scope 1 GHG emissions

GHG Emission Sources	GHGs (MT)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
NSLF Open Cell	-	179.81	-	-	-	-	-	5,034.66
NSLF Closed Cell		76.42						2,139.80
SSLF	-	25.18	-	-	-	-	-	705.04
TOTAL	-	**281.41**	-	-	-	-	-	**7,879.5**

Total CO_2e emissions from scope 1 fugitive emissions in the Solid Waste Facilities sector amounted to 7,880 MT of CO_2e in 2016. For comparison, total CO_2e emissions from scope 1 fugitive emissions in the Solid Waste Facilities sector were 11,928 MT of CO_2e and 12,367 MT of CO_2e in the 2010 and 2012 inventory years, respectively (City of Spokane, 2016d, p. 102). SSLF produced fewer emissions because this landfill closed all waste cells and stopped receiving MSW in 1988. U.S. EPA landfill models project the greatest annual emissions to be the year waste cells are closed, with a parabolic decrease in emissions in subsequent years (City of Spokane, 2016d, p. 104)

7.7.2 Scope 2 Purchased Electricity

The scope 2 emissions from the use of purchased electricity at solid waste facilities are reported in Table 90.

Table 90 – 2016 Scope 2 Purchased Electricity GHG Emissions

GHG Emission Sources	GHGs (MT)							
	CO_2	*CH_4*	*N_2O*	*PFC*	*HFC*	*SF_6*	*NF_3*	*Total CO_2e*
Scope 2 Purchased Electricity	52	-	-	-	-	-	-	52
TOTALS	**52**	-	-	-	-	-	-	**52**

The total CO_2e emissions from scope 2 purchased electricity in the Solid Waste Facilities sector was 52 MT of CO_2e in 2016.

8 RECOMMENDATIONS FOR FUTURE INVENTORIES

During the process of writing this report, the authors identified several opportunities for consideration in future GHG emissions inventory efforts in the City of Spokane. These include:

1. Continue to use the latest protocols for community-scale and local government operations GHG emissions inventories that were used in this report – i.e., the GPC and LGO Protocol, respectively. Continuing the use of these protocols will ensure consistency in the methodologies used over time to account for emissions within the City and as a results of municipal activities. Use of these protocols will also ensure that Spokane remains consistent with international best practices for GHG emissions accounting and can benchmark progress relevant to other cities using these protocols and their associated reporting platforms.
2. Clarify Ordinance C35519 regarding the City's GHG emissions reduction goals to establish how inventories, like the ones included in this report, can be used to measure progress over time and establish more specific GHG mitigation strategies. Currently, Ordinance C35519 states that it is the goal of the City of Spokane to reduce GHG emissions created by activities within the boundaries of the City by at least 30% below the 2005 baseline by 2030. What is not clear is if these "activities" include *all* activities within this geographic boundary (over which the local government may have more limited control), or include *only* those activities within the operational control of the local government. Addressing this need for clarification will help operationalize the empirical data and results from these inventories for use in establishing interim GHG mitigation goals, strategies, and actions.
3. Establish similar City-university partnerships using the Educational Partnerships for Innovation in Communities model (https://www.epicn.org/) to help facilitate the updating of future inventories. As shown in this project, partnerships like this leverage largely untapped university resources to streamline the time it takes to address real community needs through applied learning experiences and workforce training. Through this project, the seven undergraduate students were able to commit over 1,300 total hours towards the completion of the updated LGO and community-wide inventories, while also gaining valuable skills and job training. Partnerships like these are mutually beneficial for the municipal and university departments involved, and the communities they serve.
4. Identify a base year recalculation policy, including the significance threshold for recalculating base year emissions. Tracking emissions over time is an important component of developing longitudinal GHG emissions reduction strategies. However, cities like Spokane and their local governments may undergo changes overtime, including: (1) structural changes to the inventory boundaries (e.g., adjustments in the city's administrative boundary and/or changes in the inclusion/exclusion of certain activities within the boundary) and (2) changes in the emissions calculations methodologies or improvements in data accuracy. While cities should not recalculate base year emissions to account for organic growth, cities should recalculate base year

emissions if they encounter such significant changes. Otherwise, such changes may alter a city's historical emissions profile and make comparisons over time more difficult. While there exists no universal recommendation as to what constitutes a "significant" change, GHG emissions programs like the California Climate Action Registry specify numerical significance thresholds where the change threshold is 10% of the base year emissions. Spokane could consider adopting a similar significance threshold for recalculating base year emissions.

