City of Leduc's 2015 Greenhouse Gas Inventory

Corporate and Community

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Table of Contents

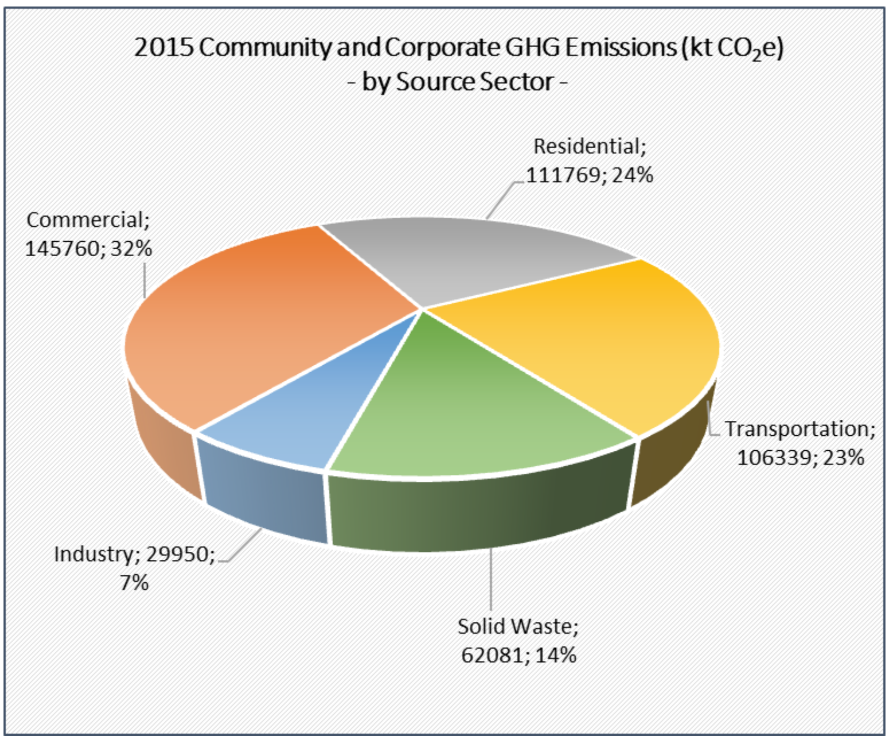
Executive Summary

The City of Leduc meets the first step in its commitment to the Federation of Canadian Municipalities Partners for Climate Protection Program Milestone 1 through this corporate and community GHG inventory and forecast.

1.1 Community and Corporate GHG Emissions

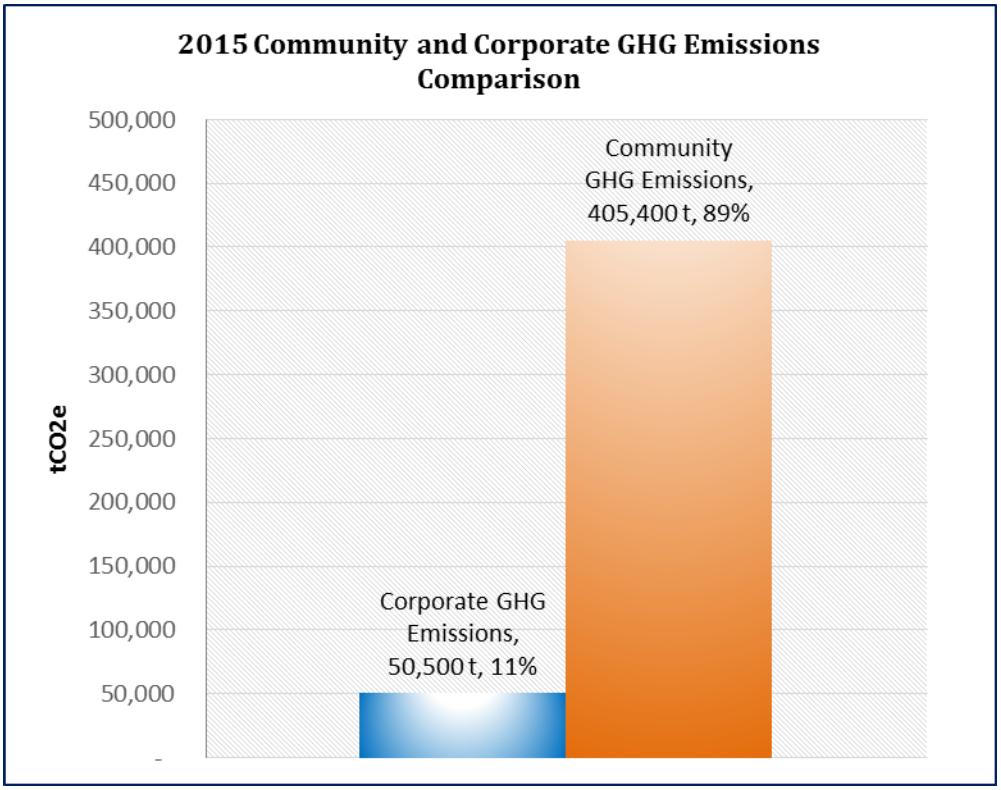
The City of Leduc emitted approximately **0.46 megatonnes** (Mt) of GHG emissions in 2015. Corporate GHG emissions represent 11 per cent of the total, whereas community GHG emissions constitute 89 per cent (see Exhibit 7). The majority of GHG emissions are from the commercial and institutional sector (32 per cent), followed by: residential (24 per cent), transportation (23 per cent), solid waste (14 per cent), and industrial (seven per cent).[1]

Exhibit 1 Community and Corporate GHG Emissions, by Source Sector



[1] For the purposes of this figure, streetlight and water & wastewater GHGs were divided into the residential and commercial sectors according to their relative contributions in the community inventory. Corporate buildings GHG emissions were added to the commercial sector.

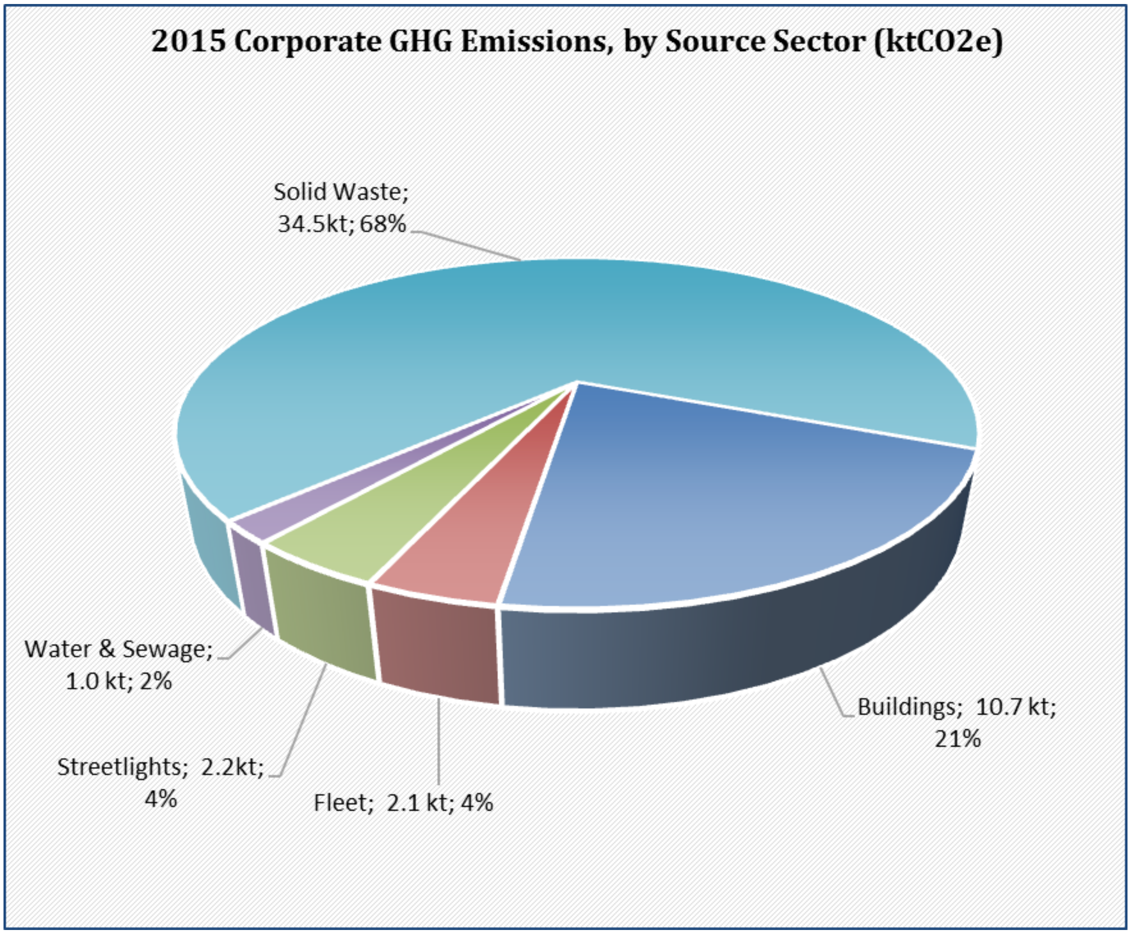
Exhibit 2 2015 Community and Corporate GHG Emissions Comparison



1.2 Corporate GHG Emissions

Total corporate GHG emissions for the City of Leduc's corporate inventory were **50,500 t CO_2e**. The majority of GHG emissions, 68 per cent, are generated by solid waste. Buildings contribute a significant amount, 21 per cent, to the total corporate GHG emissions. Streetlights and fleet each contributed 4 per cent to the total corporate GHG emissions. Finally, water and sewage represented only two per cent of Leduc's corporate GHG emissions.

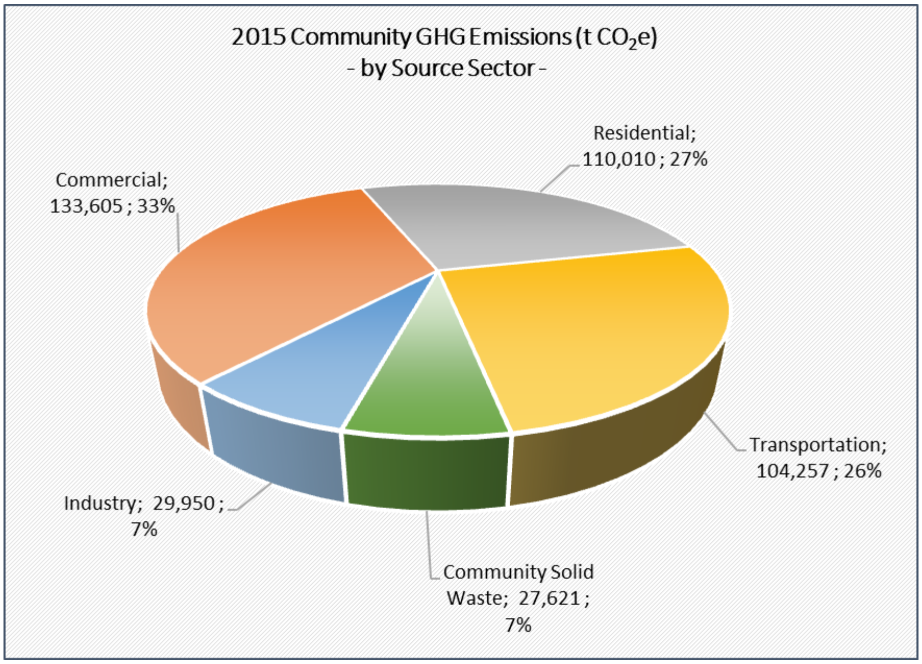
Exhibit 3 2015 Corporate GHG Emissions, by Source Sector



1.3 Community GHG Emissions

Total community GHG emissions in the City of Leduc in 2015 were approximately **405,400 t CO2e**. Just over one-third of total GHG emissions are sourced from energy consumption by commercial buildings (33 per cent, in Exhibit 4). Energy use by residential dwellings and transportation represent the next largest sources of total GHG emissions, accounting for 27 per cent and 26 per cent of the total, respectively.

Exhibit 4: 2015 Total Community GHG Emissions, by Source Sector



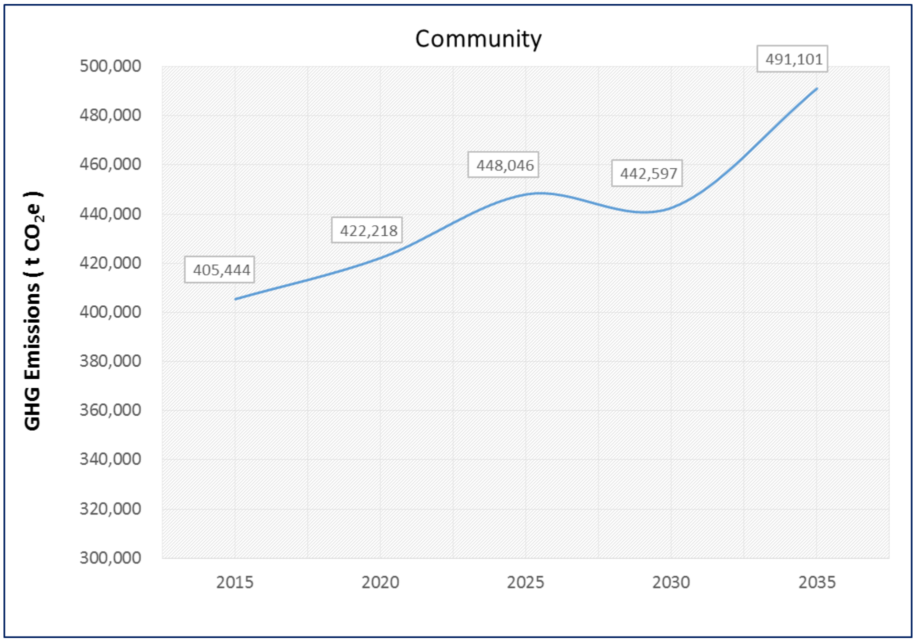
1.4 Community and Corporate GHG Emissions Forecast

By 2035, total community emissions are projected to rise to **491,101 t CO_2e**; equivalent to an annual average compound growth rate of +0.9 per cent (see Exhibit 5 below).

Between 2015 and 2035 the population of the City of Leduc is projected to increase from about 29,300 to 49,120. That is equivalent to an annual average compound growth rate of +2.6 per cent. However, over the same period total community energy consumption is projected to grow by an average of +2.2 per cent per annum. Hence, total community energy use is projected to grow at a slower rate than the population - somewhat decoupling from growth in energy use. This decoupling is partly the result of reductions in the GHG intensity of the provincial electricity grid.

Our assumption is corporate emissions will increase at the same rate as community emissions at a moderate rate of 0.9 per cent. Based on this assumption, business-as-usual corporate emissions will grow to over **60 ktCO2e** by 2035.

Exhibit 5: Projected Community GHG Emissions: 2015-2035



2 Introduction

2.1 Federation of Canadian Municipalities Partners for Climate Protection Program

The City of Leduc joined the PCP Program through a resolution carried unanimously on June 13, 2016. As a first step to meeting their commitment, the City of Leduc has met Milestone 1 by completing this corporate and community GHG inventory and forecast. The related Corporate and Community GHG Inventory adheres to the PCP Protocol (Canadian Supplement to the International Emissions Analysis Protocol, *Federation of Canadian Municipalities & ICLEI*).

The Partners for Climate Protection (PCP) program supports a network of Canadian municipal governments committed to reducing GHGs. PCP membership covers all provinces and territories and accounts for more than 65 per cent of the Canadian population. The program empowers municipalities to take action against climate change through a five-milestone process that guides members in:

- Milestone 1: creating a corporate and community GHG inventory;
- Milestone 2: setting realistic and achievable GHG reduction targets;
- Milestone 3: developing a local action plan to meet the GHG reduction target(s);
- Milestone 4: implementing plans using specific, measurable actions to reduce emissions; and
- Milestone 5: monitoring their results.

To date, approximately 202 municipalities have completed a GHG inventory under the PCP program.

2.2 Inventory Significance

Corporate and community inventories are important precursors to developing a municipal GHG reduction plan. A GHG inventory reveals which sectors and/or operations use the most energy and emit the most GHG emissions indicating where to focus GHG reduction efforts. An inventory helps municipalities track where dollars are spent on energy and carbon potentially revealing cost savings opportunities through energy conservation and efficiency efforts. By providing a reference point, the inventory can also enable energy and emissions tracking over time. It provides the necessary baseline data to which future inventories will be compared and progress measured when monitoring the effectiveness of a GHG reduction plan. Finally, an energy and GHG inventory can enable a municipality to access provincial and federal funds by demonstrating commitment to planning for GHG reduction efforts. **You can't manage what you don't measure.**

2.3 Municipalities Addressing Climate Change

There is scientific consensus that it is extremely likely (95 per cent probability or higher) that humans are causing the climate to change (Stocker, 2013). The City of Leduc has and will continue to be impacted by this changing climate: the mean annual temperature at Leduc over the last 30 years has been about +2.7°C and future projections for the Leduc region are for a further increase in mean annual temperature of 2.0°C by the 2050s (Boyd, 2014). Municipalities have an important role to play in reducing their contribution to global GHG emissions to reduce the effects of future climatic changes.

In 2009, FCM estimated that municipal governments have direct or indirect control over approximately 44 per cent of Canada's GHG emissions (EnviroEconomics, 2009). With this level of influence, municipal action is important to cost effectively reducing global GHG emissions. Municipal climate mitigation actions can benefit communities in multiple ways:

- Improving the quality of life for residents (e.g. increased transit results in greater mobility for seniors and low income residents);
- Saving communities money (e.g. more efficient municipal buildings reduce utility costs);
- Increasing community resilience to potential future regulations (e.g. shielding municipalities and citizens from increases in the carbon levy); and
- Fostering a strong sense of community pride (e.g. the community spirit generated by the City of Leduc's rooftop solar projects).

2.4 Inventory Guidance

As required by the PCP program, this inventory adheres to:

- PCP Protocol: Canadian Supplement to the International Emissions Analysis Protocol, *Federation of Canadian Municipalities & ICLEI*

This inventory has also used the following protocol as guidance:

- Global Protocol for Community-Scale Greenhouse Gas Emission Inventories, *ICLEI – Local Governments for Sustainability, World Resources Institute, & C40 Cities Climate Leadership Group*

2.4.1 Definitions

The GHG protocols used for this inventory identify three types of GHG emissions for inventory inclusion:

- Scope 1 emissions – GHG emissions from sources within the municipal boundary;
- Scope 2 emissions – GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, etc. within the municipal boundary; and
- Scope 3 emissions – All other GHG emissions that occur outside the municipal boundary as a result of activities taking place within the boundary.

3 Methodology

3.1 Leduc Inventory Parameters

The City of Leduc's GHG inventory is a precursor to its GHG reduction plan. The primary goal is to identify sectors generating significant GHG emissions and/or those increasing over time.

Leduc's GHG inventory uses its municipal boundary as its physical geographic boundary. The base year for the inventory is 2015 due to concerns for data availability in 2016. Emissions sources are determined by the PCP Protocol requirements. Anthropogenic greenhouse gases emissions included in the inventory include: CO_2, N_2O, and CH_4. Fluorinated organic emissions are excluded, because only a few very specific industries emit those GHGs in significant quantities.

In order to capture GHG emissions from all municipal assets and services, and meet the requirements of the PCP protocol, the corporate inventory includes the following sectors: buildings, fleet vehicles, street lights and traffic signals, water and wastewater, and solid waste.

In order to quantify all GHG emissions generating activities from the municipality, Leduc's community inventory includes the following sectors: residential, commercial, and industrial buildings; on-road transportation; water and wastewater; and community solid waste. Some community inventories include community wastewater and water, agriculture, industrial processes, and fugitive emissions although these are not included in Leduc's inventory. The inclusion of these sectors is currently considered optional by the PCP protocol.

3.2 Tools

The PCP Milestone Tool is a web-based GHG emissions inventory calculator. It was developed by ICLEI Canada as a resource to support FCM's PCP members in their GHG emissions reduction activities. This tool was used calculate Leduc's corporate inventory. The PCP tool uses emissions factors from Environment Canada's National Inventory report.

All One Sky's Community Inventory and Economic Analysis Tool (CI-EAT), developed by Dr. Richard Boyd, was used to generate Leduc's community GHG inventory. CI-EAT's 2015 emissions factors and energy conversion factors were adjusted to match those provided by the PCP tool.

3.3 Milestone 1 Requirements

This report meets PCP Milestone 1 requirements by outlining the corporate and community GHG inventory and forecast as well as a summary of related assumptions and data sources. This report was also generated to help ensure the City of Leduc can reproduce this inventory in future years.

In order to meet additional Milestone 1 requirements, Leduc's inventory is:

- Accurate and will inform all subsequent PCP milestones;
- Consistent and reproducible;

- Cost-efficient (did not consume staff or consultant time in an unbalanced fashion); and
- Verifiable.

The inventory uses real consumption data for the corporate inventory and, whenever possible, for the community inventory. In the absence of consumption data, the next best available data is considered activity estimates. Finally, modeled estimates are used as a final recourse.

4 Community and Corporate GHG Inventory Summary

The City of Leduc emitted approximately **0.46 megatonnes** (Mt) of GHG emissions in 2015. Corporate GHG emissions represent 11 per cent of the total, whereas community GHG emissions constitute 89 per cent. The majority of emissions are from the commercial and institutional sector (32 per cent), followed by: residential (24 per cent), transportation (23 per cent), solid waste (14 per cent), industrial (seven per cent). [2]

Exhibit 6 Community and Corporate GHG Emissions (ktCO2e), by Source Sector

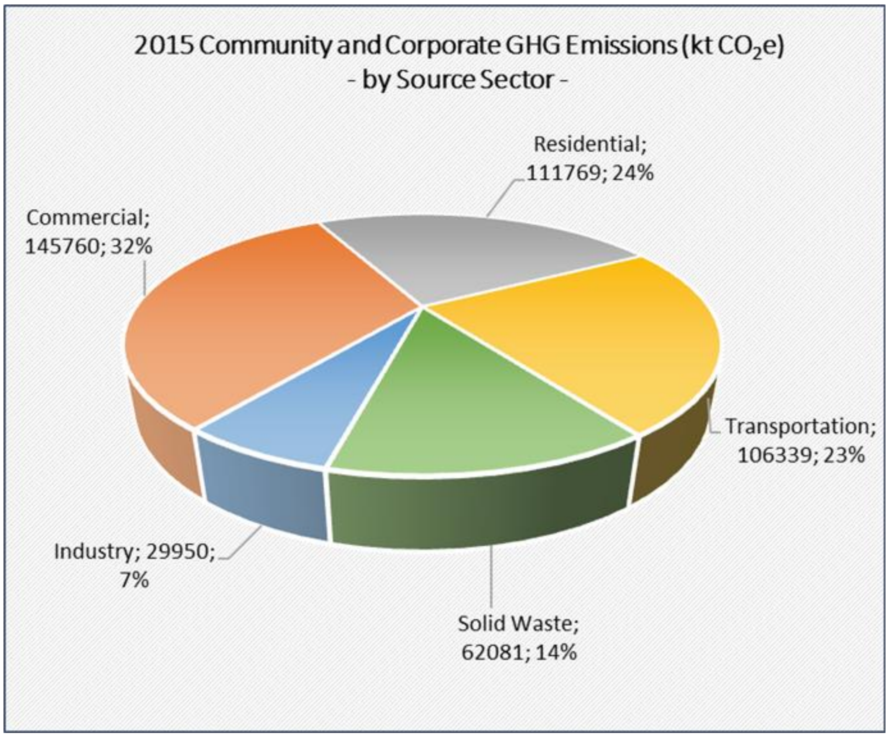


Exhibit 7 Summary of Corporate and Community GHG Emissions (tCO_2e), %

Corporate GHG Emissions	**50,500**	**11%**
Community GHG Emissions	405,400	89%
Total GHG Emissions	455,900	

[2] For the purposes of this figure, streetlight and water & wastewater GHGs were divided into the residential and commercial sectors according to their relative contributions in the community inventory. Corporate buildings GHG emissions were added to the commercial sector.

