2 Setting the context

2 Introduction

2.1 THE STATE OF PLAY

Energy and climate policy in Canada is evolving rapidly. The Canadian Government launched the Pan-Canadian Framework on Climate Change. The Framework provides new targets and pathways to achieve deep emissions reductions. An announcement by the Federal Government on carbon pricing[5] will also result in an improved business case for low carbon options.

In November 2016, the federal government submitted its long-term plan[6] to the United Nations Framework Convention on Climate Change. The plan identifies building blocks of the transition including electrification of all end-use applications that currently use fossil fuels, decarbonization of the electricity generating sector and provision of new non-emitting generation sources to accommodate the demands of electrification of new sectors, major efforts on energy efficiency and demand-side management, behavioural change, and innovation and collaboration. The role of cities is emphasized.

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5 Government of Canada. (14:10:00.0). Government of Canada announces Pan-Canadian pricing on carbon pollution [News Releases]. Retrieved November 22, 2016, from http://news.gc.ca/web/article-en.do?nid=1132149

6 Government of Canada. (2016). Canada's mid-century long-term low-greenhouse gas development strategy. Retrieved from http://unfccc.int/files/focus/long-term_strategies/application/pdf/canadas_mid-century_long-term_strategy.pdf

A detailed assessment of the Ontario Climate Action Plan[7] has already been prepared for the City of Markham. Policies include a Green Bank to help finance green technologies and retrofits, policies and incentives to support the electrification of vehicles, new building codes and retrofitting programs, new requirements to consider GHG impacts of land-use planning, support for business and innovation, and mechanisms to increase carbon storage in biological systems.

The transition to a low carbon energy system deeply implicates municipalities as various recent studies have demonstrated.[8] Municipalities have direct or indirect control over 60% of greenhouse gas emissions, including GHG emissions from transportation and buildings. If municipalities are not built to stringent low carbon standards, land-use planning and infrastructure investments can lock in energy and GHG intensive patterns of development which inhibit or make cost prohibitive efficient and low carbon alternatives.[9] Alternatively, compact urban form increases the feasibility of district energy and the introduction or improvement of public transit, in addition to reducing the financial cost and the GHG impact of providing municipal services such as roads, water and wastewater conveyance, fire protection, and transportation, and even provision of home-based health care. Land use planning can therefore enable, inhibit or prevent attaining a low or zero carbon economy.

The flip side of these considerations is that there are major opportunities for low carbon energy and GHG reductions, that a municipality can directly or indirectly unlock:

- Compact land-use patterns of development can increase walkability and access to a broad suite of destinations;

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7 Government of Ontario. (2016). Ontario's five year climate change action plan 2016-2020.

8 The Global Commission on the Economy and Climate. (2014). Better growth, better climate: The new climate economy report. Retrieved from http://newclimateeconomy.report/2014/wp-content/uploads/2014/08/NCE-cities-web.pdf; Seto, K. C., Dhakal, S., Bigio, A., Blanco, H., Delgado, G. C., Dewar, D., … others. (2014). Human settlements, infrastructure and spatial planning. Retrieved from http://pure.iiasa.ac.at/11114/; International Energy Agency. (2016). Energy technology perspectives 2016: Towards sustainable urban energy systems.

9 Erickson, P., & Tempest, K. (2015). Keeping cities green: Avoiding carbon lock-in due to urban development. Stockholm Environment Institute. Retrieved from https://www.sei-international.org/mediamanager/documents/Publications/Climate/SEI-WP-2015-11-C40-Cities-carbon-lock-in.pdf

- Investments in transit can aim to significantly increase transit mode share;
- Decarbonizing the heating system will build on existing investments in district energy;
- New building codes can future-proof buildings by ensuring that all energy services can be addressed with electrical systems and that demands for energy are minimal;
- Ongoing retrofit programs can reduce thermal and electrical load requirements, while transitioning buildings to electric power systems; and
- Enhanced waste diversion systems can generate biogas for use in commercial vehicles.

2.2 THE MUNICIPAL ENERGY PLAN

The purpose of the City of Markham's Municipal Energy Plan (MEP) is to prepare a comprehensive long term energy plan that will improve energy efficiency, and reduce energy consumption and greenhouse gas emissions in established and new community areas. The MEP provides a roadmap to achieve the objective of net zero energy and emissions[10] by 2050 as outlined in the Energy & Climate priority in the Greenprint, Markham's Community Sustainability Plan. In order to identify the roadmap, the MEP explores a range of questions, including the following:

- How is energy used in the City?
- What are the factors which influence patterns of energy use?
- What are the greenhouse gas emissions associated with the use of energy?
- What are the financial implications of energy use?
- What are the opportunities for saving energy?
- What are the opportunities for reducing GHG emissions?

Cities constitute energy systems, and how they are planned, built and lived in determine the levels and patterns of

10 The MEP considers the impact on energy and emissions of pursuing net zero waste and water (included in Markham's Greenprint net zero objective), but does not include an action to specifically achieve net zero waste and water. The City is considering these targets in separate endeavours.

greenhouse gas emissions attributed to them. Figure 9 illustrates the components of a municipal energy and emissions system. The population requires buildings for housing and work; and these buildings consume energy. The spatial relationship between dwellings and places of work determines the pattern of travel and influences the modes of travel selected. The length and number of trips and the mode choice determine energy consumption for transportation.

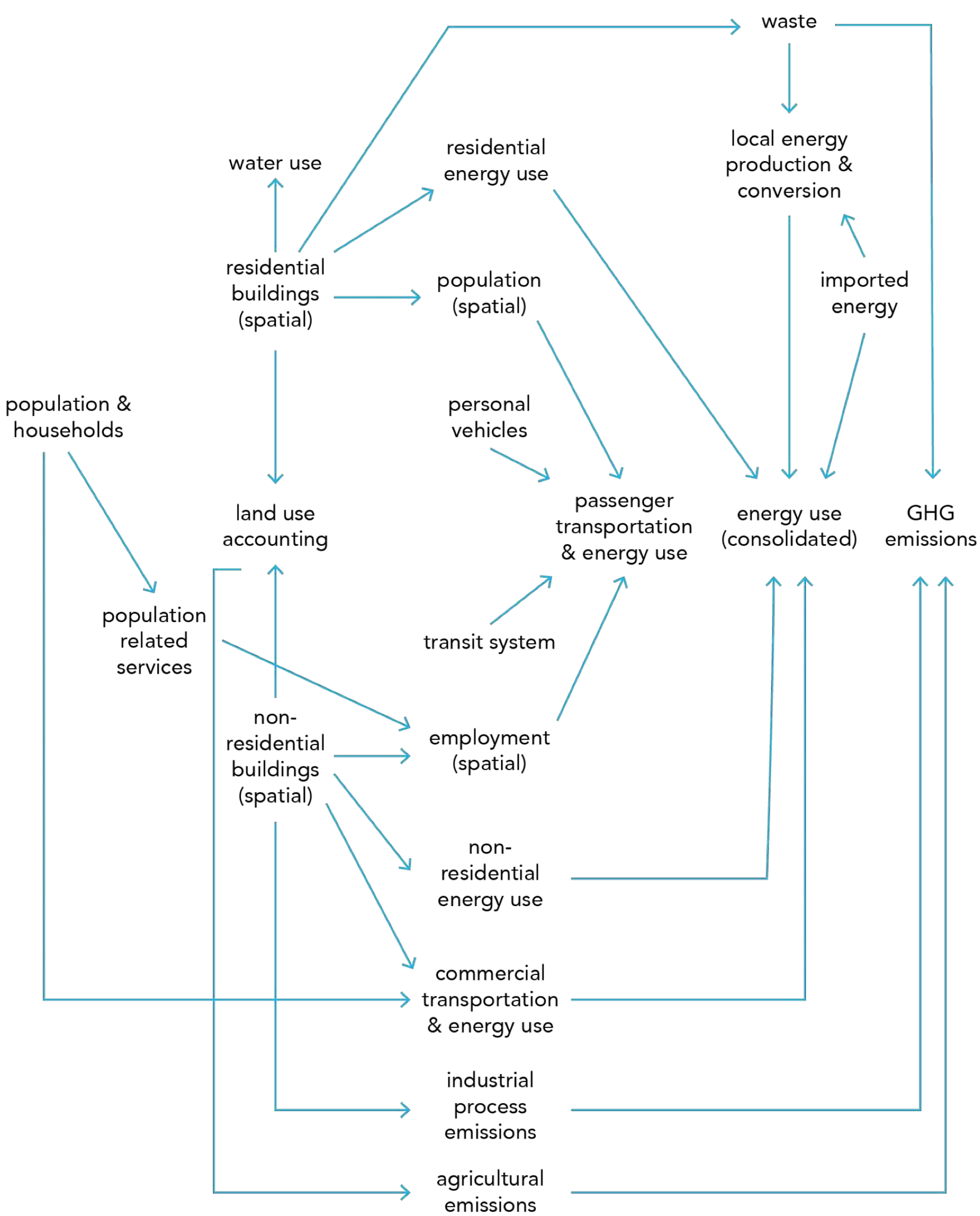


Figure 9. An illustration of municipal energy and emissions systems.

2.3 THE DEFINITION OF NET ZERO

The City of Markham's Greenprint establishes the long term goal of net zero energy and emissions by 2050. However, the MEP focuses on GHG emissions associated with energy consumption. For the purposes of Markham's MEP, the definition of net zero is as follows:

A net zero energy emissions Markham is one that has greatly reduced energy needs through efficiency gains and conservation. Annual energy needs for vehicles, thermal, and electricity are met by sustainable and non-fossil fuel sources, carbon offsets and/or carbon sequestration (where feasible within Markham), resulting in an annual net zero balance of greenhouse gas emissions.

The definition of net zero emissions includes GHG emissions associated with the consumption of energy within Markham, including emissions from buildings, transportation, and energy production activities. Emissions resulting directly from waste are excluded under this definition; but emissions resulting from the transportation of waste are included in the transportation sector.

The target of net zero, unlike that of absolute zero, allows for some GHG emissions, as long as those emissions are offset. For example, the City may consume energy at one point in time that results in GHG emissions but at other points the generation of surplus renewable energy can offset those GHG emissions, resulting in a balance of zero GHG emissions.

ABSOLUTE ZERO EMISSIONS TRAJECTORY

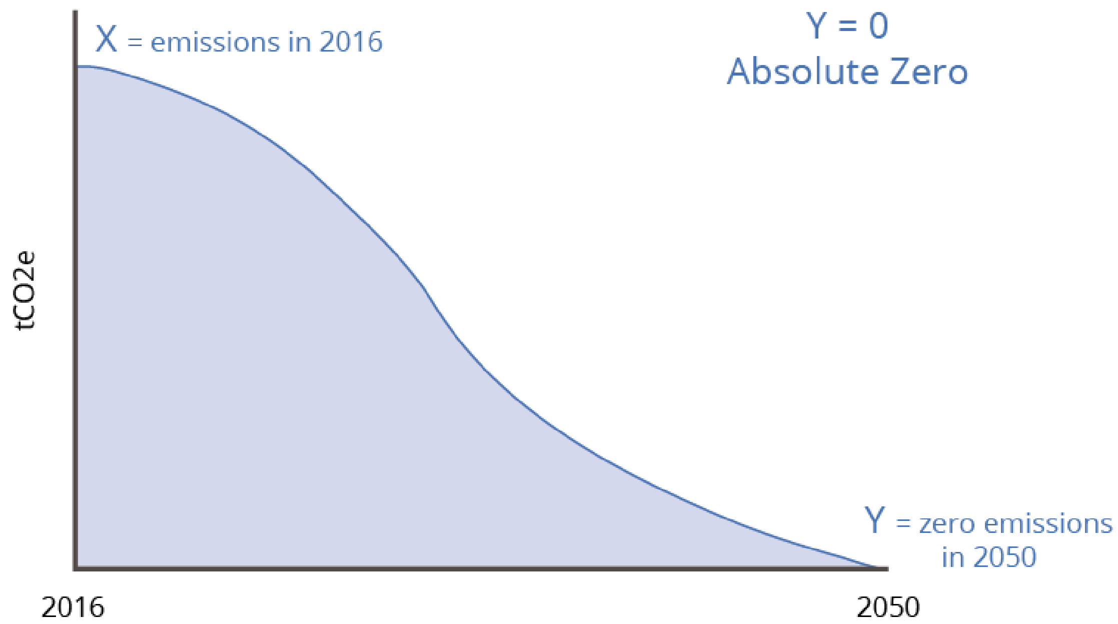


Figure 10. Sample projection of absolute zero in 2050. Achieving "absolute" zero by 2050 means that by 2050, or in the year 2050, there are zero emissions produced from any energy consuming activities. Y represents zero GHG emissions in 2050.

NET ZERO EMISSIONS TRAJECTORY

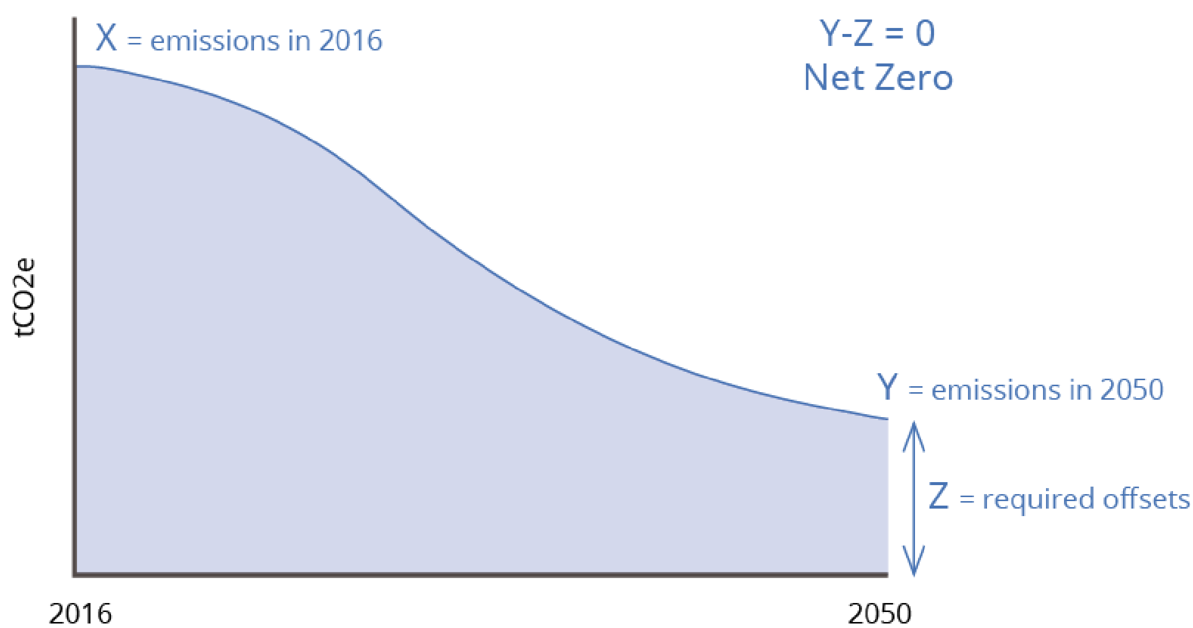


Figure 11. Sample projection of net zero using offsets in 2050. The offset (Z) is equal to the amount of GHG emissions produced in 2050 (Y), resulting in net zero emissions.

1 Decrease overall local energy consumption in all sectors

2 Switch to low carbon renewable sources of energy

3 Increase local energy generation from renewable sources.

2.4 A STRATEGY TO GET TO NET ZERO

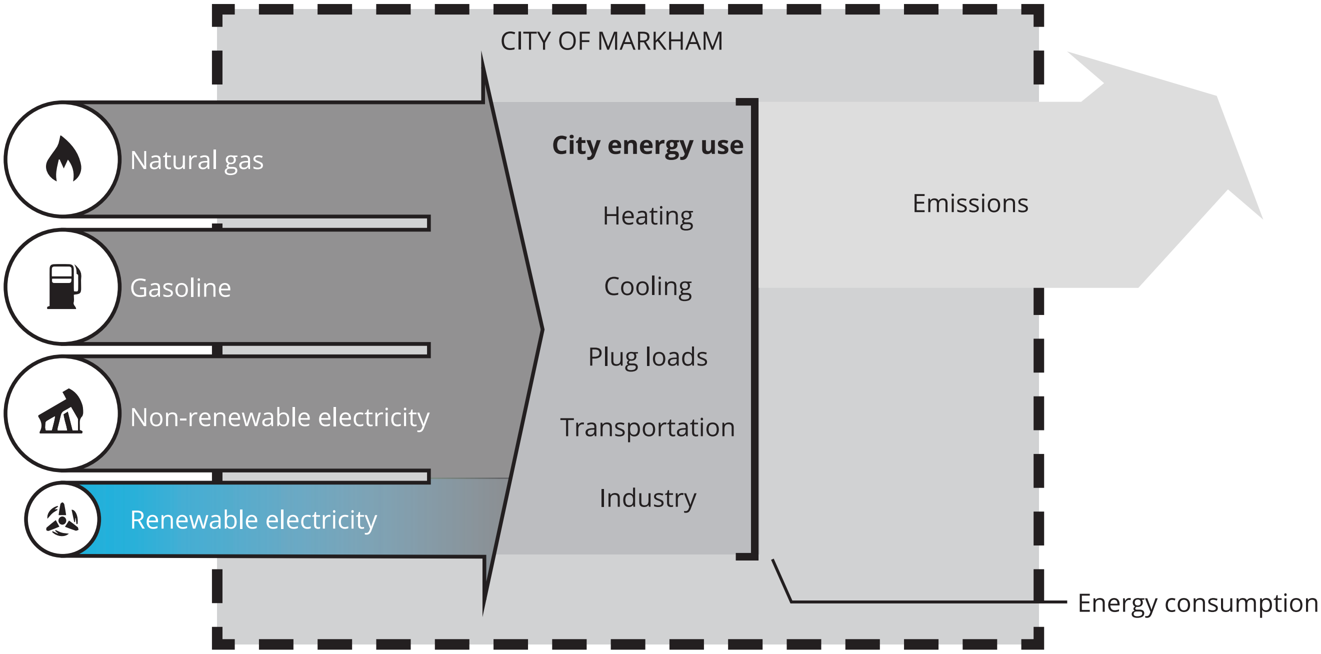
The long term vision to reach net zero by 2050 is guided by three main principles:

1. Decrease overall local energy consumption in all sectors;
2. Switch to low carbon renewable sources of energy; and,
3. Increase local energy generation from renewable sources.