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APPENDIX A: CITY INVENTORY REPORTING AND INFORMATION SYSTEM (CIRIS) RESULTS OVERVIEW

The following summary table is a copy of the results overview tab from the Excel-based CIRIS reporting platform used to report the results from the 2016 community-wide inventory.

NAME OF CITY:	Spokane, United States of America	**POPULATION:**	215,114
LEVEL:	BASIC+	**LAND AREA (km2):**	180
INVENTORY YEAR:	2016	**GDP (US$ million):**	

GHG Emissions Source (By Sector)		Total GHGs (metric tonnes CO2e)					
		Scope 1	Scope 2	Scope 3	BASIC	BASIC+	BASIC+ S3
STATIONARY ENERGY	Energy use (all emissions except I.4.4)	516,058	587,418	24,848	1,103,476	1,128,324	1,128,324
	Energy generation supplied to the grid (I.4.4)						
TRANSPORTATION	(all II emissions)	764,627		202,967	764,627	967,595	967,595
WASTE	Waste generated in the city (III.X.1 and III.X.2)	10,416		2,382	12,798	12,798	12,798
	Waste generated outside city (III.X.3)						
IPPU	(all IV emissions)						
AFOLU	(all V emissions)	79				79	79
OTHER SCOPE 3	(all VI emissions)						
TOTAL		**1,291,181**	587,418	230,197	**1,880,901**	**2,108,796**	**2,108,796**

GPC ref No.	GHG Emissions Source (By Sector and Sub-sector)	Total GHGs (metric tonnes CO_2e)			
		Scope 1	Scope 2	Scope 3	Total
I	STATIONARY ENERGY				
I.1	Residential buildings	231,444	273,499	11,569	516,512
I.2	Commercial and institutional buildings and facilities	160,637	294,482	12,457	467,576
I.3	Manufacturing industries and construction	14,701	19,393	820	34,914
I.4.1/2/3	Energy industries	100,488	43	2	100,533
I.4.4	Energy generation supplied to the grid				
I.5	Agriculture, forestry and fishing activities	1,674	NO	NE	1,674
I.6	Non-specified sources	889	NO	NE	889
I.7	Fugitive emissions from mining, processing, storage, and transportation of coal	NO			
I.8	Fugitive emissions from oil and natural gas systems	6,226			6,226
SUB-TOTAL	(city induced framework only)	**516,058**	**587,418**	**24,848**	**1,128,324**
II	TRANSPORTATION				
II.1	On-road transportation	703,889	NE	4,577	708,466
II.2	Railways	45,530	NE	57,604	103,134
II.3	Waterborne navigation	NO	NE	100	100
II.4	Aviation	14,999	NE	140,687	155,687
II.5	Off-road transportation	209	NE	NO	209
SUB-TOTAL	(city induced framework only)	**764,627**		**202,967**	**967,595**
III	WASTE				
III.1.1/2	Solid waste generated in the city	7,174		705	7,880
III.2.1/2	Biological waste generated in the city			1,677	1,677
III.3.1/2	Incinerated and burned waste generated in the city				
III.4.1/2	Wastewater generated in the city	3,242			3,242
III.1.3	Solid waste generated outside the city				
III.2.3	Biological waste generated outside the city				
III.3.3	Incinerated and burned waste generated outside city				
III.4.3	Wastewater generated outside the city				
SUB-TOTAL	(city induced framework only)	**10,416**		**2,382**	**12,798**
IV	INDUSTRIAL PROCESSES and PRODUCT USES				
IV.1	Emissions from industrial processes occurring in the city boundary	NE			
IV.2	Emissions from product use occurring within the city boundary	NE			
SUB-TOTAL	(city induced framework only)				
V	AGRICULTURE, FORESTRY and OTHER LAND USE				
V.1	Emissions from livestock	NE			
V.2	Emissions from land	58			58
V.3	Emissions from aggregate sources and non-CO2 emission sources on land	22			22
SUB-TOTAL	(city induced framework only)	**79**			**79**
VI	OTHER SCOPE 3				
VI.1	Other Scope 3			NE	
TOTAL	(city induced framework only)	**1,291,181**	**587,418**	**230,197**	**2,108,796**

APPENDIX B: THE CLIMATE REGISTRY LGO STANDARD INVENTORY REPORT GHG INVENTORY DETAILS

The following summary table is a copy of the inventory details tab from Excel-based LGO Standard Inventory Report used to report the results from the 2016 LGO inventory.