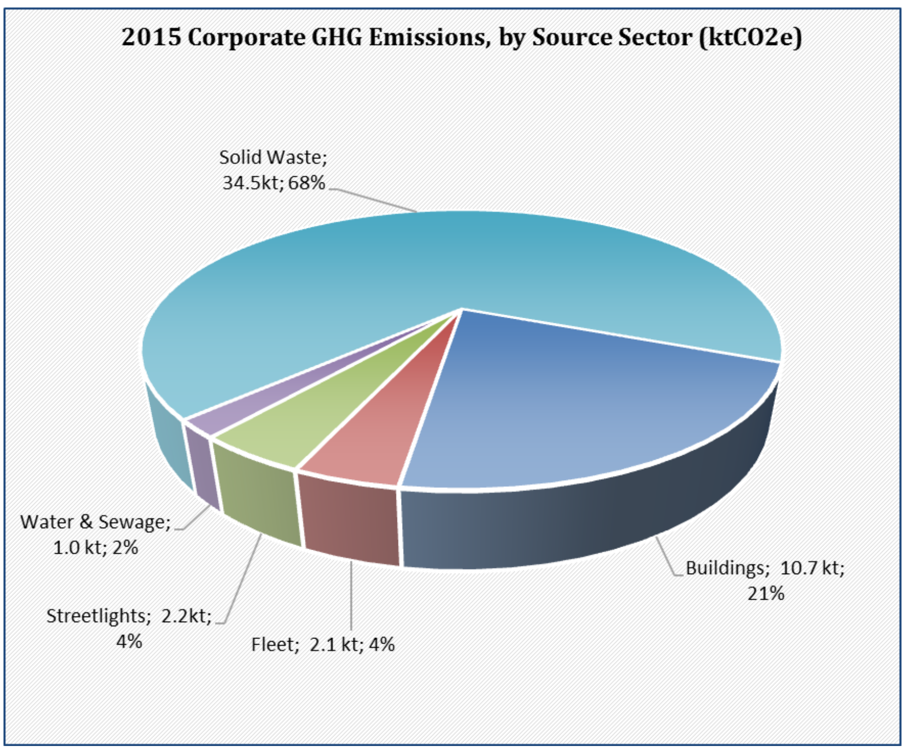
5 Corporate GHG Inventory

Total corporate GHG emissions for the City of Leduc's corporate inventory were **50,500 t CO_2e**. The large majority of emissions, 68 per cent, are generated by solid waste (see Exhibit 8 below). Buildings contribute a significant amount, 21 per cent of the total corporate emissions. Streetlights and Fleet each contributed 4 per cent to the total corporate emissions. Finally, water and sewage represent only one per cent of Leduc's corporate emissions. See Exhibit 38 and Exhibit 39 in the Appendix for tables with numeric details.

Solid waste contributes a significant amount to corporate emissions for two reasons:

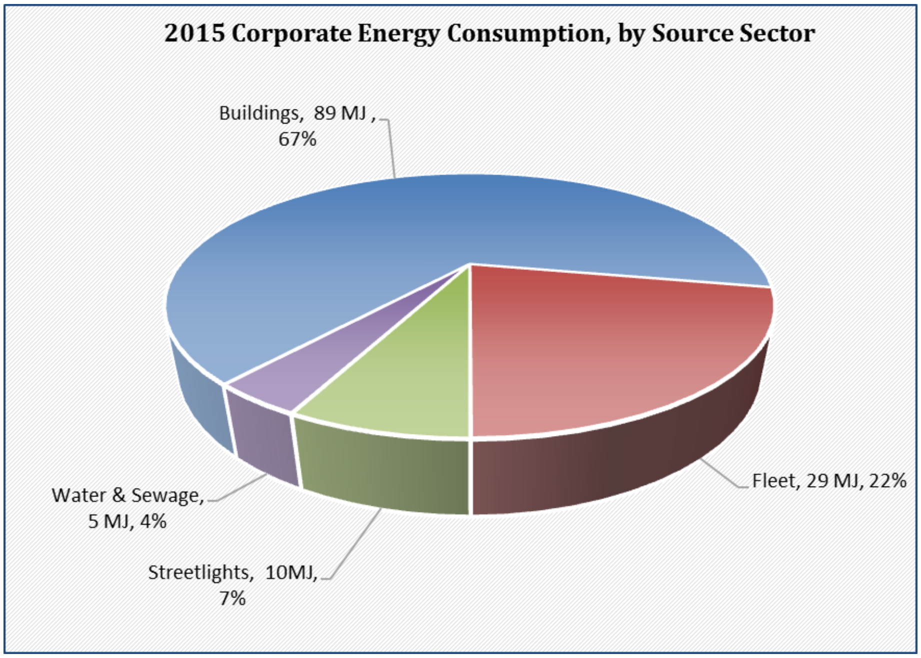
1) The City of Leduc's management contribution to the Leduc and District Regional Waste Management Authority requires that all direct emissions from the landfill be attributed to their corporate inventory given the City has direct operational control over how these emissions are managed; and
2) Solid waste emissions were calculated using the methane commitment method which overestimates actual GHG emissions released in 2015. See Section 5.5 for further details.

Exhibit 8 2015 Corporate GHG Emissions ($ktCO_2e$), by Source Sector



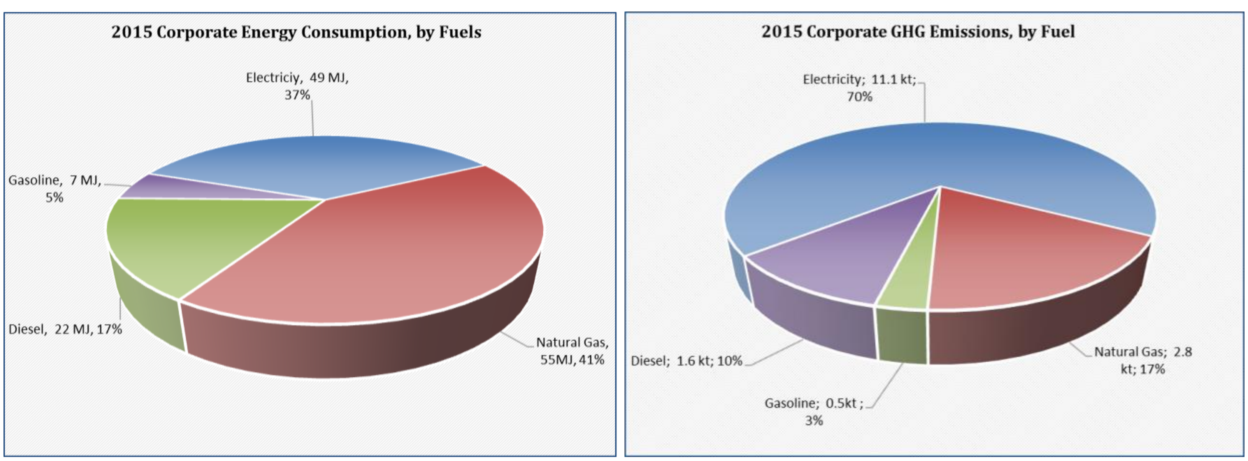
The building sector is the greatest contributor to Leduc's corporate energy consumption (see Exhibit 10 below) - consuming 67% of the total corporate energy in 2015. Subsequently, the next greatest corporate energy consumers are fleet (22 per cent), streetlights (seven per cent), and water & sewage (four per cent), respectively.

Exhibit 9 2015 Corporate Energy Consumption, by Source Sector



Comparing corporate GHG emissions by fuel and energy consumption by fuel highlights the impact of Alberta's relatively high grid intensity factor (see Exhibit 10 below). Electricity consumption represents only 37 per cent of Leduc's total corporate energy consumption, in 2015, but contributes to 70 per cent of the GHG emissions.

Exhibit 10 Comparison of 2015 Corporate GHG Emissions and Energy Consumption, by Fuel



5.1 Buildings

The buildings sector includes energy use in all Leduc's buildings and facilities owned and/or operated by the City, including those leased to a person or another legal entity (e.g. not for profit organizations, social housing, etc.).

5.1.1 Leduc Context

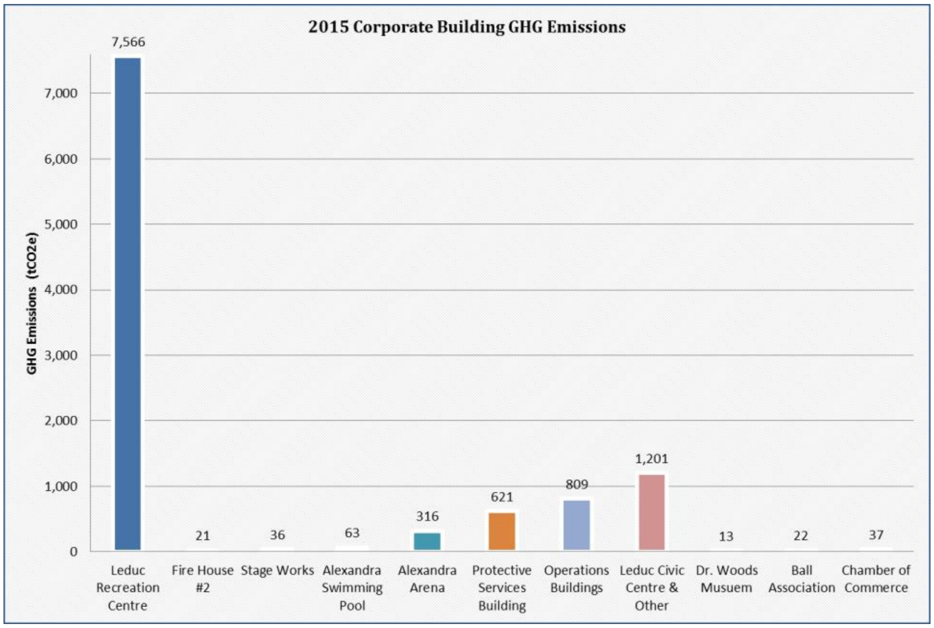
The City of Leduc has approximately 11 significant buildings/facilities[3]. Another three buildings (LA Crude, Lions Campground, and Leduc Drama) are located on City land but are not owned or operated by the City. Six additional buildings are on City land and leased to not-for-profit organizations - Chamber of Commerce, Ball Association, Dr. Woods Museum, Telford House, Kinsmen Hall, and Boy Scout Hall. Data was not available for the latter three of these buildings. We have estimated that these buildings would add approximately 100 tonnes to the corporate building GHG emissions which represents less than 1% of the GHG contribution to corporate buildings.

5.1.2 GHG Emissions

In 2015, buildings and facilities emitted **10,705 tonnes of CO_2e** emissions which represents 20% of total corporate emissions or 67% of corporate energy related emissions. Of all corporate buildings, the Leduc Recreation Centre consumes the most energy and generates the most GHG emissions. At almost 29,000 m^2, this facility is about fives times as large as the next largest building (Leduc Civic Centre).

[3] Operations buildings include approximately three major buildings as well as some small out-buildings.

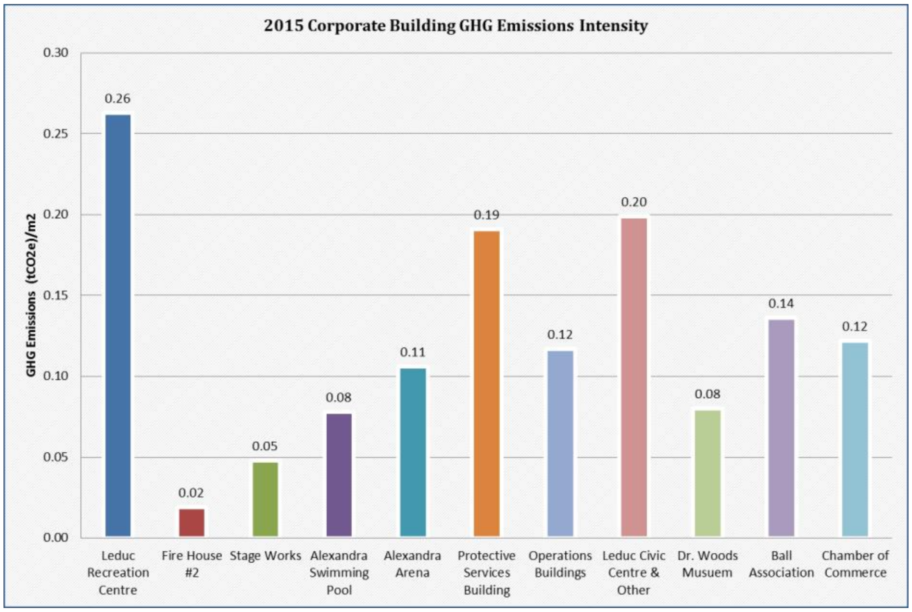
Exhibit 11 2015 GHG Emissions per Corporate Building



Adjusting for size, the GHG emissions per square meter better highlights buildings with more GHG intensive activities and/or less efficient building (see Exhibit 12). The GHG intensity of some of the buildings is also affected by:

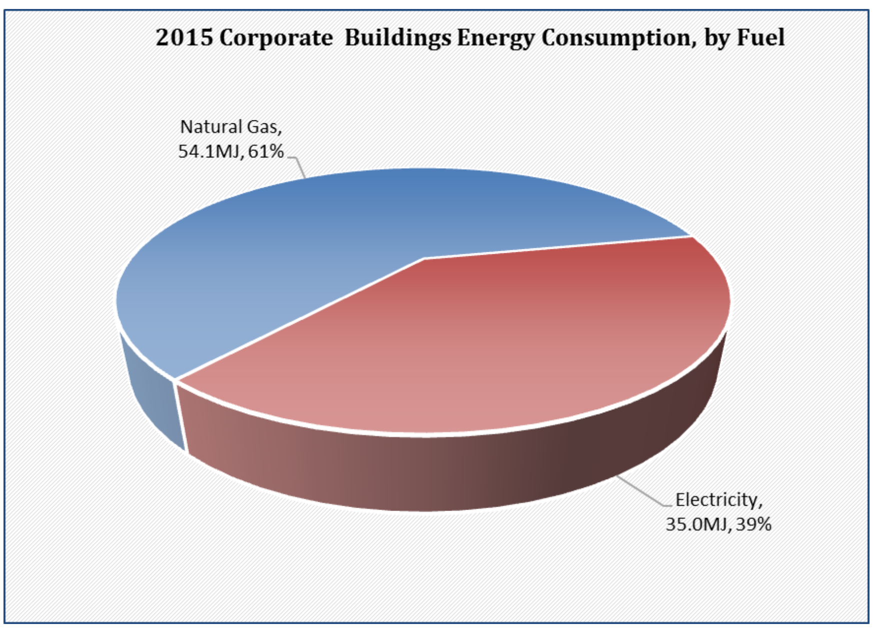
- Leduc Recreation Centre hosts GHG intensive activities including a pool and arena;
- Due to metering arrangements, the Leduc Civic Centre includes the energy use of Alexandra Arena's ice plant services and the Leduc Library;
- Protective Services Building hosts several loading bays and the Handy bus electrical service; and
- Alexandra Swimming Pool is an outdoor pool but the indoor facility is heated year round.

Exhibit 12 2015 GHG Emissions Intensity per Square Meter per Corporate Building



The majority of energy, 61 per cent, used by Leduc's buildings is natural gas (see Exhibit 13 below). Electricity is the only other fuel used in their buildings (39 percent of energy use). See Exhibit 40 in the Appendix for a table with numerical details.

Exhibit 13 2015 Corporate Buildings Energy Consumption, by Fuel



5.1.3 Data sources

- Enmax electricity records inputted into Asset Planner

- Gas Alberta natural gas records inputted into Asset Planner
- Enmax customer lease excel spreadsheet of photovoltaic systems
- Queries sent to: the Ball Association, Chamber of Commerce, Dr. Woods Museum, Telford House, Kinsmen Hall and Boy Scout Hall.

5.2 Fleet

The corporate fleet sector includes GHG emissions from the use of motor fuels in corporate vehicles and equipment. We have divided the sector into: off-road equipment, light duty automobiles, light duty trucks, staff's use of personal vehicles for municipal purposes, heavy duty vehicles, organics waste disposal trucks, recycling waste disposal trucks, solid waste disposal trucks, transit buses, and Leduc Assisted Transit Service (LATS).

5.2.1 Leduc Context

In 2015, Leduc's corporate fleet totaled 165 vehicles and pieces of equipment (see Exhibit 41 in the Appendix for a table outlining corporate fleet numbers). Leduc has seven light duty automobiles, 63 light duty trucks, 11 heavy duty vehicles, and 50 off-road equipment units (e.g. mowers, snowblowers, loaders, tractors, graders, backhoes etc.). Leduc Transit is a service that links the City of Leduc, the County of Leduc, Nisku, the Edmonton International Airport and the City of Edmonton. It has six short and nine full size buses. Leduc fire and ambulance emergency services have five light duty trucks, 6 heavy duty trucks, and two off-road vehicles. Leduc's solid waste collection is contracted out to Green for Life. A total of six trucks are used for recycling, organic waste collection, and garbage collection.

Within Leduc's fleet, roughly 25 per cent of the heavy duty fuel use, and roughly 35 per cent of the off-road equipment is to meet winter snow removal requirements. In addition, for heavy snowfall years, Leduc contracts out as 50 per cent or more of their snow removal services. For 2015, a light snowfall year, roughly only 5 per cent of snow removal services are contracted out and therefore are missing from the corporate inventory.

5.2.2 GHG Emissions

In 2015, Leduc's corporate fleet emitted **2082 tonnes of CO_2e** (see Exhibit 41 in Appendix below). The top five emitters in the fleet include:

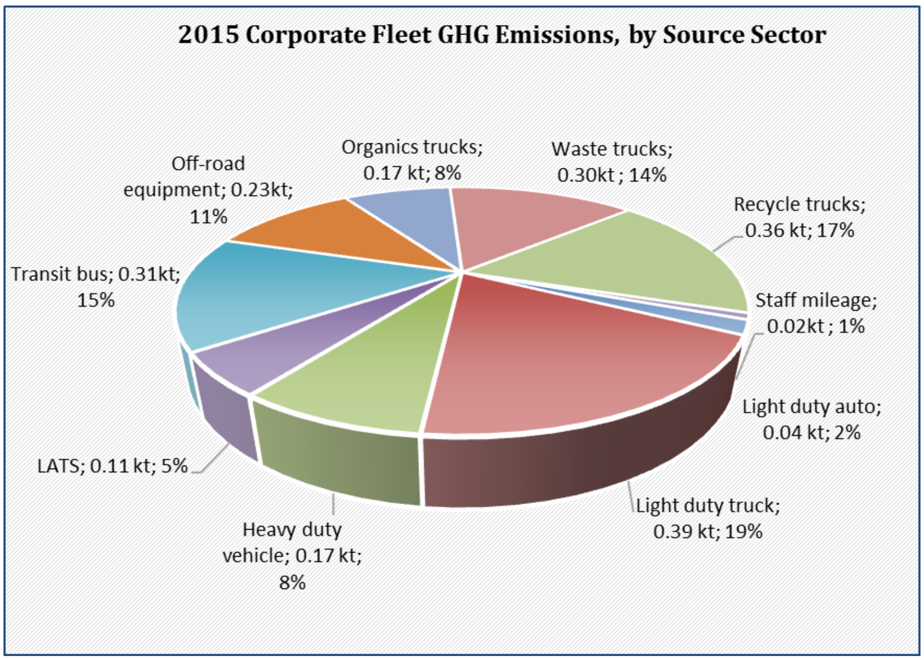
1) Light duty trucks (19 per cent),
2) Recycling waste disposal trucks (17 per cent),
3) Transit buses (15 per cent),
4) Waste trucks (14 per cent), and

Off-road equipment (11 per cent) (see

5) Exhibit 14 below).

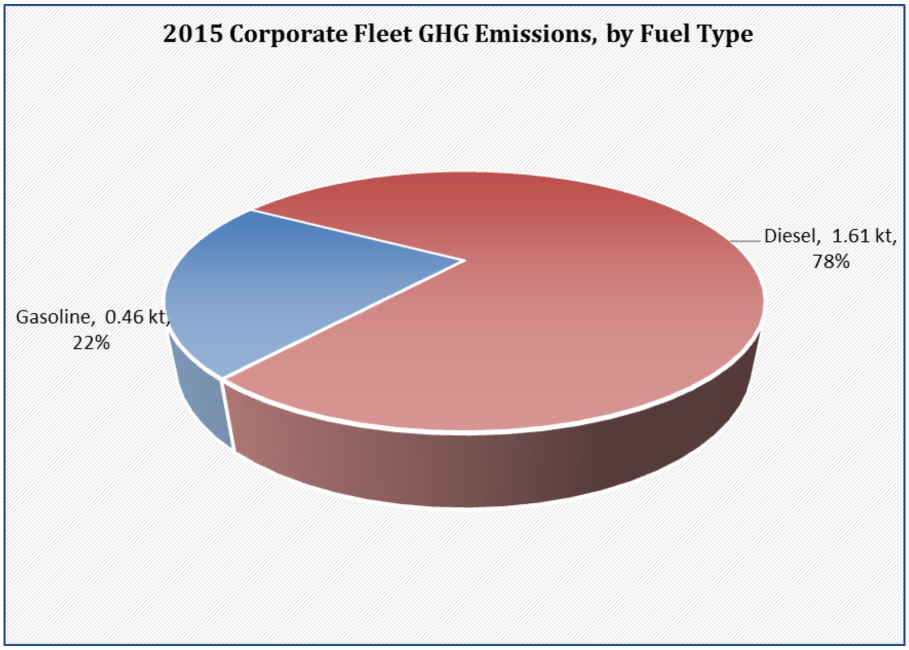
The remaining contributions were made by heavy duty vehicles (eight per cent), organics waste disposal trucks (eight per cent), Leduc Assisted Transit Service (LATS) (eight per cent), light duty automobiles (two per cent), and staff use of personal vehicles (one per cent).[4] The vast majority of fleet GHG emissions were generated by diesel fuel, 78 per cent, and the remaining produced by gasoline. See Exhibit 41 in the Appendix for further details.

Exhibit 14 2015 Corporate Fleet GHG Emissions, by Source Sector



[4] It was not possible to obtain energy consumption data on contracted snow removal. 2015 had minimal snow fall therefore approximately 95 percent of snow removal was completed by the City of Leduc. It is estimated that 25% of the heavy duty fleet emissions and 36% of the off-road diesel fleet emissions come from snow removal or collectively a total of 124 tonnes of CO_2e. Assuming this figure represents 95% of the snow removal, the inventory is lacking approximate 6 tonnes of CO_2e. In other years, missing snow removal data could represent up to 62 tonnes of CO_2e or only .01 per cent of the inventory.

Exhibit 15 2015 Corporate Fleet GHG Emissions, by Fuel Type



5.2.3 Data sources

- Fleet fuel expenditure, and staff expensed mileage records;
- Queries sent to: Green for Life waste management services; and
- Statistics Canada. Table 326-0009 - Average retail prices for gasoline and fuel oil, by urban centre, monthly (cents per litre).

5.3 Street Lights and Traffic Signals

GHG emissions from outdoor public lighting are included in this inventory sector including: streetlights, park lighting, traffic signals, and other outdoor lighting. Outdoor lighting that is attached to a building and incorporated into the building's energy bill will be included in the buildings category.

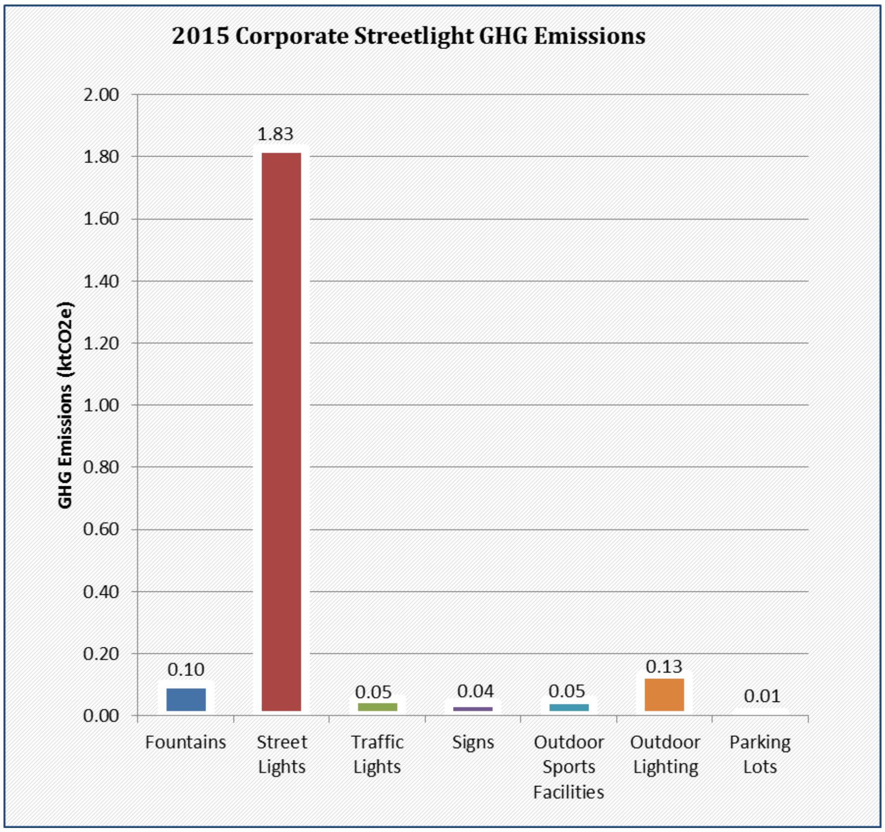
5.3.1 Leduc Context

Leduc has approximately 3000 streetlights, as well as traffic signals, water fountains, and other outdoor lighting. Each streetlight on average uses 751 kWh per year. In 2015, Leduc had already began to convert to LED streetlights (upon replacement).