These principles guide both the selection of actions and the manner in which the actions are evaluated. The first priority is to reduce energy consumption, through reductions in energy demand and improvements in the efficiency of the energy system on both the supply and demand side. The second priority is to switch from fossil-fuel-based energy sources to renewable energy. The third priority is to generate as much renewable energy as possible locally to maximize the local economic benefit and to ensure a resilient energy system. Remaining GHG emissions are then offset either by exporting renewable energy or storing GHG emissions in carbon sinks, preferably within the City boundary. These steps are further illustrated in Figure 12.

The energy system is complex and interrelated, and many of the actions serve more than one of these three principles. For example, building retrofits can reduce the amount of energy required for space heating (through envelope improvements), and improve the efficiency of the energy used in the building (through equipment upgrades). Additionally, solar photovoltaic panels could be installed on the roof, which facilitates both a switch to a source of zero carbon renewable electricity, and counts as local energy generation.

1a. CURRENT STATE (2016)



1b. NET ZERO ENERGY & EMISSIONS (2050)

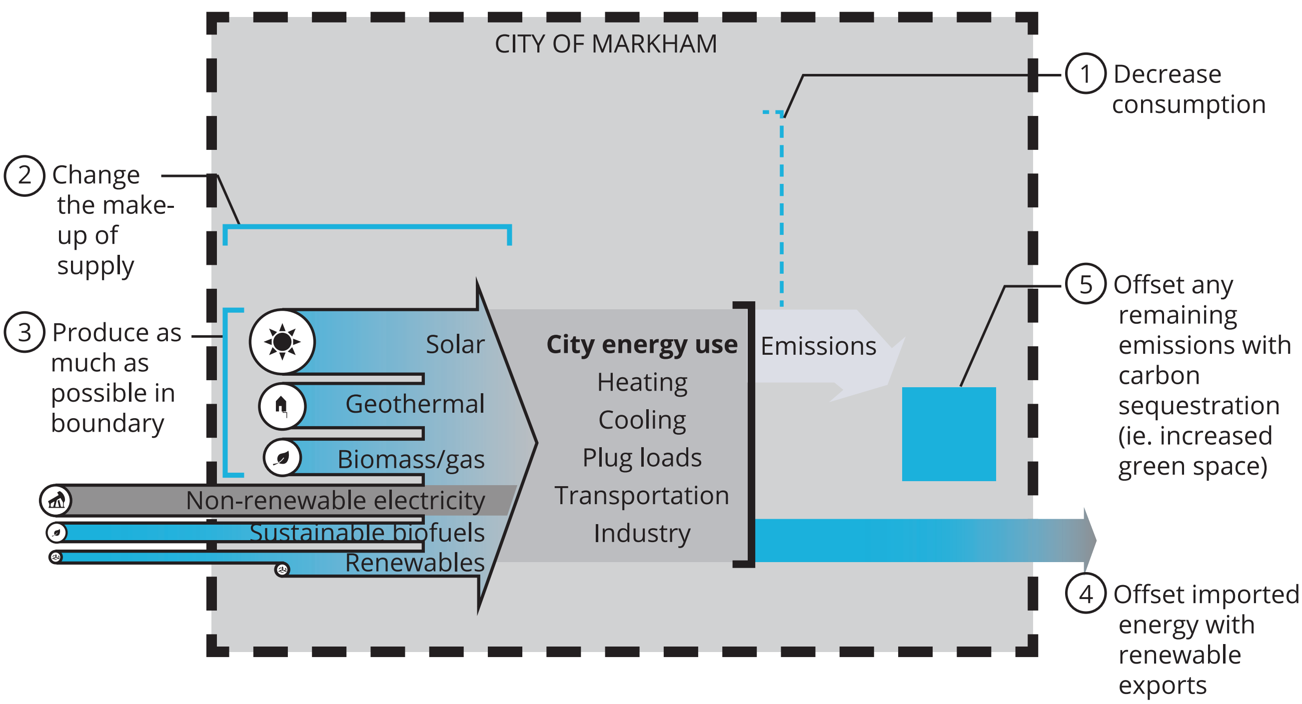


Figure 12. Illustration of the net zero principles to the City of Markham's energy system.

3 The process of developing the net zero plan

The MEP included three primary stages of activities, depicted in Figure 13.

Figure 13. Process diagram.

STAGE 1: CURRENT CONDITIONS

A **document review/situational analysis** was undertaken to understand the current context for energy and emissions in Markham. This included: a review of municipal, regional, provincial and federal policy on municipal energy and emissions; projected growth and demographic trends in various sectors; and, review of all plans, policies, programs, targets, actions, and initiatives currently planned, approved, funded and/or underway at all levels of government such that they could be incorporated into the BAU assumptions (Appendix 2).

After a process of **data collection**, **calibration** and analysis, a **baseline energy and emissions inventory** for the City for the year 2011 was completed.

Informed by the review/situational analysis and the baseline inventory, a **business-as-usual (BAU) scenario** was developed for the period from 2012 to 2050 to illustrate energy use and greenhouse gas emissions for the City of Markham, if no additional policies, actions or strategies are implemented (beyond those assumed in the BAU).

STAGE 2: IDENTIFYING ACTIONS

The next stage involved the development of an **actions matrix**, a catalogue of actions based on research of best practices of municipalities to reduce energy consumption and greenhouse gas emissions. The matrix was reviewed with City staff and additional refinement and analysis was undertaken to develop a list of actions relevant to the context of Markham. This process was informed by the results of the BAU analysis, which provided insight on the major drivers of emissions in the City and therefore helped to identify areas with emissions reduction potential.

Modelling assumptions and parameters were developed for each action. These assumptions were derived from a detailed review of academic literature, and the application or modelling of the action in another city. Initially, assumptions for one low carbon scenario were developed – the moderate scenario – and after analysis of the initial results, a more ambitious low carbon scenario was developed.

Both the actions and the assumptions will evolve as the plan is implemented and will need to be revisited periodically, as discussed in Chapter 15 Monitoring and evaluation.

STAGE 3: EVALUATING LOW CARBON FUTURES

Stage 3 involved the **modelling and testing of the actions** to develop an integrated scenario. In total, two scenarios were developed and modelled for the period of 2016[11] to 2050; however, further reductions in the order of 0.16 $MtCO_2e$ are needed to meet the net zero objective. A discussion on how this may be achieved is included in Section 5.1.

The types of actions are the same for both scenarios; the only differences are in the assumptions associated with the rate of application or the level of ambition for certain actions.

11 The model is calibrated with a 2011 baseline year; the BAU scenario was developed for the period 2012–2050, using observed data to calibrate to the year 2015. The LC scenarios, which explore the impact on future unobserved years, start in 2016.

3.1 ENGAGING STAKEHOLDERS

A Stakeholder Working Group (SWG) was established by the City of Markham to provide recommendations and feedback towards the development of Markham's Municipal Energy Plan through:

- Identifying energy opportunities and solutions to increase local energy production and conservation
- Identifying synergies between industry stakeholders to implement MEP recommendations and actions
- Providing input on MEP development and engage residents and the community

The SWG members demonstrate either energy industry knowledge, an interest in the energy industry, and/or are residents in the City. SWG members include senior staff from Alectra Utilities, Enbridge Gas Distribution, York Region/York Region Transit, local businesses and organizations, residents, internal staff, developers, Toronto & Region Conservation (TRCA), school boards, Independent Electricity System Operator (IESO), Markham District Energy, and others.

The SWG were engaged from Stages 1 through 3 noted on the previous pages, providing input, feedback, and recommendations to inform the BAU and low carbon scenarios.

A NOTE ABOUT MODELLING

The relationship between land-use planning, the form of the built environment, transportation systems, energy consumption and GHG emissions is complex and varies from one municipality to the next. While there are common themes and specific actions that likely make sense in every context, in order to relate potential outcomes of actions to targets and policies—and to understand the financial implications—a model is generally required.

A model is a conceptual abstraction of an existing or proposed real system. It captures characteristics of interest, consisting at its essence of inputs, calculations and outputs. Models are used to explore the results of scenarios and to evaluate the impacts of actions. Models, do not however, make predictions, as the future is inherently uncertain. They do, however, provide important insight on the implications of decision and investments.

CityInSight, an integrated energy, emissions and finance model was used for the City of Markham's MEP. CityInSight was developed by SSG and whatIf? Technologies and is a stocks and flows model which incorporates the accounting framework of the Global Protocol for City-Scale GHG Emissions Inventories.

Table 5. Characteristics of CityInSight.

CHARACTERISTIC	DESCRIPTION
INTEGRATED	Designed to account for and to model all sectors that relate to energy and emissions at a city scale while describing the relationships between sectors.
STOCKS AND FLOWS	For any given year various factors shape this picture of energy and emissions flows, including: the population and the energy services it requires; commercial floorspace; energy production and trade; the deployed technologies which deliver energy services (service technologies); and the deployed technologies which transform energy sources to currencies (harvesting technologies). The model makes an explicit mathematical relationship between these factors – some contextual and some part of the energy consuming or producing infrastructure – and the energy flow picture. Some factors are modelled as stocks – counts of similar things, classified by various properties. For example, population is modelled as a stock of people classified by age and gender. Population change over time is projected by accounting for: the natural aging process, inflows (births, immigration) and outflows (deaths, emigration). The fleet of personal use vehicles, an example of a service technology, is modelled as a stock of vehicles classified by size, engine type and model year with a similarly classified fuel consumption intensity. As with population, projecting change in the vehicle stock involves aging vehicles and accounting for major inflows (new vehicle sales) and major outflows (vehicle discards). This stock-turnover approach is applied to other service technologies (e.g. furnaces, water heaters) and also harvesting technologies (e.g. electricity generating capacity).
SCENARIO-BASED	Once calibrated, CityInSight enables the creation of scenarios to explore different possible futures. Each scenario can consist of either one or a combination of policies, actions and strategies.
SPATIAL	The configuration of the built environment determines the ability of people to walk and cycle, accessibility to transit, feasibility of district energy and other aspects. CityInSight therefore includes a full spatial dimension that can include as many zones as are deemed appropriate. The spatial component to the model can be integrated with City GIS systems, land-use projections and transportation modelling.
ACCOUNTING FRAMEWORK	CityInSight is designed according to the accounting framework of the GHGProtocol for Cities, the international standard for emissions inventories for cities.

CHARACTERISTIC	DESCRIPTION
ECONOMIC IMPACTS	The model incorporates a full financial analysis of costs related to energy (expenditures on energy) and emissions (carbon pricing, social cost of carbon), as well as operating and capital costs for policies, strategies and actions. The model generates marginal abatement curves to illustrate the cost and/or savings of policies, strategies and actions. CityInSight also accounts for the impact of policies, strategies and actions on household incomes and public and business expenditures.
OPEN SOURCE	CityInSight is open source and can be used on an ongoing basis without additional costs such as licensing fees or otherwise.
VISUALIZATIONS	An interactive visualization platform can be used to enable staff and other stakeholders to explore the results of the scenarios.

4 What are the current conditions?

The first step in identifying a low carbon pathway for a city is to specify the baseline year, a key reference point against which future reductions are measured.

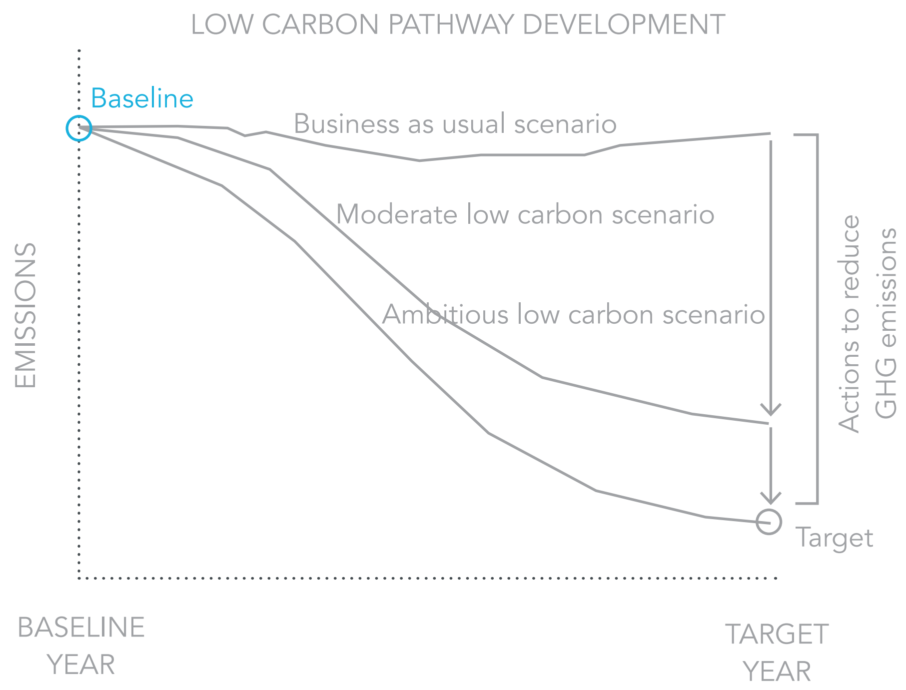


Figure 14. The development of low carbon scenarios, represented visually.

4.1 2011: THE BASELINE YEAR

The year 2011 is used as the baseline year within the model. The modelling approach requires the calibration of a base year system state (initial conditions) using as much observed data as possible in order to develop an internally consistent snapshot of the city. The census is a key source of data and at the time of modelling, the last census year for which data was available was 2011. Additionally, the Transportation Tomorrow Survey and the long range transportation modelling conducted by the Region of York follow the census year 2011. As a result of these factors, 2011 represents the most recent year for which significant data sources overlap and is therefore the best choice for model calibration and baseline.

4.2 THE GEOGRAPHY OF MARKHAM

Zones allow for the exploration of what happens in a smaller unit of geography of a City, as well as providing a structure that enables a description of how people move from one location to another. A system of 110 zones has been defined for transportation modelling in the City of Markham; these were used as the primary unit of analysis (Figure 15). These zones also align with building, population and transportation analysis and projections used by the Region of York.

Figure 15. Transport zones in Markham.

4.3 THE POPULATION OF MARKHAM

In 2011, the City of Markham consisted of 311,400 people, distributed relatively equally across all age cohorts (Figure 16).

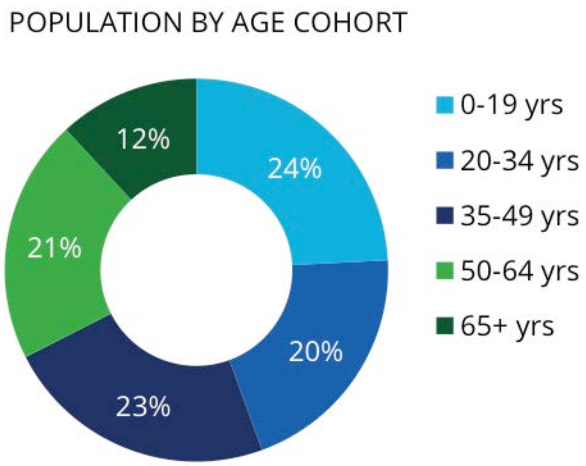


Figure 16. Markham population, 2011.

