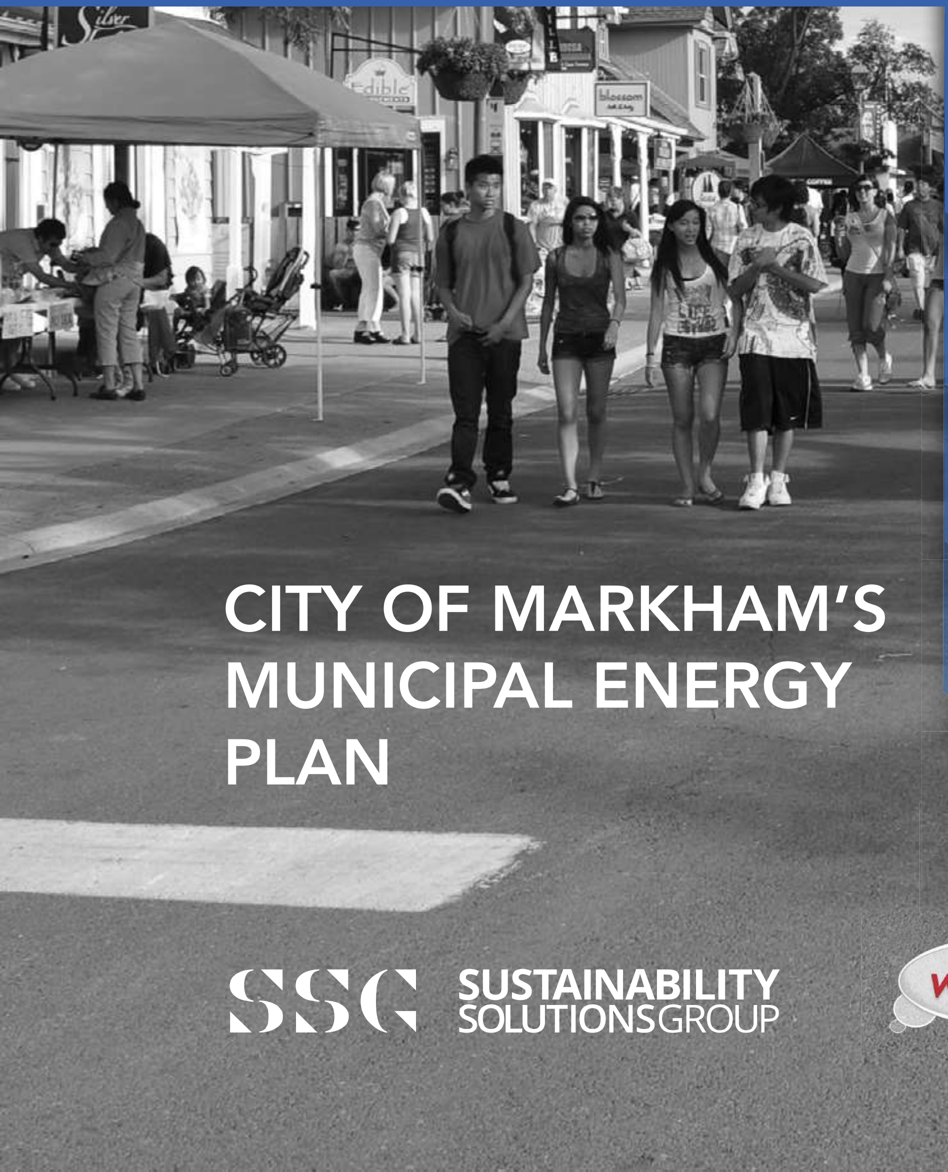
Getting to zero



CITY OF MARKHAM'S MUNICIPAL ENERGY PLAN

SSG SUSTAINABILITY SOLUTIONS GROUP

whatIf?

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KEY ENERGY AND EMISSIONS UNITS

GHG EMISSIONS

1 ktCO2e = 1,000 tCO2e

1 MtCO2e = 1,000,000 tCO2e

ENERGY

1 MJ= 0.0001 GJ

1 TJ= 1,000 GJ

1 PJ= 1,000,000 GJ

1 GJ= 278 kWh

1 MWh= 1,000 kWh

1 GWh=1,000,000 kWh

1 Executive summary

A ROADMAP TO ACHIEVE THE OBJECTIVE OF NET ZERO ENERGY AND EMISSIONS

The Municipal Energy Plan will improve energy efficiency, and reduce energy consumption and greenhouse gas emissions in established and new community areas.

The City of Markham's Municipal Energy Plan is a comprehensive long-term city-wide 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[1] 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?

1 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 a strategy to achieve net zero waste and water, which is a separate effort.

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 guided both the selection of actions and the manner in which actions were 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 sides. 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.

Stage 1	Stage 2	Stage 3
SETTING THE CONTEXT	**EXPLORING THE ACTIONS**	**EVALUATING SCENARIOS**
> Document review / situational analysis	> Actions matrix	> Modelling
> Data collection	> Actions assumptions	> Low carbon - moderate scenario
> Calibration & baseline		> Low carbon - ambitious scenario
> Business-as-usual (BAU) scenario		

Figure 1. Process diagram

THE PROCESS OF DEVELOPING THE MEP

Stage 1: Setting the context

A **document review/situational analysis** was undertaken to understand the current context for energy and emissions in Markham. This process 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.