GHG Emissions Summary (All Units in Metric Tons Unless Stated Otherwise)

BUILDINGS & OTHER FACILITIES								
SCOPE 1	**CO_2e**	**CO_2**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**NF_3**
Stationary Combustion	2661.82	2661.77	0.05	-	-	-	-	-
Fugitive Emissions	-	-	-	-	-	-	-	-
Total Direct Emissions from Buildings & Other Facilities	2661.82	2661.77	0.05	0.00	0.00	0.00	0.00	0.00
SCOPE 2 - MARKET-BASED	**CO_2e**	**CO_2**	**CH_4**	**N_2O**				
Purchased Electricity	11475.41	-	-	-				
Purchased Steam	-	-	-	-				
Purchased Heating	-	-	-	-				
Purchased Cooling	-	-	-	-				
Total Market-Based Scope 2 Emissions	11475.41	0.00	0.00	0.00				

STREETLIGHTS AND TRAFFIC SIGNALS								
SCOPE 2 - MARKET-BASED	**CO_2e**	**CO_2**	**CH_4**	**N_2O**				
Purchased Electricity	1387.52	-	-	-				
Total Market-Based Scope 2 Emissions	1387.52	-	-	-				
SCOPE 3	**CO_2e**	**CO_2**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**NF_3**
Avista Contracted Street Lighting	1488.38	-	-	-	-	-	-	-
Total Scope 3 Emissions	1488.38	-	-	-	-	-	-	-

WATER DELIVERY FACILITIES								
SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
Stationary Combustion	209.00	209.00	-	-	-	-	-	-
Total Direct Emissions from Water Delivery Facilities	209.00	209.00	-	-	-	-	-	-

SCOPE 2 - MARKET-BASED	CO_2e	CO_2	CH_4	N_2O
Purchased Electricity	6846.49	-	-	-
Purchased Steam	-	-	-	-
Purchased Heating	-	-	-	-
Purchased Cooling	-	-	-	-
Total Market-Based Scope 2 Emissions	6846.49	0.00	0.00	0.00

WASTEWATER FACILITIES								
SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
Stationary Combustion	471.98	471.51	0.25	0.13	-	-	-	-
Process Emissions	2683.50	-	-	-	-	-	-	-
Fugitive Emissions	558.00	-	-	-	-	-	-	-
Total Direct Emissions from Wastewater Facilities	3713.48	471.51	0.25	0.13	0.00	0.00	0.00	0.00

SCOPE 2 - MARKET-BASED	CO_2e	CO_2	CH_4	N_2O
Purchased Electricity	5020.64	-	-	-
Purchased Steam	-	-	-	-
Purchased Heating	-	-	-	-
Purchased Cooling	-	-	-	-
Total Market-Based Scope 2 Emissions	5020.64	0.00	0.00	0.00

VEHICLE FLEET**								
SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
Mobile Combustion	9990.40	9941.00	0.78	0.104	-	-	-	-
Fugitive Emissions	80.00	-	-	-	0.62	-	-	-
Stationary Combustion	-	-	-	-	-	-	-	-
Total Direct Emissions from Vehicle Fleet	10070.40	9941.00	0.78	0.104	0.62	0.00	0.00	0.00

SCOPE 3	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
Employee Commuting	-	-	-	-	-	-	-	-
Employee Business Travel	105.10	104.76	1.24E-03	3.35E-03	-	-	-	-
	105.10	104.76	0.00	0.00	0.00	0.00	0.00	0.00

POWER GENERATION FACILITIES								
SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
Stationary Combustion	100438	95305	82	11	-	-	-	-
Process Emissions	-	-	-	-	-	-	-	-
Fugitive Emissions	-	-	-	-	-	-	-	-
Total Direct Emissions from Power Generation Facilities	100438	95305	82	11	0.00	0.00	0.00	0.00

SCOPE 2 - MARKET-BASED	CO_2e	CO_2	CH_4	N_2O
Purchased Electricity	43.26	-	-	-
Purchased Steam	-	-	-	-
Purchased Heating	-	-	-	-
Purchased Cooling	-	-	-	-
Total Market-Based Scope 2 Emissions	43.26	0.00	0.00	0.00