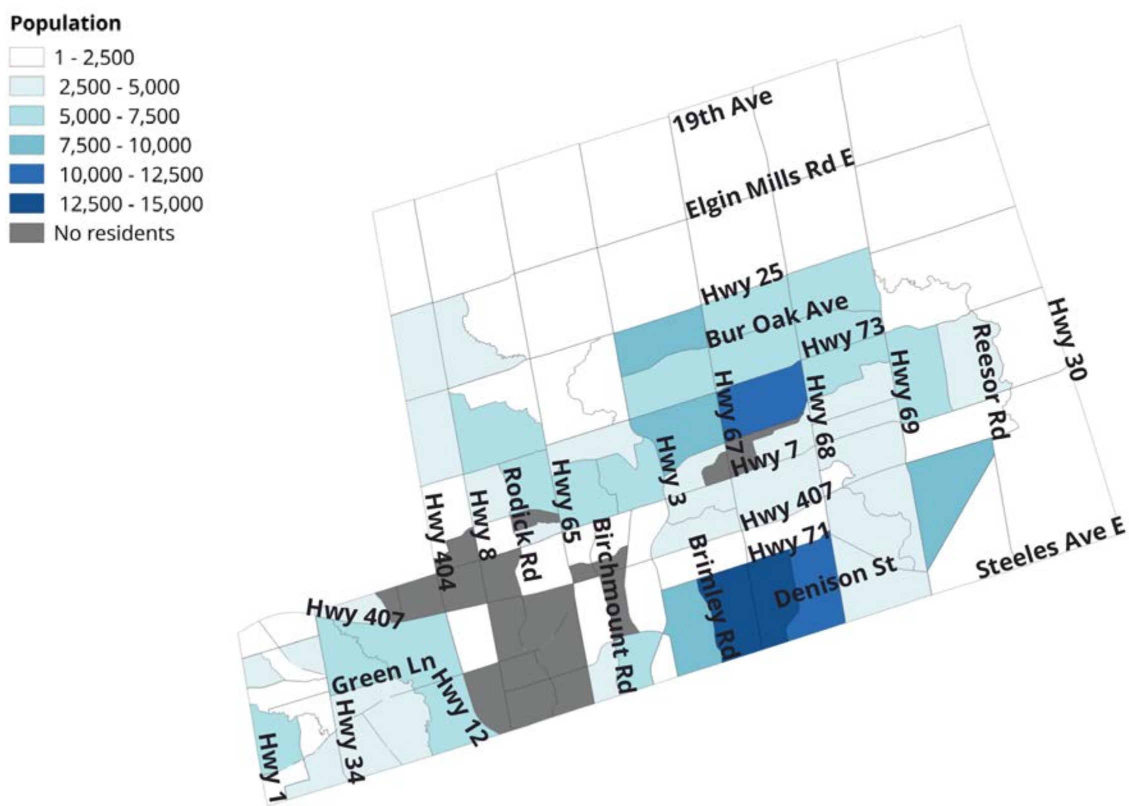


Figure 17. Markham resident distribution, 2011.

4.3.1 Where do people live?

The City of Markham's population (or residents) is dispersed unevenly across the city, with two areas of concentration around the areas of Raymerville in central Markham, and Millliken Mills/Middlefield (south-central). Figure 17 illustrates the number of residents located in each zone. Markham Centre exhibits higher resident numbers compared with surrounding zones.

4.3.2 What do people do for work?

There were approximately 160,900 jobs in Markham. These jobs were distributed relatively evenly across 3 major job categories.

There is a ratio of ONE JOB to every TWO PEOPLE that live in the City of Markham

EMPLOYMENT BY JOB TYPE

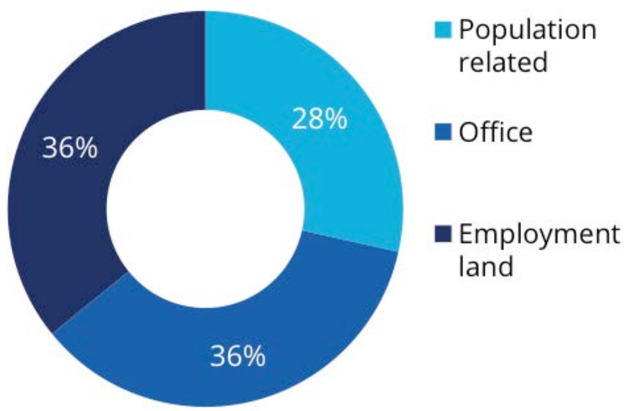


Figure 18. Markham employment, 2011.

Table 6. Definition of employment types.

EMPLOYMENT TYPE	DEFINITION
POPULATION-RELATED	Located within communities and includes jobs that serve the local population such as retail services, education services, municipal government services, social, community and health services, and local office uses.
OFFICE	Occurs in office buildings of 1,860 square metres (20,000 sq ft.) or larger.
EMPLOYMENT LAND	Located on Employment Lands (industrial or business parks) and typically require large areas of vacant designated greenfield land in strategic locations along major transportation routes (i.e. 400-series highways) and near existing markets.

4.4 WHAT KIND OF BUILDINGS DO PEOPLE LIVE IN?

TOTAL FLOORSPACE BY TYPE

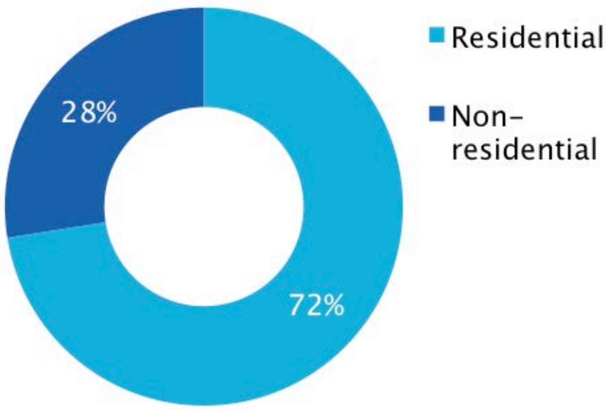


Figure 19. Total floorspace by type, 2011.

Total floorspace in Markham amounts to approximately 23.7 million square metres, which is dominated by residential use, accounting for almost three quarters of total floorspace (Figure 19).

Just under 3/4 of the total floorspace in Markham is RESIDENTIAL.

The **average dwelling** in the City of Markham is just over **2,000** square feet.

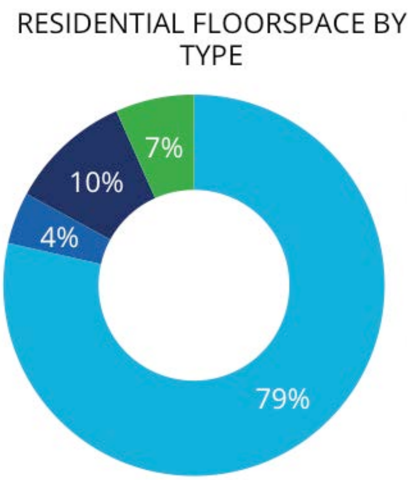


Figure 20. Residential floorspace by type, 2011.

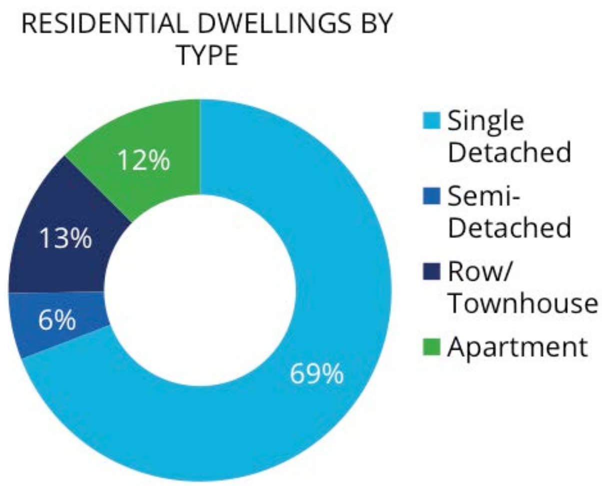


Figure 21. Residential dwellings by type, 2011.

Markham residents lived in approximately 92,400 dwellings. The distribution of these dwellings across residential building type was significantly dominated (69%) by single detached homes (Figure 20). These dwellings made up approximately 17.2 million square metres of floorspace, 79% of which was associated with single detached homes (Figure 21).

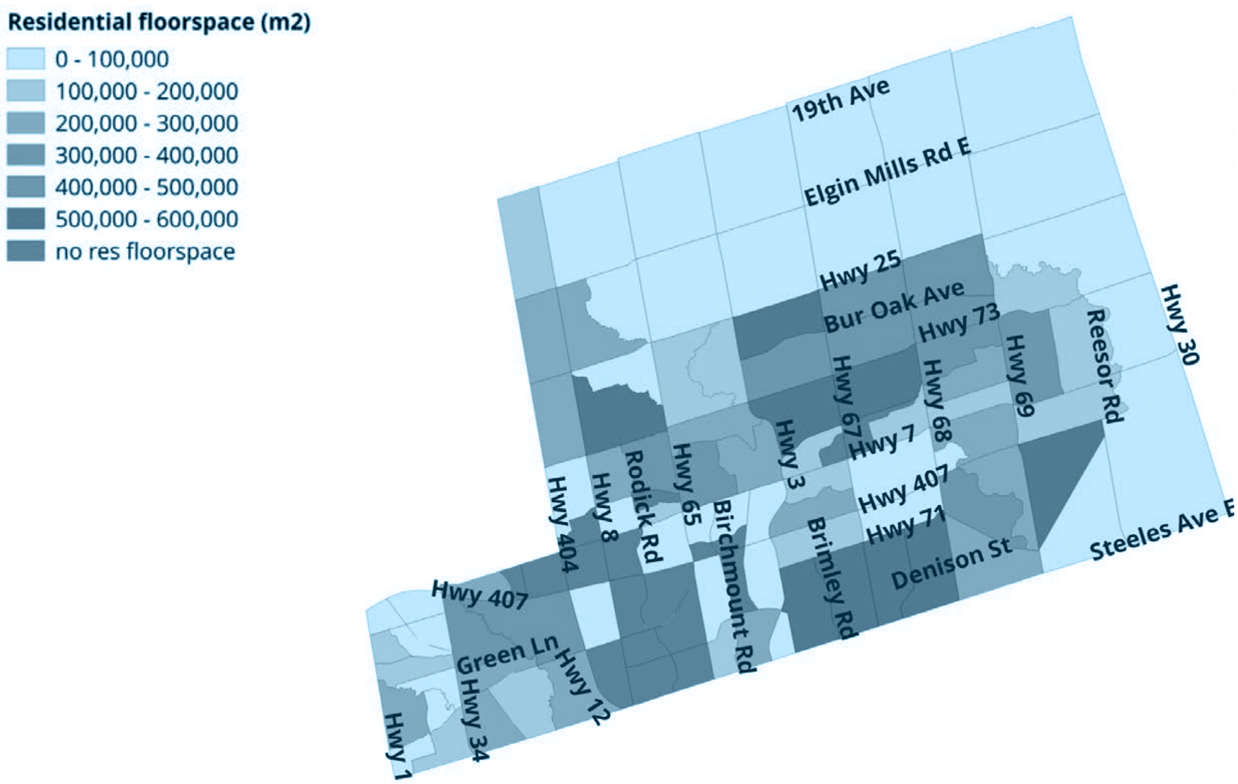


Figure 22. Residential floorspace distribution, 2011.

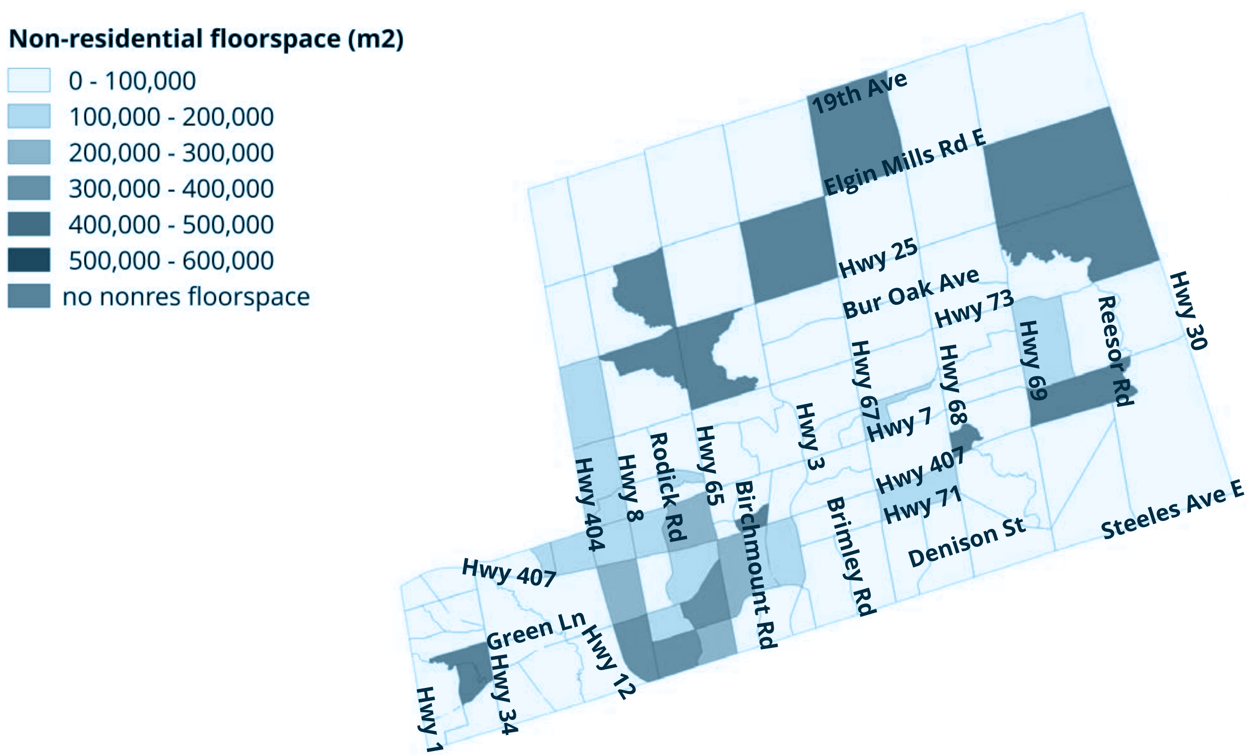


Figure 23. Non-residential floorspace distribution, 2011.

Figure 22 illustrates the distribution of residential floorspace across the city. It shows the total residential floorspace (within a range) located in each zone. Darker coloured zones indicate areas with higher levels of residential floorspace, generally associated with higher levels of residential building density. Higher residential building densities are noticeable in Markham Centre, which aligns with residential population distribution (Figure 17).

Non-residential floorspace amounted to approximately 6.5 million square meters. Just below half of total non-residential floorspace (49%) was made up of employment land (Figure 24). Figure 23 illustrates the distribution of non-residential floorspace across the city, indicating total non-residential floorspace (within a range) located in each zone. Non-residential areas are prominent in the southern part of the city, in particular the area south of Hwy 407 and east of Hwy 404.

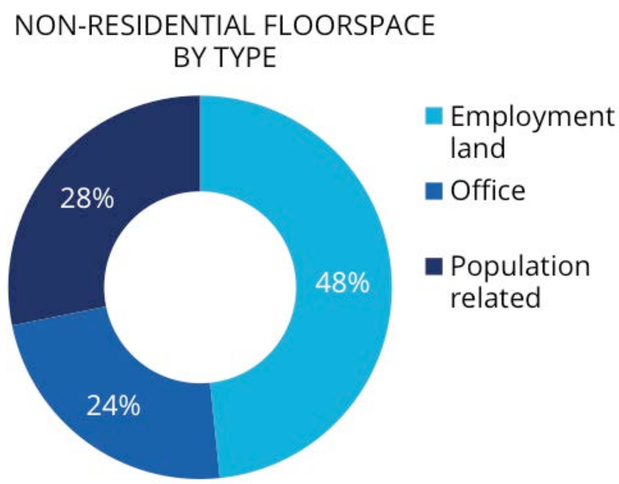


Figure 24. Non-residential floorspace by type, 2011: employment land (industrial and business parks), office (buildings larger than 20,000 sf), and population related (services such as schools and government offices).

4.5 THE RELATIONSHIP BETWEEN ENERGY AND EMISSIONS

4.5.1 How much energy is used?

Total modelled energy consumption for the City of Markham for the baseline year 2011 amounts to approximately 29.67 PJ.[12] Buildings account for two thirds of energy use; with the remainder being consumed in the transportation sector (Figure 25). Natural gas is the most significant fuel type, accounting for 47% of total energy, followed by gasoline at 29% (Figure 26).

Natural gas dominates energy use within buildings; this is followed by gasoline used for transportation. Fuel shown as "other" refers primarily to biomass.

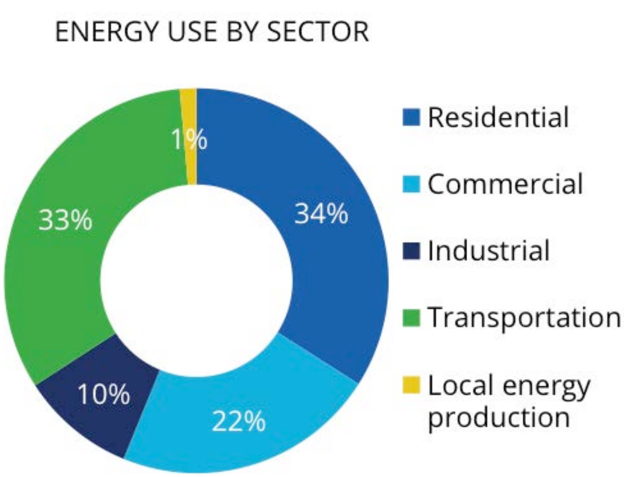


Figure 25. Energy use by sector, 2011

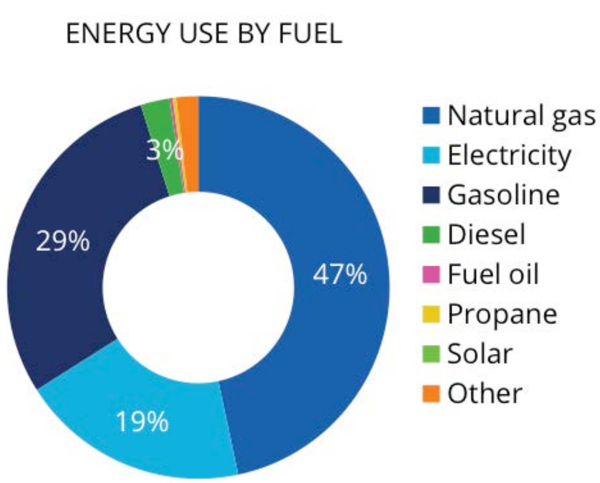


Figure 26. Energy use by fuel, 2011.