A process of **data collection resulted** in the development of a **baseline energy and emissions inventory** for the City for the year 2011.

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.

Stage 2: Exploring the actions

The next stage involved the development of an **actions matrix**, a catalogue of actions based on research of best practices of municipal actions to reduce energy consumption and greenhouse gas emissions. The matrix was reviewed with City staff and refined, resulting in a list of actions relevant to the context of Markham. The identification of actions was informed by the results of the BAU, which provided insight on the major drivers of emissions in the City.

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 other cities. Initially, assumptions for one low carbon scenario were developed – the moderate scenario, which achieved an 80% reduction in emissions. After analysis of the initial results, a more ambitious low carbon scenario was developed in order to more closely approach the objective of net zero.

Stage 3: Evaluating scenarios

Stage 3 involved the **modelling and testing of the actions** to develop an integrated scenario. Two low carbon scenarios were developed and modelled for the period of 2016[2] to 2050. The types of actions do not differ between the two low carbon scenarios; the only differences are in the assumptions associated with the rate of application or the level of ambition for certain actions in order to approach the net zero energy emissions target.

The ambitious low carbon scenario results nearly achieves this target by 2050, with just 0.16 $MtCO_2e$ remaining. Additional strategies such as offsets or purchases of green energy are therefore required to fully achieve the net zero objective.

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2 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 low carbon scenarios, which explore the impact on future unobserved years, start in 2016.

ENGAGEMENT

A Stakeholder Working Group (SWG) was established in 2014 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 were engaged through stages 1–3 noted above, providing input, feedback, and recommendations to inform the BAU and low carbon scenarios.

MODELLING

A detailed energy, emissions and finance model called CityInSight was used to evaluate scenarios for the City of Markham. The modelling process involved:

1. The development of a baseline for the year 2011, which is calibrated against observed data from the utilities and other sources;

2. The creation of the BAU scenario;

3. The modelling of actions to reduce GHG emissions;

4. The creation of 'moderate' and 'ambitious' low carbon scenarios (LC-mod, and LC-amb, respectively) which integrate the actions; and

5. The identification of targets.

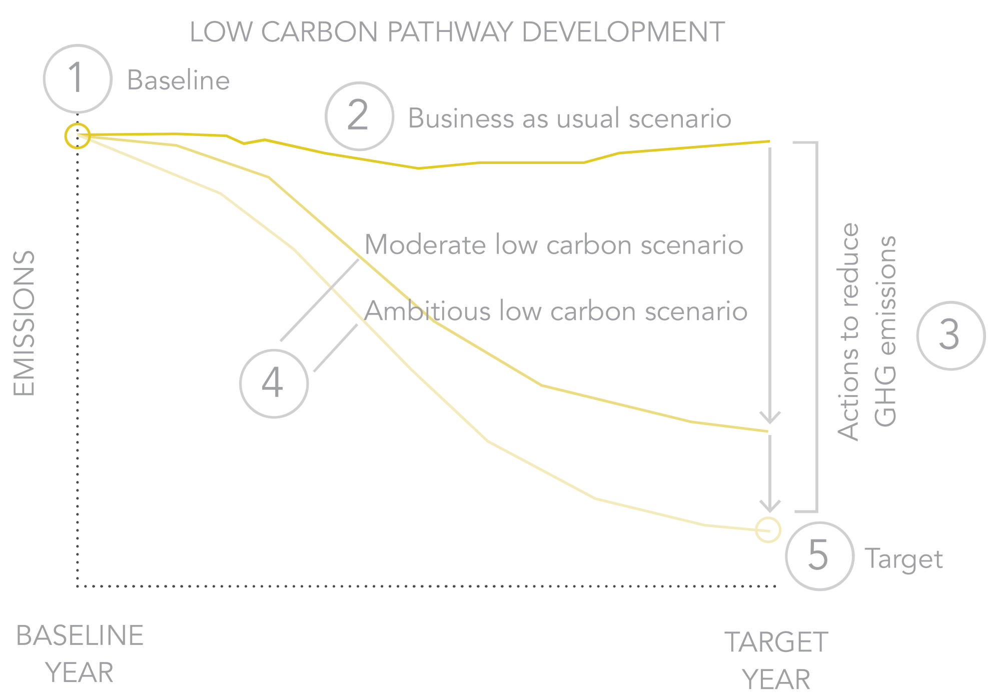

Figure 2. Steps used to model future scenarios for the City of Markham.

Energy and emissions in the baseline year

Total modelled energy consumption for the City of Markham for the baseline year 2011 amounts to approximately 29.69 Peta Joules. Buildings account for two thirds of energy use; with the remainder being consumed in the transportation sector. Natural gas is the most significant fuel type, accounting for 47% of total energy, followed by gasoline at 29%. Total GHG emissions for the City of Markham for the baseline year 2011 were 1.779 megatonnes of carbon dioxide equivalent (CO_2e). The buildings sector stands out as a dominant contributor to overall emissions, accounting for 49% of total emissions, followed by transportation at 37%.