5.3.2 GHG Emissions

In 2015, streetlights and other outdoor lighting emitted **2215 tonnes CO_2e** and contributed four per cent of Leduc's total corporate GHG emissions. The vast majority of energy consumed and GHGs emitted in this sector are from streetlights (see Exhibit 16 below). See Exhibit 42 in the Appendix for further details.

Exhibit 16 2015 Corporate Streetlight GHG Emissions



5.3.3 Data sources

- Enmax electricity records

5.4 Waste and Wastewater Infrastructure

This component of the corporate inventory includes GHG emissions generated by municipal water and wastewater infrastructure, such as lift and pumping stations, reservoirs and storage tanks, and treatment facilities.

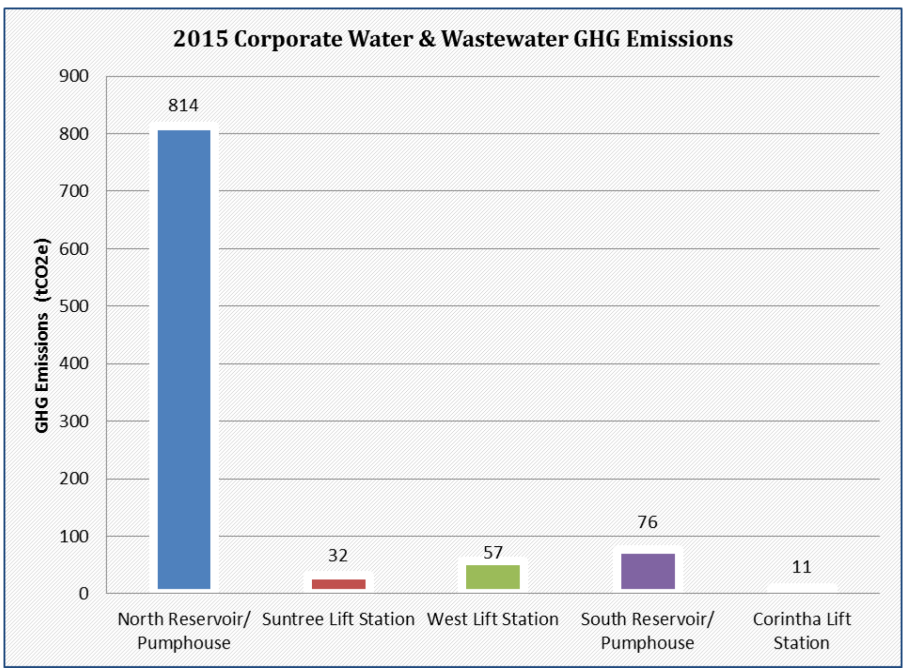
5.4.1 Leduc Context

City of Leduc purchases our water and waste water treatment through the Capital Region Southwest Water Services Commission. City water comes from the E.L Smith and Rossdale water treatment plants in Edmonton and Leduc's wastewater is sent to the Goldbar treatment plant in Edmonton. Given these facilities are owned and operated by a body other than the City of Leduc, the related emissions may be excluded from the corporate GHG inventory given the City of Leduc is not responsible for its management. We have included emissions from reservoirs/pumphouses, and lift stations as the City owns and operates this infrastructure.

5.4.2 GHG Emissions

In 2015, waste and wastewater infrastructure emitted **992 tonnes of CO_2e** emissions and represents two percent of Leduc's corporate GHG inventory. See Exhibit 43 in the Appendix for further details.

Exhibit 17 2015 Corporate Water & Sewage GHG Emissions



5.4.3 Data sources

- Epcor Water Distribution and Transmission data

5.5 Solid Waste

GHG emissions from solid waste disposed in a landfill are generated is by the anaerobic (an absence of oxygen) decomposition of organic waste. Significant amounts of methane are generated at landfills contributing about four percent of global and Canadian anthropogenic (human caused) GHG emissions (Environment Canada, 2016; Contribution of Working Group III to the Fifth Assessment (Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Minx), 2014).

In order to calculate GHG emissions from solid waste, we used the methane commitment model as outlined in ICLEI's Global Protocol for Community-Scale Greenhouse Gas Emission Inventories and IPCC sources (Intergovernmental Panel on Climate Change, 1996; Intergovernmental Panel on Climate Change, 2000). The model has the following disadvantages:

- Quantifies current and future emissions for the solid waste disposed in the inventory year and treats emissions from current and future years as equal. This approach is inconsistent with other GHG emissions outlined in the inventory, overestimates the emission reduction potential of avoided landfill disposal of solid waste, and does not provide greater value to current versus future emission reductions (ie does not discount GHG emissions); and
- Does not count current emissions from historic waste in landfills, thus does not allow quantification of emission reduction potential of these emissions.

We also applied the equation within ICLEI's GHG protocol based on IPCC's 2006 Guidelines for National Greenhouse Gas Inventories to quantify the emissions associated with biological treatment of solid waste (ie composting). Assumptions on the breakdown of organic waste is based on a 2014 waste characterization study completed on the Leduc and District Regional Waste Management (LDRWM) Facility (TRI Environmental Consulting, 2014) and the breakdown between residential and industrial/commercial waste are based on figures from the LDRWM Authority.

5.5.1 Leduc Context

Leduc residential solid waste and half of commercial/industrial is transported to the LDRWM Facility. In operation since June 27, 1978, its member municipalities include: Beaumont, Calmar, City of Leduc, Leduc County and Devon.

The FCM GHG protocol requires local government to estimate the direct GHG emissions generated from all waste disposed at a landfill, if the local government owns or operations the facility. In this sense, the protocol requires the local government to report 100 per cent of the emissions from operations over which it has control. GHG emission from solid waste in Leduc are considered scope three emissions as the waste is treated at a facility outside of the city boundary but the operation is administered by the City of Leduc on behalf of the LDRWM authority. While the City of Leduc administers the LDRWM Facility, they do not have full management control over the facility. LDRWM facility decision-making is divided equally between all participating municipalities. Hence, for Leduc's corporate inventory, we have only included Leduc's contribution of solid waste to the LDRWM facility (see solid waste tonnage amounts for the corporate inventory outlined in Exhibit 18 below.[5]

[5] GHG emissions from the buildings and vehicles on site were not quantified.

Commercial solid waste in Leduc is collected by private contractors engaged by local businesses. Based on engagement with solid waste disposal companies, roughly 50 per cent of Leduc's commercial waste is not sent to the Leduc and District landfill (Alston, 2015). There are eleven alternative facilities in the region accepting various types of waste. We have quantified this commercial waste and included in Leduc's community inventory for two reasons:

1) City of Leduc has no management authority over this waste therefore the related emissions should not be considered corporate; and
2) The related GHG emissions are considered scope three generated by businesses within Leduc and therefore should be included in the inventory.

The solid waste tonnage used to quantify solid waste GHG emissions for the community inventory are outlined in Exhibit 18 below.

Exhibit 18 Leduc Solid Waste Tonnage Amounts and related GHG Emissions

		Waste tonnage (t)	GHG Emissions (tCO2e)
	Leduc Solid Waste to LDRWM facility for GHG Quantification	26,364	
Corporate Inventory	Residential Solid Waste to LDRWM Landfill	5,059	
	Commercial Solid Waste to LDRWM Landfill	18,522	
	Residential and Commercial Solid Waste to LDRWM Landfill	*23,581*	33,747
	Residential Organics Diverted	2,783	713
	Total GHGs		34,459
Community Inventory	Commercial Solid Waste to Other Facilities	18,522	27,621
	Total Leduc Solid Waste Landfilled for GHG Quantification	42,103	
	Total Leduc Solid Waste for GHG Quantification	44,886	62,081
	Total Commercial Organic Waste (for potential diversion)	23,635	

5.5.2 GHG Emissions

Approximately **33,747 tCO_2e** is associated with the 23,581 tonnes of solid waste that was sent to the LDRWM facility in 2015 by the City of Leduc. Leduc's residential composting program diverted 2,783 tonnes of waste from the landfill. Composting produces a nominal amount of GHG emissions if managed properly. The City of Leduc's composting facility produced 608 tCO_2e for the organics processed in 2015. A total of 34,459 tonnes are associated with Leduc's solid waste send to the LDRWM landfill and the waste diverted to their composting facility (see Exhibit 18 above).

5.5.3 Data sources

- Central Waste Management Commission (Red Deer Area) and Leduc and District Regional Waste Management Authority (Leduc) Waste Composition Study (TRI Environmental Consulting, 2014)
- LDRWMF invoices - curbside organic tonnage
- LDRWMF Authority 2015 annual report - solid waste tonnage

5.6 Project Impacts

The City of Leduc has already made significant progress in reducing their corporate GHG emissions, as highlighted by three existing GHG reduction projects: solar photovoltaic installations, LED streetlights, and residential organics diversion. Based on the latest figures for each project, collective these three projects reduced Leduc's GHG emissions by **4,878 tCO_2e** per year (see Exhibit 19). Based on the solar installations and LED streetlights, future GHG emissions will be reduced by roughly five per cent per year. [6] The GHG savings associated with composting are for purely illustrative purposes, as they do not represent incremental GHG emissions reductions. The incremental transportation associated with composting has not been deducted and these emissions represent non-discounted lifecycle emissions associated with the compost diverted in 2015.

Exhibit 19 GHG and Energy Impacts of Select Leduc GHG Reduction Projects

	Electricity generated/reduced (kWh/year)	t CO2e reduced/avoided per year	% GHG reduction 2015 corporate inventory
Solar Installations	1,614,728[7]	1,324	3%
LED Streetlights	1,140,400	935	2%
Composting		2619	5%
Total		4,878	

5.6.1 Solar Installations

In 2016, the City of Leduc installed 1.11 megawatt (MW) photovoltaic (PV) rooftop installation on their recreation centre. The project is Canada's largest rooftop solar array (25% larger than any other commercial rooftop system in Canada) which increased Alberta's solar generating capacity by 10 per cent. Over 24 years, on average, this array will produce 955 MWh per year[8]. Leduc also installed

[6] Composting was being implemented in 2015 therefore these savings are already taken into account in Leduc's 2015 inventory.
[7] Based on electricity generation expected for 2017.
[8] Average electricity generation over 24 years.

another photovoltaic system, 620 kW, on the Operations Buildings. This array will produce, on average, approximately 530 MWH per year. This will provide more than 100 per cent of the electrical needs for the Operations Buildings. These projects will reduce Leduc's future corporate GHG emissions by approximately three per cent.

5.6.2 LED Streetlights

In 2014, council indicated they had a preference for LED streetlights opting for a replacement upon failure approach. In 2016, it was decided that all streetlights will be replaced with LED lights, and the full conversion will be completed in 2017. LED streetlight installation in Leduc will save approximately 1,140,400 kWh/year cutting streetlight electricity consumption by about half. The lighting upgrade will save the City of Leduc over $22,000 in electricity costs.[9] It is expected that Leduc's corporate GHG emissions will be cut by roughly two per cent due to the installation of LED streetlights.

5.6.3 Composting

In 2015, the residential curbside composting program diverted 2783 tonnes of organic waste through Leduc's single family residential organics waste diversion curb-side collection for Leduc. Undiscounted gross GHG emissions associated with the composting program in 2015 is 2619 tCO2e.

[9] The cost savings are less than the energy savings as FortisElectric is paying for the light replacement therefore Leduc doesn't incur all of the electricity cost savings.

6 Corporate Forecast

6.1 Methodology

The purpose of Leduc's business-as-usual (BAU) corporate forecast is to estimate future GHG emission levels in the absence of further local government action on climate change. We extrapolate future emission levels based on the observed correlation between projected population growth for the City of Leduc (2015-2035) and projected total community GHG emissions over the same period. Our forecast does not incorporate any GHG reduction projects that came in place after 2015.

6.2 GHG Forecast

Our assumption is corporate emissions will increase at the same rate as community emissions at a moderate rate of 0.9 per cent. Based on this assumption, corporate emissions grow to just over **60 ktCO2e** by 2035.

Exhibit 20 Corporate GHG Emission Forecast

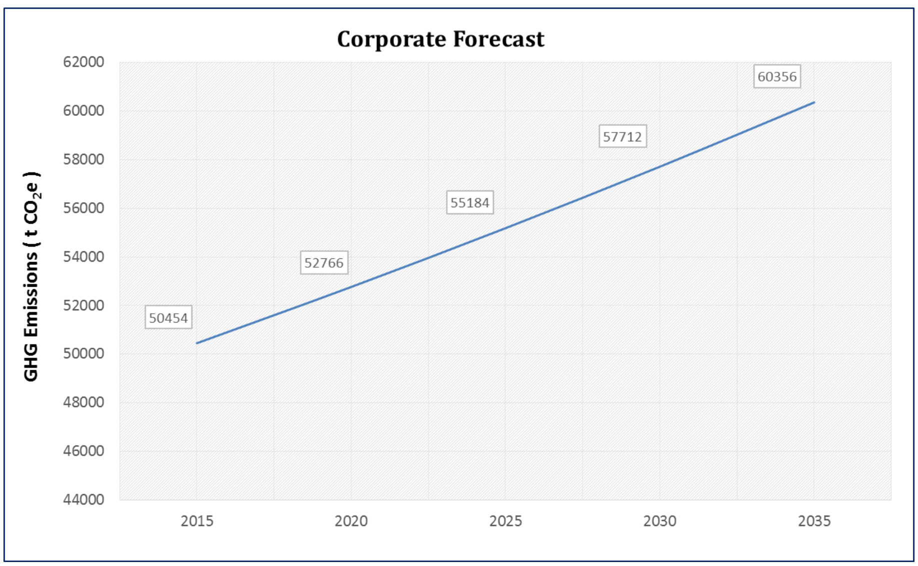
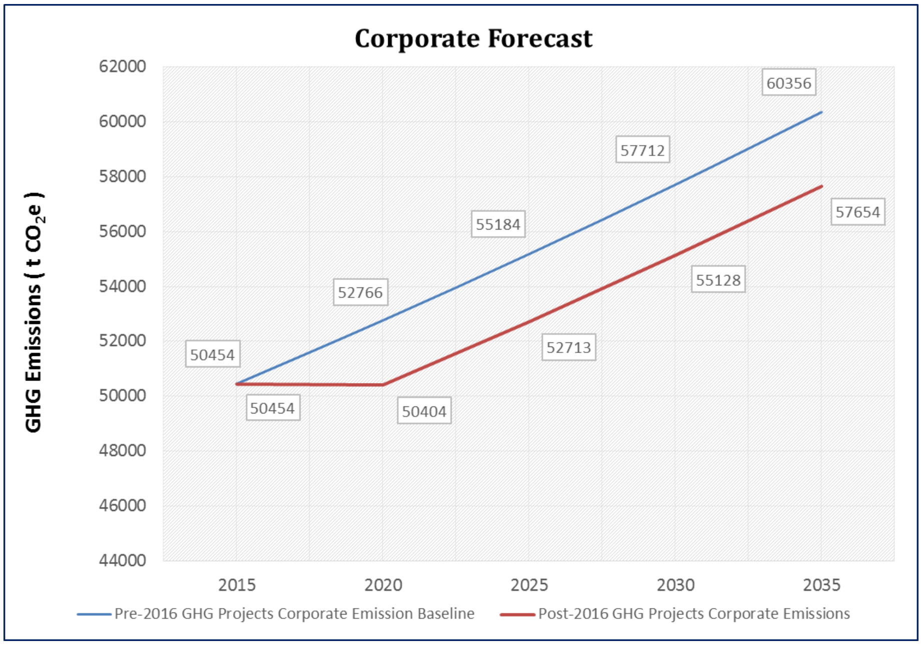


Exhibit 21 outlines the predicted impact of Leduc's existing PV projects and LED streetlight replacement on the corporate GHG forecast.[10]

[10] Due to our rudimentary application of the corporate GHG emissions growth, inherent in our assumption is that any growth in streetlights would not install LED streetlights.

Exhibit 21 Corporate GHG Emission Forecast, PV and LED Streetlight Impacts over time



6.3 Data Sources

- Growth based on output from CI-EAT model for Leduc's community GHG inventory

7 Community GHG Inventory

7.1 Leduc Context

The City of Leduc is one of the fastest-growing cities in Alberta, largely due to its long history as a key hub in Alberta's energy sector. With proximity to Alberta's primary highway, the City of Edmonton, the Edmonton International Airport, and two business/industrial parks, Leduc produces a unique GHG profile.

Between 2009 and 2016 the city grew by more than 8,970 residents, from 21,530 to 30,500; equivalent to an annual average compound growth rate of +5.1 per cent. Leduc still experienced population growth from 2015 to 2016 (+4.1 per cent), despite Alberta's economic downturn. Growth in the City is expected to continue, reaching about 49,120 (47,155-52,695) by 2035. Residential dwellings are similarly projected to grow from 11,730 in 2016 to about 20,465 (19,650-21,955) by 2035.

Concurrently, this growth will increase demand for energy with potentially significant consequences for GHG emissions, unless action is taken to decouple GHG emissions from economic growth of the city. Judiciously selected and timely actions can promote "green growth" with rising prosperity and falling GHG emissions.

7.2 Emissions Source Sectors

Community energy use and associated GHG emissions are calculated for the following broad source sectors for the period 2015-2035:

- Residential buildings;
- Commercial buildings;
- Industrial buildings and operations (processes);
- Road transportation; and
- Waste collection and disposal.

We discuss the GHG impacts of the potable water supply but do not include in the community inventory – reasoning is outlined in section 7.4.

In terms of energy use, the following fuels are considered: motor gasoline (including ethanol blends), diesel fuel oil (including biodiesel blends), liquid natural gases, natural gas, electricity and heavy fuel oil.

7.1 2015 Community GHG Inventory Summary

Total community GHG emissions in the City of Leduc in 2015 were about **405,400 t CO2e**. Note: in generating this total, the sector-specific values provided above for commercial buildings and transportation have been adjusted for corporate building and fleet emissions to avoid double counting. Corporate fleet cars, for example, will be included in the total stock of light duty vehicles registered in the City of Leduc. Similarly, electricity and natural gas sales to corporate buildings will be included in total sales data for commercial customer classes, which served as the starting point for estimating community GHG emissions from commercial buildings in Leduc.

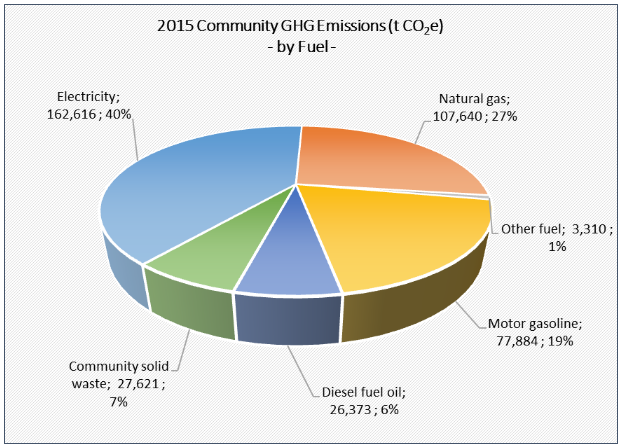
Residential buildings, commercial buildings, transportation, and industry were responsible for 27 per cent, 33 per cent, 26 per cent, and 7 per cent of the total, respectively (see panel (a) in Exhibit 22). The remaining 7 per cent were sourced from commercial solid waste.

In terms of energy sources, 40 per cent and 27 per cent of total GHG emissions resulted from, respectively, electricity and natural gas consumption (see panel (a) in Exhibit 22). Motor gasoline accounts for 19 per cent of total GHG emissions.

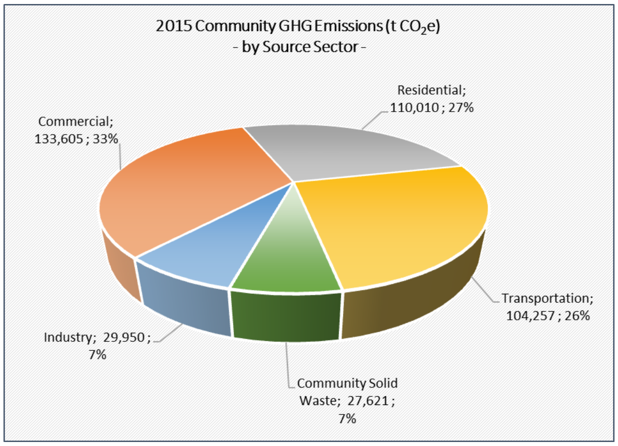
These community GHG inventory summary figures are adjusted to deduct the corporate inventory GHG emissions in buildings, fleet, streetlight, and wastewater & water. The detailed sectoral data in the remainder of this inventory includes GHG emissions and energy use from both the community and the corporate inventory. For numbers for each sector that do not include the corporate GHG emissions see Appendix 18.

Exhibit 22: Total Community GHG Emissions in 2015, by Energy Source and by Source Sector

(a) Emissions by Energy Source

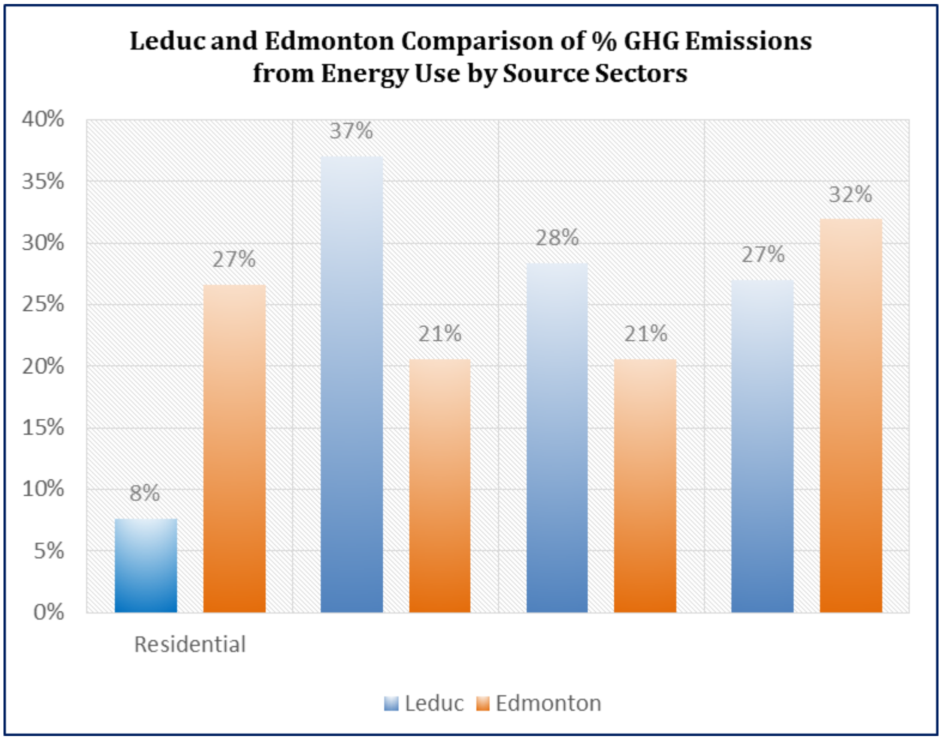


(b) Emissions by Source Sector



The City of Edmonton provides a comparison to Leduc's relative contribution of GHG emissions per energy source sector.[11] In 2012, Edmonton's transportation accounted for 32 per cent of total community energy use. Residential buildings, commercial buildings and industry accounted for, respectively, 21 per cent, 21 per cent and 27 per cent. Leduc's 2015 total GHG inventory energy source sectors include: transportation (27 per cent), residential (28 per cent), commercial (37 per cent), and industrial (8 per cent).[12]

Exhibit 23 Leduc and Edmonton Comparison of % GHG Emissions from Energy Source Sectors



Source: Edmonton's Community Energy Transition Strategy (2015, page 18)

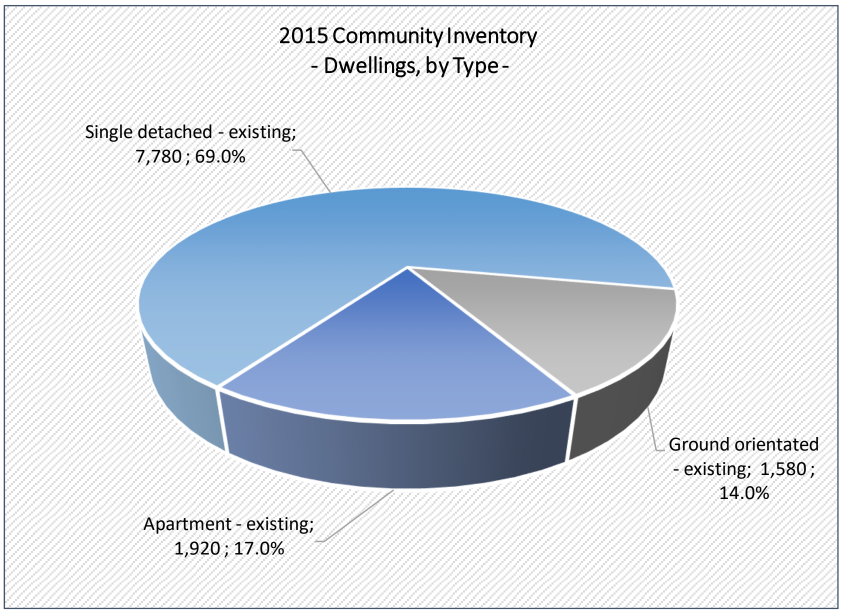
[11] Added Leduc's corporate and community inventories to provide a fair comparison to Edmonton's total GHG inventory.
[12] Added Leduc's corporate and community inventories to provide a fair comparison to Edmonton's total GHG inventory.