12 1PJ = 1 million GJ

ENERGY USE in Markham totalled

95 GJ per person.

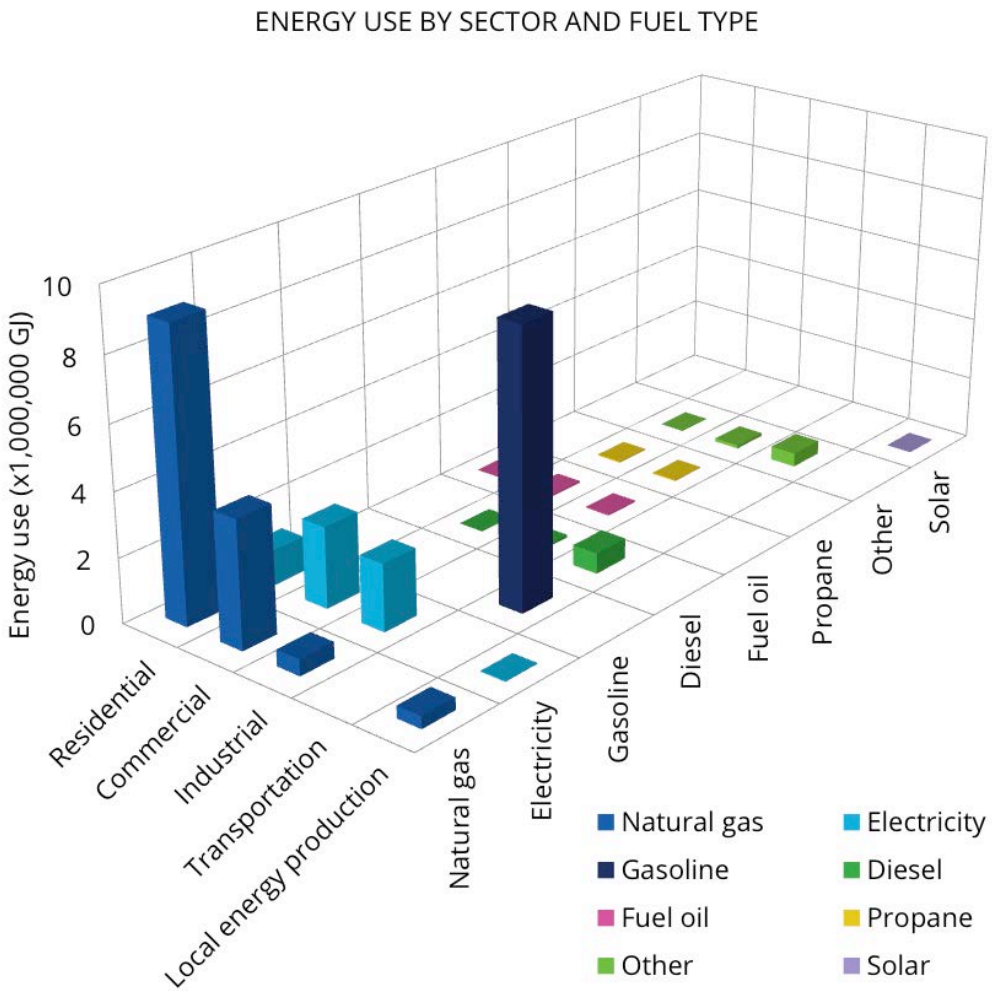


Figure 27. Energy use by sector and fuel, 2011.

NATURAL GAS and GASOLINE account for

3/4 of Markham's energy consumption.

Figure 28 illustrates the energy flow of the City of Markham. *Elec. Gen* and *Thermal Networks* represent local energy production: electricity produced through combined heat and power (CHP) and solar, and thermal energy produced through district energy respectively, within the boundary of Markham. It is assumed that both the electricity and thermal energy produced within the boundary is consumed by the buildings sector within the boundary; that is, in the baseline year, there is no export of energy outside of Markham's boundary. Note that energy use and losses associated with upstream extraction, processes and transportation of energy are considered outside of the boundary and were therefore not analysed.

CONVERSION LOSSES account for 42% of the energy consumed in Markham. Almost 80% of the conversion losses are from transportation.

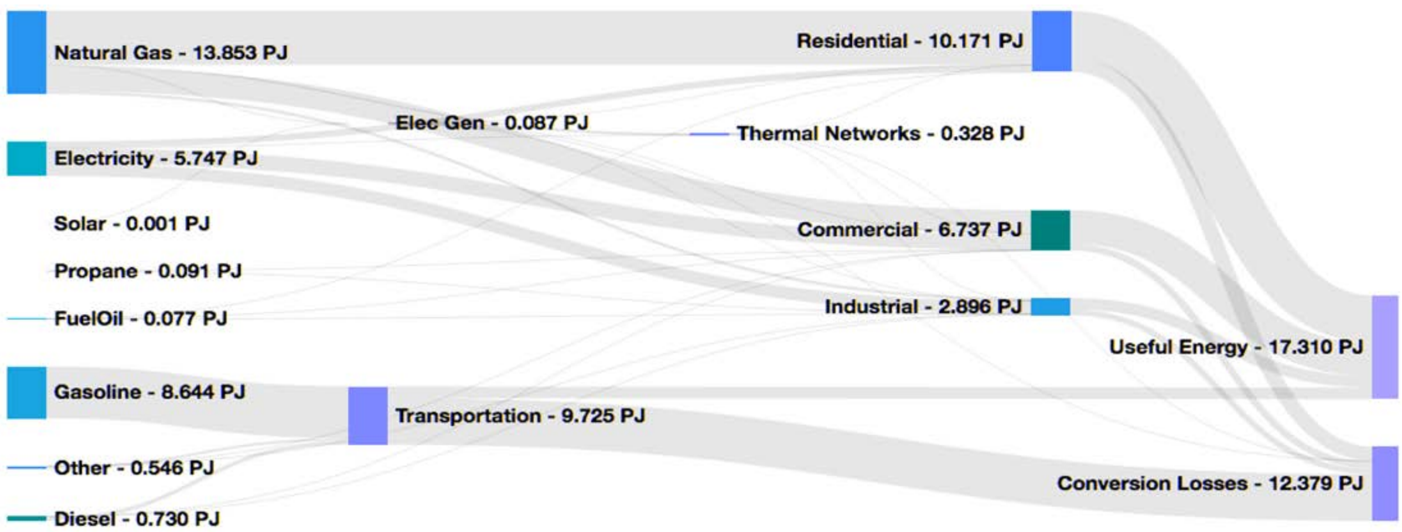


Figure 28. Energy flow, 2011.

4.5.2 What is Markham's GHG footprint?

Total modelled emissions for the City of Markham for the baseline year 2011 amounts to 1,779,700 tonnes of carbon dioxide equivalent (CO_2e). A breakdown of emissions by sector is shown in Table 7.

The buildings sector stands out as a dominant contributor to overall emissions, accounting for 49% of total emissions. This is followed by transportation at 37%, and to a lesser extent, waste and wastewater. In addition to the major sectors, fugitive emissions from natural gas systems amount to 9,300 tonnes CO_2e. Fugitive emissions account for unintentional emissions associated with the transportation and distribution of natural gas within the city including equipment leaks, and accidental releases.

Table 7. Total emissions for Markham, 2011.

SECTOR	TONNE CO_2e
BUILDINGS	877,450
TRANSPORTATION	665,000
WASTE & WASTEWATER	227,950
FUGITIVE EMISSIONS	9,300
TOTAL	1,779,700

The average GHG emissions in the City of Markham are

5.7 tCO_2e per person.

The buildings and transportation sectors together account for 1,542,450 tonnes CO_2e; the emissions within these sectors are a direct result of fuel consumption, in comparison with waste, where emissions are as a result of the decomposition of waste.

Of the emissions within buildings and transport, natural gas accounts for 44% (Figure 30). Natural gas is the largest contributor to total emissions within the buildings sector and within the city overall. Gasoline is the second largest contributor at 40%, and the largest contributor to emissions within the transportation sector (Figure 31).

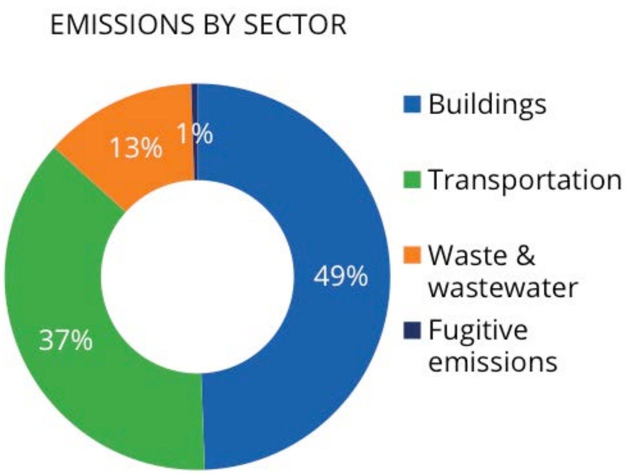


Figure 29. Markham emissions by sector, 2011.

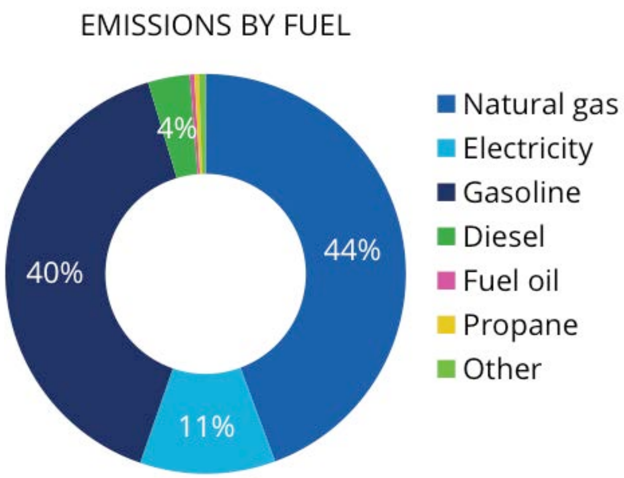


Figure 30. Markham emissions by fuel, 2011.

NATURAL GAS and GASOLINE account for 84% of the GHG emissions in Markham. Electricity accounts for just 11%.

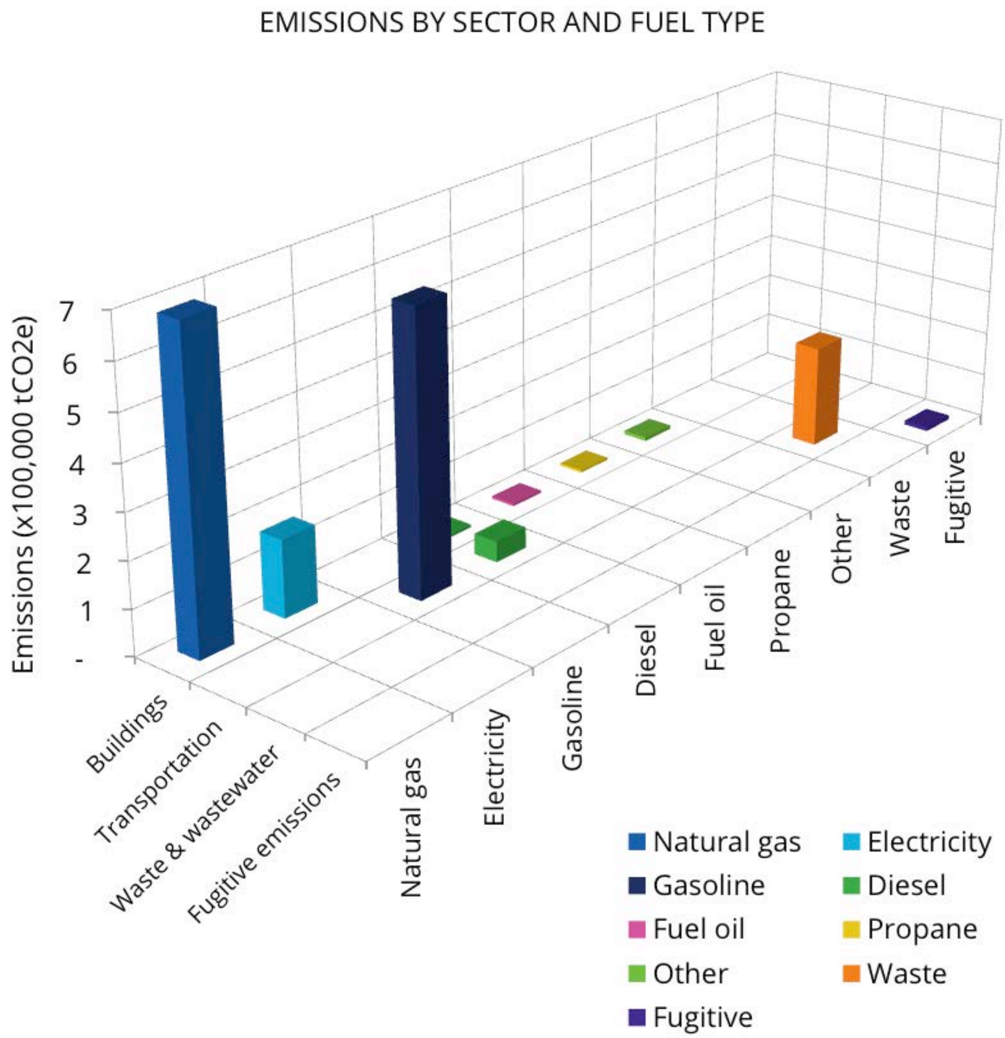


Figure 31. Markham emissions by sector and fuel, 2011.

4.5.3 The role of buildings

4.5.3.1 ENERGY USE IN BUILDINGS

Building energy use amounted to 19,964,000 GJ in 2011, and was shared almost equally between the residential sector (51%) and the non-residential sector (47%) (Figure 32). The remaining 2% accounts for the energy (consumption of fuels) that is used in the production of locally generated energy.

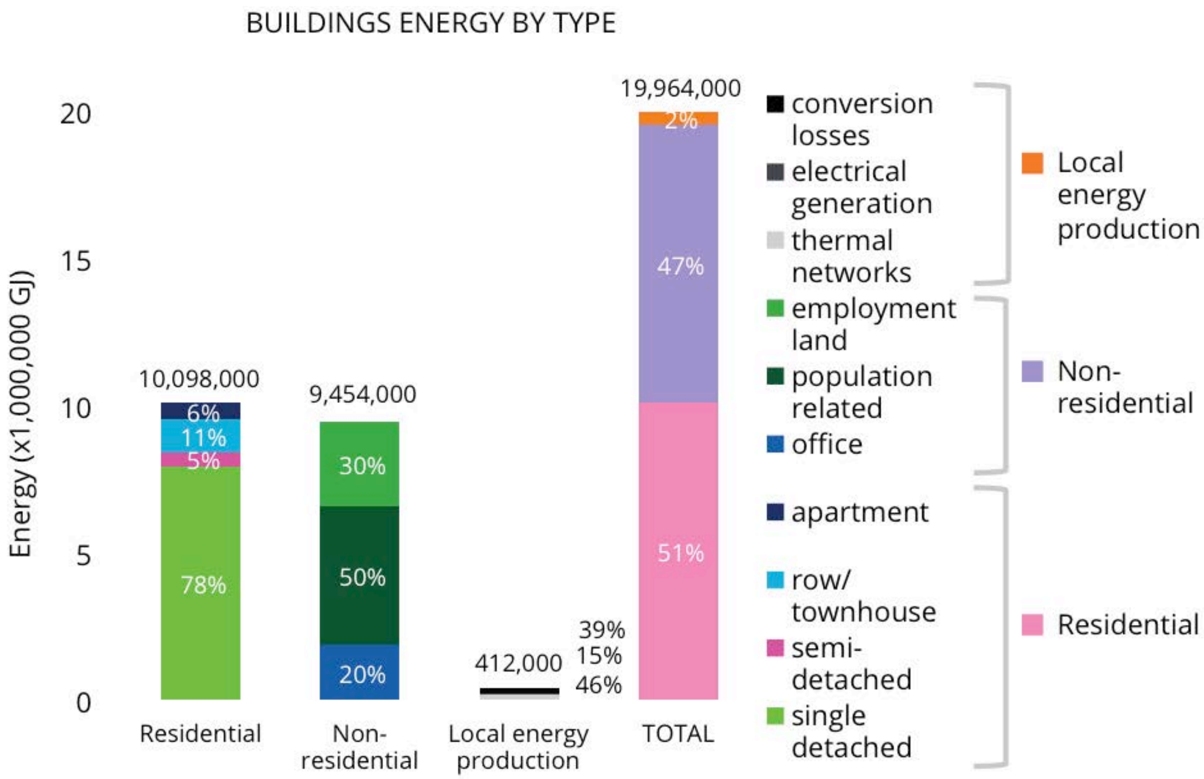


Figure 32. Buildings energy use by building type, 2011.[13]

Within the residential sector, single detached homes account for the majority of energy use, amounting to 78% of total residential energy use. This is followed by row/townhomes at 11%, and to a lesser extent, apartments (6%) and semi-detached homes (5%).