ENERGY USE BY SECTOR AND FUEL TYPE

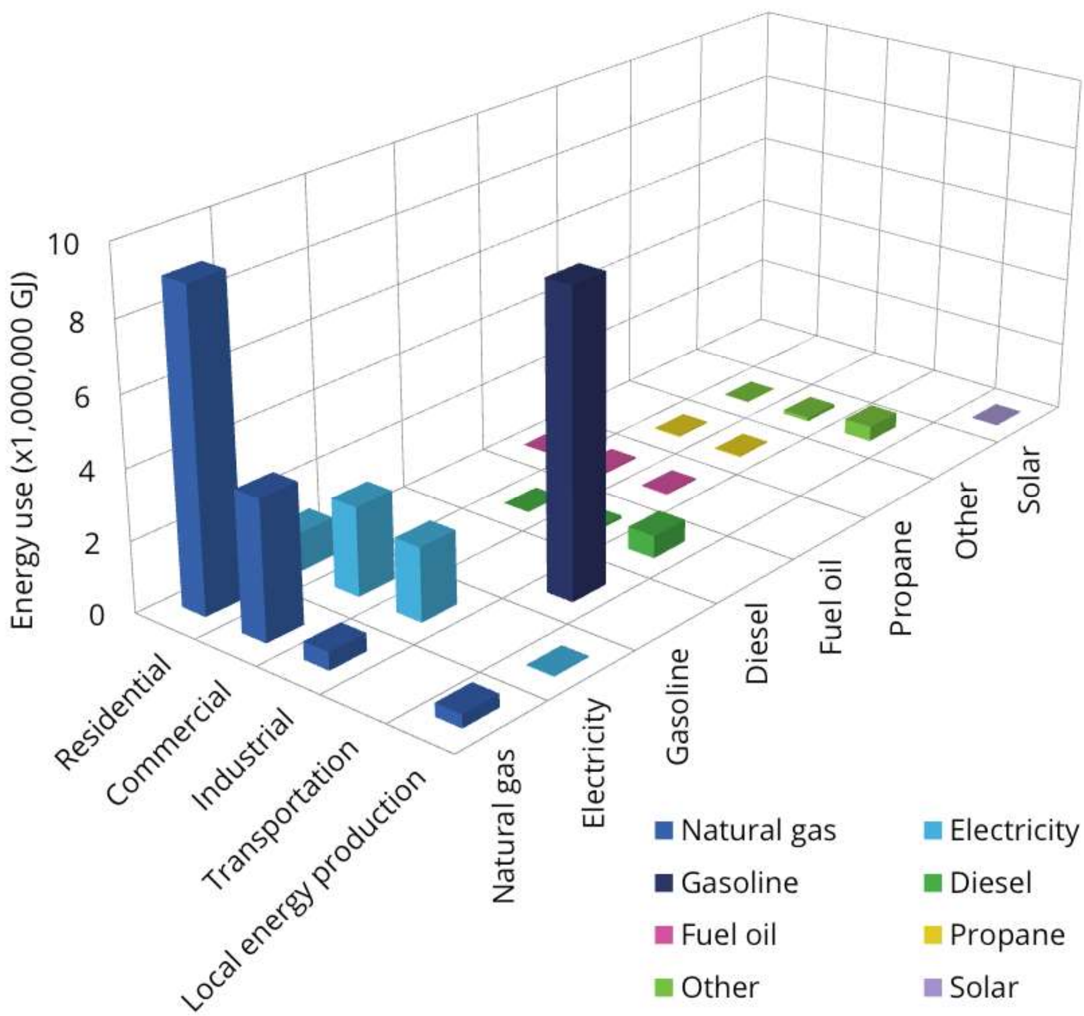

Figure 3. Total energy use by sector and fuel type.

Business as usual

While the population continues to grow, the BAU projections indicate that emissions have a slightly decreasing trajectory, from 1.78 $MtCO_2e$ in 2011, to 1.75 $MtCO_2e$ in 2050. The primary drivers for this reduction are reduced GHG emissions from electricity, improved vehicle fuel efficiency standards, a decrease in heating degree days due to a warming climate, ongoing retrofits of buildings and increasing numbers of electric vehicles.

Twenty-two actions were identified in the buildings, energy and transport sectors, including enhanced energy performance in new construction, retrofits of existing buildings, additional renewable energy both on buildings and on a larger scale, electrification of vehicles and enhanced mode shifting to walking, cycling and transit. The actions are described in Table 1.