7.2 Residential Buildings

In 2015 the City of Leduc contained approximately 11,280 residential dwellings (see Exhibit 24):

- Single detached dwellings = 7,780 (or 69%);
- Ground orientated dwellings (duplexes, row houses, townhouses) = 1,580 (or 14%); and
- Apartment dwellings = 1,920 (or 17%).

Exhibit 24: Residential Dwellings in City of Leduc in 2015



Total utility sales to residential customer classes amounted to 1,234,650 GJ; of which 76 per cent was natural gas and 24 per cent was electricity.

This information was input to the CI-EAT tool to calculate energy use and GHG emissions from residential buildings over the period 2015-2035 (estimated projections are presented in Section 7.6).

Total GHG emissions from residential dwellings in 2015 amounted to about **110,010 t CO_2e**. Exhibit 25 shows the contribution of each dwelling type to this total. In terms of energy source, about 44 per cent of total GHG emissions is due to natural gas use and about 56 per cent is due to electricity use.

Single detached dwellings accounted for about 84 per cent of total energy consumption in 2015; ground orientated dwellings (duplexes, row houses, townhouses) and apartments consumed about 9 per cent and 7 per cent, respectively.

Exhibit 25: GHG Emissions from Residential Dwellings in 2015, By Dwelling Type and Energy Source

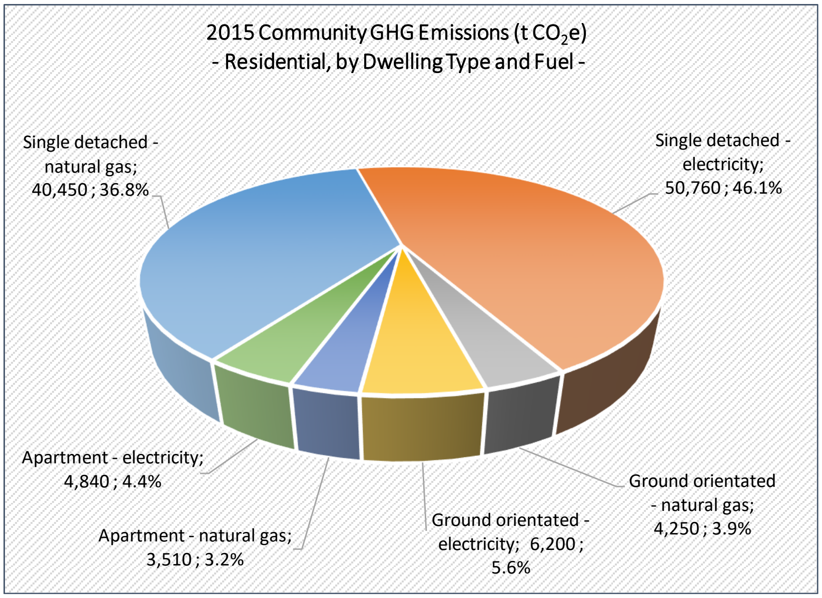
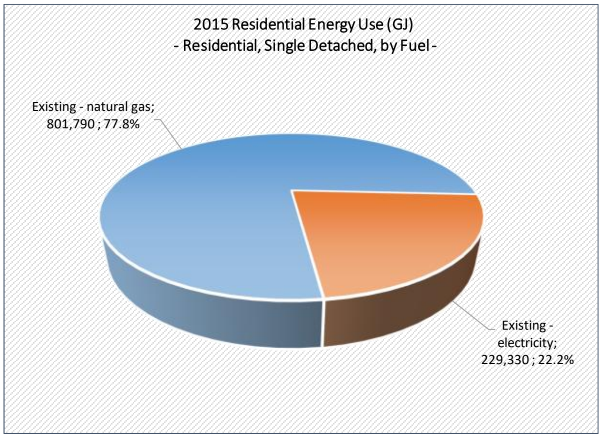


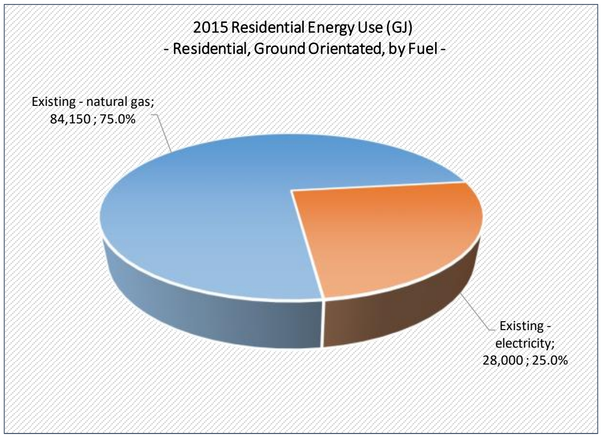
Exhibit 26 breaks down total utility sales to residential customer classes in 2015 by type of dwelling and energy source.

Exhibit 26: Energy Use in Residential Dwellings in 2015, by Dwelling Type and Energy Source

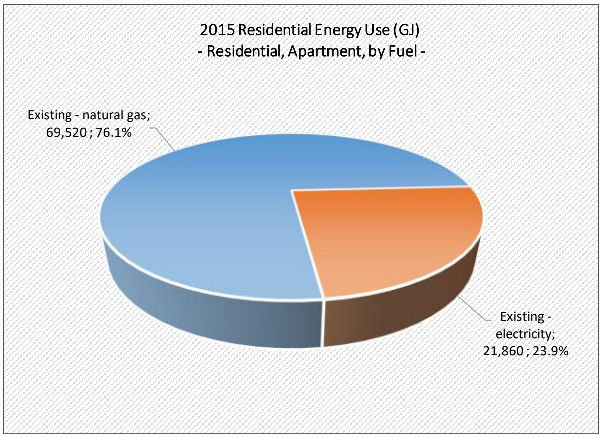
(a) Single Detached



(b) Ground Orientated



(c) Apartments



7.1 Commercial Buildings

Total utility sales to commercial customer classes in 2015 amounted to 1,265,620 GJ; of which 61 per cent was natural gas and 39 per cent was electricity (see panel (a) in Exhibit 27).

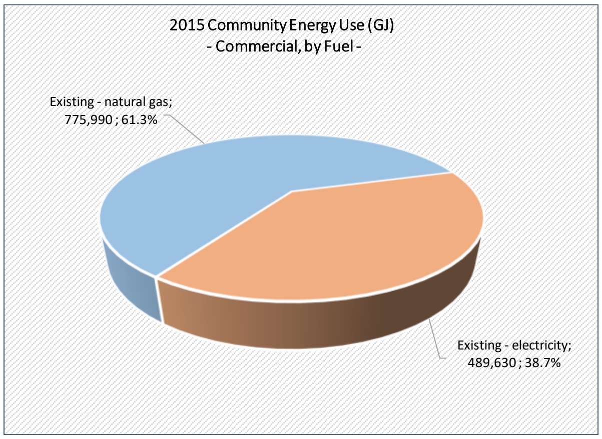
The stock of commercial buildings in 2015 was estimated from "assessment" data provided by the City of Leduc. Approximately 1,251,700 square meters (m^2) of commercial floorspace was identified for 2015, encompassing premises for wholesale trade, retail trade, transportation and warehousing, offices, accommodation and food services.

This information was input to the CI-EAT tool to calculate energy use and GHG emissions from commercial buildings over the period 2015-2035. Floorspace data was not available for schools and healthcare facilities. Consequently, projected energy use and GHG emissions (after 2015) are only influenced by energy consumption patterns and energy use intensities of wholesale trade, retail trade, transportation and warehousing, offices, accommodation and food services. Note: total energy use and GHG emissions for 2015 are unaffected by the omission of schools and healthcare facilities.

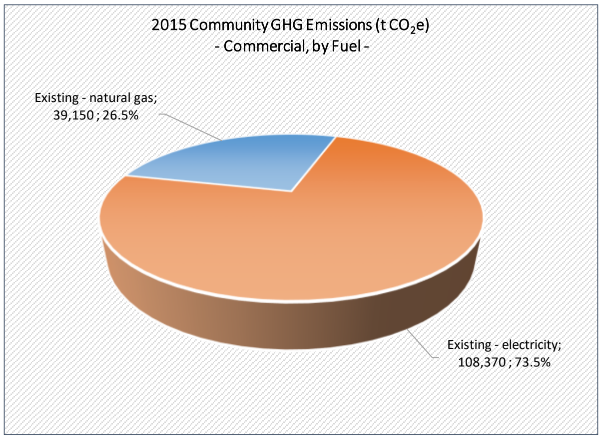
Total GHG emissions from commercial buildings in 2015 amounted to about **147,520 t CO_2e**. As shown in Panel (b) of Exhibit 27, about 27 per cent of total GHG emissions is due to natural gas use and about 63 per cent is due to electricity use.

Exhibit 27: Energy Use and GHG Emissions by Commercial Buildings in 2015, by Energy Source

(a) Energy Use



(b) GHG Emissions



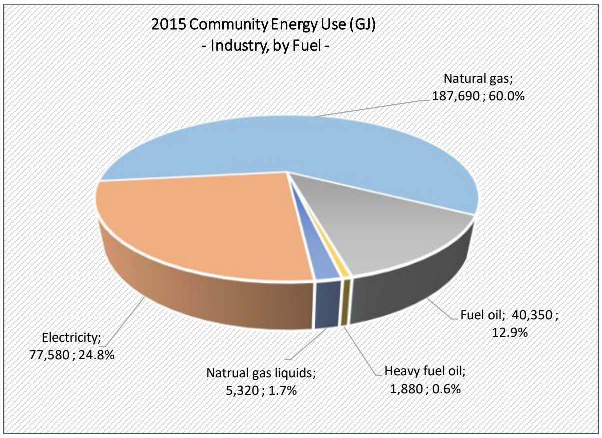
7.2 Industrial Buildings and Operations

Total utility sales of natural gas and electricity to industrial customer classes in 2015 amounted to 265,580 GJ. However, unlike with residential and commercial buildings, natural gas and electricity use do not account for nearly 100 per cent of total energy use by industry. Industry data from NRCAN's Comprehensive Energy Use Database was thus used to derive multipliers that could be applied to total natural gas and electricity sales to estimate consumption of other fuels by industry – namely, diesel fuel oil, heavy fuel oil and natural gas liquids. The multipliers were derived from "construction" and "manufacturing" data – two industrial activities most likely to occur within the City of Leduc. Accounting for use of these other fuels by industry in Leduc, total energy use by industrial buildings and operations in 2015 was estimated at 312,820 GJ. Panel (a) in Exhibit 28 provides a breakdown of this total by energy source.

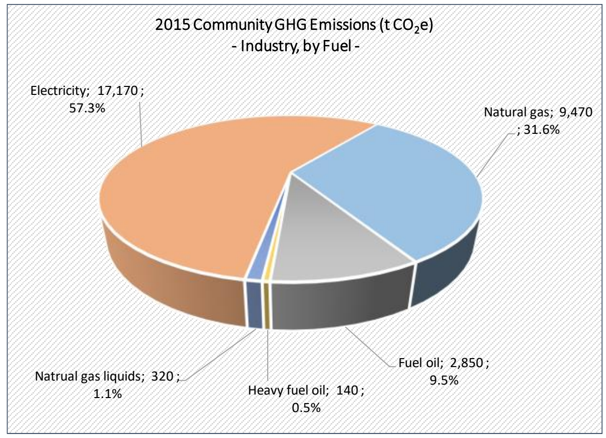
Total GHG emissions from industrial buildings and operations in 2015 amounted to about **29,950 t CO_2e**. As shown in Panel (b) of Exhibit 28 the largest source of GHG emissions is electricity consumption (57 per cent of total emissions).

Exhibit 28: Energy Use and GHG Emissions by Industry in 2015, by Energy Source

(a) Energy Use



(b) GHG Emissions



7.3 Transportation

Road transportation is divided into the following categories: (1) light duty vehicles (passenger cars, sports utility vehicles); (2) light duty trucks (light passenger and freight pick-up trucks, all types of vans); (3) heavy duty trucks; (4) buses (school, urban and inter-city); and (5) motorcycles (which also includes mopeds). Vehicles within these categories have similar road fuel mixes, technology choices, and average fuel economies.

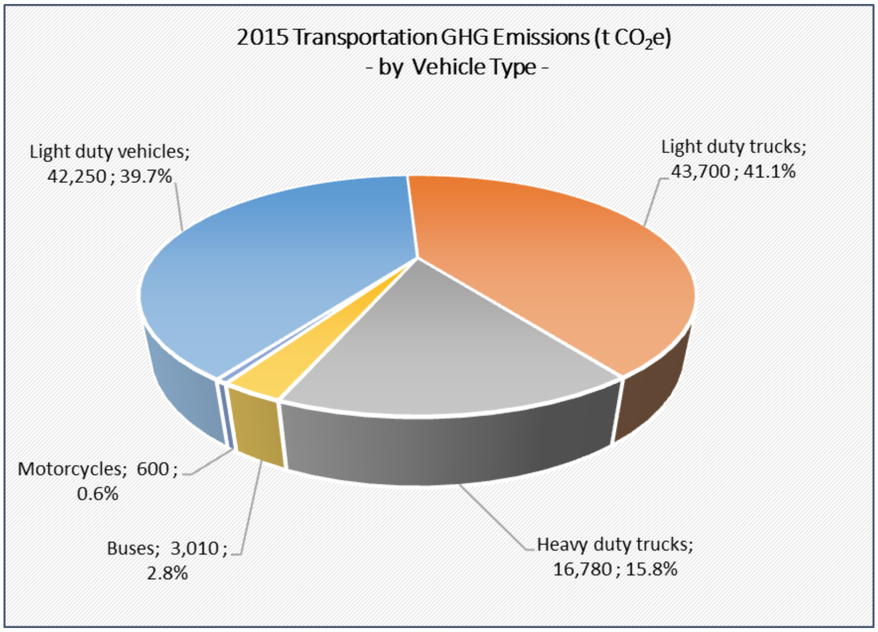
Data on the total stock of road vehicles registered in the City of Leduc in 2015-16[13], by vehicle type, was obtained from Alberta Transportation. The total stock of registered vehicles was also broken down by fuel source; but not by vehicle type *and* fuel source, which is needed for the analysis. Hence, data on vehicle type *and* fuel source for the Edmonton Capital Region was used to allocate the total stock of each type of vehicle between different fuel sources. In effect, the relative shares of (say) gasoline, diesel, hybrid, etc. of all passenger cars registered in Leduc are assumed to be the same as in the Edmonton Capital Region. The breakdown of vehicle types if specific to Leduc.

Information on the total stock of vehicle by type and by fuel source was input to the CI-EAT tool to calculate corresponding energy use and GHG emissions over the period 2015-2035. Since it was not possible to delineate between total annual vehicle kilometres driven within the boundaries of the City of Leduc and those drive outside those boundaries, it was not possible to distinguish between Scope 1 and Scope 3 GHG emissions. The figures presented below include Scope 1, Scope 2 and Scope 3 emissions associated with the total stock of road vehicles registered in the City of Leduc in 2015-16.

[13] The stock data does not correspond to a calendar year, but rather from March 2015 to March 2016. Hence, estimated GHG emissions presented for 2015 actual result from vehicles registered up to March 2016.

The majority of community transportation related GHG emissions (41 per cent) come from light trucks closely followed by light duty vehicles (40 per cent). The remaining emissions are made up of: heavy duty trucks (16 per cent), buses (three per cent), and motorcycles (one per cent). The total 2015 GHG emissions from transportation are 106,340 tCO_2e.

Exhibit 29 2015 Transportation GHG Emissions, by Vehicle Type



7.3.1 Light Duty Vehicles

The total stock of light duty vehicles (including all types of passenger cars and sports utility vehicles) registered in the City of Leduc in 2015 was about 15,160, of which there were:

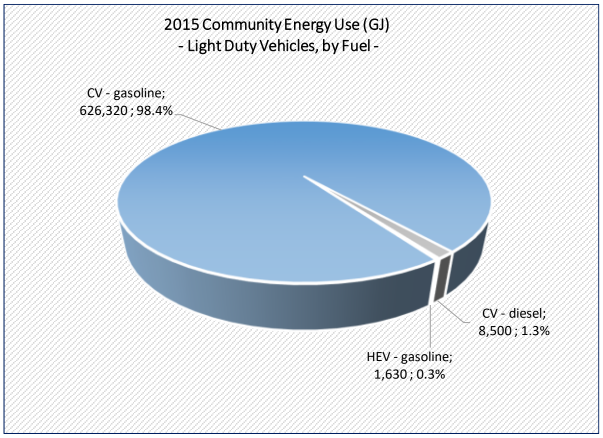
- 14,870 conventional gasoline vehicles (denoted CV-gasoline);
- 220 conventional diesel vehicles (denoted CV-diesel); and
- 70 conventional hybrid electric vehicles (denoted HEV).

There were no plug-in electric vehicles (denoted PHEV) or battery electric vehicles (denoted BEV).

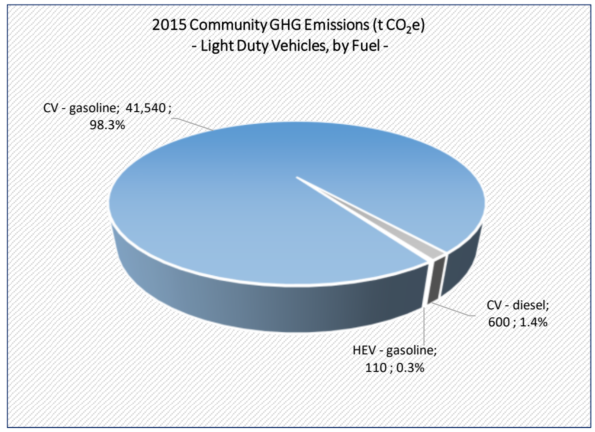
Total energy consumption by light duty vehicles in 2015 was estimated at 636,460 GJ; 98 per cent of which was sourced from motor gasoline (see panel (a) in Exhibit 30). Associated GHG emissions amounted to **42,250 t CO_2e** (see panel (b) in Exhibit 30).

Exhibit 30: Energy Use and GHG Emissions by Light Duty Vehicles in 2015, by Energy Source

(a) Energy Use



(b) GHG Emissions



7.3.2 Light Duty Trucks

The total stock of light duty trucks (including all types of pick-ups and vans) registered in the City of Leduc in 2015 was about 11,980, of which there were:

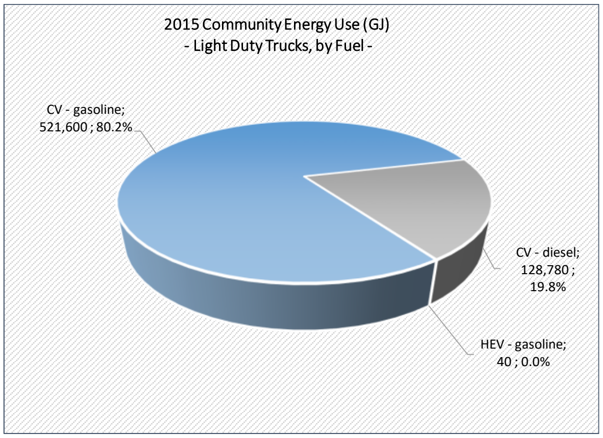
- 9,510 conventional gasoline vehicles;
- 2,470 conventional diesel vehicles; and
- 1 conventional hybrid electric vehicle.

There were no plug-in electric vehicles or battery electric vehicles.

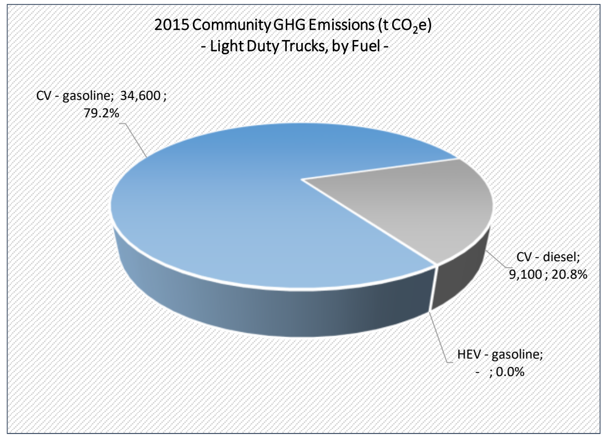
Total energy consumption by light duty trucks in 2015 was estimated at 650,420 GJ; 80 per cent of which was sourced from motor gasoline (see panel (a) in Exhibit 31). Associated GHG emissions amounted to **43,700 t CO_2e** (see panel (b) in Exhibit 31). Motor gasoline accounts for a similar share of total GHG emissions (i.e., 79 per cent). Note: total GHG emissions from the single conventional electric hybrid vehicle are lost when rounding to the nearest 10 units; they were estimated at about 3 t CO_2e.

Exhibit 31: Energy Use and GHG Emissions by Light Duty Trucks in 2015, by Energy Source

(a) Energy Use



(b) GHG Emissions



7.3.3 Heavy Duty Trucks

The total stock of heavy duty trucks registered in the City of Leduc in 2015 was about 600, of which there were:

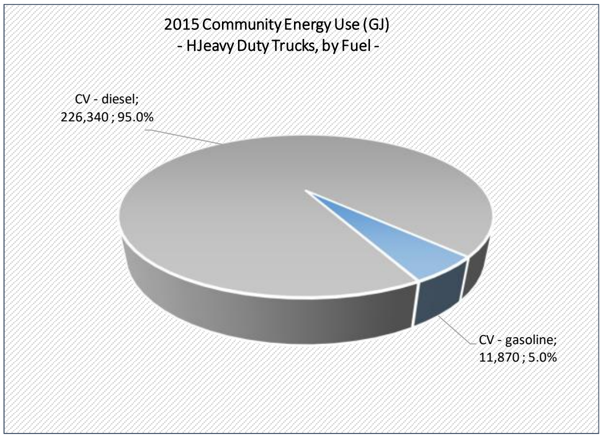
- 60 conventional gasoline vehicles; and
- 540 conventional diesel vehicles.

There were no conventional hybrid electric vehicles, plug-in electric vehicles or battery electric vehicles.

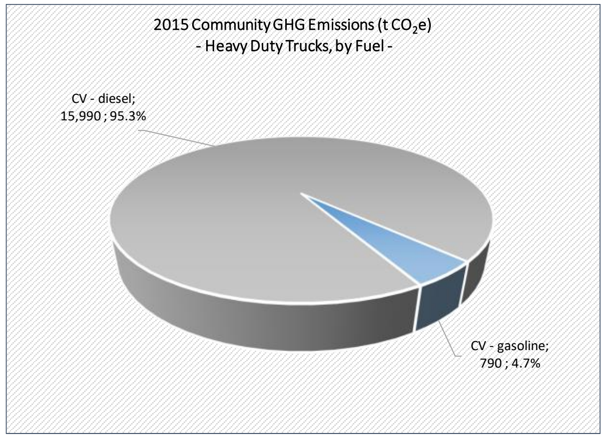
Total energy consumption by heavy duty trucks in 2015 was estimated at 238,210 GJ; 95 per cent of which was sourced from diesel fuel oil (see panel (a) in Exhibit 32). Associated GHG emissions amounted to **16,780 t CO_2e** (see panel (b) in Exhibit 32). Diesel fuel oil accounts for a similar share of total GHG emissions (i.e., 95 per cent).