13 Local energy production consists of Markham District Energy and solar PV.

Energy use in DWELLINGS averages

33 GJ per person.

The non-residential sector appears to have a more distributed energy consumption profile amongst building types, but is still dominated by population related uses (50%), followed by employment land (30%) and office space (20%).[14]

Within Markham, energy consumed in the process of local energy production amounted to 412,000 GJ. District energy produced approximately 190,000 GJ (46%), electricity generation amounted to approximately 63,600 GJ (15%) and the remaining 39% can be attributed to conversion losses. Note that energy produced locally is assumed to be consumed locally by the residential and non-residential sectors. Energy consumption totals shown for the residential and non-residential sectors in Figure 32 do not include the consumption of local energy so as to avoid double counting.

SINGLE FAMILY HOMES account for nearly

80% of residential dwelling energy use.

14 With reference to Figure 32, energy consumption in the non-residential buildings sector is indicated according to Commercial and Industrial uses. The non-residential categories used in Figure 32 are per the York Region's growth projection categories. For clarity, Office and Population related uses have been considered Commercial, and Employment land has been considered Industrial.

2% of the total ENERGY used in buildings is generated locally using district energy and solar power. This will need to increase significantly for the City to achieve net zero.

ENERGY BY END USE

Residential buildings are dominated by space heating, which accounts for 72% of total residential energy use (Figure 33), followed by water heating at 21%. In the non-residential sector, space heating remains dominant (43%), followed by industrial/manufacturing uses (22%), plug loads (16%), and space cooling (9%). In total, space heating remains dominant within the buildings sector, accounting for 57% of energy use. This is followed by water heating (12%), industrial/ manufacturing end uses (10%), and plug loads (9%).

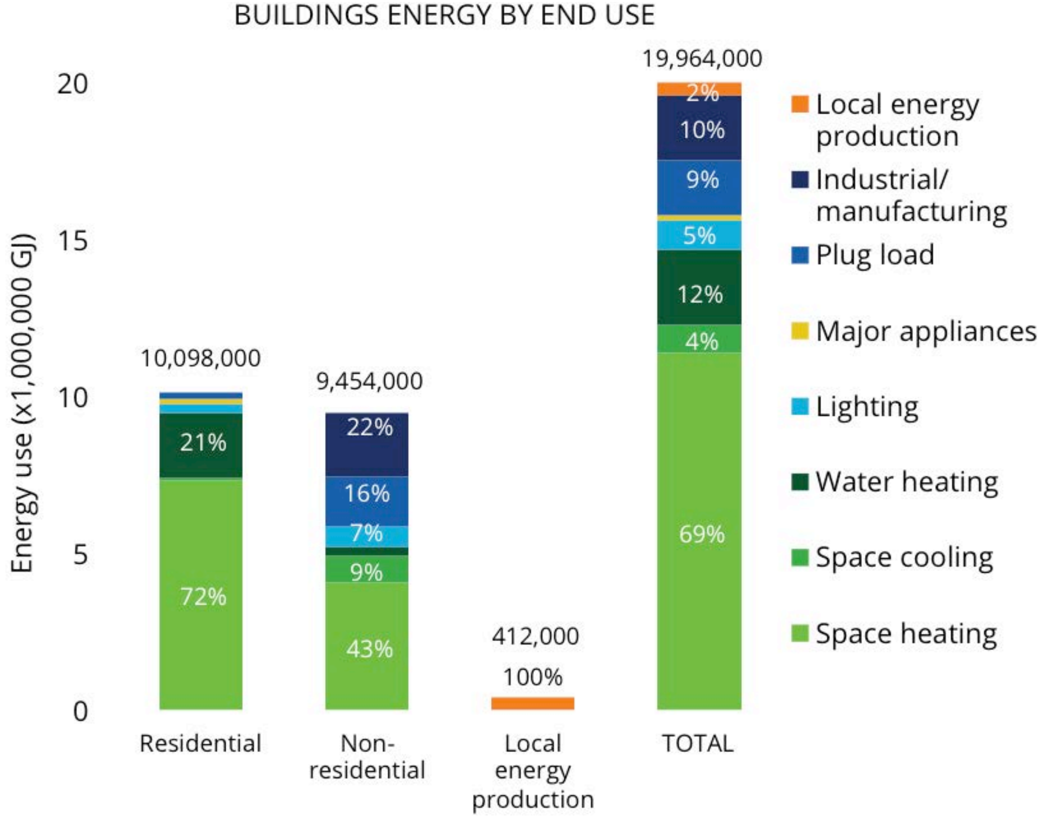


Figure 33. Buildings energy use by end use, 2011.

SPACE HEATING accounts for nearly 3/4 of total energy use in buildings.

ENERGY BY FUEL TYPE

Natural gas accounts for a significant portion (89%) of energy use within residential buildings; which is predominantly used to provide space heating (Figure 34). Electricity plays a much lesser role, accounting for only 11% of energy use. Non-residential buildings use natural gas (47%) and electricity (49%) more equally than residential buildings; which is used to supply a more varied profile of energy end uses. Locally generated energy is predominantly produced through the consumption of natural gas (92%) which is used to produce heat distributed through thermal networks. Solar PV generation is at 8% of local energy generation.

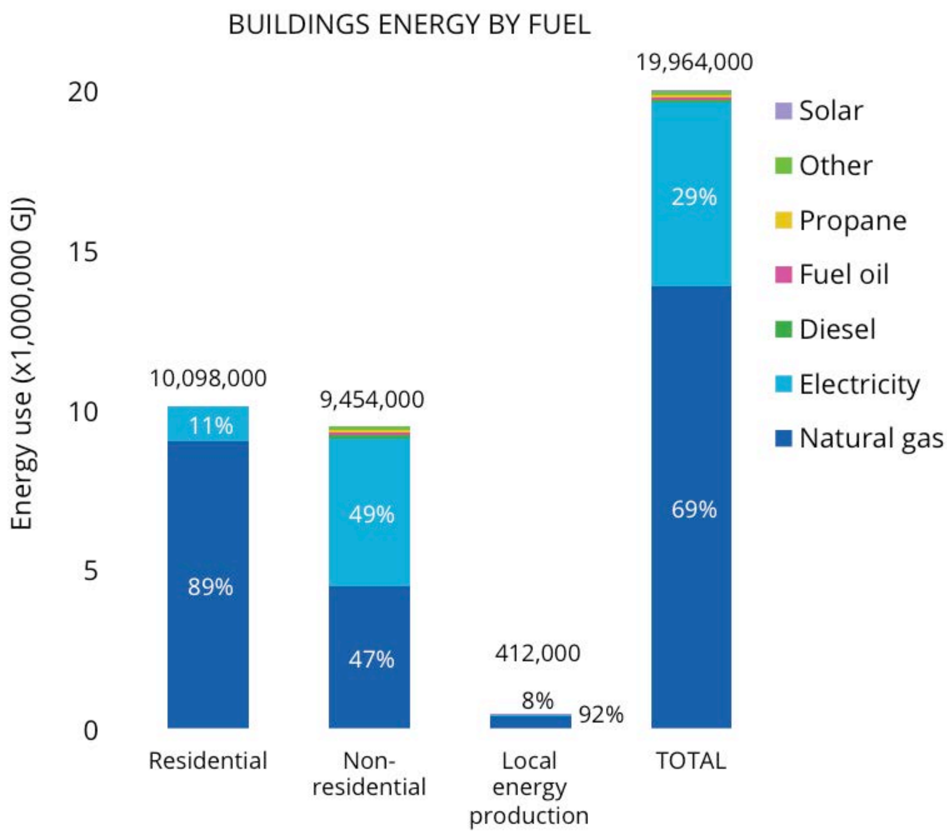


Figure 34. Buildings energy use by fuel, 2011.

Of the total **energy** used in residential **buildings**,

NATURAL GAS accounts for **89%**.

4.5.3.2 MAPPING ENERGY USE

The series of maps below represent the spatial distribution of energy consumption within the buildings sector across the City of Markham. Three types of maps, detailed in , have been produced to represent all buildings (total buildings sector), residential buildings, and non-residential buildings; and include all fuel (represented in equivalent GJ) consumed in these sectors. In all cases, energy is mapped at the transport zone level.

Table 8. Energy map definitions.

MAP TYPE	DEFINITION	CALCULATION	COMMENTS
TOTAL ENERGY	Total energy (GJ) consumed	Energy consumed (GJ) in zone	Provides an indication of areas that have high energy consumption in total such as hotspots. The results are not necessarily consistent with building densities, highlighting for example industrial areas with high demand but low building densities.
ENERGY DENSITY	Energy consumed per area of developable land (GJ/ha)	Energy consumed in zone (GJ) / total area of zone (ha).	Areas of high energy densities are generally consistent with areas that have high building densities, a visual indication of potential district energy opportunities.
ENERGY INTENSITY	Energy consumed per area of floorspace (GJ/m2).	Energy consumed in zone (GJ) / total floorspace of energy consuming buildings in zone (m2).	Energy intensity (also known as energy use intensity or EUI) is a unit of measure that describes the overall efficiency or performance of a building(s), either individually, or within an area. At a zone level, it is an indicator of the efficiency of the building stock in the relevant area.

Energy used in the City of Markham is focussed in slightly more than 1/2 of the area of the City.

TOTAL ENERGY MAPS

Figure 35 shows total energy by zone across the City, illustrating a fairly equal distribution of energy demand in built up areas. Residential energy demand (Figure 36) shows fairly well distributed loads across zones, with higher loads noticeable in Markham Centre. Energy demand for non-residential buildings appears to be more focussed in the southwest part of the City, which is consistent with the distribution of non-residential floorspace (Figure 37).

Non-residential and residential ENERGY USE generally do not overlap in zones.

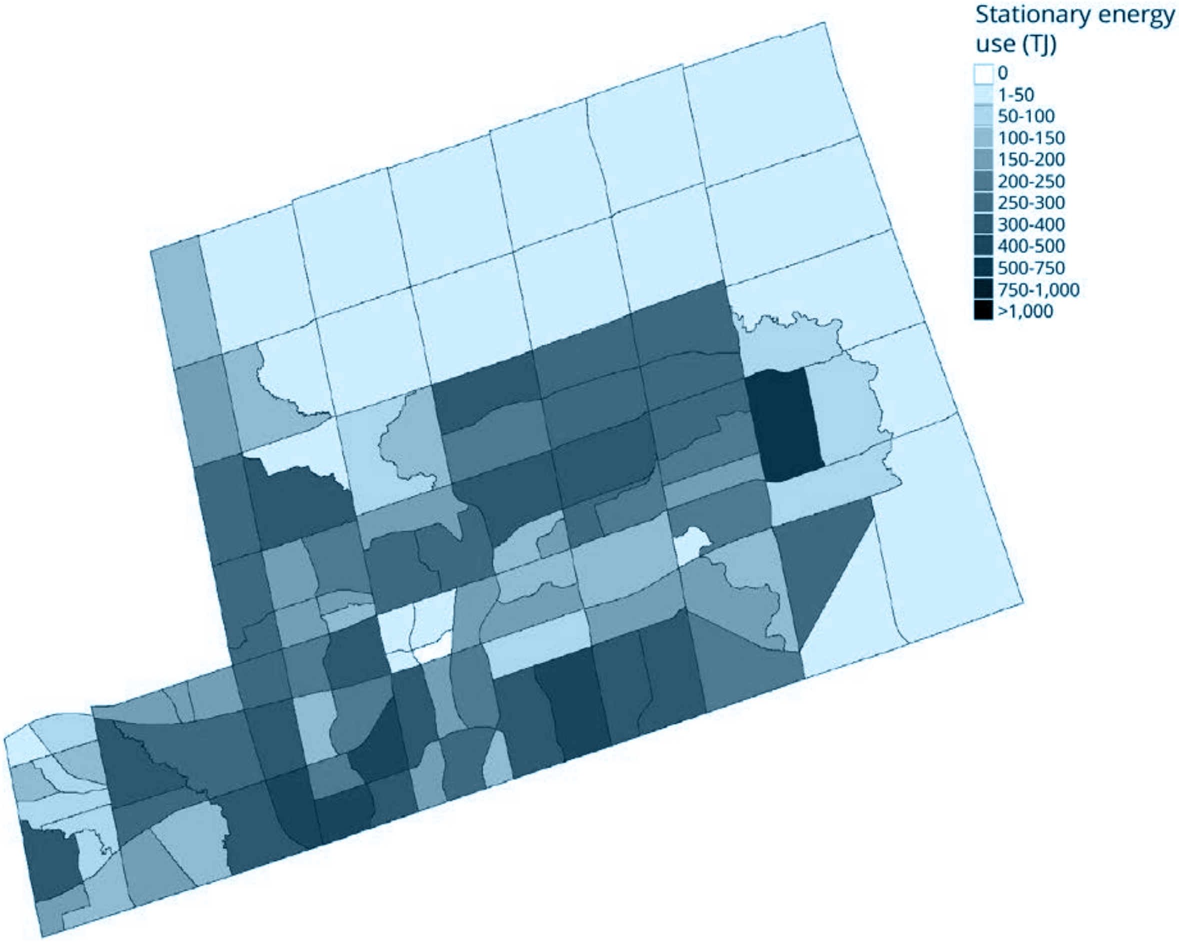


Figure 35. Total energy (TJ) by zone; all buildings, 2011.

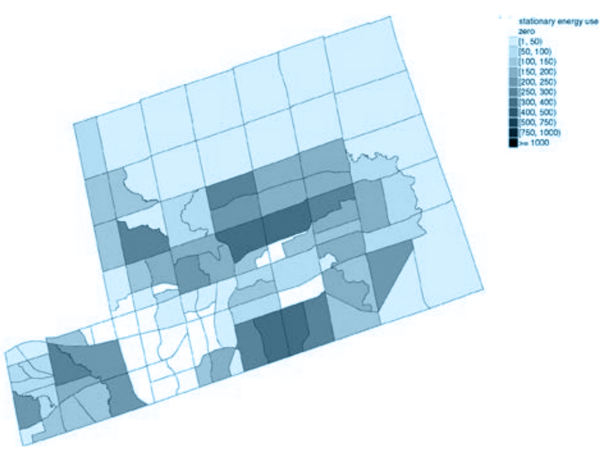


Figure 36. Total energy (TJ) by zone; residential buildings, 2011.

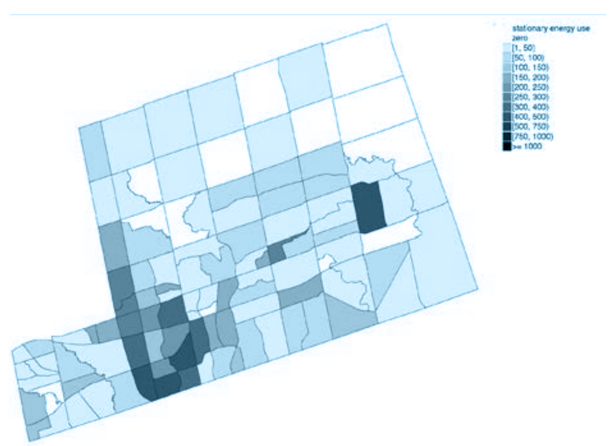


Figure 37. Total energy (TJ) by zone; non-residential buildings, 2011.

Note: 1TJ equals 1,000 GJ.

High energy density is primarily caused by NON-RESIDENTIAL buildings.

ENERGY DENSITY MAPS

Energy density, an indication of energy consumed per land area, is less equally distributed across the City, with higher densities noticeable in the southwest, indicating high levels of total energy demand relative to the land area by zone (Figure 38).

Residential energy densities (Figure 39) are higher in Markham Centre than in the surrounding suburbs. This is consistent with the relative residential building densities in these areas; residential apartment buildings consume more energy per land area than single family homes, as there are significantly more dwelling units/floorspace in comparison.

Non-residential energy density is again focused in the southwest part of the City, and is noticeably higher when compared with residential energy densities. This is due to non-residential buildings (industrial uses in particular), using significantly more energy per land area than residential uses.