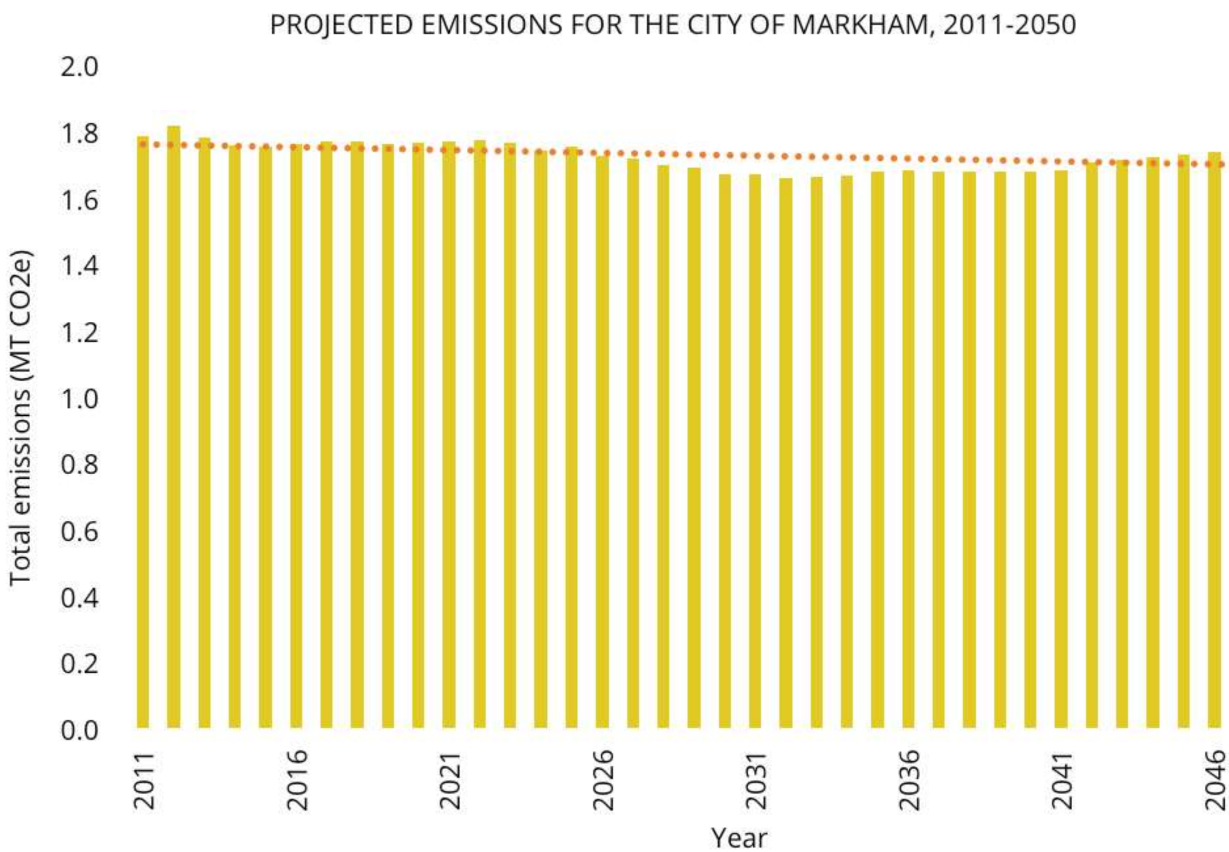

Figure 4. Projected BAU GHG emissions for Markham, 2011–2050.

THE LOW CARBON SCENARIOS

Two low carbon scenarios were developed. The first scenario, LC-mod, represents a major effort to reduce GHG emissions but was not sufficient to achieve the net zero energy emissions target. LC-amb is an ambitious version of LC-mod, with the same set of actions but more aggressive targets in order to achieve an outcome closer to the objective of net zero energy emissions by 2050. Table 1 provides a summary of the actions. For detailed assumptions related to the actions in the scenarios see Appendix 1.

The emissions descent pathways of the two low carbon scenarios over time are illustrated relative to the BAU scenario in Figure 5.

Table 1. Actions modelled in the low carbon scenarios.

BUILDINGS		LC-MOD	LC-AMB
NEW BUILDINGS - BUILDING CODES & STANDARDS			
1	Residential - New residential housing development targets net zero, including solar PV	✓	✓
2	Multi-residential (incl. condominiums), & ICI (institutional, commercial and industrial) - Passivehouse standard applied to multi-unit residential, commercial and institutional buildings	✓	✓
3	Renewable energy installation requirements or incentives on multi-res, commercial and institutional buildings	✓	✓
EXISTING BUILDINGS - RETROFITTING			
4	Retrofit homes prior to 1980	✓	✓
5	Retrofit homes after 1980	✓	✓
6	Retrofits in ICI sector	✓	✓
7	Retrofits of multi-residential	✓	✓
8	Re-commissioning of buildings	✓	✓
9	Renovation threshold requirement to meet codes and standard	✓	✓

RENEWABLE ENERGY GENERATION (ON-SITE, BUILDING SCALE)			
10	Installation of heat pumps: air and ground source residential	✓	✓
11	Installation of heat pumps: air and ground source commercial	✓	✓
12	Solar PV - Net metering all existing buildings	✓	✓
13	Solar heating/hot water	✓	✓
ENERGY GENERATION			
LOW OR ZERO CARBON ENERGY GENERATION (COMMUNITY SCALE)			
14	Solar PV - ground mount	✓	✓
15	Switch district energy to renewable natural gas		✓
16	Energy storage	✓	✓
17	Renewable natural gas		✓
TRANSPORT			
TRANSIT			
18	Electrify transit system	✓	✓
ACTIVE			
19	Increase/improve cycling & walking infrastructure	✓	✓
20	Car free zones	✓	✓
PRIVATE/PERSONAL USE			
21	Electrify personal vehicles	✓	✓
22	Electrify commercial vehicles	✓	✓

✓ LC-mod assumption

✓ (shaded) LC-amb assumption (higher level of ambition than LC-mod)