DIRECT BIOGENIC EMISSIONS	CO_2e	CO_2
Stationary Combustion	136713.00	-
Total Direct Biogenic Emissions	136713.00	0.00

INDICATORS*	
Electricity consumption by government operations (MWh)	147.15

SOLID WASTE FACILITIES								
SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
Stationary Combustion	-	-	-	-	-	-	-	-
Process Emissions	-	-	-	-	-	-	-	-
Fugitive Emissions	7879.50	-	281.41	-	-	-	-	-
Total Direct Emissions from Solid Waste Facilities	7879.50	0.00	281.41	0.00	0.00	0.00	0.00	0.00

SCOPE 2 - MARKET-BASED	CO_2e	CO_2	CH_4	N_2O
Purchased Electricity	52.00	-	-	-
Purchased Steam	-	-	-	-
Purchased Heating	-	-	-	-
Purchased Cooling	-	-	-	-
Total Market-Based Scope 2 Emissions	52.00	0.00	0.00	0.00

TOTAL EMISSIONS								
	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
SCOPE 1	124971.82	108588.05	364.25	10.96	0.62	0.00	0.00	0.00
DIRECT BIOGENIC EMISSIONS	136713.00	-	-	-	-	-	-	-
INDIRECT BIOGENIC EMISSIONS - MARKET-BASED	1387.52	-	-	-	-	-	-	-
SCOPE 2 - MARKET-BASED	24825.60	-	-	-	-	-	-	-
SCOPE 3	1593.48	104.76	-	-	-	-	-	-

APPENDIX C: N_2O AND CH_4 EMISSION FACTORS FOR VEHICLE TYPE AND MODEL YEAR

Table 91 – N_2O and CH_4 Emission factors for vehicle type and model year (U.S. EPA Center for Corporate Climate Leadership, 2018a)

Model Year	**CH_4 Emission Factor**	**N_2O Emission Factor**
Gasoline: Passenger cars		
1980	0.1326	0.0499
1984-93	0.0704	0.0647
1994	0.0531	0.0560
1995	0.0358	0.0473
1996	0.0272	0.0426
1997	0.0268	0.0422
1998	0.0241	0.0379
1999	0.0216	0.0337
2000	0.0178	0.0273
2001	0.0110	0.0158
2002	0.0107	0.0153
2003	0.0115	0.0133
2004	0.0157	0.0063
2005	0.0164	0.0051
2006	0.0161	0.0057
2007	0.0170	0.0041
2008	0.0172	0.0038
2009-present	0.0173	0.0036
Gasoline Light Trucks (Vans, Pickup Trucks, SUVs)		
Model Year	**CH_4 Emission Factor**	**N_2O Emission Factor**
1979-80	0.1594	0.0555
1981	0.1479	0.0660
1982	0.1442	0.0681
1983	0.1368	0.0722
1984	0.1294	0.0764
1985	0.1220	0.0806
1986	0.1146	0.0848
1987-93	0.0813	0.1035
1994	0.0646	0.0982
1995	0.0517	0.0908
1996	0.0452	0.0871
1997	0.0452	0.0871
1998	0.0412	0.0778
1999	0.0333	0.0593
2000	0.0340	0.0607
2001	0.0221	0.0328

2002	0.0242	0.0378
Gasoline Heavy Duty Vehicles		
Model Year	**CH_4 Emission Factor**	**N_2O Emission Factor**
<1981	0.4604	0.0497
1982-84	0.4492	0.0538
1985-86	0.4090	0.0515
1987	0.3675	0.0849
1988-1989	0.3492	0.0933
1990-1995	0.3246	0.1142
1996	0.1278	0.1680
1997	0.0924	0.1726
1998	0.0655	0.1750
1999	0.0648	0.1721
2000	0.0630	0.1650
2001	0.0578	0.1435
2002	0.0634	0.1664
2003	0.0603	0.1534
2004	0.0323	0.0195
2005	0.0329	0.0162
2006	0.0318	0.0227
2007	0.0333	0.0134

Table 92 – N_2O and CH_4 Emission factors for vehicle types and years(California Air Resources Board, 2010, p. 216)