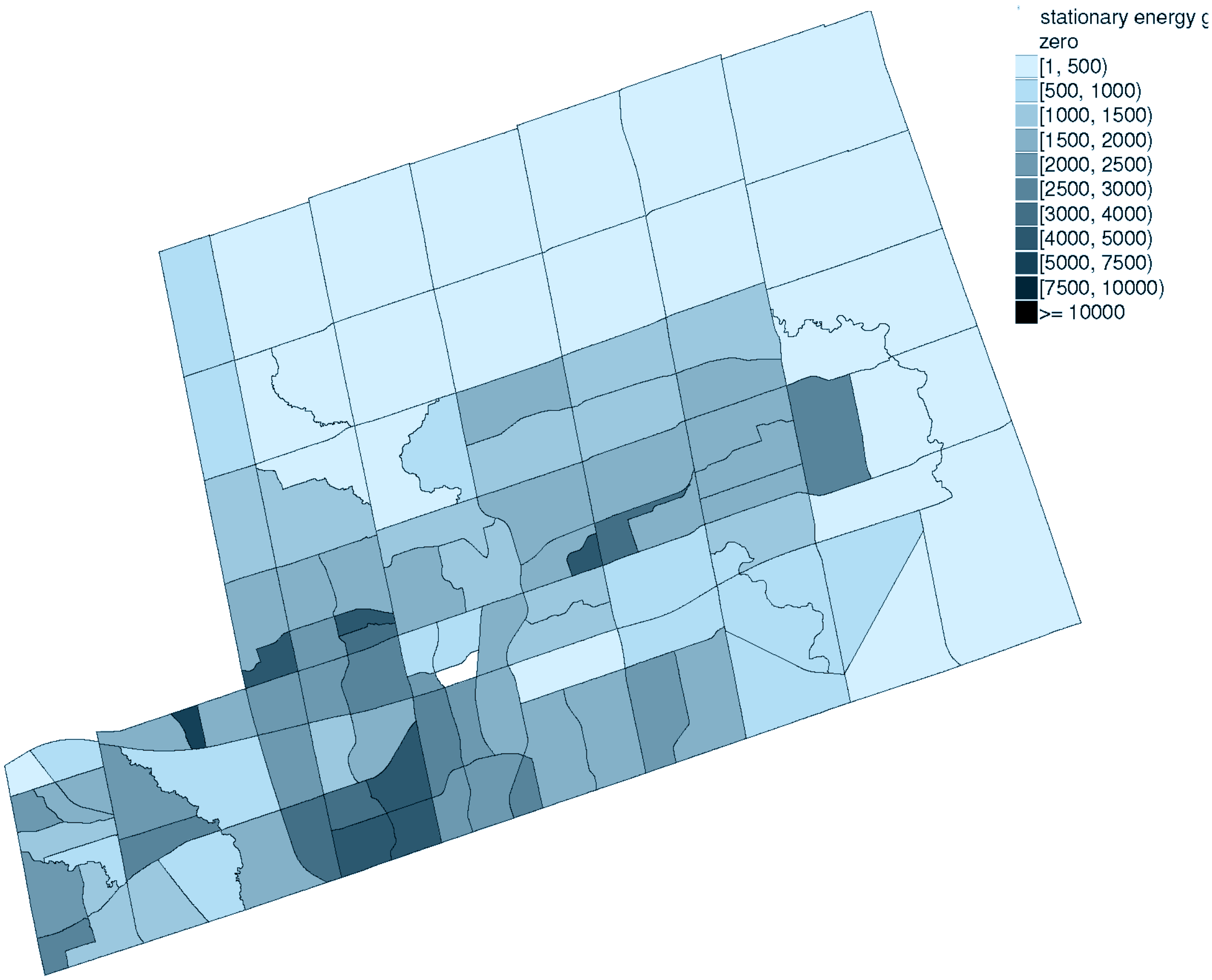


Figure 38. Energy density (GJ/ha) by zone; all buildings, 2011.

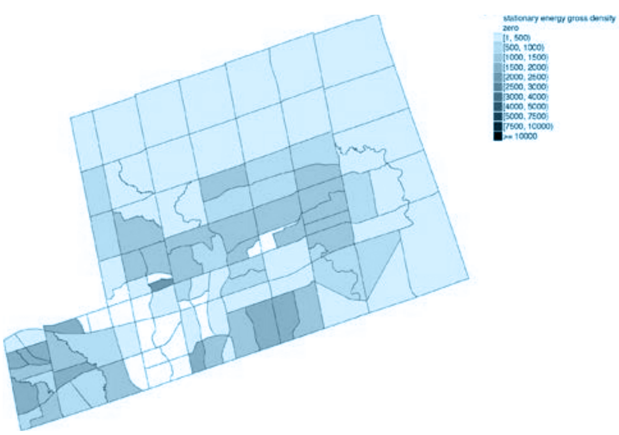


Figure 39. Energy density (GJ/ha) by zone; residential buildings, 2011.

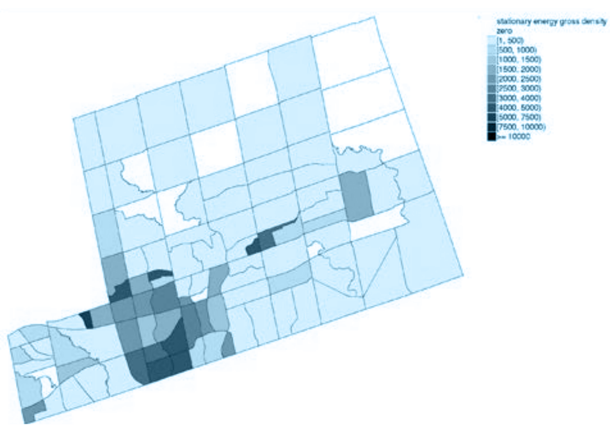


Figure 40. Energy density (GJ/ha) by zone; non-residential buildings, 2011.

Some of the most INEFFICIENT BUILDINGS are in areas of very low population density.

ENERGY INTENSITY MAPS

Energy intensity, an indication of energy consumed per square metre of building floorspace, shows large variation across the City. Higher intensities are noticeable in the non-residential southwest, as well as in the outlying residential suburbs (Figure 41). This indicates a combination of:

- Residential energy intensities being higher in the suburbs than Markham Centre (Figure 42); this indicates that apartment buildings (in Markham Centre) use less energy than single detached homes (in the surrounding suburbs) on a per square metre basis.
- Non-residential energy intensities (Figure 43) being significantly higher than residential energy intensities, indicating that non-residential buildings use significantly more energy than residential buildings on a per square metre basis.

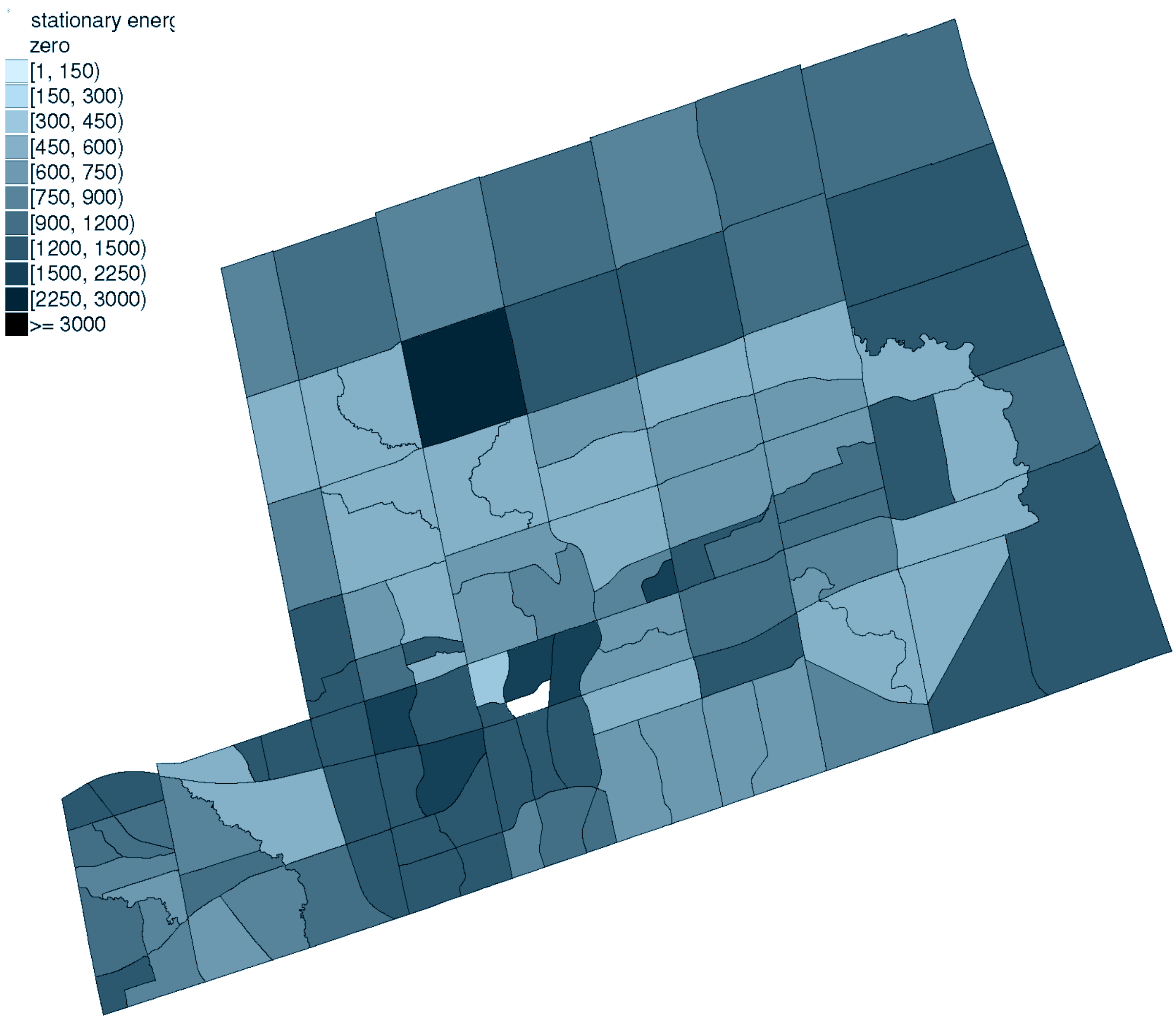


Figure 41. Energy intensity (MJ/m²) by zone; all buildings, 2011.

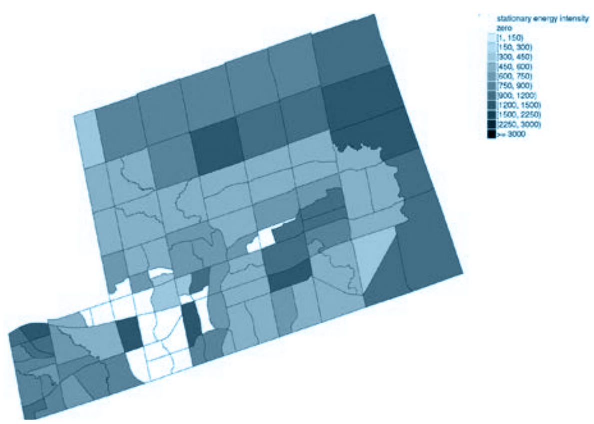


Figure 42. Energy intensity (MJ/m²) by zone; residential buildings, 2011.

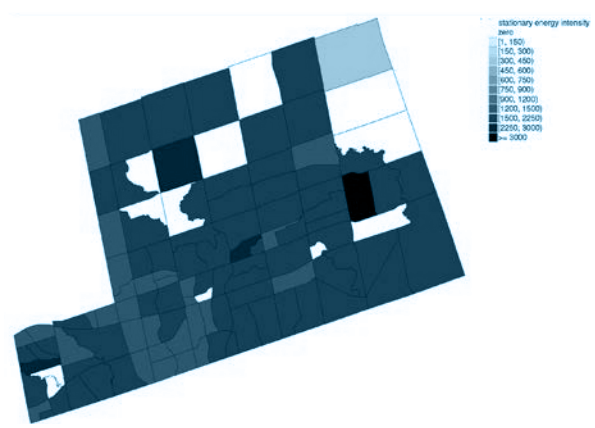


Figure 43. Energy intensity (MJ/m²) by zone; non-residential buildings, 2011.

4.5.4 GHG emissions from buildings

EMISSIONS BY BUILDING TYPE

The buildings sector accounts for 877,450 tCO_2e, approximately 49% of total emissions for the City. Residential buildings account for the majority of emissions (54%) within the sector, with non-residential at 44%, and local energy production at 2% (Figure 44).

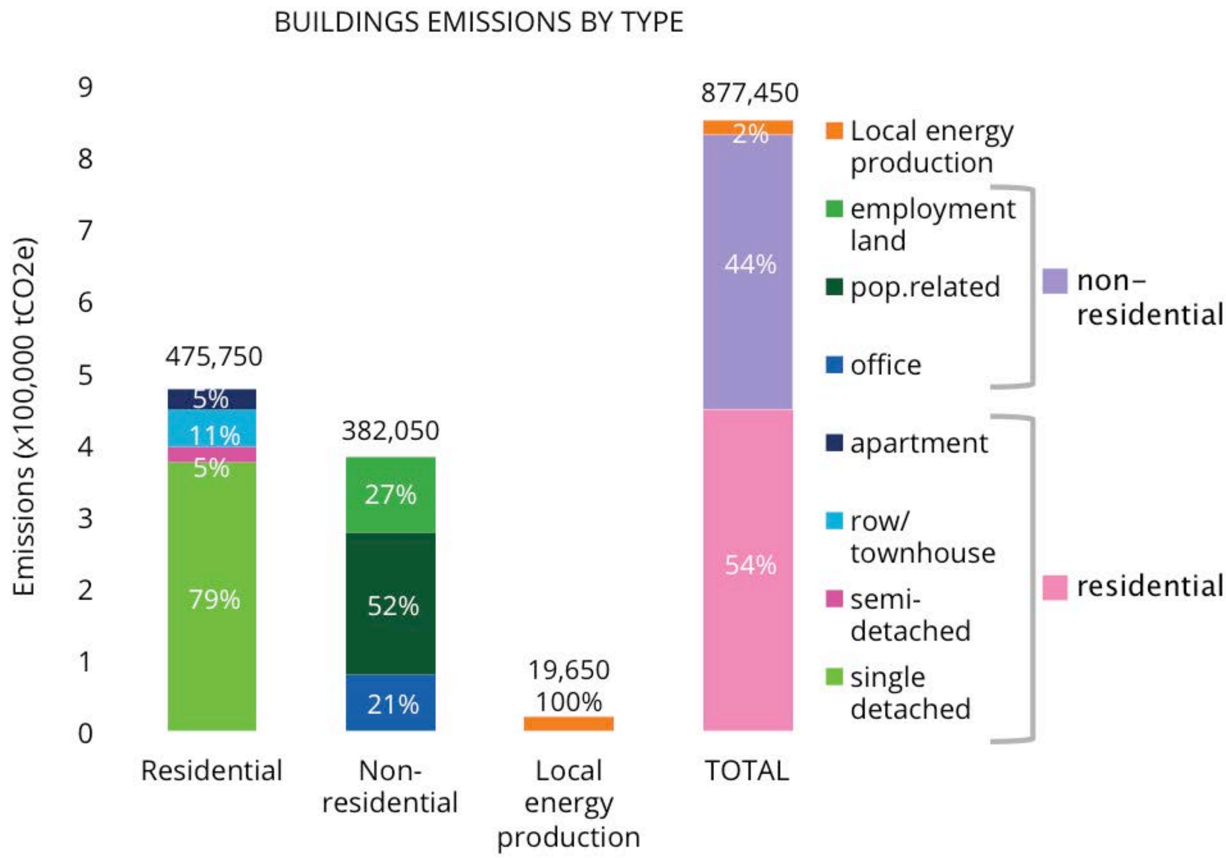


Figure 44. Buildings emissions use by building type, 2011.

In BUILDINGS on the whole, natural gas accounts for just over 3/4 of the total GHG emissions.

Within the residential sector, single detached homes account for the majority of emissions (79%) of total residential emissions, which amount to 475,750 tCO_2e. This is followed by row/townhomes at 11%, and to a lesser extent, apartments (5%) and semi-detached homes (5%).

The non-residential sector has a more distributed emissions profile amongst buildings types, but is dominated by population related uses (52%), followed by employment land (27%) and office space (21%).

Emissions related to the process of local energy production amount to 19,650 tCO_2e. It is assumed that energy produced locally is consumed locally by the residential and non-residential sectors, and therefore, these emissions should be attributed to those sectors. Note, however, that the emissions totals shown for the residential and non-residential sectors in Figure 44 do not include the emissions associated with local energy in order to avoid double counting, as they are reported under local energy production.

EMISSIONS BY END USE

The emissions associated with space heating make up the majority of total residential emissions, accounting for 76% of the total (Figure 45). Water heating is the second highest contributor at 20%.

In the non-residential sector, space heating remains the dominant emissions contributor at 50%, followed by industrial/manufacturing (22%), plug loads (13%), and space cooling (9%).

In total, space heating remains the dominant emissions contributor, accounting for 63% of total buildings emissions. This is followed by water heating (12%), industrial/manufacturing end uses (9%), and plug load (6%).

> In the residential sector, space and water heating account for 95% of the GHG emissions versus just over 50% in the non-residential sector.