Exhibit 32: Energy Use and GHG Emissions by Heavy Duty Trucks in 2015, by Energy Source

(a) Energy Use



(b) GHG Emissions



7.3.4 Buses

The total stock of buses (including school, urban and inter-city vehicles) registered in the City of Leduc in 2015 was 62, of which there were:

- 17 conventional gasoline vehicles; and
- 45 conventional diesel vehicles.

There were no conventional hybrid electric vehicles, plug-in electric vehicles or battery electric vehicles.

Total energy consumption by buses in 2015 was estimated at 43,220 GJ; 75 per cent of which was sourced from diesel fuel oil and 25 per cent from motor gasoline (see panel (a) in Exhibit 33). Associated GHG emissions amounted to **3,010 t CO_2e** (see panel (b) in Exhibit 33). Diesel fuel oil (76 per cent) and motor gasoline (24 per cent) account for similar shares of total GHG emissions.

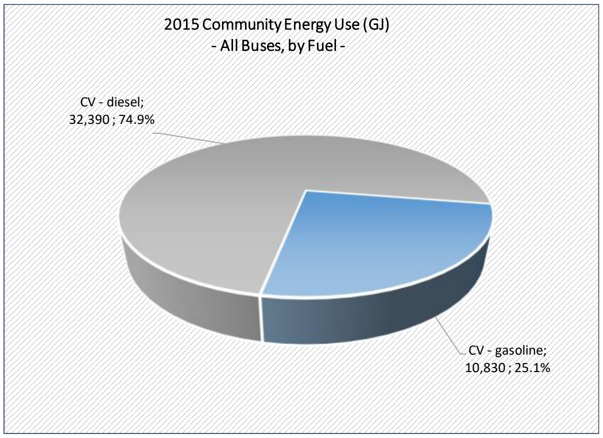
7.3.5 Motorcycles

The total stock of motorcycles (including mopeds) registered in the City of Leduc in 2015 was about 600; all of which were fueled by motor gasoline.

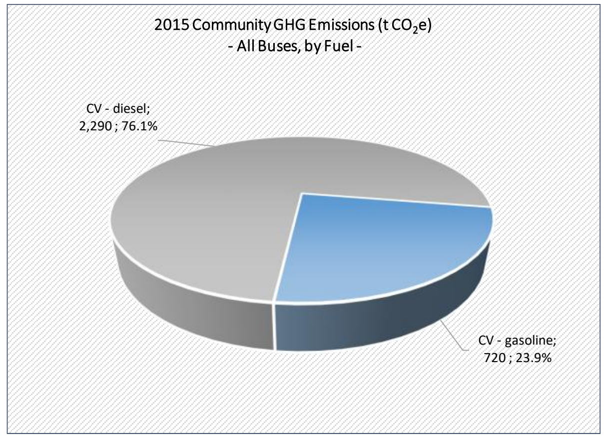
Total motor gasoline consumption by motorcycles in 2015 was estimated at 9,090 GJ. Associated GHG emissions amounted to **600 t CO_2e**.

Exhibit 33: Energy Use and GHG Emissions by Buses in 2015, by Energy Source

(a) Energy Use



(b) GHG Emissions



7.4 Water and Wastewater

The FCM GHG protocol does not require GHG emissions from water and wastewater to be included in a corporate inventory if treatment is managed by a nearby municipality (as is the case with the City of Leduc). The FCM protocol also does not require the inclusion of these GHG emissions in a community GHG inventory.

The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) requires that energy emissions from water and wastewater processing as well as methane emissions from wastewater treatment be included in a GHG corporate inventory irrespective of whether another municipality manages the processing. In order for Leduc's inventory to become GPC compliant, we would require additional information to quantify all wastewater and water treatment GHG emissions.[14] At minimum, we have outlined the GHG emissions from the data we have already obtained, although we did not include these emissions in the total amount of GHG emissions for the community inventory.

Per data from EPCOR, about 3,024,800 m^3 of potable water was supplied to customers in the City of Leduc in 2015. That equates to roughly 103 m^3 per capita per year or 283 litres per capita per day. This water was supplied from the Rossdale and EL Smith water treatment plants in the City of Edmonton. These plants collectively produced 139,217,000 m^3 of potable water in 2015, and in doing so, consumed 92,705 GJ of natural gas and 269,980 GJ of electricity. Producing one m^3 of potable water thus used roughly 0.7 MJ of natural gas and 1.9 MJ of electricity. Hence, in supplying 3,024,800 m^3 of potable water to the City of Leduc in 2015, these water treatment plants consumed about 2,015 GJ and 5,865 GJ of natural gas and electricity, respectively. Corresponding total GHG emissions

[14] The missing data included: amount of electricity and/or natural gas used to treat Leduc's wastewater as well as the annual per capita protein consumption, and the per capita Biochemical Oxygen Demand (BOD).

in 2015 equate to **1,400 t CO_2e**, of which 100 t CO_2e is sourced from natural gas use and 1,300 t CO_2e is sourced from electricity use.

The collection and treatment of wastewater at a facility will also give rise to GHG emissions. Besides GHG emissions associated with the consumption of energy involved in the wastewater treatment process, the process itself will also likely give rise to fugitive emissions of CO_2, CH_4 and N_2O. GHG emissions from wastewater treatment collection and treatment will vary based on the composition and type of influent (household versus commercial versus industrial wastewater), the volume of wastewater, and the specific treatment processes used. In the absence of data for all these variables, GHG emissions associated with wastewater management have not been calculated or included in the community inventory.

7.5 Commercial Solid Waste

As noted in Section 5.5, approximately 50 per cent of commercial solid waste generated by businesses in Leduc is collected by private contractors, and taken for disposal at alternative landfills in the region. For the reasons provided in Section 5.5, GHG emissions associated with the disposal of this waste is included within the community inventory.

In 2015, 50 per cent of solid waste generated by businesses in the City of Leduc amounted to about 18,522 tonnes. Using the Methane Commitment Model (see Section 5.5), total GHG emissions resulting from the disposal of this amount of solid waste to landfill is about **27,621 t CO_2e**.

7.6 Methodology and Data Sources

The community GHG emission inventory for 2015 and over the period 2016-2035 was generated using the Community Inventory and Economic Analysis Tool (CI-EAT) – an Excel-based model for simulating the lifetime environmental and economic consequences of policies, programs and projects to save energy and reduce GHG emissions at the community level.

CI-EAT is applied in three steps:

1. First, it generates an inventory of energy consumption and GHG emission for a defined base year (in this case, 2015) and a defined geographical boundary (in this case, the City of Leduc).

Energy use and GHG emissions are calculated for the following source sectors:

- Residential buildings (single detached, ground orientated and apartments);
- Commercial buildings;
- Industrial buildings and operations;
- Road transportation (light duty vehicles, light duty trucks, heavy duty trucks, buses, motorcycles); and
- Potable water supply.

GHG emissions associated with solid waste collection and disposal are calculated off-model.

For each source sector, energy use (and subsequently GHG emissions) is broken down by fuel (e.g., electricity, natural gas, motor gasoline, etc.). For residential and commercial buildings, energy use is further disaggregated by end-use (e.g., space heating and cooling, lighting, appliances, water heating, auxiliary equipment and motors). Vehicles are disaggregated by technology: conventional gasoline and diesel vehicles, conventional electric hybrids, plug-in hybrids and battery electric vehicles.

Like any other GHG inventory tool, the base year inventory is given by:

Activity statistic x **energy use intensity** = energy use x **emission factor** = GHG emissions

Examples of activity statistics include: total commercial floorspace, total single detached dwellings, total m^3 of potable water supplied, total registered passenger cars, etc. These variables are community-specific and were largely provided by the City of Leduc. In some cases, the activity statistic used is a compound variable. For instance, for transportation, the total number of registered vehicles is combined with values for the average distance travelled annually by that type of vehicle.

Examples of energy use intensities include: GJ of natural gas for space heating per m^2 of single detached dwellings or per m^2 of commercial floorspace, litres of motor gasoline per 100 km travelled by a passenger car, etc. These data, along with emission factors, are contained within CI-EAT; they are Alberta-specific (and Edmonton-specific), and are continually updated as new information is published. Note: to ensure consistency with the corporate inventory, the emission factors in CI-EAT were re-set to match those used in the PCP Tool.

2. Second, the inventory of energy consumption and GHG emission generated for the base year is projected into the future—in this case, over the period 2015-2035. This creates a so-called Reference Case, which serves as the baseline for evaluating the triple bottom line impacts energy saving and GHG emission reduction initiatives.

CI-EAT makes projections for each variable in the equation above: activity statistics, energy intensities and emission factors.

Where available, projections of activity statistics are based on existing Leduc-specific projections (e.g., the number of residential dwellings over time). For other activity statistics (e.g., commercial floorspace, number of registered passenger cars or light duty trucks) CI-EAT derives 'multipliers' from time series analysis of relationships between relevant activity statistics and key socioeconomic variables for the Edmonton Capital Region. First, CI-EAT identifies the strongest historical relationship between the activity statistic (say, registered motorcycles) and total population, total households, total employment, total real GDP. From the variable with the strongest relationship, a multiplier is calculated, which is given by the ratio of the percentage change in the activity statistic to the percentage change in the socioeconomic variable. The resulting multiplier is then applied to available projections of the socioeconomic variable for the City of Leduc. This provides a Leduc-specific projection for the activity statistic.

Projections of energy use intensities and emission factors are built-into the model, based on a combination of statistically analysis of past trends in Alberta data and future policies and regulations.

3. Third, a portfolio of energy saving and GHG emission reduction initiatives is formulated (including the characterization of lifetime costs and effectiveness measures) and input to CI-EAT, generating a new set of projections for the community; this we refer to as the Low Carbon Case. The relative environmental and economic merits of the portfolio of initiatives (and individual initiatives) as investments is determined by contrasting the Low Carbon Case and the Reference Case. This third step is the focus of the next phase of the project.

8 Community Forecast

8.1 Projections for 2016-2035

Total community GHG emissions in 2015 were estimated at **405,444 t CO_2e**. By 2035 total emissions are projected to rise to **491,101 t CO_2e**; equivalent to an annual average compound growth rate of +0.9 per cent. Over the same period, total community energy consumption is projected to rise from 4,390,490 GJ to 6,788,000; equivalent to an annual average compound growth rate of +2.2 per cent. Hence, the GHG-intensity of energy used in Leduc is projected to fall. This is the result of reductions in the GHG intensity of the provincial electricity grid due, in part, to the Alberta Climate Leadership Plan—see Exhibit 34.

Exhibit 34: GHG Emission Intensity of the Provincial Electricity Grid: 2015-2035

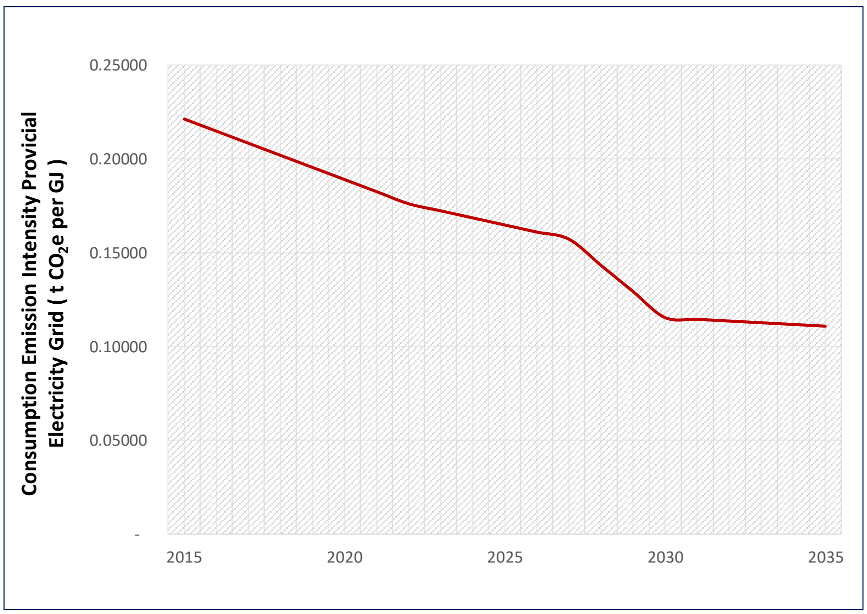


Exhibit 35 shows the time profile of total community GHG emissions over the period 2015-2035. The S-shape nature of the line in Exhibit 35 is a direct result of the changing emissivity of the provincial grid over the same period.

Exhibit 35: Projected Community GHG Emissions: 2015-2035

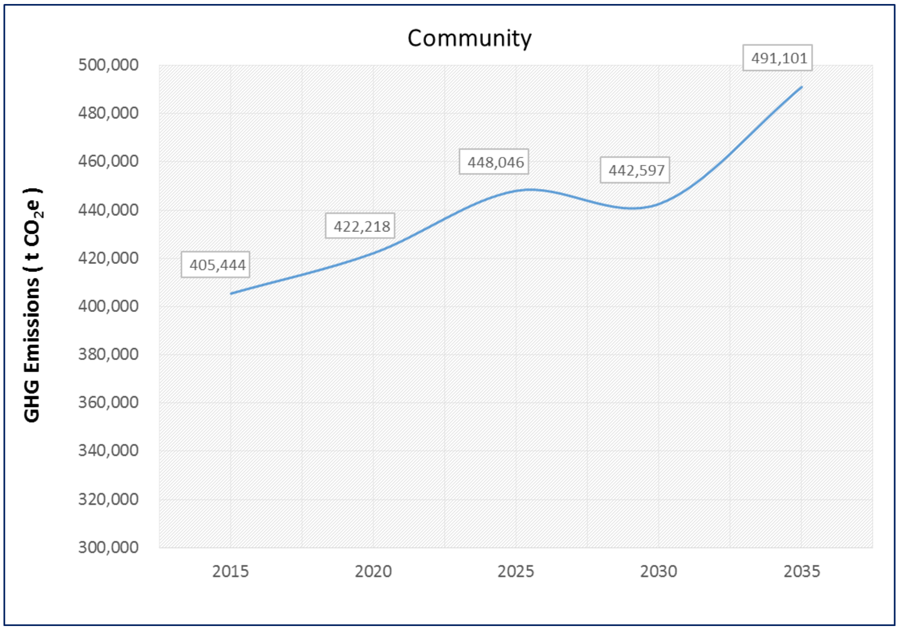
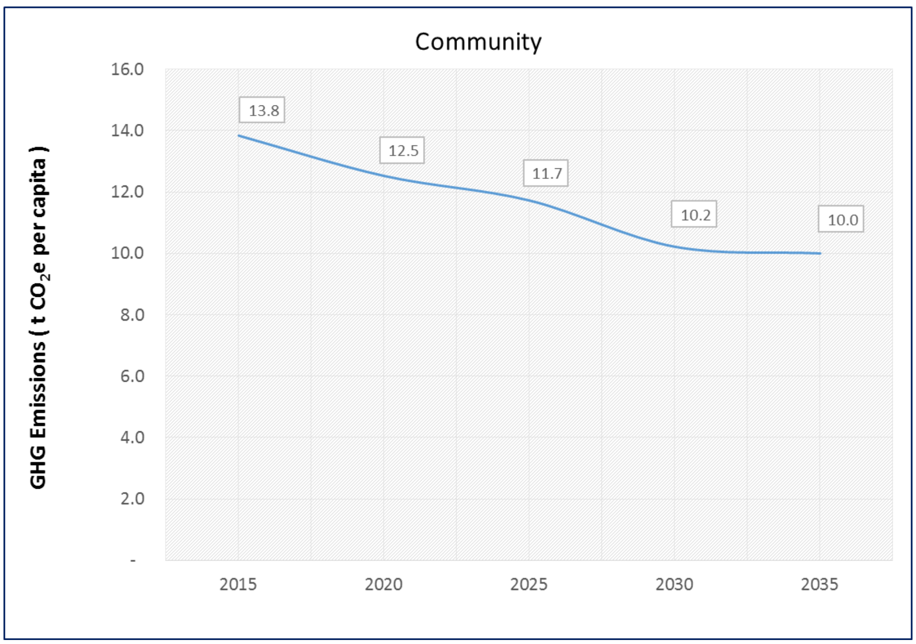


Exhibit 36: Projected Community GHG Emissions per Capita: 2015-2035



In 2015, total community GHG emissions per capita were about **13.8 t CO_2e**. By 2035, per capita total emissions are projected to fall to **10.0 t CO_2e**. This is partly due to reductions in the GHG intensity of the provincial grid, but also partly due to energy efficiency improvements across source sectors.

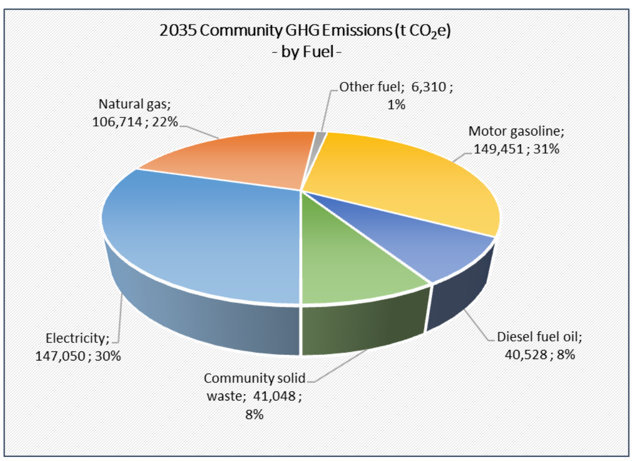
Between 2015 and 2035 the population of the City of Leduc is projected to increase from about 29,300 to 49,120. That is equivalent to an annual average compound growth rate of +2.6 per cent. However, over the same period total community energy consumption is projected to grow by an average of +2.2 per cent per annum. Hence, total community energy use is projected to grow at a slower rate than the population. Hence, population growth is projected to somewhat decouple from growth in energy use. This is also observed when comparing total community energy use in 2015 and 2035; in 2015 it was about 150 GJ per capita, while in 2035 it is projected at about 138 GJ per capita.

Exhibit 37 summarizes the contribution of fuels and source sectors to projected total community GHG emissions in 2035. Contrasting panel (b) in Exhibit 37 with panel (b) in Exhibit 22 reveals that transportation is projected to see a significant relative increase in GHG emissions—increasing its share of total community emissions from 26 per cent in 2015 to over 40 per cent by 2035. The relative shares of commercial buildings and, to a lesser extent, residential dwellings are projected to decline moderately between 2015 and 2035. Indeed, absolute GHG emissions from commercial buildings are projected to decline by 2035, despite projected growth in commercial floorspace; this is primarily due to concurrent reductions in the emissivity of the provincial electricity grid.

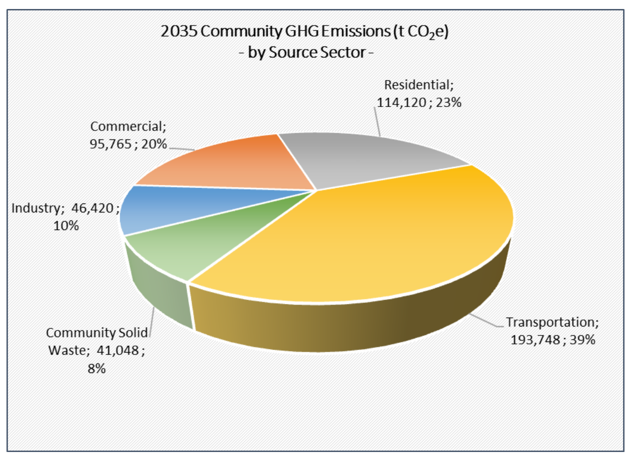
A detailed breakdown of community inventory at five-year intervals over the period 2015-2035 is provided in. Further details for individual source sectors can be found in the attached appendices.

Exhibit 37: Total Community GHG Emissions in 2035, by Energy Source and by Source Sector

(a) Emissions by Energy Source



(b) Emissions by Source Sector



9 Appendix: Corporate GHG Emissions and Energy Consumption Tables

Exhibit 38 2015 Corporate GHG Emissions and Total Energy Consumption, by Source Sector

	Total GHG Emissions (tCO2e)	Total Energy Consumption (GJ)
Buildings	10,706	89,088
Fleet	2,082	29,604
Streetlights	2,215	9,725
Water & Sewage	992	5,128
Solid Waste	34,459	-
Total (t CO2e)	50,454	**133,294**

Exhibit 39 2015 Corporate Energy Consumption, by Fuel

Source	Energy Consumption (GJ)
Electricity	48,884
Natural Gas	55,057
Diesel	22,361
Gasoline	7,244
Total	133,294

Exhibit 40 2015 Corporate Building Energy Consumption, GHG Emissions, and Sector Details

	GHG Emissions (tCO2e)							
Building Name	Electricity	Natural Gas	Total	GHG Intensity (t/m2)	Total Energy (GJ)	Electricity (MWh)	Natural Gas (GJ)	Expenditure ($)
Leduc Recreation Centre	5895	1672	7,566	0.26	58,996	7,189	33,114	$861,090
Fire House #2	20	1	21	0.02	111	25	23	$2,733
Stage Works	24	12	36	0.05	339	29	234	$6,010
Alexandra Swimming Pool	32	32	63	0.08	767	39	628	$12,730
Alexandra Arena	181	135	316	0.11	3,472	221	2,678	$43,560
Protective Services Building	447	174	621	0.19	5,412	545	3,452	$66,650
Operations Buildings	423	386	809	0.12	9,503	516	7,644	$106,550
Leduc Civic Centre	901	300	1,201	0.20	9,894	1,099	5,938	$163,590
Dr. Woods Museum	4	9	13	0.08	190	5	171	$0
Ball Association	19	3	22	0.14	149	23	66	$0
Chamber of Commerce	31	6	37	0.12	254	38	116	$0
Total	7,978	2,730	10,705		89,087	9,729	54,064	1,262,913

Exhibit 41 2015 Corporate Fleet Energy Consumption, GHG Emissions, and Sector Details

Vehicle Name	Energy Consumption (GJ)	Energy Consumption (Gasoline l)	Energy Consumption (Diesel l)	GHG Emissions (t)	Vehicle kilometers travelled (km)	Number of vehicles
Light Duty Auto	585	16,719	-	38	54,844	7
Light Duty Truck	5,836	134,124	29,818	390	671,402	68
Heavy Duty Vehicle	2,391	-	62,438	169	90,207	17
LATS	1,666	47,601	-	109	126,508	6
Transit Bus	4,404	-	114,988	312	400,687	9
Off-Road Equipment	2,902	1,351	74,525	227	-	52
Organics	2,397	-	62,572	170	176,758	2
Waste	4,159	-	108,599	295	306,777	2
Recycle	5,013	-	130,892	355	369,751	2
Staff mileage	251	7,178		17	23,548	-
Total	29,604	206,972	583,832	2,082	2,220,482	165

Exhibit 42 2015 Street Light Energy, GHG emissions, and Sector Details

Lighting Group	Energy Consumption (MWh)	GHG Emissions (t)
Fountains	126	103
Street Lights	2,227	1826
Traffic Lights	65	54
Signs	49	40
Outdoor Sports Facilities	62	51
Outdoor Lighting	161	132
Parking Lots	11	9
Total	2,702	2215

Exhibit 43 2015 Water and Wastewater Energy and GHG Emissions

Facility Name	Total Energy Consumption (GJ)	Electricity Consumption (MWh)	Natural Gas Consumption (GJ)
North Reservoir/ Pumphouse	3,723	981	190
Suntree Lift Station	241	32	127
West Lift Station	604	42	452
South Reservoir/ Pumphouse	510	79	224
Corintha Lift Station	50	14	0
Total	5,128	1,149	993