Diesel Passenger Cars		
Model Year	**CH_4 Emission Factor**	**N_2O Emission Factor**
1960-1982	0.0012	0.0006
1983-1995	0.0010	0.0005
1996+	0.0010	0.0005
Totals		
Diesel Light Duty Trucks		
Model Year	**CH_4 Emission Factor**	**N_2O Emission Factor**
1960-1982	0.0017	0.0011
1983-1995	0.0014	0.0009
1996+	0.0015	0.0010
Totals		
Diesel Heavy Duty Vehicles		
Model Year	**CH_4 Emission Factor**	**N_2O Emission Factor**
All Years	0.0048	0.0051
Totals		
Compressed Natural Gas (CNG) vehicles		
Model Year	**CH_4 Emission Factor**	**N_2O Emission Factor**
All Years	0.175	2
Totals		

Vehicle Type	CO2 Factor (kg / unit)	CH4 Factor (g / unit)	N2O Factor (g / unit)
Passenger Car [A]	0.343	0.019	0.011
Light-Duty Truck [B]	0.472	0.019	0.018
Motorcycle	0.189	0.070	0.007
Intercity Rail (i.e. Amtrak) [C]	0.140	0.0087	0.0031
Commuter Rail [D]	0.161	0.0081	0.0032
Transit Rail (i.e. Subway, Tram) [E]	0.119	0.0025	0.0017
Bus	0.056	0.0013	0.0009
Air Travel - Short Haul (< 300 miles)	0.225	0.0039	0.0072
Air Travel - Medium Haul (>= 300 miles, < 2300 miles)	0.136	0.0006	0.0043
Air Travel - Long Haul (>= 2300 miles)	0.166	0.0006	0.0053

APPENDIX D: LIST OF EQUATIONS

Equation	No.	Section
$GHG\ emission = activiy\ data \times emission\ factor \times unit\ conversion$	(1)	Sec. 4.1.1.2
$CO_2e = CO_{2_{emissions}} + (CH_{4_{emissions}} \times 28) + (N_2O_{emissions} \times 265)$	(2)	Sec. 4.1.1.2
$\text{CH}_4 \text{ emitted } CO_2e\ (MT) = LFG_{collected} \times \%CH_4 \times \left\{(1-DE) + \left[\left(\frac{1-CE}{CE}\right) \times (1-OX)\right]\right\} \times unit\ conversion \times GWP$	(3)	Sec. 4.3.1.2
$CH_4\ Emissions = (\Sigma_i(\text{m}_i \times EF_{CH_{4_i}}) \times 10^{-3} - R)$	(4)	Sec. 4.3.2.2
$N_2O\ Emissions = (\Sigma_i(m_i \times EF_{N_2O_i}) \times 10^{-3})$	(5)	Sec. 4.3.2.2
$CO_2e\ (MT) = Digester\ Gas \times F_{CH_4} \times \rho(CH_4) \times (1-DE) \times 0.0283 \times 365.25 \times 10^{-6} \times GWP$	(6)	Sec. 4.3.2.2
$CO_2e\ (MT) = ((P_{total} \times F_{ind-com}) \times EF\ nit/denit \times 10^{-6}) \times GWP$	(7)	Sec. 4.3.2.2
$CO_2e\ (MT) = N\ load \times EF\ effluent \times 365.25 \times 10^{-3} \times \frac{44}{28} \times GWP$	(8)	Sec. 4.3.2.2
$CO_2e \text{ emissions}_{lands\ not\ converted} = land\ type_{ha} \times EF_{land\ remaining\ as\ land}$	(9)	Sec. 4.5.1.2
$CO_2e \text{ emissions}_{lands\ converted} = land\ type_{ha} \times EF_{land\ converted\ to\ land}$	(10)	Sec. 4.5.1.2
$Total\ wastewater\ CO_2e = stationary\ CH_{4\ incomplete\ combustion} + stationary\ CH_{4\ natural\ gas} + process\ N_2O_{nitrification/denitrification} + process\ N_2O_{effluent}$	(11)	Sec. 5.4.3.2
$Total\ CO_2\ emissions\ for\ mobile\ combustion\ (MT) = CO_{2_{diesel}} + CO_{2_{gasoline}} + CO_{2_{natural\ gas}} + CO_{2_{propane}}$	(12)	Sec. 5.6.1.2
$Total\ annual\ emissions = (inital\ inventory\ of\ R134A - final\ inventory\ of\ R134A + additions\ to\ inventory - sutractions\ from\ inventory - change\ to\ nameplate\ capacity) \div 1{,}000$	(13)	Sec. 5.6.2.2
$\text{CH}_4 \text{ emitted } CO_2e\ (MT) = LFG_{collected} \times \%CH_4 \times \left\{(1-DE) + \left[\left(\frac{1-CE}{CE}\right) \times (1-OX)\right]\right\} \times unit\ conversion \times GWP$	(14)	5.8.1.2