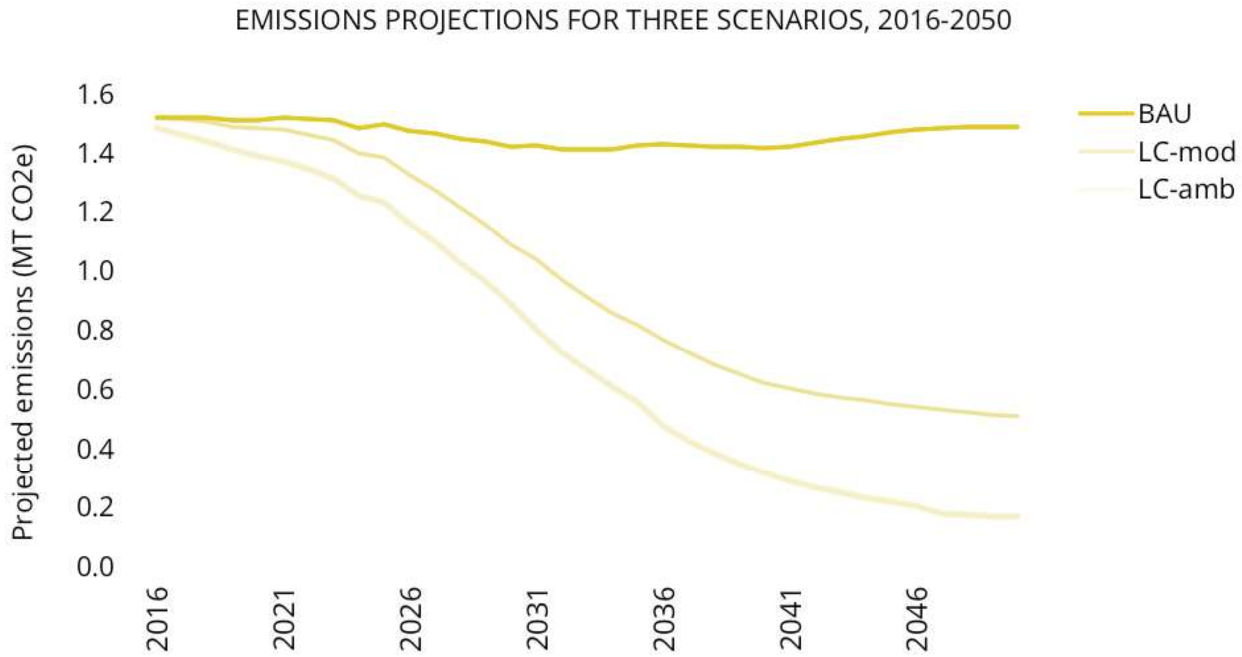

Figure 5. BAU, LC-mod and LC-amb projections, 2016–2050.

Table 2. Summary results of the scenarios.[3]

SCENARIO	2050 ($ktCO_2e$)	% CHANGE OVER 2011	2050 (tCO_2e/ CAPITA)	% CHANGE OVER 2011
BAU	1,478	-5%	2.55	-49%
LC-MOD	501	-68%	0.87	-83%
LC-AMB	162	-90%	0.28	-94%

3 Because of the focus of the net zero definition on GHG emissions from energy sources, GHG emissions from waste have been removed from these calculations.

THE FINANCIAL IMPACTS

A low carbon City is also a lower cost City.

Total expenditures were evaluated in each of the three scenarios, which include capital investments, operating expenditures and revenues in buildings, transportation and energy. A result of negative expenditures indicates that the low carbon scenario results in financial savings, whereas a positive number indicates an increase in expenditures over the BAU scenario.

The BAU scenario projects that a total of $120 billion will be spent on buildings, transportation and energy in the City of Markham between 2017 and 2050, including capital and operating expenditures. The LC-amb and LC-mod scenarios project savings of approximately $7 billion and $8 billion respectively over that same time period. This reduction represents the net of increased and decreased expenditures for households, businesses, the municipality and the energy sector, summed up year over year for the period.

By the year 2050, household energy costs for transportation and homes will decline by 60% on a per capita basis as a result of significant efficiency gains. Vehicle costs (excluding energy but including capital and maintenance) are another major source of savings; per capita vehicle costs will decline by two thirds by 2050 over 2016, as a result of a shared, electric vehicle fleet, which requires fewer vehicles and reduced maintenance.

The capital investments associated with the low carbon scenarios are more intensive in the early years, resulting in initial increases in expenditures of approximately $700 million between 2017 and 2027. This increase ranges from 1% to 5% per year over the background rate of expenditures on buildings, transportation and energy for the first ten years. By 2028, total expenditures are lower in both low carbon scenarios than in the BAU scenario, as illustrated in Figure 7. LC-mod's reduction is greater than that of LC-amb because of the more ambitious investment in heat pumps in LC-amb, required to achieve deeper GHG reductions.

The combination of the actions in the LC-amb result in a **DECREASE IN TOTAL EXPENDITURES** (capital and operating) in the buildings, transportation and energy sectors over the business-as-usual (BAU) scenario, of **$7 BILLION** between 2017 and 2050 in 2017 (constant) dollars.