10 Appendix: Community Inventory: Residential Buildings

Exhibit 44: Projection of Residential Dwellings 2015-2035

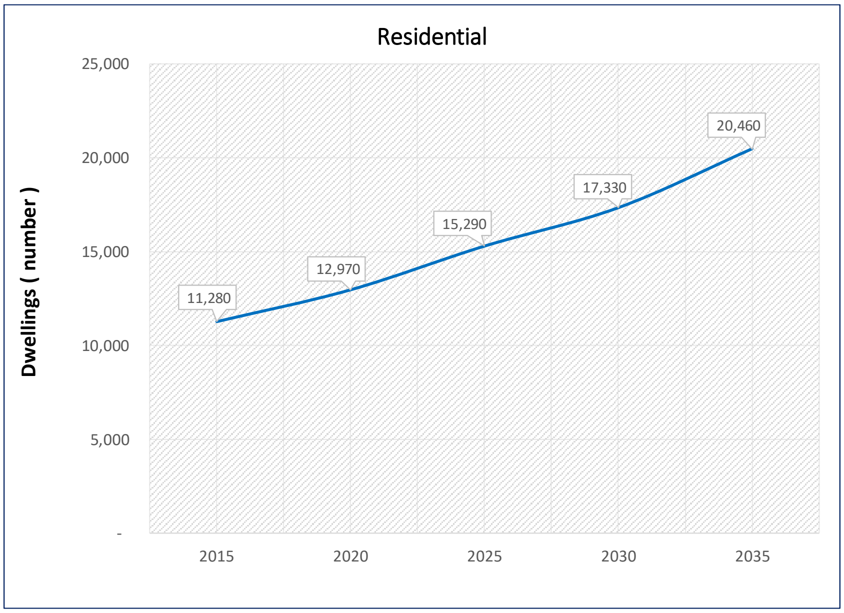
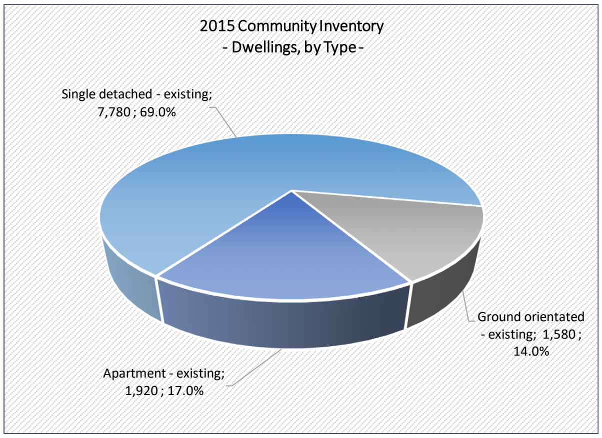


Exhibit 45: Residential Dwellings by Dwelling Type and by Vintage in 2015 vs 2035

(a) 2015



(b) 2035

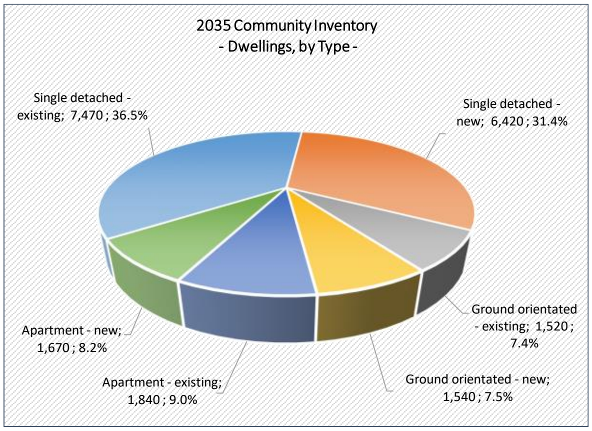


Exhibit 46: Projection of Energy Consumption by Residential Dwellings 2015-2035

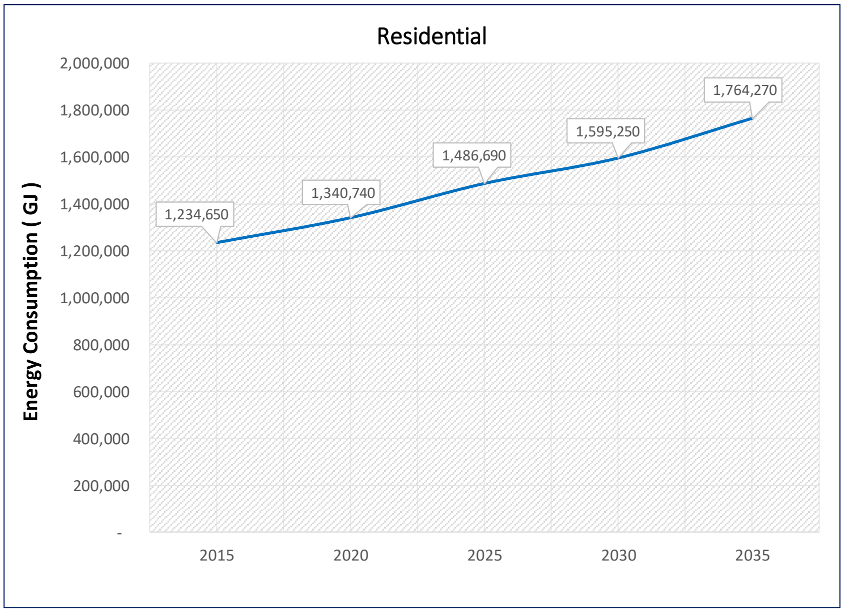


Exhibit 47: Projection of GHG Emissions by Residential Dwellings 2015-2035

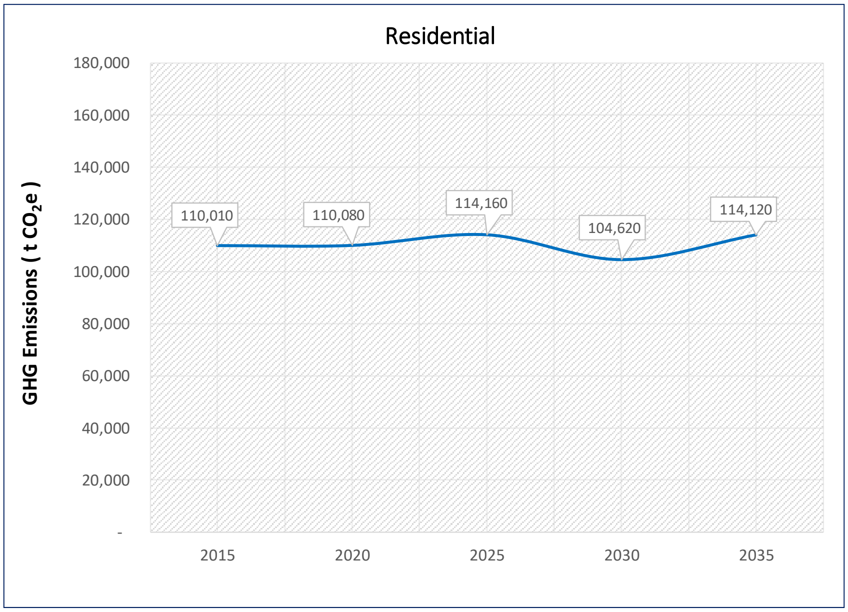
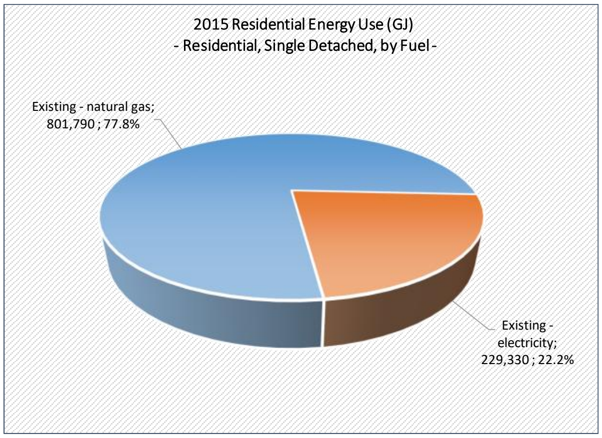


Exhibit 48: Energy Use by Single Detached Dwellings by Vintage and by Fuel in 2015 vs 2035

(a) 2015



(b) 2035

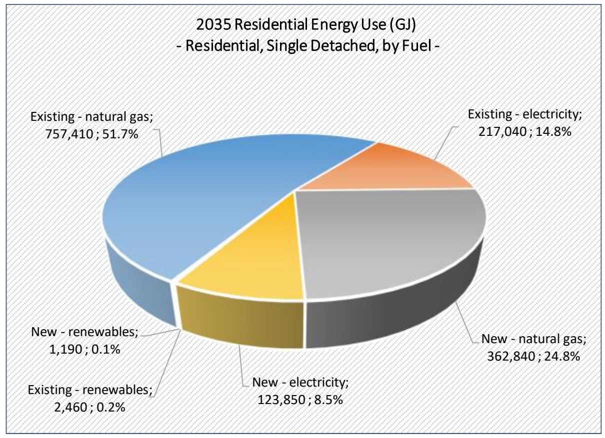
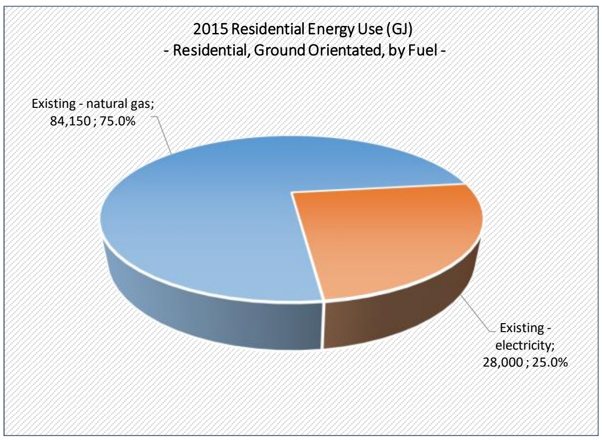


Exhibit 49: Energy Use by Ground Orientated Dwellings by Vintage and by Fuel in 2015 vs 2035

(a) 2015



(b) 2035

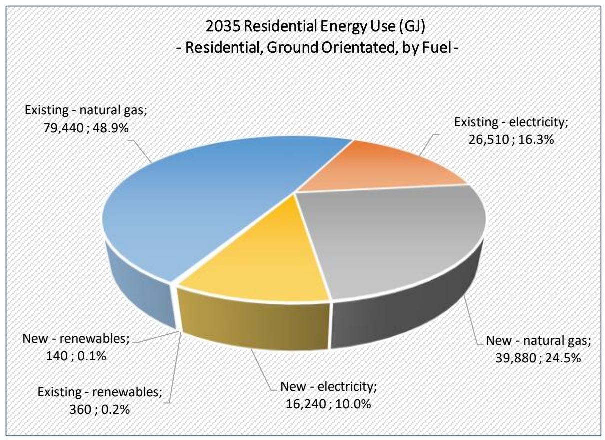
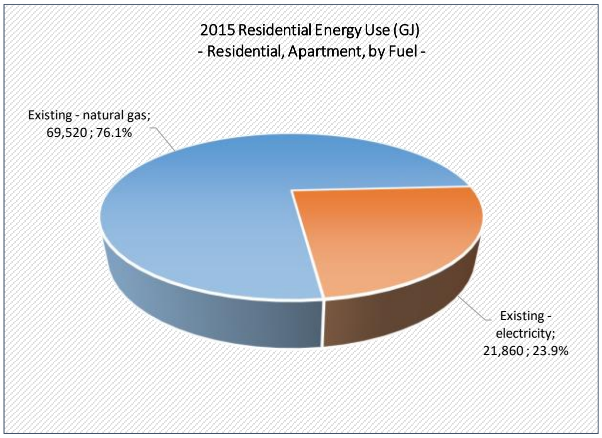


Exhibit 50: Energy Use by Apartments by Vintage and by Fuel in 2015 vs 2035

(a) 2015



(b) 2035

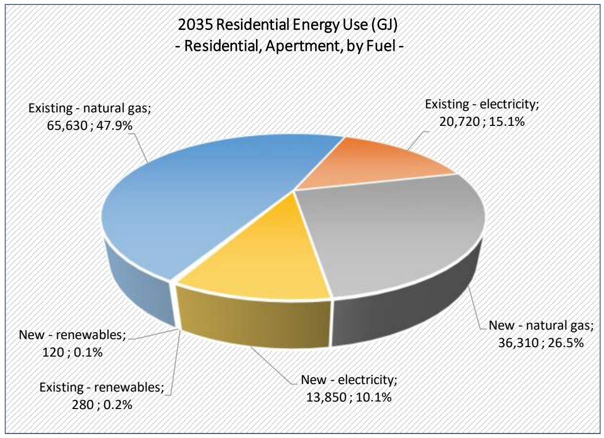
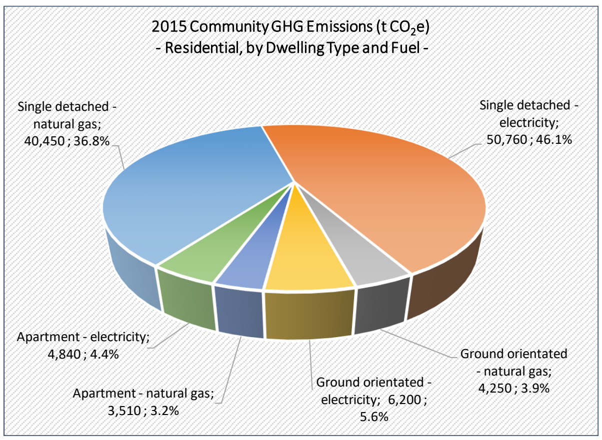
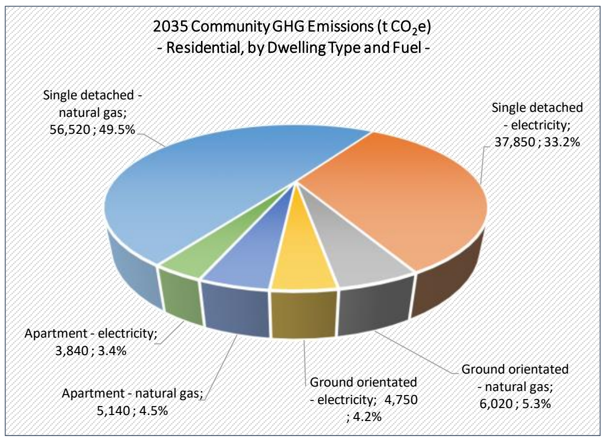


Exhibit 51: GHG Emissions by Dwelling Type and Energy Source in 2015 vs 2035

(a) 2015



(b) 2035



11 Appendix: Community Inventory: Commercial Buildings

Exhibit 52: Projection of Commercial Floorspace 2015-2035

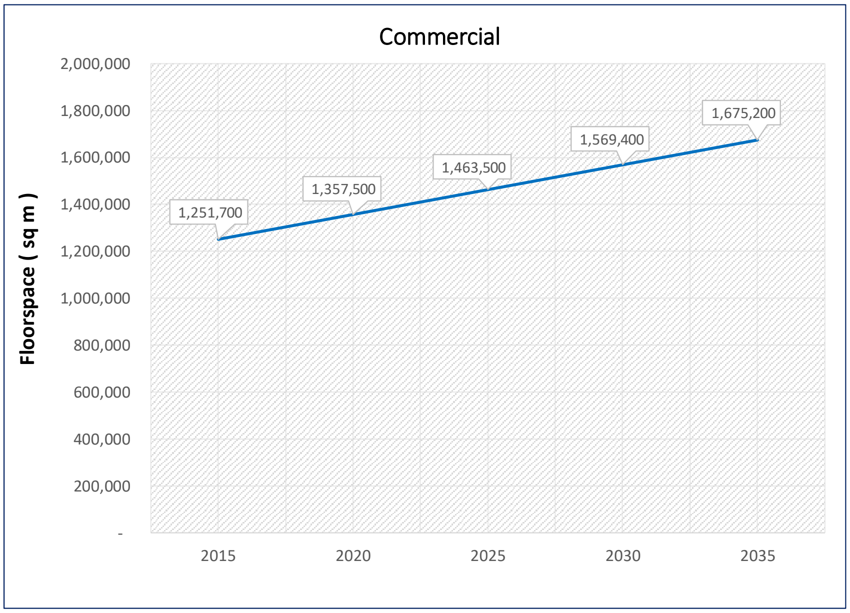


Exhibit 53: Projection of Energy Consumption by Commercial Buildings 2015-2035

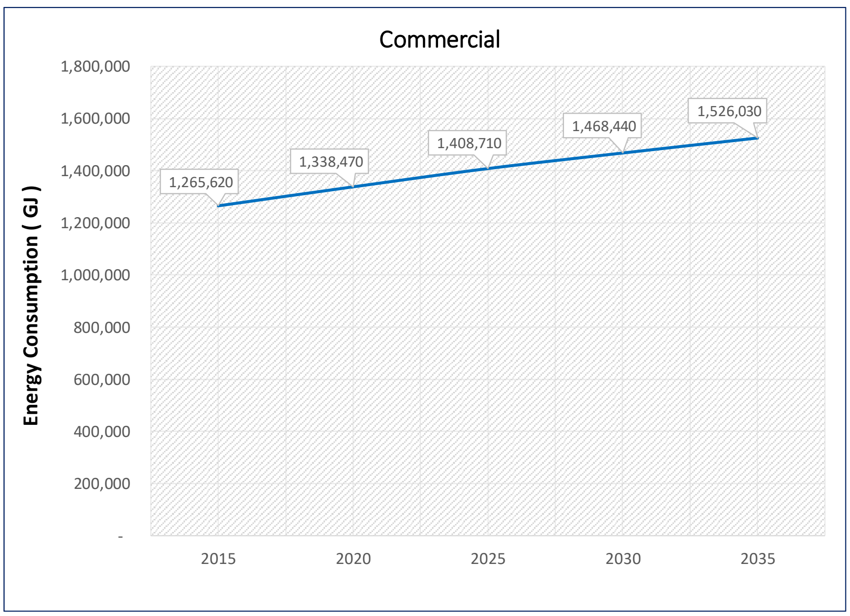


Exhibit 54: Projection of GHG Emissions by Commercial Buildings 2015-2035

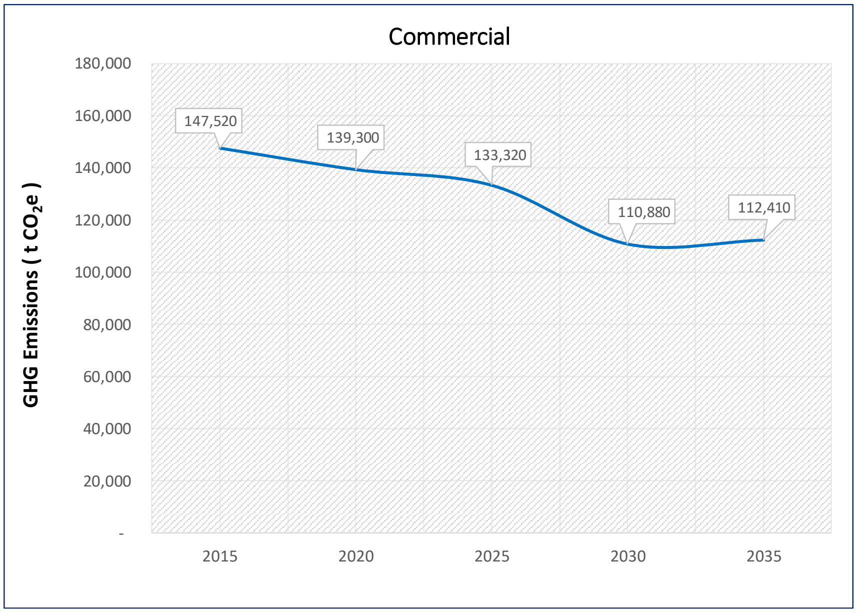
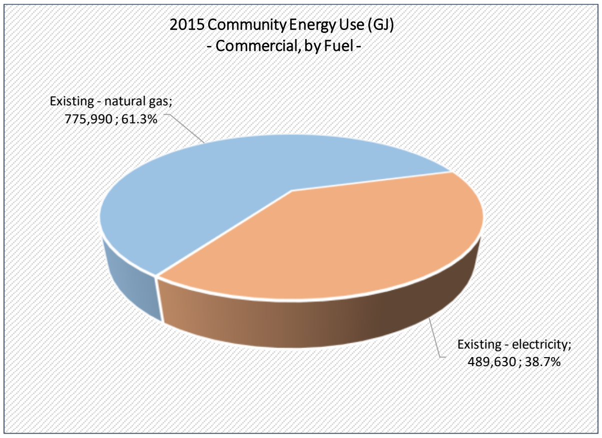


Exhibit 55: Energy Use by Commercial Buildings by Vintage and by Fuel in 2015 vs 2035

(a) 2015



(b) 2035

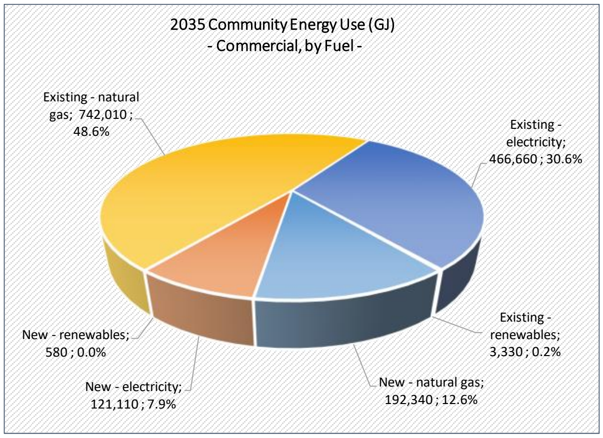
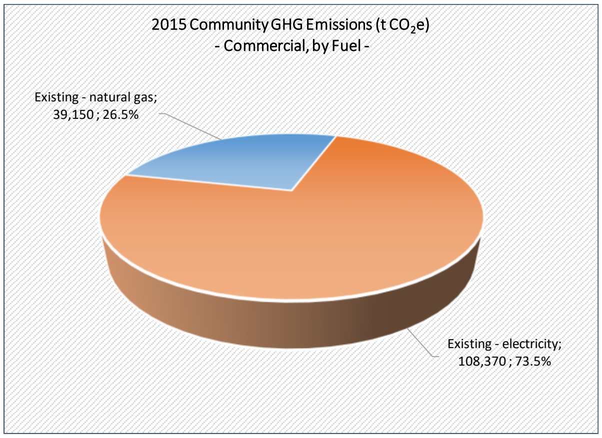
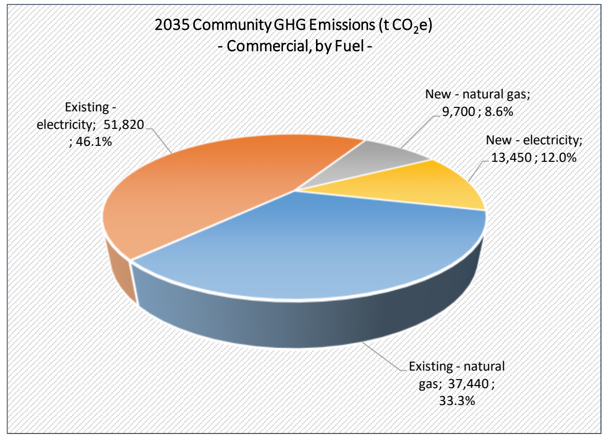


Exhibit 56: GHG Emissions by Commercial Buildings by Vintage and by Fuel in 2015 vs 2035