APPENDIX E: CONTACT INFORMATION

Name	Email	Documents Provided
Albin, Rhonda (City of Spokane)	ralbin@spokanecity.org	*Annual Report: Energy Recover/Incineration*
Beale, Perry (WSDA Natural Resources Assessment Section)	pbeale@agr.wa.gov	
Bisenius, Deborah (City of Spokane)	dbisenius@spokanecity.org	*2016 Biogas Usage.4.24.17*
Brannen, James (Union Pacific)	jlbrannen@UP.com	*UPRR 2017 Estimated Fuel Consumption in Washington*
Breen, Matt (Spokane International Airport) (Spokane Felts Field)	mbreen@spokaneairports.net	
Farthing, Nicole (Amtrak)	Nicole.Farthing@amtrack.com	
Lyons, Dr. John (Avista Utilities)	john.lyons@avistacorp.com	*City of Spokane 2016.KBooth.5.15.18*
Maruffo, Amanda (Burlington Northern Santa Fe Railway)	Amanda.maruffo@BNSF.com	*2017 Washington State Fuel Data*
Myers, Bill (GIS manager)	bmyers@spokanecity.org	
Otterstrom, Karl (Spokane Transit Authority)	kotterstrom@spokanetransit.com	
Philips, Charlie (Spokane Transit Authority)	cphillips@spokanetransit.com	
Stewart, Ryan (Spokane Regional Transportation Council)	rstewart@srtc.org	*2015 SRTC Model for VMT*
Swan, Ian (Inland Power and Light)	ians@inlandpower.com	
Vigeland, Kelle (City of Spokane)	kvigeland@spokanecity.com	*LFWST3521 2016 Flare Station YTD* *Southside Landfill Flare Station YEAR 2016* *GHG3220 2016 NSLF Equation HH-1-Closed* *GHG3220 2016 NSLF Equation HH-5-Closed* *GHG3220 2016 NSLF Equation HH-6 HH-7 HH8-Closed* *GHG3220 2016 NSLF Equation HH-1-Open* *GHG3220 2016 NSLF Equation HH-6 HH-7 HH-8-Open* *GHG3220 2016 NSLF Equation HH-5-Open* *GHG3220 2016 NSLF Equation HH-4*

APPENDIX F: STUDENT TESTIMONIALS

Wesley Davis (*Buildings and Other Facilities*, *Street Lighting and Traffic Signals*, *Water Delivery Facilities*, *and Power Generation Facilities* sectors in the Local Government Operations Inventory) – As someone who was born and raised in Spokane, I have seen the positive changes that have been made in our city over the past few decades. Spokane is now, more than ever, a modern and forward-thinking city much many of its Pacific Northwest neighbors. I was honored to be able to work with the City of Spokane on this greenhouse gas inventory. Working with the City helped foster my professional development while also allowing me to meet some of the wonderful people who drive Spokane's continued development. I was able to see first-hand, the support and passion many of our leaders have towards issues regarding sustainability. I hope that projects like these will continue into the future, promoting mutually beneficial University-community connections.

Chelsey Hand (*Stationary Energy* sector in the Community-Wide Inventory) – When dwelling upon the results of the latest Intergovernmental Panel on Climate Change Assessment Report (AR5) and the challenges we face as a result of anthropogenic climate change, I feel a sense of obligation to use my time and efforts to play a role in addressing it. Therefore, the most fulfilling part of working on this project was understanding how my individual actions taken during the course of this project (e.g., collaborating with different partners, gathering detailed activity data, and using the latest methods for calculating greenhouse gas emissions) could ultimately be used to guide social and political measures aimed at addressing greenhouse gas emissions mitigation efforts. I am grateful for the opportunity to have worked on this project and hope that the time (and often painstaking effort) that we put into this project will be used in the future to reduce Spokane's GHG emissions and allow the City to do its part in addressing the global challenge of climate change.