BUILDINGS EMISSIONS BY END USE

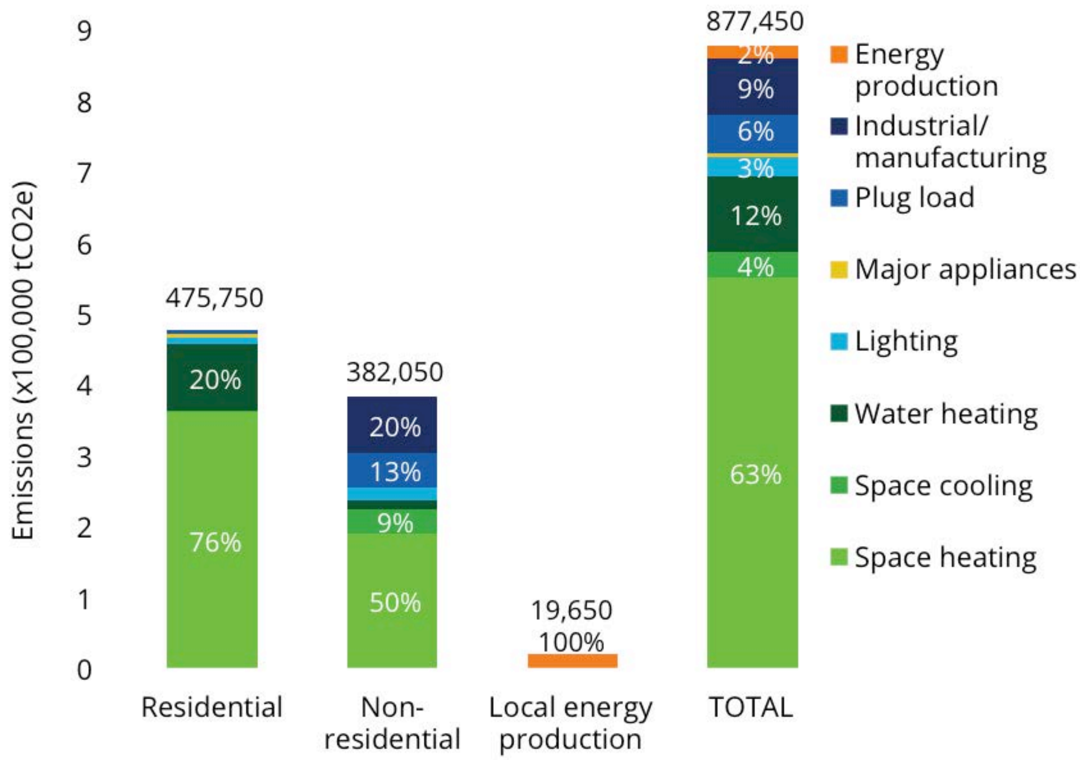


Figure 45. Buildings emissions use by end use, 2011.

EMISSIONS BY FUEL

Natural gas accounts for over three quarters (78%) of emissions within the buildings sector, followed by electricity 18% (Figure 46).

Natural gas accounts for a significant portion (93%) of emissions within residential buildings; which is predominantly used to provide space heating. Electricity plays a much lesser role, accounting for only 7% of energy use.

Non-residential emissions are also dominated by natural gas (58%), but not the the same extent as residential. Electricity accounts for (36%).

Emissions from local energy production are almost exclusively from the consumption of natural gas (98%).

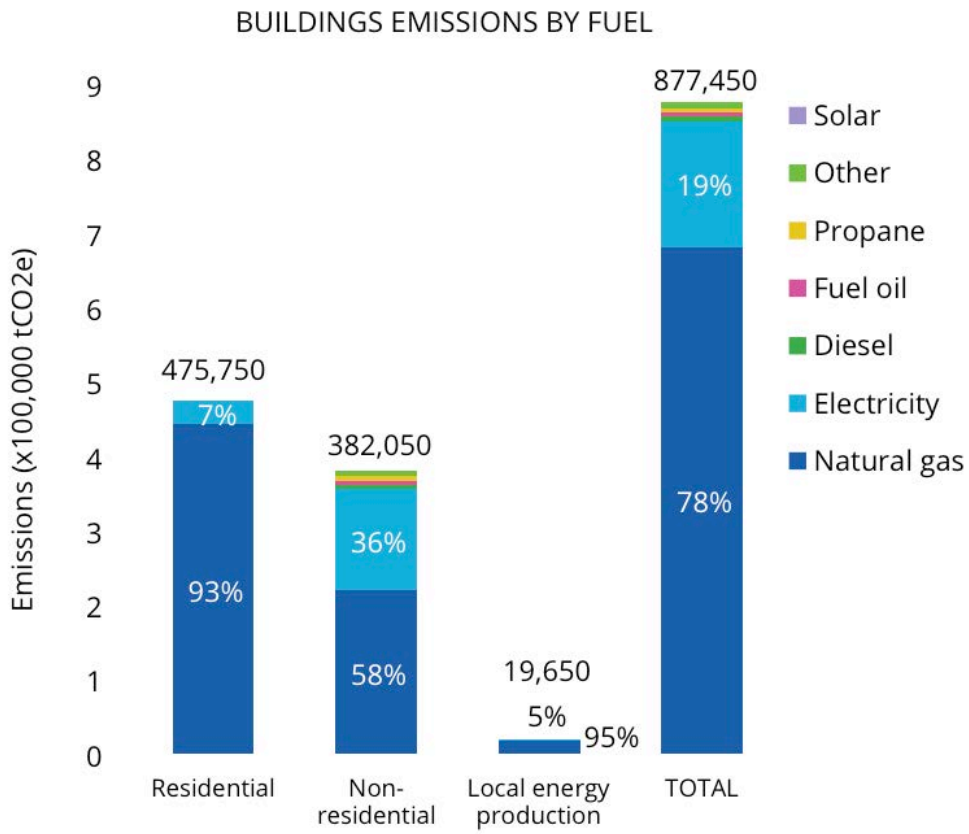


Figure 46. Buildings emissions by fuel, 2011.

BUILDINGS ENERGY AND EMISSIONS COMPARISON

Figure 47 and Figure 48 show buildings energy and emissions respectively, by sub-sector and fuel type. Notice that when comparing these two figures alongside each other, and in particular when looking at the difference in energy use compared with emissions in the non-residential sector, there are significantly lower emissions for electricity than for natural gas, while there is a more equal distribution between these two fuels from an energy use perspective.

The higher emissions for natural gas compared with electricity that can be observed here are as a result of natural gas having a significantly higher emissions factor than Ontario's relatively "clean" electrical grid.

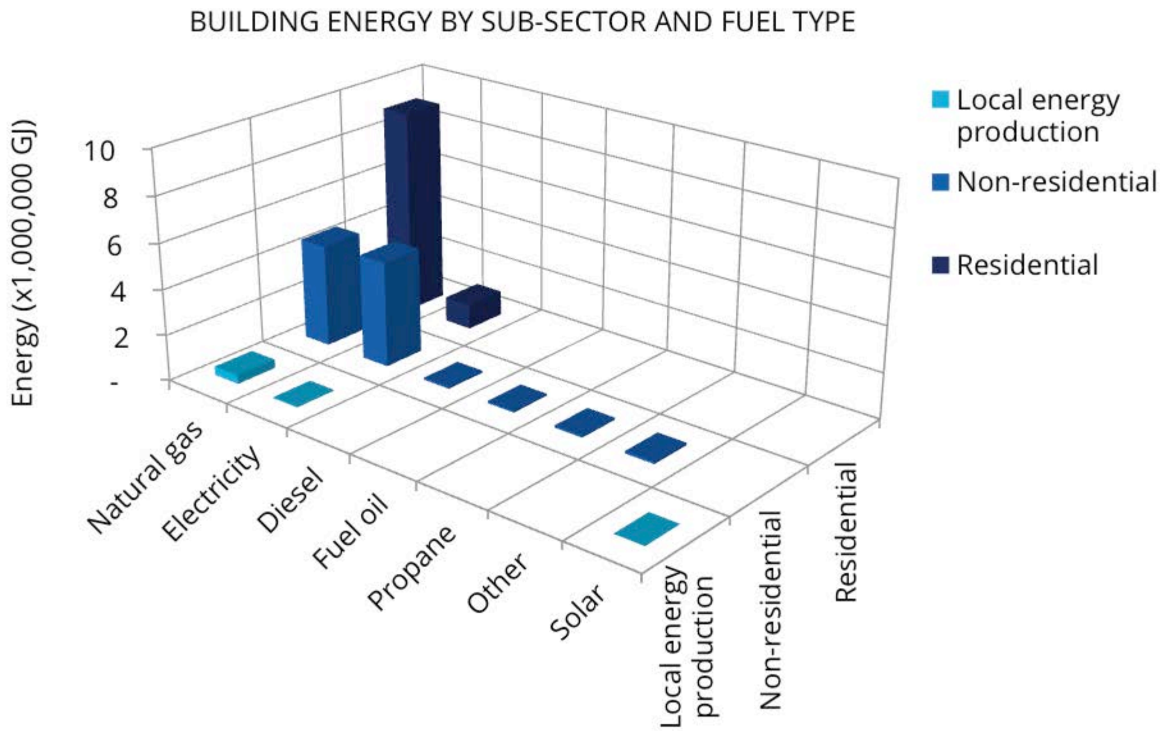


Figure 47. Buildings energy use by sub-sector and fuel type, 2011.

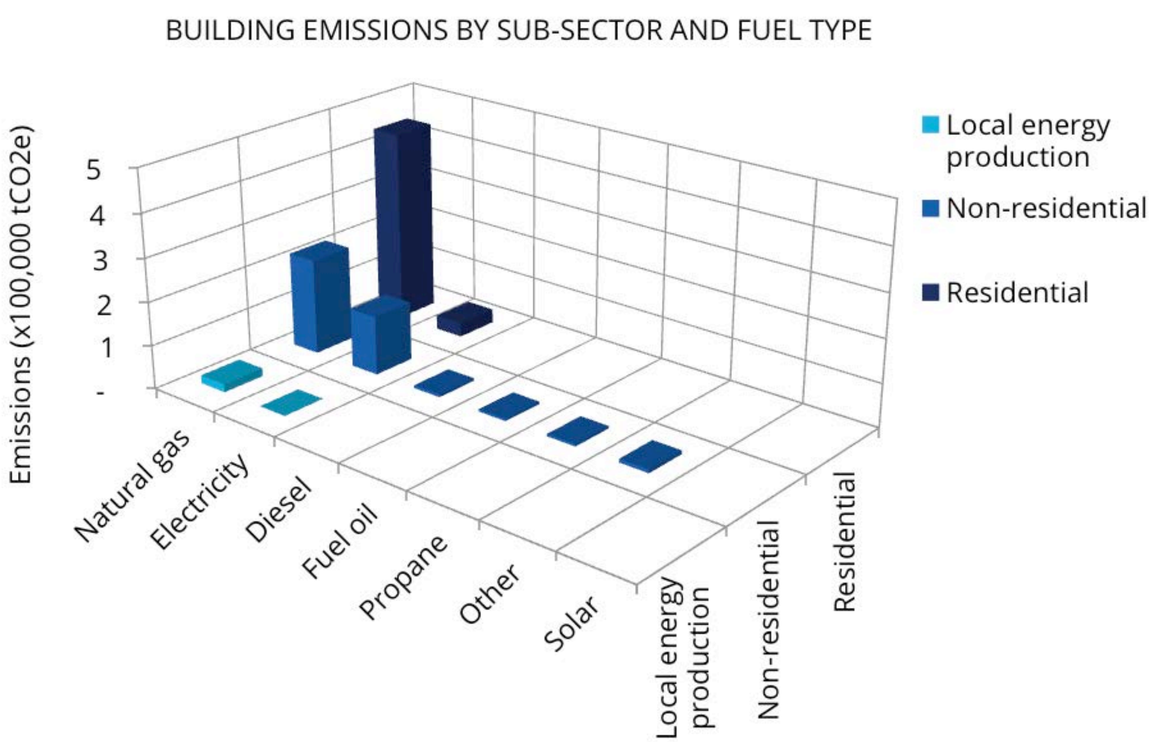


Figure 48. Buildings emissions by sub-sector and fuel type, 2011.

4.5.5 The impact of transportation

4.5.5.1 ENERGY USE IN THE TRANSPORTATION SECTOR

The transportation sector consumed approximately 9,285,500 GJ of energy in 2011, the majority of which was consumed by personal vehicles (80%) that predominantly use gasoline (93%) (Figure 49). Of the vehicle stock, cars (46%) and light trucks (47%) are the predominant energy consumers.

4.5.5.2 GHG EMISSIONS FROM TRANSPORTATION

The transportation sector accounts for 665,000 tonnes CO_2e, approximately 37% of total emissions for the city. Emissions within the transport sector are dominated by gasoline (93%) (Figure 50). The majority of emissions come from personal vehicles (80%). When looking at vehicle stocks, emissions come predominantly from cars (47%) and light trucks (47%); a large proportion of light trucks are owned as personal vehicles.

4.5.5.3 HOW FAR DO PEOPLE TRAVEL AND HOW DO THEY GET AROUND?

Travel in Markham is categorized according to three different categories of trips – internal, external outbound and external inbound – as illustrated in Figure 51. Four different types of those trips based on their origin are also considered – home to work, home to school, home to other, and non-home-based.

Transportation energy use totalled 30 GJ per person of which 24 GJ was for household travel.

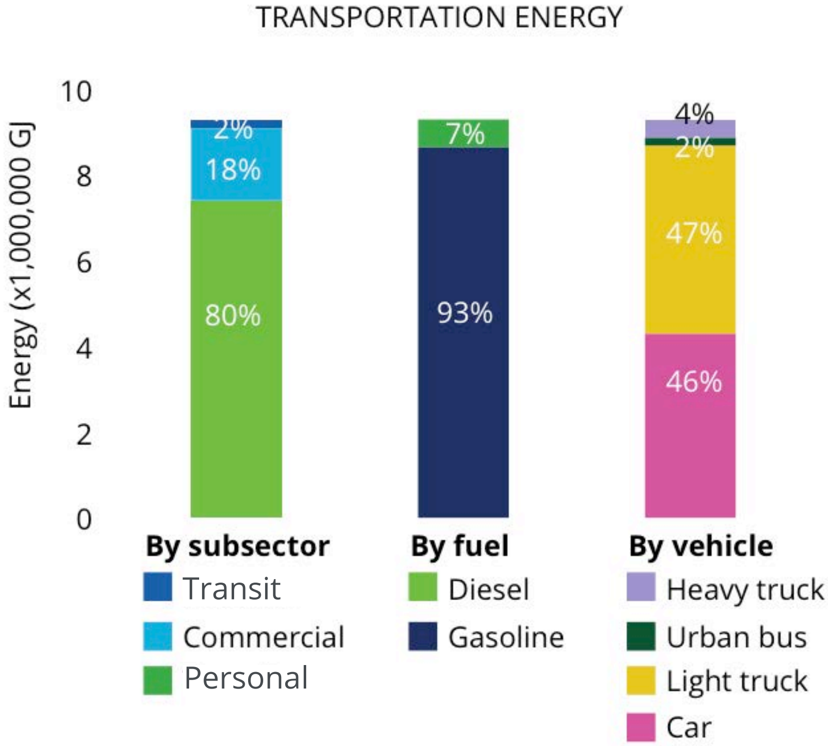


Figure 49. Transportation energy by subsector, fuel and vehicles type, 2011.

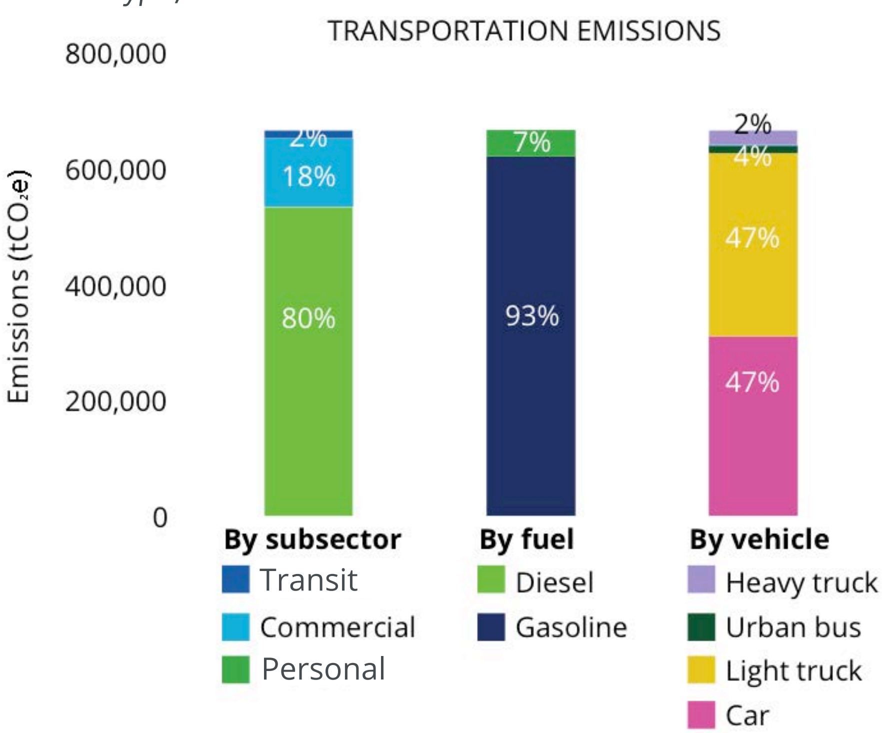


Figure 50. Transportation emissions by subsector, fuel and vehicle type, 2011.