(a) 2015



(b) 2035



12 Appendix: Community Inventory: Industrial Buildings and Processes

Exhibit 57: Projection of Energy Consumption by Industry 2015-2035

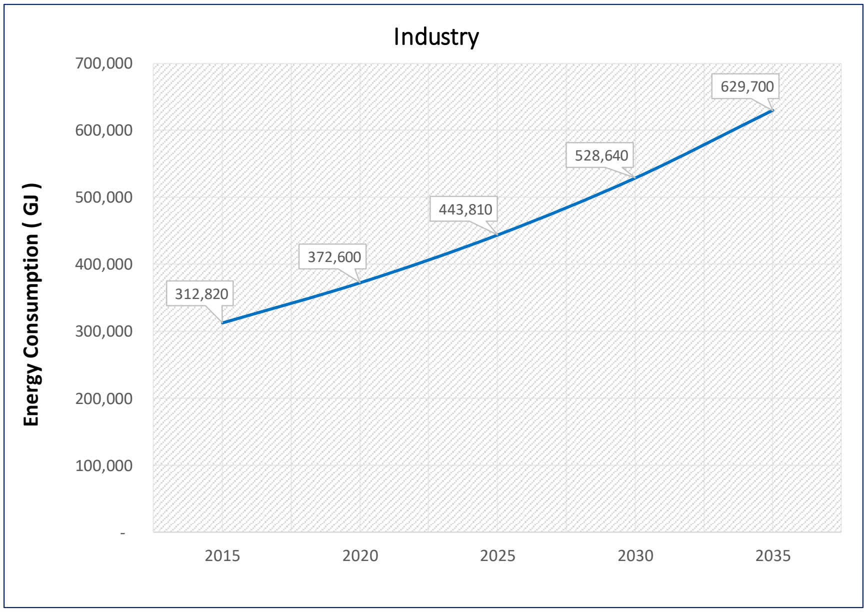


Exhibit 58: Projection of GHG Emissions by Industry 2015-2035

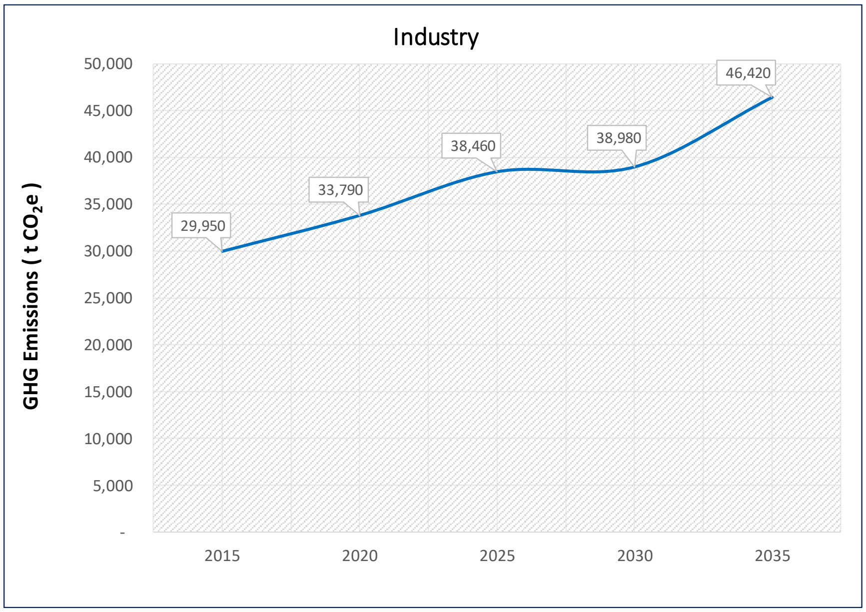
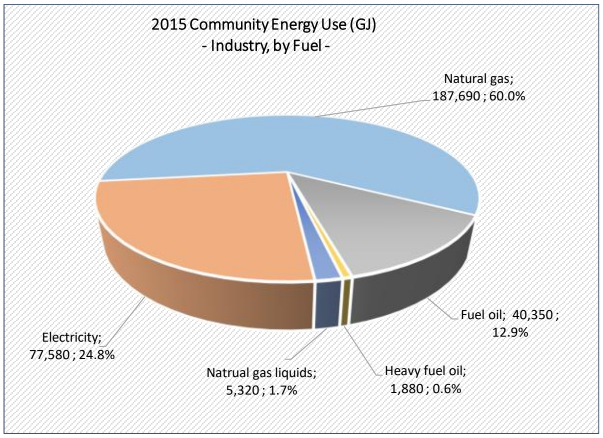


Exhibit 59: Energy Use by Industry by Fuel in 2015 vs 2035

(a) 2015



(b) 2035

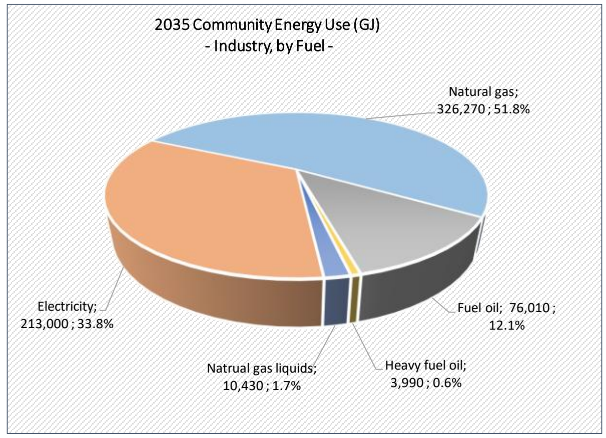
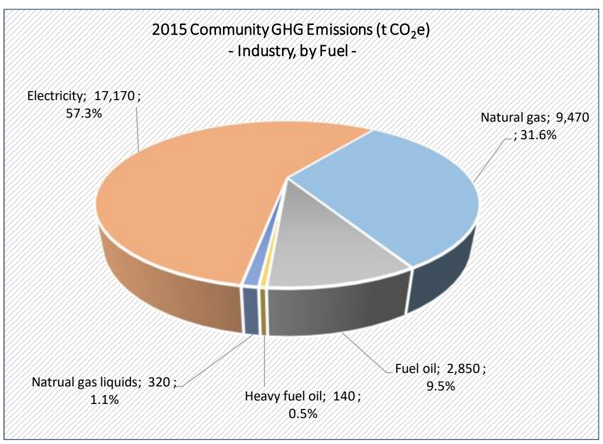
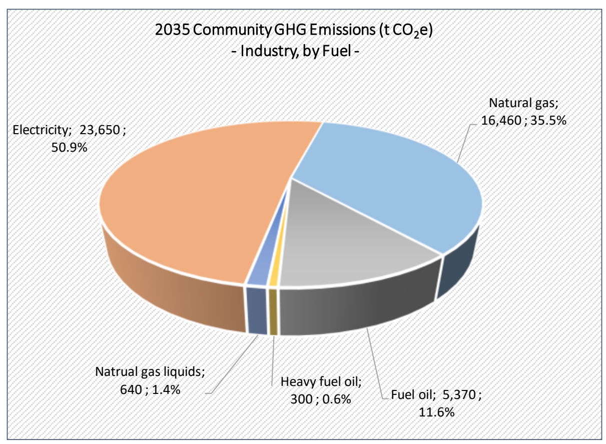


Exhibit 60: GHG Emissions by Industry by Fuel in 2015 vs 2035

(a) 2015



(b) 2035



13 Appendix: Community Inventory: Light Duty Vehicles

Exhibit 61: Projection of Vehicle Stock 2015-2035

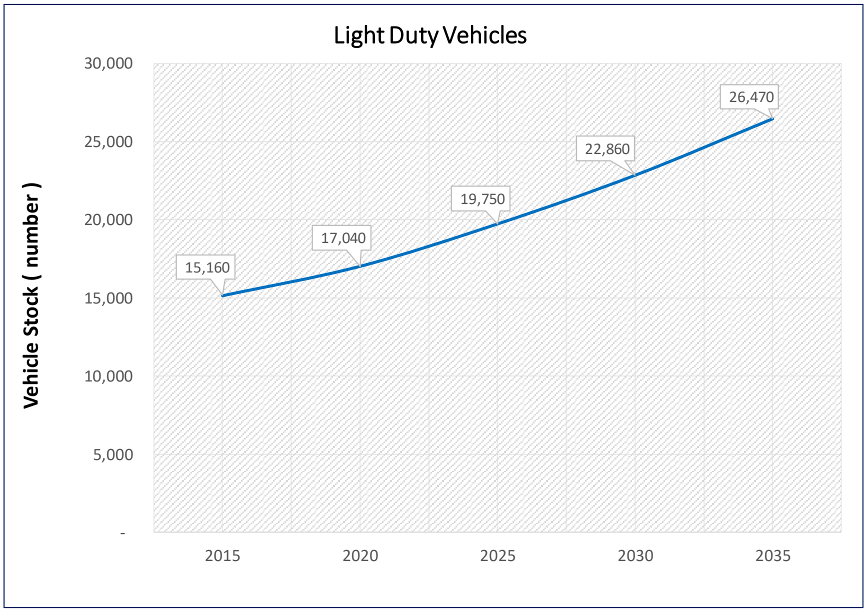


Exhibit 62: Projection of Energy Consumption 2015-2035

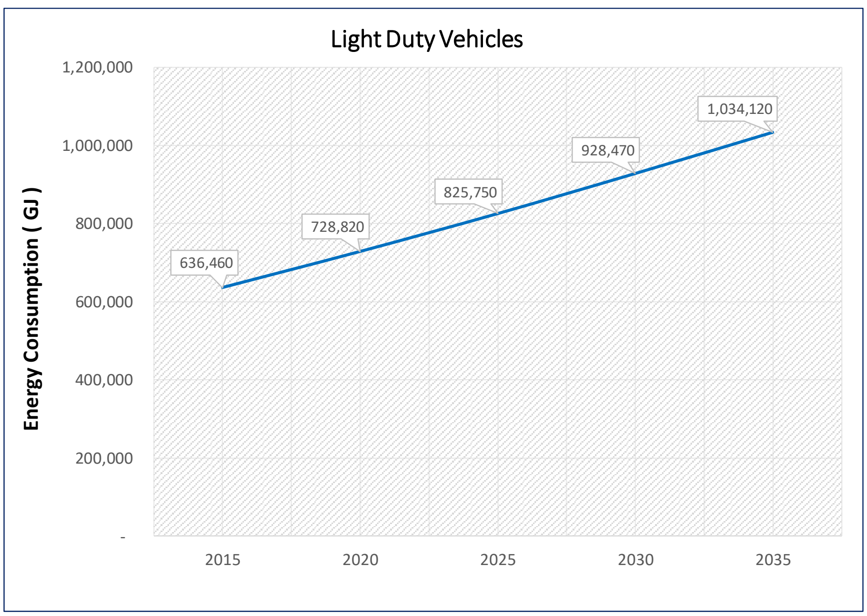


Exhibit 63: Projection of GHG Emissions 2015-2035

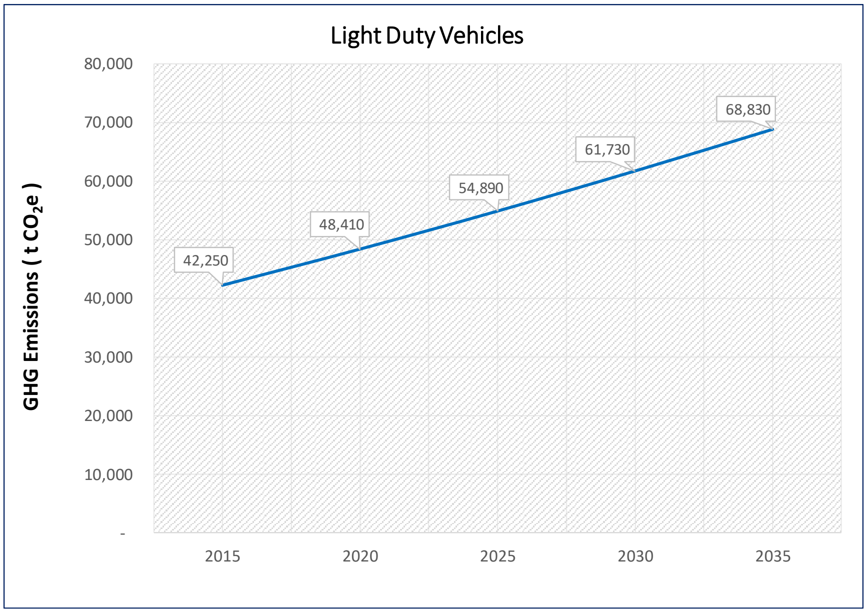
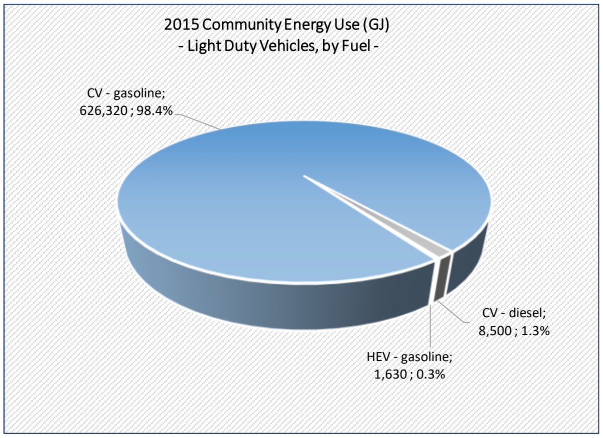


Exhibit 64: Energy Use by Vehicle Type and by Fuel in 2015 vs 2035

(a) 2015



(b) 2035

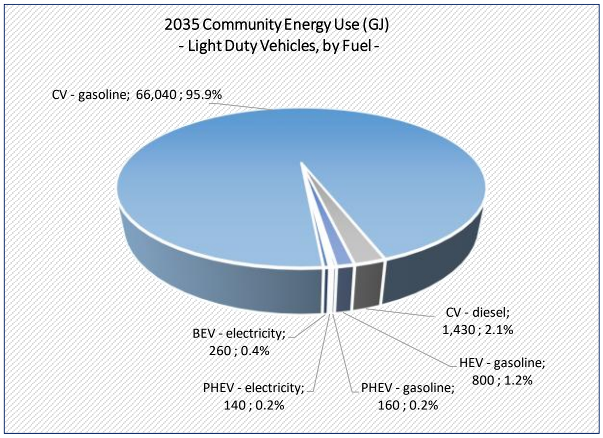
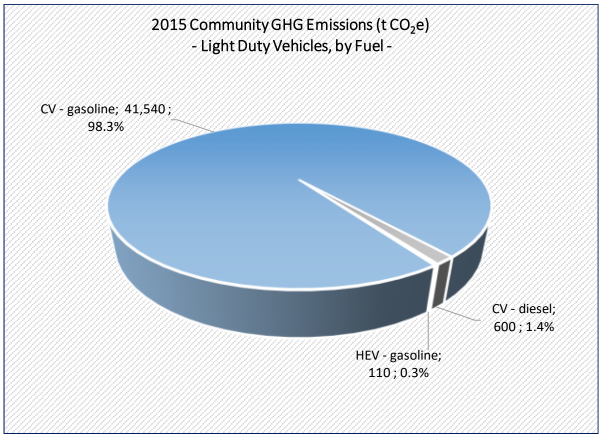
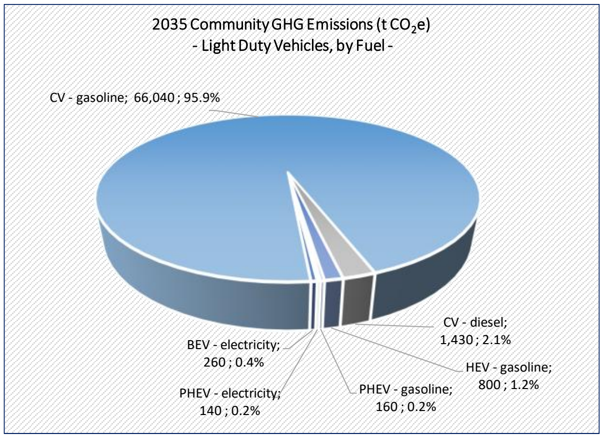


Exhibit 65: GHG Emissions by Vehicle Type and by Fuel in 2015 vs 2035

(a) 2015



(b) 2035



14 Appendix: Community Inventory: Light Duty Trucks

Exhibit 66: Projection of Vehicle Stock 2015-2035

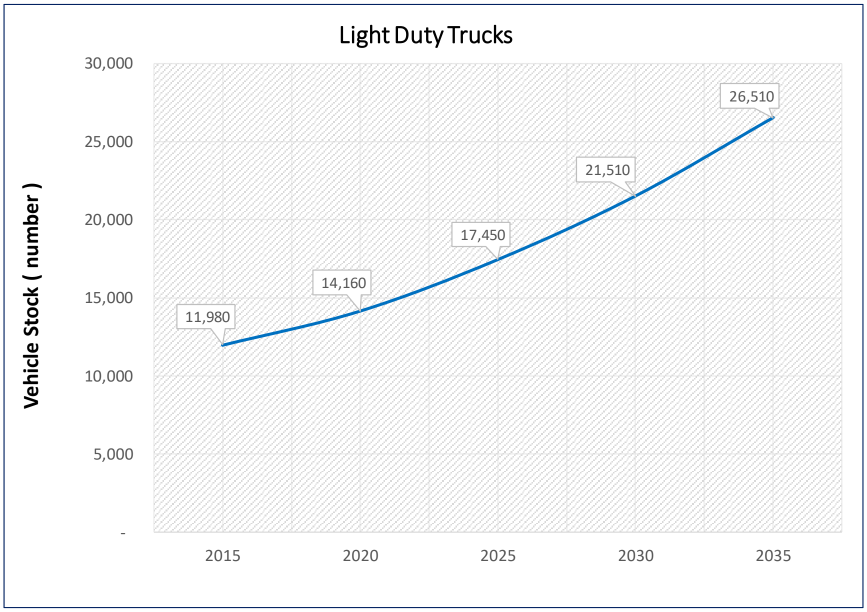


Exhibit 67: Projection of Energy Consumption 2015-2035

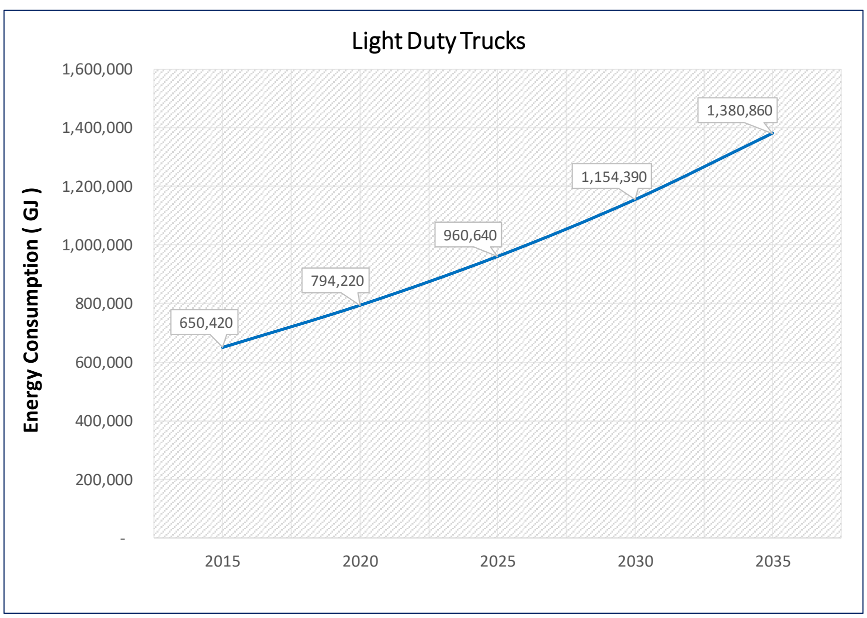


Exhibit 68: Projection of GHG Emissions 2015-2035

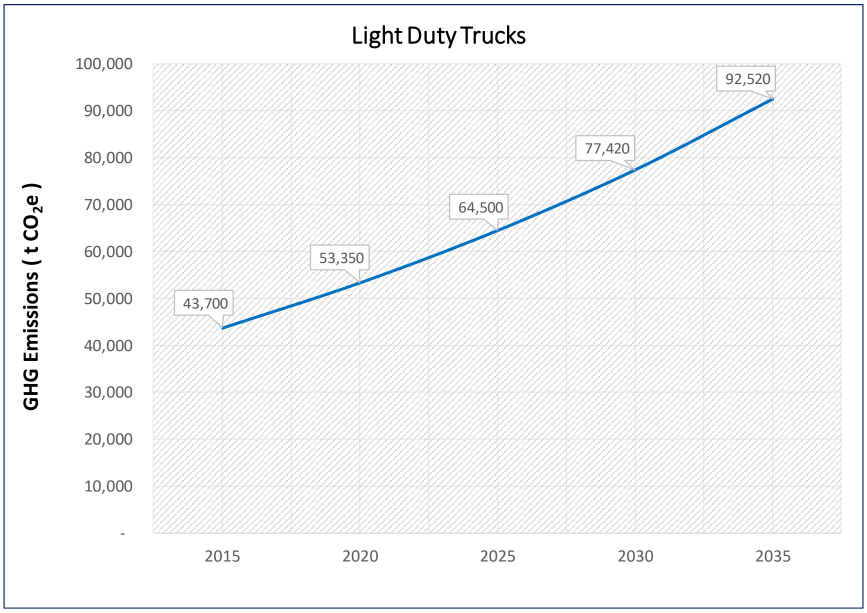
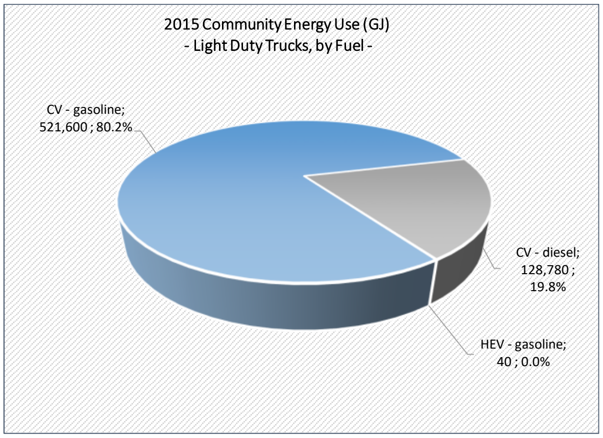


Exhibit 69: Energy Use by Vehicle Type and by Fuel in 2015 vs 2035

(a) 2015



(b) 2035

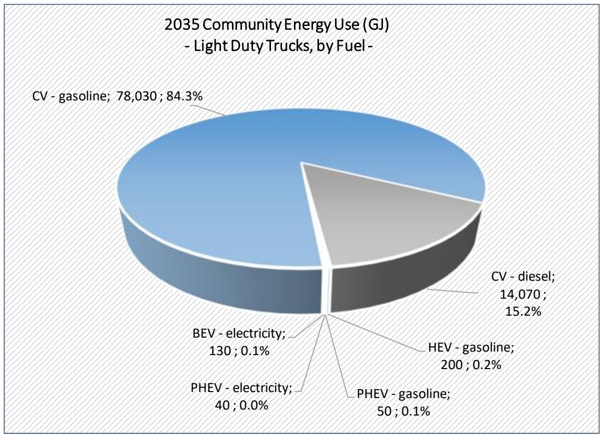
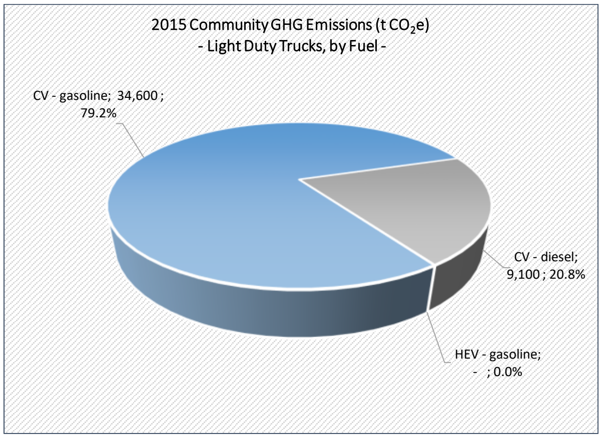
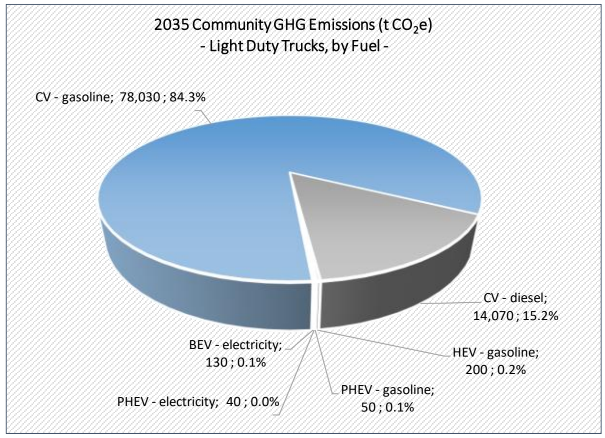