Jena Jadallah (*Wastewater Facilities and Solid Waste Facilities* sectors in the Local Government Operations Inventory) – This project has been filled with rewarding experiences that allowed me to grow as a student and gain valuable professional development. The topic of climate change seemed so distant, however, through working on this greenhouse gas emissions inventory, I have recognized the possibility of solutions and partnership first-hand. I never realized the amount of detailed and diligent work it would take to gather the necessary data from the many reports provided for the calculations. While we had copious amounts of data, completing the details took time, but it was all worth it for the citizens of Spokane! It was worthwhile to use the protocols that are consistent across most cities, and I look forward to using the skills I gained from this project in many situations in my career. Not only did I learn how to complete an inventory, as a team, we were able to maintain a professional standard whether in an academic setting or presenting results to government officials. As my time at Gonzaga

University is ending, I am so thankful that I was able to be exposed to, and provide for, the greater Spokane community as well as make efforts to combat climate change.

Austin Kaesemeyer (*Transportation* sector in the Community-Wide Inventory) – Working on this greenhouse gas emissions inventory as part of my senior capstone project has been a tremendously rewarding experience. This project not only improved my professionalism, it also helped strengthen the technical writing and communication skills that have been essential to my coursework at Gonzaga. As a life-long resident of Spokane, I was able to get a glimpse of the unique relationship between the local government and my fellow residents in the Spokane Community. This inventory will not only help government officials develop policies that will combat climate change, but it also provides the citizens of Spokane with a transparent resource that will help them identify the impact that their actions may have on the environment. While science and technology are constantly improving, it is the actions of the citizens that will drive the force behind emissions reduction.

Dawson Matthews (*IPPU* and *AFOLU* sector in the Community-Wide Inventory) – The problems we face today as a global community are more complex than ever before. They require creative solutions and collective action – not individualistic decisions. For some, climate change and sustainability efforts are about the everyday decisions, like whether to compost or buy a new hybrid car instead of continuing to drive their old gas guzzler (Maniates, 2002). But for many others, climate change is a harsh reality: it is a force that displaces them from their homeland and robs them of their most basic human necessities; every day (Marshall, 2016). Some countries and communities have played a larger role in climate change than others, yet we *all* must work together to address the issues we have created. Significant change will only occur when we all realize that we are all connected to this issue—that we are all part of the problem, but also part of the solution. This project allowed me to expand the technical GIS skills I learned through my university studies to a pressing community issue. The privilege I was granted working on a project that has the potential to change institutional policy and strengthen the Spokane community gave me a great sense of belonging as student and as a community member.

Marshall, Nicole. (2016) Forced Environmental Migration: Ethical Considerations for Emerging Migration Policy. *Ethics, Policy & Environment* 19:1, pages 1-18.

Maniates, Michael. (2002) Individualization: Plant a Tree, Buy a Bike, Save the World? P. 43-66 in Thomas Princen, Michael Maniates and Ken Conca (eds.), *Confronting Consumption*. Cambridge, MA: The MIT Press.

Luke Schumm (*Vehicle Fleet* sector in the Local Government Operations Inventory) – This project was very rewarding in many ways, I enjoyed gaining personal experience in this field, bonding with my team members, and the satisfaction from overcoming challenges. Perhaps the most rewarding aspect has been seeing the appreciation of our work from the client and members of the City. It really makes our time and efforts feel valuable. It has been interesting putting my knowledge of greenhouse gases and city emissions to use and seeing firsthand how they are applied at the local government level. The experience I have gained working in this professional setting, and with local government operations, has been very beneficial to my academic experience. The most surprising aspect of the project was realizing the amount of time and attention to detail needed to complete an inventory like this. While the bulk of the data was be readily available, it required more investigation and diligent work to fill in the final areas that were not easy to access, all while maintaining a high standard of work. Overall, I very much enjoyed working on this project, and I look forward to applying these new skills to work in the future!

Freddie Winter (*Waste* sector in the Community-Wide Inventory) **–** This project allowed me to expand my professional skills, as well as my perspective on climate change. The most gratifying part of our work was being able to apply this international protocol to Spokane, creating a professional document, and presenting this report to the local government officials. Being able to see the report I helped generate influence the city I have lived in for the past four years was very fulfilling. This project also helped me better understand the inner workings of a city and the impact residents have on the environment. Climate change is an increasingly urgent issue, and quantifying the anthropogenic effect is the first step to creating a sustainable city. Through my work on this project, I was surprised to learn how the actions of a single person can impact the larger community. Making a change requires the cooperation of all residents working toward a common goal for a sustainable future. This endeavor allowed me to practice my professional skills through meeting with City employees and presenting my findings, as well as applying the technical research and writings skills in a document meant to help the larger community that I have become a part of during my time at Gonzaga.