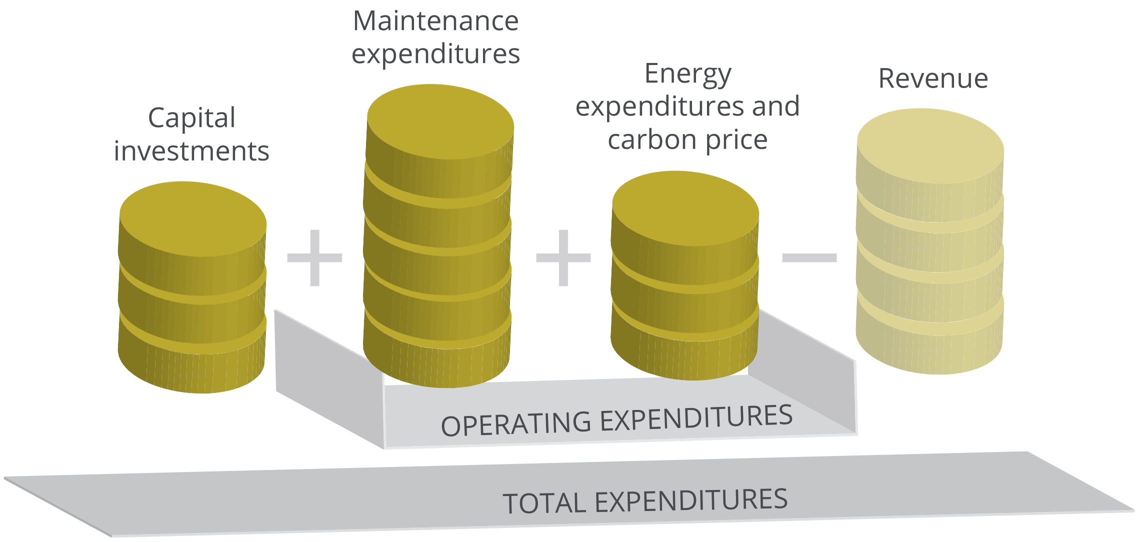

Figure 6. Framework used to evaluate the financial impacts of the scenarios.

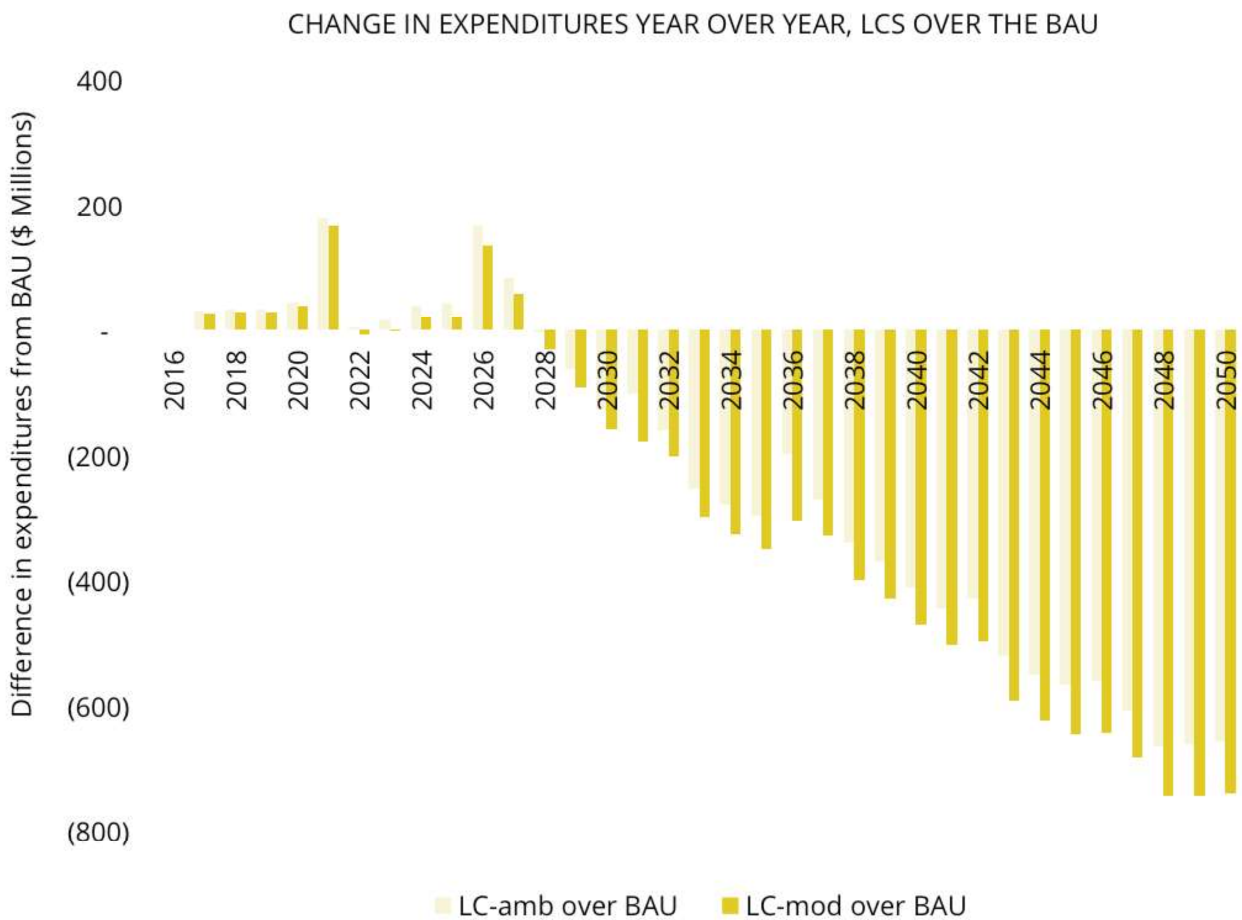

Figure 7. Expenditures in the LC amb and LC mod over the BAU.