Exhibit 70: GHG Emissions by Vehicle Type and by Fuel in 2015 vs 2035

(a) 2015



(b) 2035



15 Appendix: Community Inventory: Heavy Duty Trucks

Exhibit 71: Projection of Vehicle Stock 2015-2035

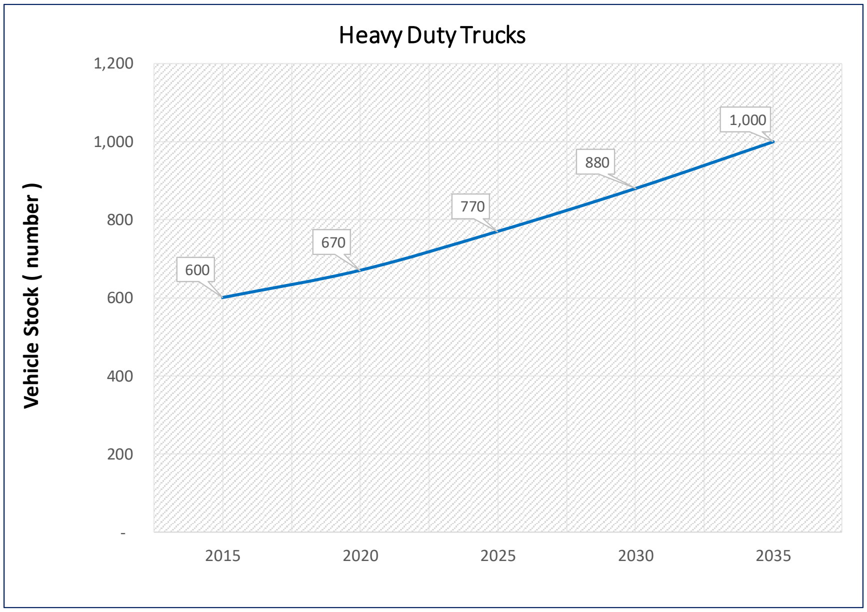


Exhibit 72: Projection of Energy Consumption 2015-2035

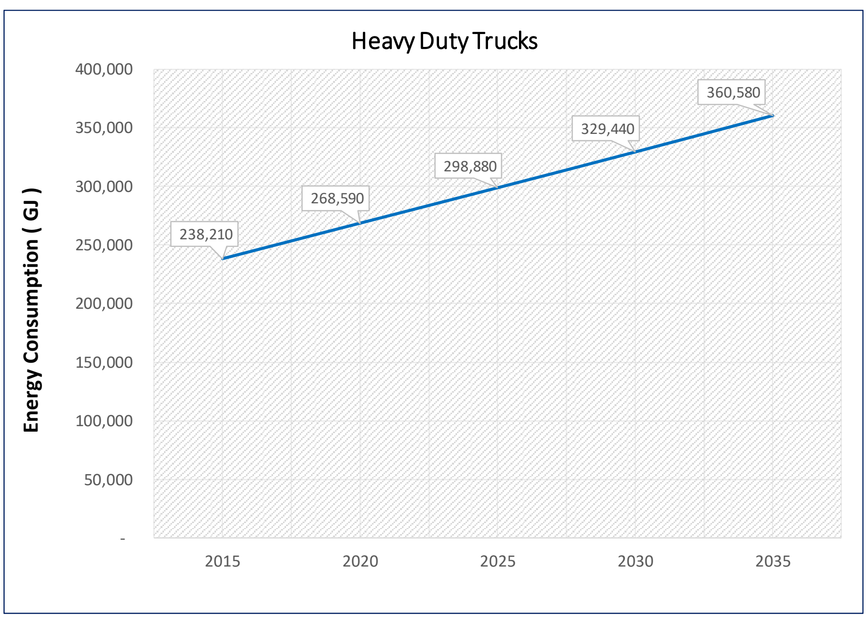


Exhibit 73: Projection of GHG Emissions 2015-2035

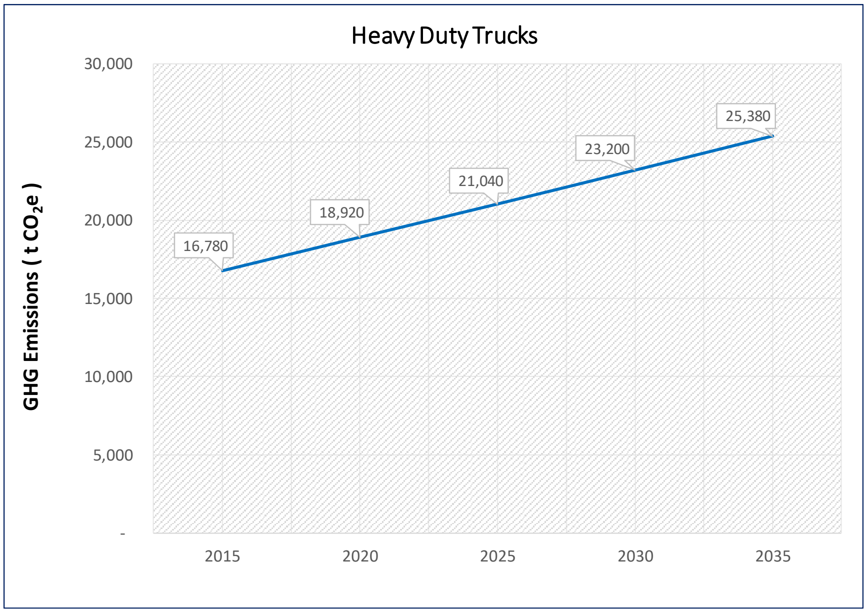
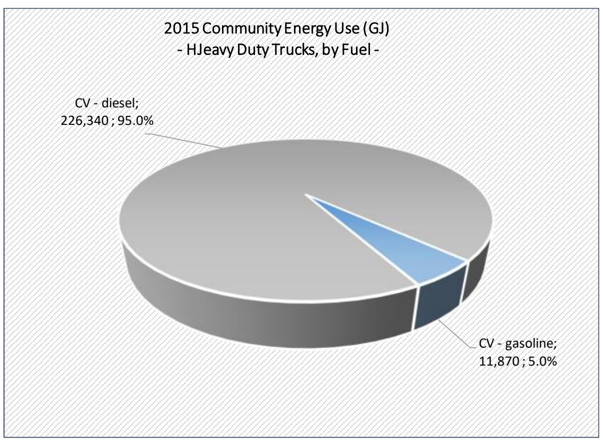


Exhibit 74: Energy Use by Vehicle Type and by Fuel in 2015 vs 2035

(a) 2015



(b) 2035

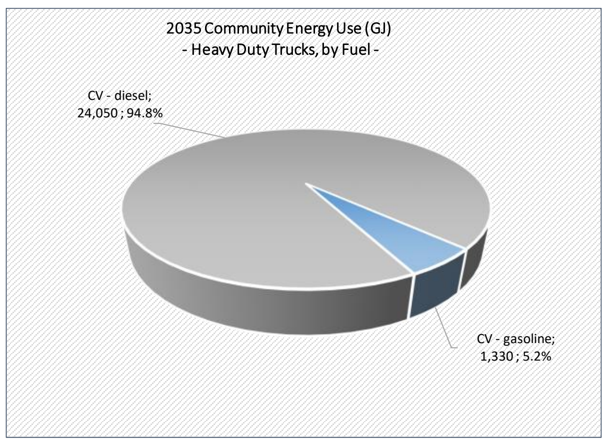
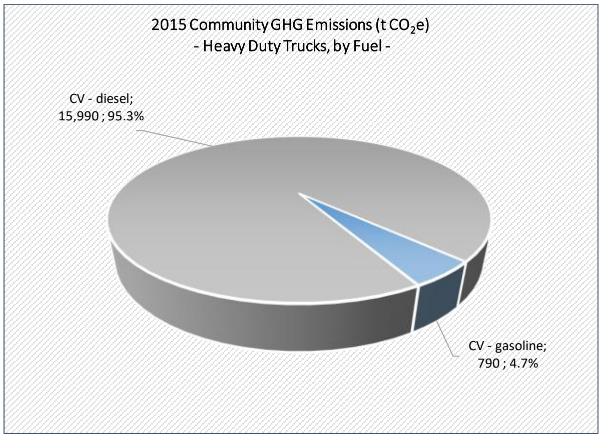
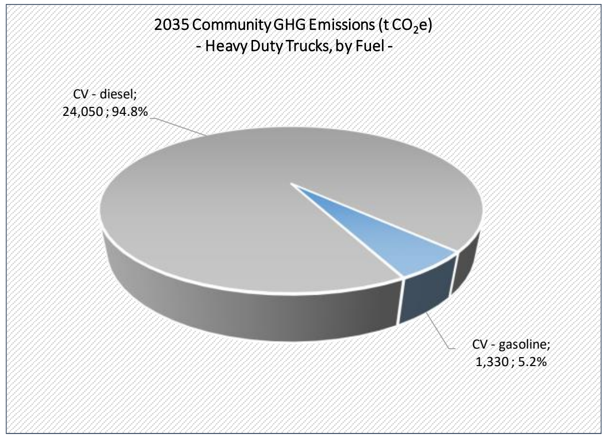


Exhibit 75: GHG Emissions by Vehicle Type and by Fuel in 2015 vs 2035

(a) 2015



(b) 2035



16 Appendix: Community Inventory: Buses

Exhibit 76: Projection of Vehicle Stock 2015-2035

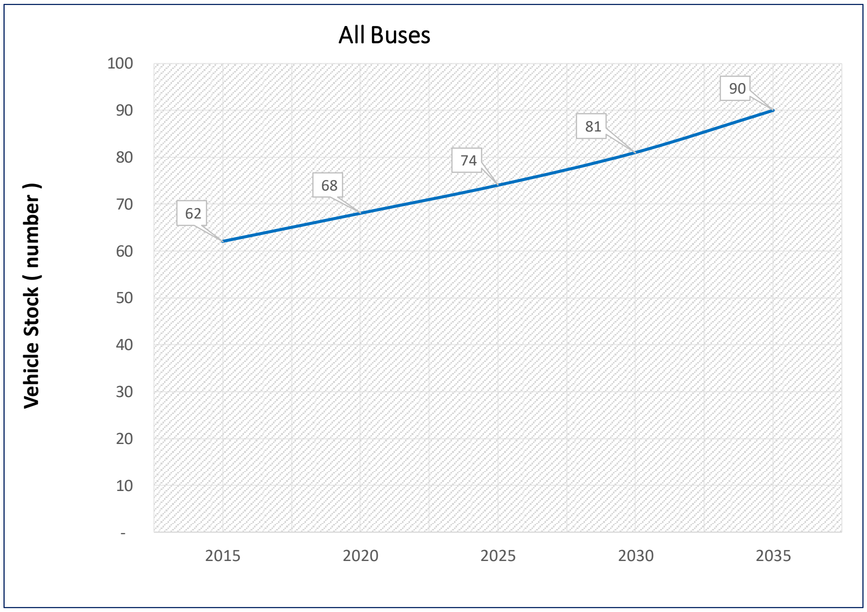


Exhibit 77: Projection of Energy Consumption 2015-2035

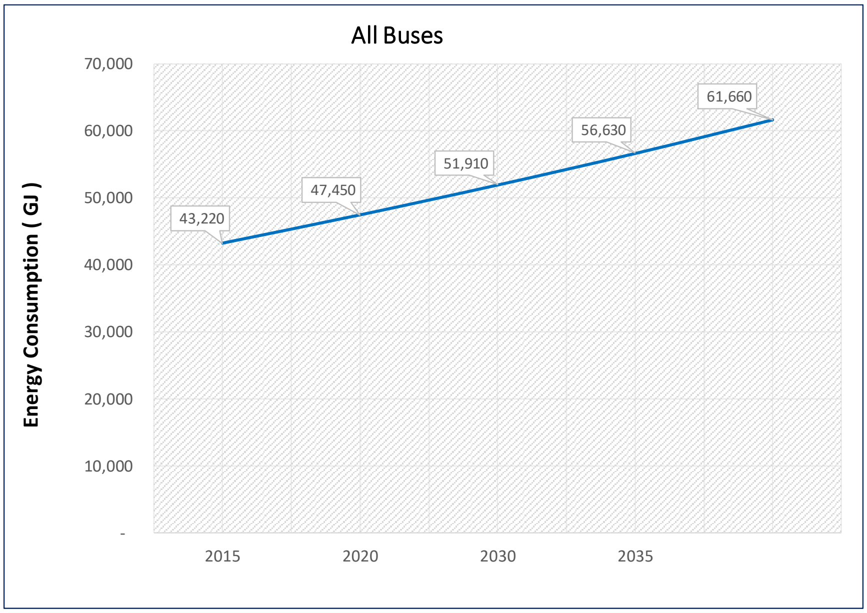


Exhibit 78: Projection of GHG Emissions 2015-2035

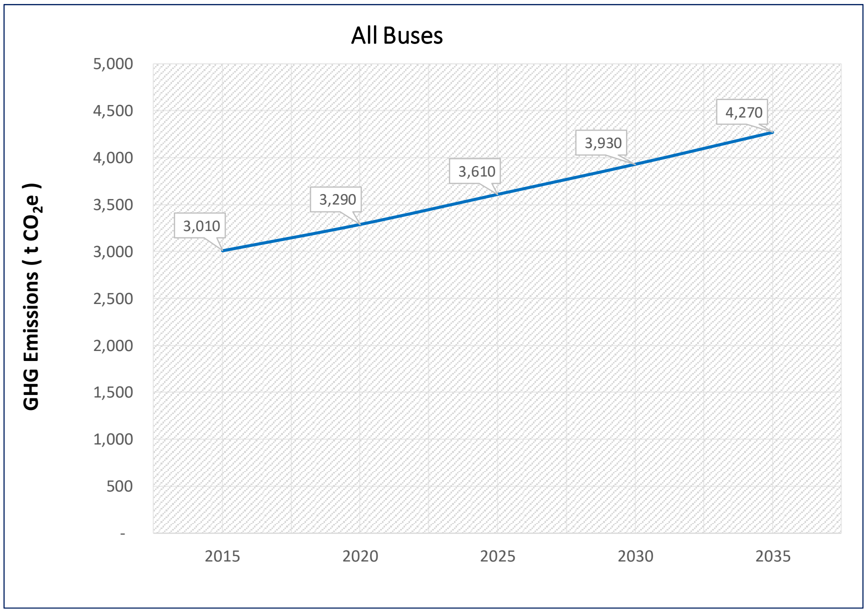
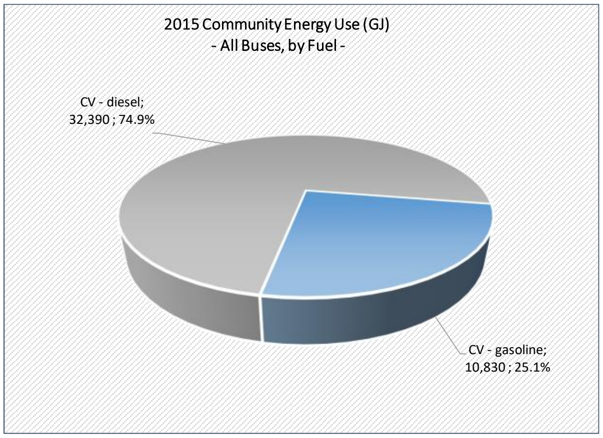


Exhibit 79: Energy Use by Vehicle Type and by Fuel in 2015 vs 2035

(a) 2015



(b) 2035

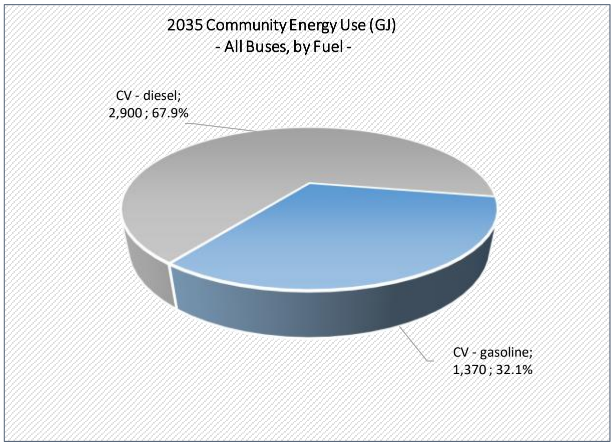
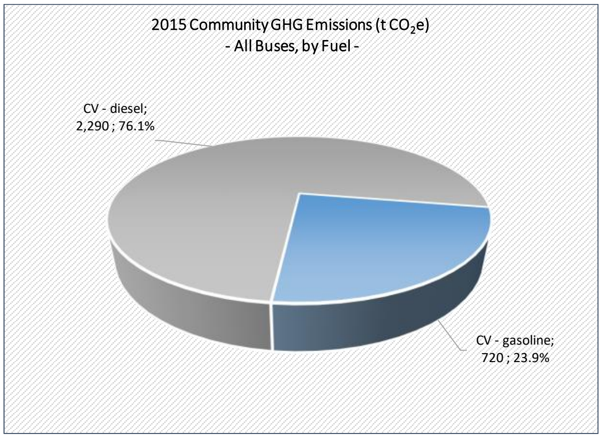
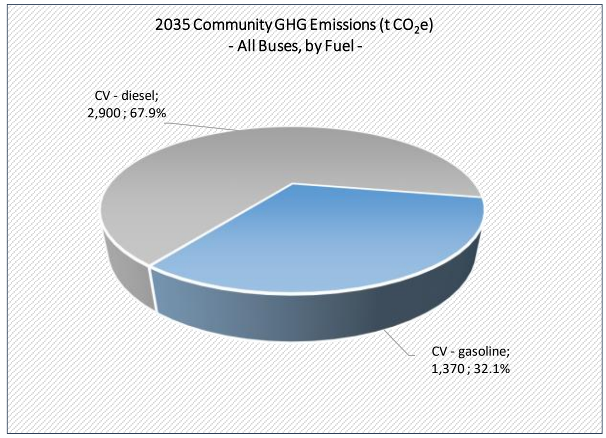


Exhibit 80: GHG Emissions by Vehicle Type and by Fuel in 2015 vs 2035

(a) 2015



(b) 2035



17 Appendix: Community Inventory: Motorcycles

Exhibit 81: Projection of Vehicle Stock 2015-2035

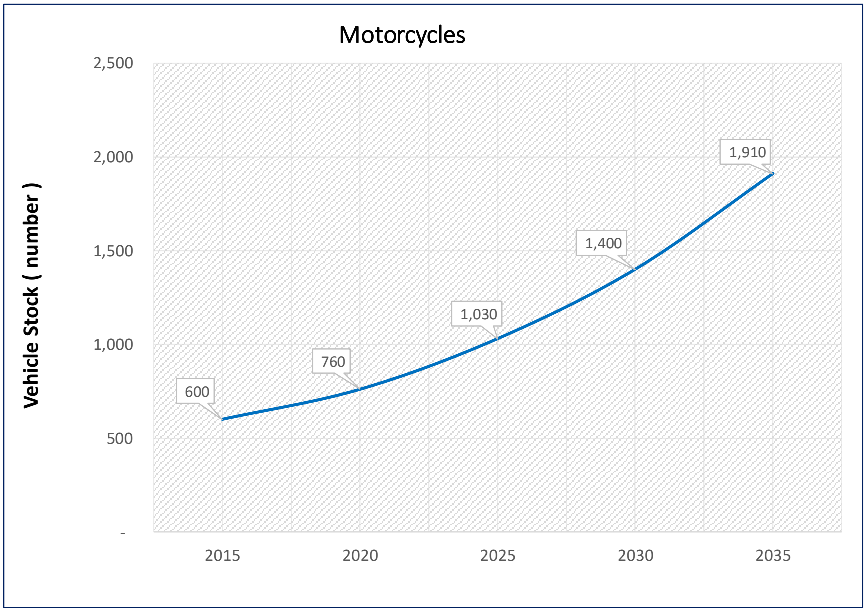


Exhibit 82: Projection of Energy Consumption 2015-2035

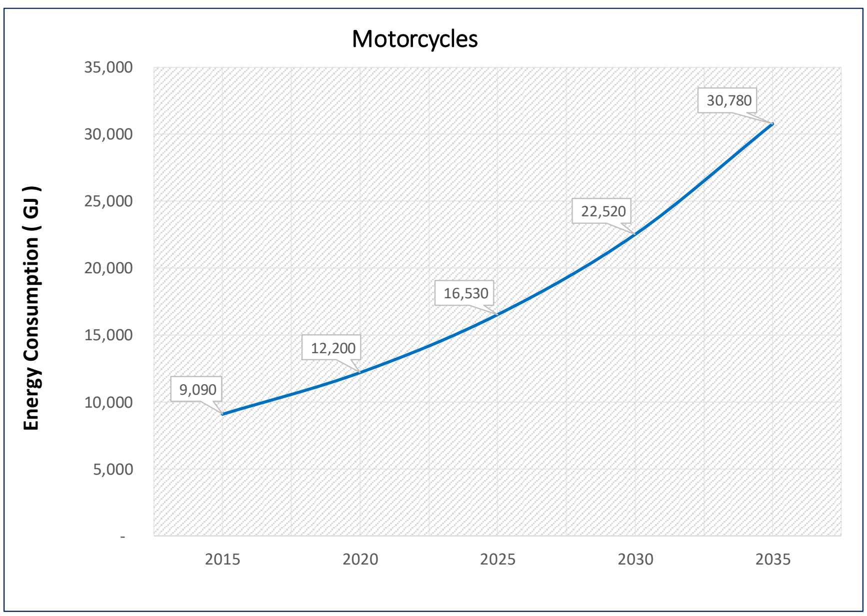
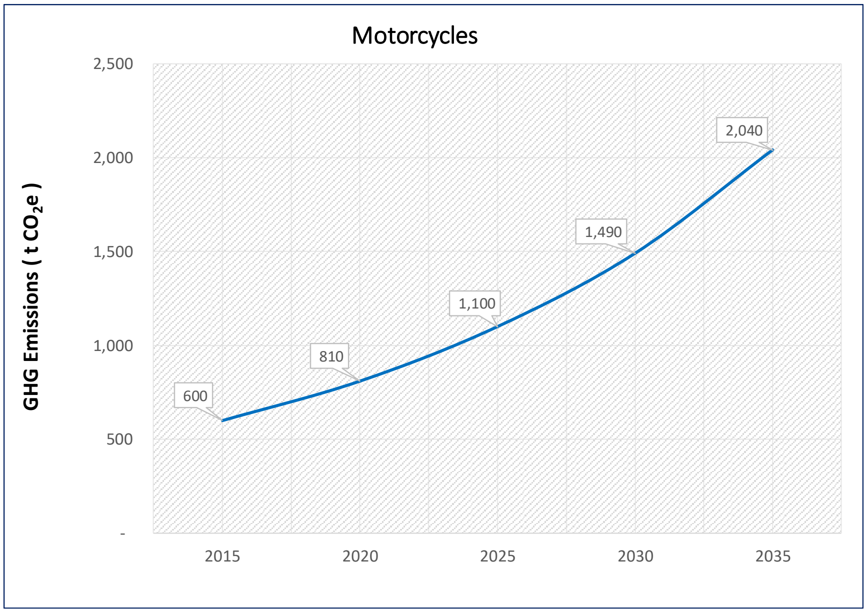


Exhibit 83: Projection of GHG Emissions 2015-2035



Note: All GHG emissions by motorcycles are sourced from the consumption of motor gasoline.

18 Appendix: Community Inventory Forecast

Exhibit 84: Projected Community GHG Emissions by Energy Source and by Source Sector: 2015-2035[15]

	2015	2020	2025	2030	2035
Industry					
Electricity	17,170	18,960	21,310	19,200	23,650
Natural gas	9,470	10,910	12,550	14,390	16,460
Other fuel	3,310	3,920	4,600	5,390	6,310
Sub-total	**29,950**	**33,790**	**38,460**	**38,980**	**46,420**
Commercial					
Electricity	97,236	86,265	77,592	52,764	51,950
Natural gas	36,370	38,483	40,509	42,200	43,814
Sub-total	**133,605**	**124,748**	**118,101**	**94,964**	**95,765**
Residential					
Electricity	48,210	52,190	57,650	61,570	67,680
Natural gas	61,800	57,890	56,510	43,050	46,440
Sub-total	**110,010**	**110,080**	**114,160**	**104,620**	**114,120**
Transportation					
Motor gasoline	77,884	92,292	108,839	127,866	149,451
Diesel fuel oil	26,373	30,239	33,832	37,242	40,528
Electricity	-	230	730	1,610	3,770
Sub-total	**104,257**	**122,762**	**143,402**	**166,717**	**193,748**
By Energy Source					
Electricity	162,616	157,645	157,282	135,144	147,050
Natural gas	107,640	107,283	109,569	99,640	106,714
Other fuel	3,310	3,920	4,600	5,390	6,310
Motor gasoline	77,884	92,292	108,839	127,866	149,451
Diesel fuel oil	26,373	30,239	33,832	37,242	40,528
Sub-total	**377,822**	**391,380**	**414,123**	**405,281**	**450,053**
Commercial Waste					
Commercial solid waste	27,621	30,839	33,923	37,316	41,048
Total Community	**405,444**	**422,218**	**448,046**	**442,597**	**491,101**
Population	29,304	33,717	38,222	43,329	49,118
Per capita emissions	13.8	12.5	11.7	10.2	10.0

Note: for industry, "other fuels" include heavy fuel oil, diesel fuel oil and natural gas liquids

[15] Does not include corporate emissions.

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