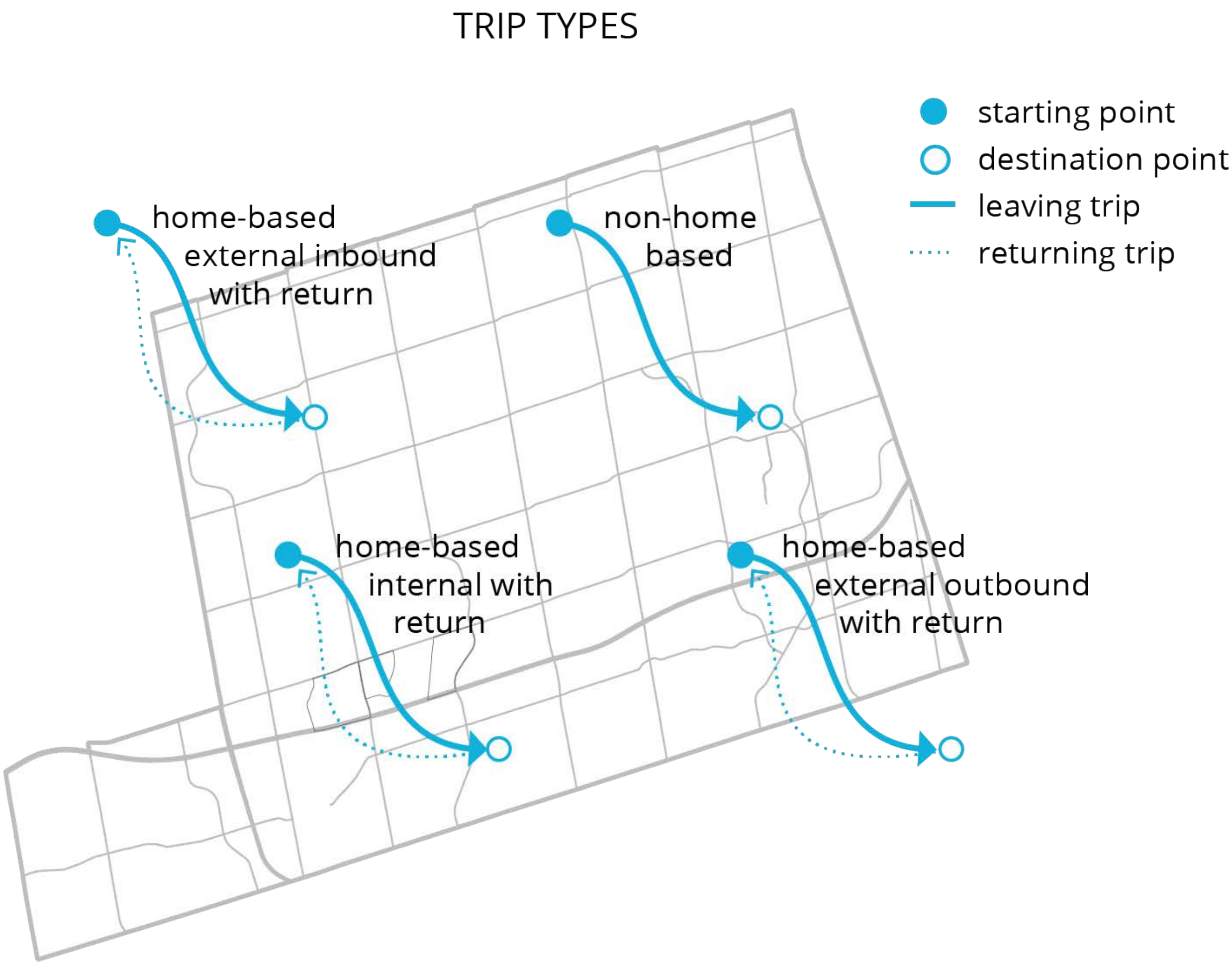


Figure 51. Conceptual diagram of trip categories. Home-based trip types include: work, school, and other.

Just under 1/2 of vehicle trips occur within Markham; the other half are to destinations outside the City boundaries.

The majority of daily trips made in Markham are home-to-other trips, of which approximately half take place as internal trips within the boundary of Markham (Figure 54). Mode share is significantly dominated by personal vehicle use (Figure 52); however, higher shares of active transport and transit are more common for internal trips. As trip distance increases when travelling outside of the city boundary (Figure 53), vehicle trips (ie. vehicle mode share) increases. Personal use vehicle kilometres travelled (VKT) (Figure 55) are highest for home-to-other trips, followed by home-to-work trips. A significant portion of home-to-work personal use VKTs are either external-outbound, or external-inbound.

COMMUTING TRIPS account for 1/3 of all trips.

The average **internal trip** is just under **5 km** in length, while an **external trip** averages just under **20 km**.

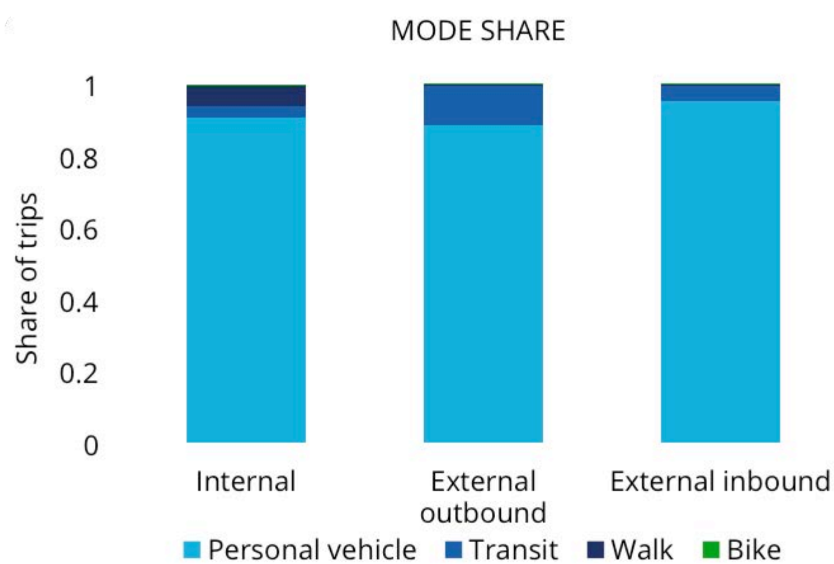


Figure 52. Mode share, 2011.

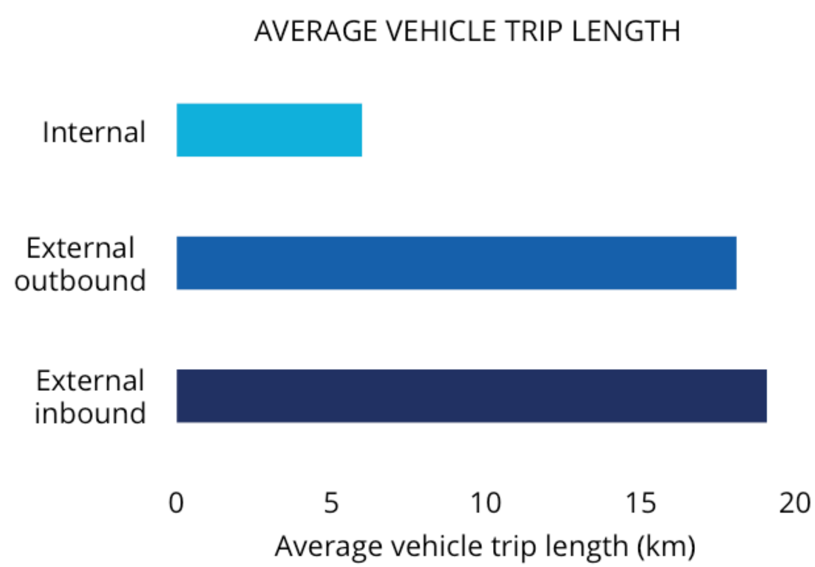


Figure 53. Average vehicle trip length, 2011.

The average **vehicle** in Markham travels just under

12,000 km per year.

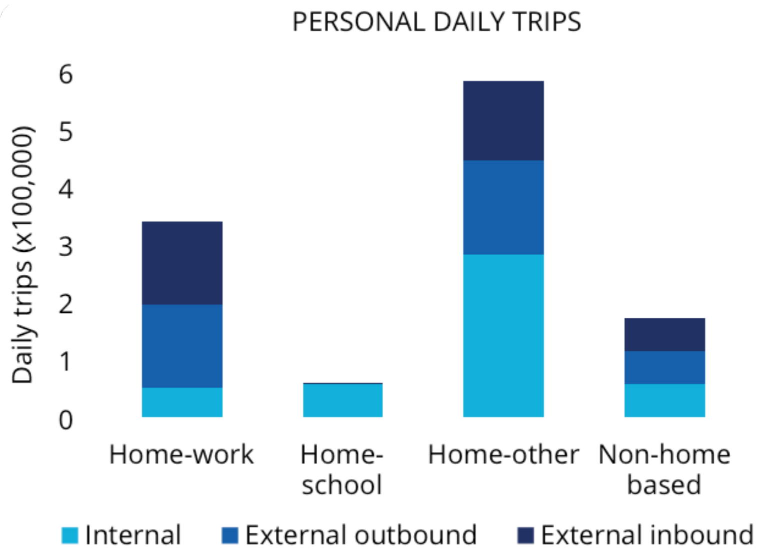


Figure 54. Personal daily trips, 2011.

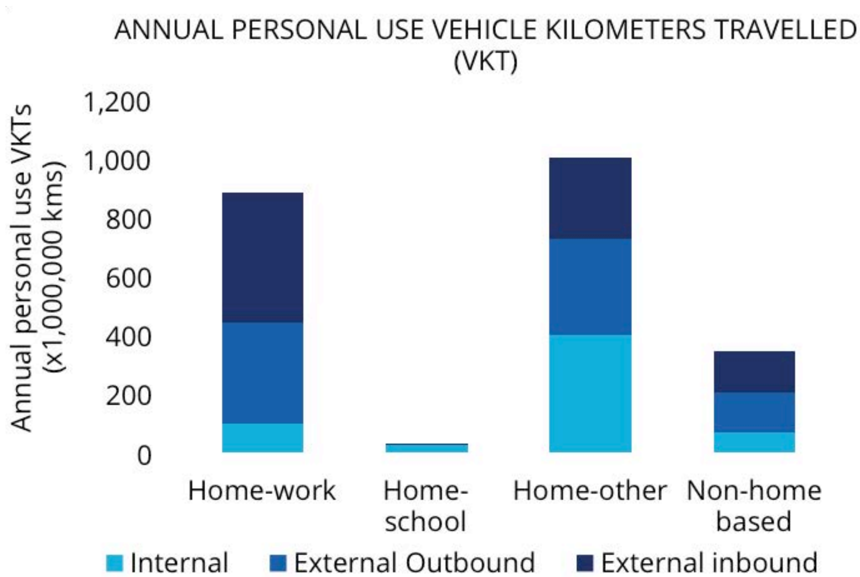


Figure 55. Annual personal use VKT, 2011.

4.5.6 The impact of waste

The waste sector accounts for 227,950 tonnes CO_2e, approximately 13% of total emissions for the City. Within the sector, emissions from solid waste account for 64,100 tonnes CO_2e (28%), with wastewater accounting for 163,850 tonnes CO_2e (72%) (Figure 56).

Solid waste emissions come predominantly from landfills (86%), with the remainder from biological treatment (Figure 56). In 2011, solid waste from Markham was sent to Green Lane Landfill in St. Thomas, ON, and Niagara Waste Landfill in Thorold, ON. Landfill emissions account for the residual solid waste produced by Markham residents that was sent to landfills in 2011, as well as emissions from the former

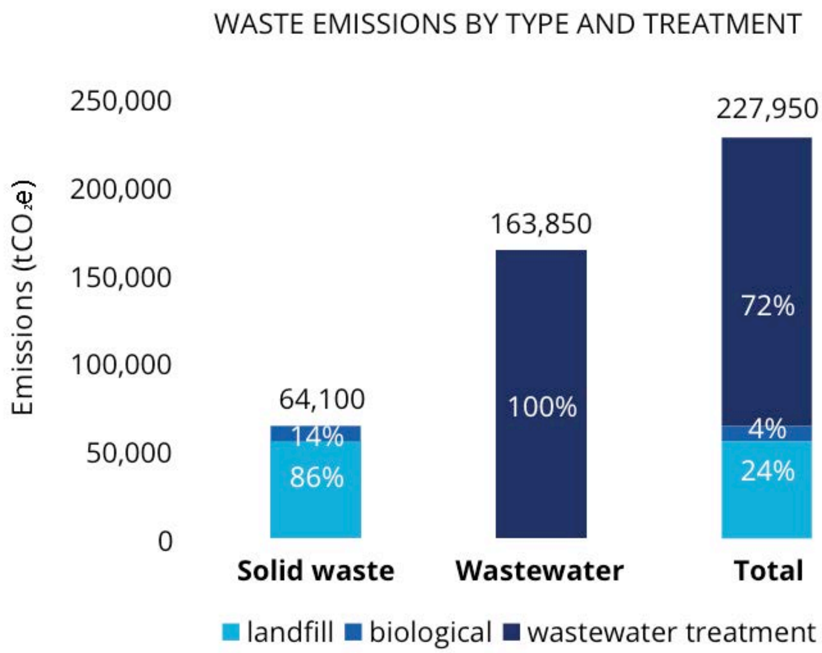


Figure 56. Waste emissions by type and treatment, 2011.

The average person in Markham produced **369 kg** of **SOLID WASTE**, of which 148 kg went to landfill, or 40%.

Sabiston Landfill.[15]

Biological treatment refers to waste that is treated in a sorting facility through composting and/or anaerobic digestion. In 2011, organics were sent to Orgaworld in London, ON, for biological treatment.

The recycling of solid waste results in zero waste emissions; the emissions associated with the energy used at recycling facilities is accounted for under the buildings sector. Similarly, emissions associated with the transportation of waste are accounted for under the transportation sector.

Wastewater emissions amount to 163,850 tonnes CO_2e, which makes up 72% of total waste emissions for the city (Figure 56). These emissions are a result of wastewater generated by the residents of Markham that is treated at the York Region's Duffin Creek Treatment Plant.

In 2011, Markham produced approximately 114,800 tonnes of solid waste. Half consisted of compostable materials (50%), followed by paper (21%) and other waste (21%) (Figure 57). Of this waste, 40% was sent to landfills, with the remainder being biologically treated (34%), and recycled (26%) (Figure 58).

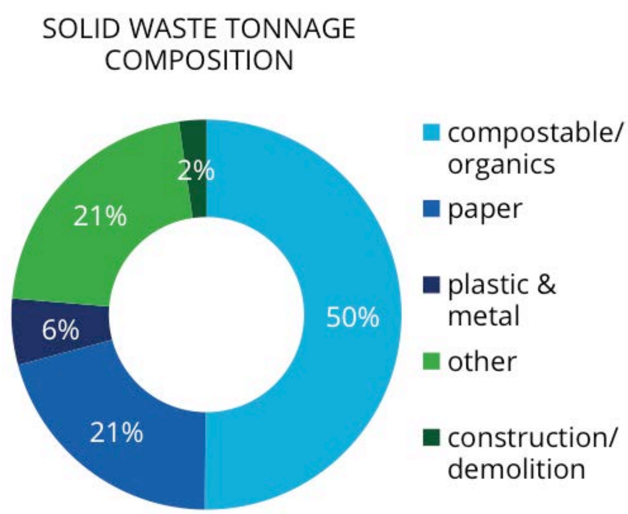


Figure 57. Waste tonnage composition, 2011.

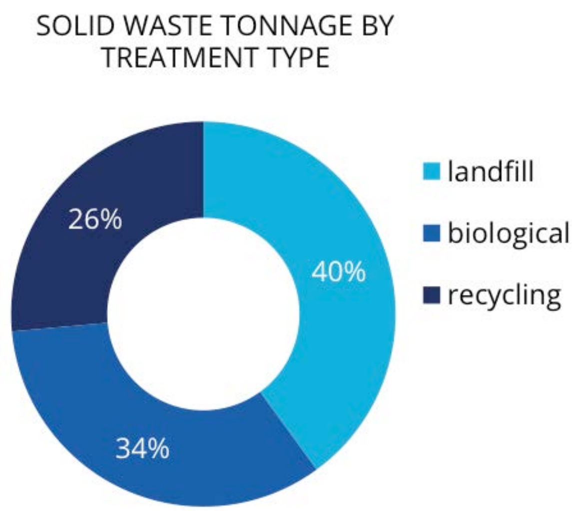


Figure 58. Waste tonnage by treatment type, 2011.

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15 The GPC protocol requires that emissions from all the waste in a landfill (associated with Markham) be reported, regardless of when it was added. Therefore, aside from the former Sabiston landfill, emissions from waste added to landfills outside of Markham should be included as Scope 3. Due to a lack of data, the Markham solid waste emissions value only includes emissions from waste generated by Markham residents and added to landfills outside the boundary in 2011; it does not include the total value of emissions associated with waste from Markham residents in landfills outside the boundary over the landfill's lifetime.

4.6 KEY QUESTIONS

The analysis of current conditions in Markham provide considerable insight on the direction required to reduce GHG emissions. Key questions to explore that emerged from the analysis of current conditions are as follows:

- What is the transition away from gasoline for transportation?
- What is the role of increased walking, cycling and transit?
- What is the role of electric vehicles?
- How can thermal loads for buildings be transitioned to renewable sources?
- What is the role of retrofits and building standards?
- What is the role of electricity for heating?