The capital investments in LC-amb result in the creation of an additional 35,000 person-years of employment between 2018 and 2050, primarily in the building sector. Employment will decline in the automotive sector as fewer vehicles will be required, but this decline is projected to be offset by increased requirement for jobs in retrofits and decentralized renewable energy.

There are multiple business and investment opportunities for projects with a positive net present value (NPV) for the municipality, households and businesses. All but seven of the actions in the low carbon scenarios are projected to result in financial savings. Opportunities include residential and commercial building retrofits, residential and commercial solar PV, energy storage, shared, autonomous vehicles and financing programs. Businesses and residents are projected to benefit from reduced exposure to fluctuating energy prices in general and oil prices specifically.

Additional co-benefits associated with the low carbon scenario, such as reduced air pollution, reduced congestion and improved health outcomes have not been quantified, but will result in increases in social and economic welfare. Further, the benefits of increased resilience as a result of the investments in the energy system have not been quantified, nor has the benefit of avoided damage from climate change impacts. These aspects, even without quantification, further enhance the business case for the net zero target.

While the LC-amb scenario achieves significant emissions reductions, it does not fully achieve the net zero energy emissions target. In order to fully achieve the target, an additional expenditure on green electricity and renewable natural gas is required. Using a carbon offset strategy, the cost would be approximately $3 million in 2050; alternatively, purchasing green electricity would cost approximately $85 million in 2050. It is also possible that by 2050 advancements in technologies may facilitate the achievement of the target with carbon offsets or purchases of green energy.

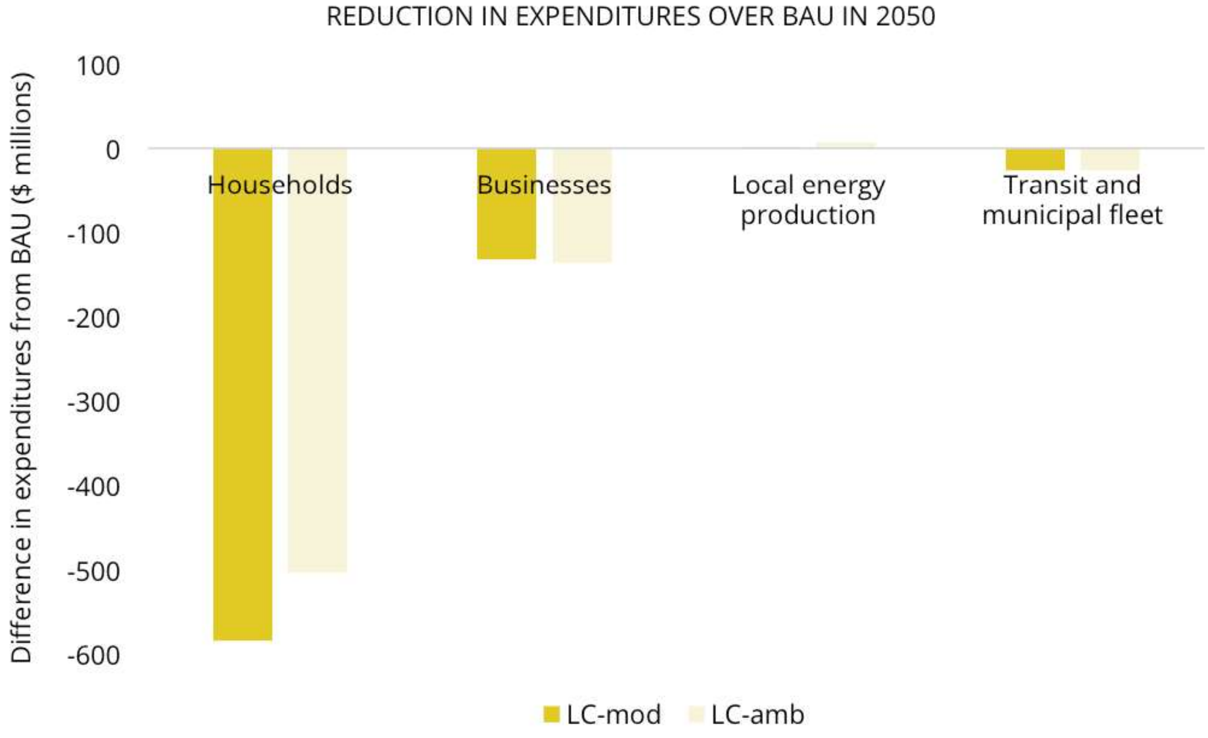

Figure 8. Total expenditures are lower in both scenarios for all sectors by 2050.

IMPLEMENTING THE ACTIONS

Each of the actions is supported by programs, capacity and a financing strategy, and in many cases, the same strategy can address multiple actions. A number of the programs build on existing efforts already underway by the City of Markham or strategies that have been implemented in other jurisdictions in Ontario. The recommend programs detailed on page 17 to page 21 are designed to launch the City of Markham on to the low carbon pathway lending to its achievement of the net zero energy emissions target.

THE PROGRAMS

Markham Green Standard

The Markham Green Standard (MGS) is a parallel effort to Toronto's Green Standard (TGS), which is currently being updated to require advanced building energy performance when approving zoning bylaw amendments, site plans and draft plans of subdivisions.[4] As part of this update, the City of Toronto has developed a specific pathway to net zero emissions buildings. The City of Markham can synchronize with that program both for energy performance and for other sustainability considerations.

The new version of the TGS uses a performance-based approach which incrementally increases over time, providing certainty to developers and the building industry. Additionally, the incremental costs for the standards were assessed for different building types and the incremental cost was 6% or less for each building type. The TGS includes three types of intensity targets – a total energy demand, a thermal energy demand, and GHG intensity – which apply to Part 3: Buildings. Part 3 buildings exceed 600 m2 in building area or exceed three storeys in building height.

It is recommended that Markham also establish targets for net zero energy for single family dwellings, which TGS does not cover. The City is currently working on a Net Zero Energy and Emissions pilot project which will help to inform the direction of the residential component of the MGS.

Markham High Performance Building Initiative

The Initiative will support building retrofits in the residential, commercial and industrial sectors as well as building recommissioning. Specific programs will be developed for each sector using the local improvement charge mechanism.

4 For details on the updated TGS, see The City of Toronto Zero Emissions Building Framework: https://www1.toronto.ca/City%20Of%20Toronto/City%20Planning/Developing%20Toronto/Files/pdf/TGS/Zero%20Emissions%20Buildings%20Framework%20Report.pdf

Markham Energy Co-operative

The City of Markham has expertise in solar photovoltaic (PV) and district energy. Building on this expertise, an arm's length energy cooperative can be launched with the mandate of achieving the renewable energy goals in the MEP. Designed as a multi-stakeholder cooperative, members can include the City, utilities, businesses and individuals.

Markham Electric Vehicle Strategy

The Electric Vehicle Strategy will be a multi-departmental coordinated effort by the City to support the increased uptake of electric vehicles. Strategies will include preferential parking rules, an enhanced network of appropriate charging stations, requirements for charging stations in buildings, and other supports.

Low Carbon City Planning

Many of the enabling conditions for low carbon strategies result from city planning. Wherever possible, the City should enhance its efforts to support land-use patterns focussed on complete, compact community design to enable district energy, walking and cycling, and frequent transit. The City has developed a terms of reference for community energy planning which aims to achieve these objectives at the scale of secondary plans.

Local improvement charge

The City of Markham can use Local Improvement Charges (LICs), further detailed in Appendix 7. LICs are a financing mechanism authorized by O.Reg. 322/12 under the Municipal Act, 2001 for building retrofits, and assuming that a future legal opinion identifies LICs are also applicable, for the cost increment of new construction of high performance houses and buildings over code. Additional funding can be raised through green bonds or climate bonds.

Table 3. Implementation mechanisms.

ACTION	PROGRAMS	CAPACITY	FINANCE	ENGAGEMENT
NEW CONSTRUCTION				
Residential - New residential housing development targets net zero, including solar PV	Markham Green Standard	City of Markham Planning	Local improvement charge (potential) +other incentives	Net zero engagement strategy
Multi-residential (incl. condominiums) & commercial and institutional - Passivehouse standard applied to multi-unit residential and commercial buildings				
Renewable energy installation requirements or incentives on multi-res, institutional, commercial and industrial buildings				
EXISTING BUILDINGS				
Retrofit homes prior to 1980	Markham High Performance Buildings Initiative	City of Markham, utilities	Local improvement charge	Net zero engagement strategy
Retrofit homes after 1980				
Retrofits in ICI sector				
Retrofits of multi-residential				
Re-commissioning of buildings			Utility partnerships	
Renovation threshold requirement to meet codes and standard	Markham Green Standard	City of Markham Planning	Local improvement charge	

ACTION	PROGRAMS	CAPACITY	FINANCE	ENGAGEMENT
RENEWABLE ENERGY GENERATION, BUILDING SCALE				
Installation of heat pumps: air and ground source residential	Markham High Performance Buildings Initiative	City of Markham, utilities, private sector	Local improvement charge	Net zero engagement strategy
Installation of heat pumps: air and ground source commercial				
Solar PV - net metering all existing buildings	Markham Energy Co-operative			
Solar heating/hot water				
LOW OR ZERO CARBON ENERGY GENERATION				
Solar PV - ground mount	Markham Energy Co-operative	Private sector	Green/ climate bonds	Net zero engagement strategy
Switch district energy to renewable natural gas	Markham District Energy Corporation	Markham District Energy Corporation		
Energy storage		Markham District Energy Corporation, private sector		
Renewable natural gas	Markham Energy Co-operative	Private sector	To be identified	

ACTION	PROGRAMS	CAPACITY	FINANCE	ENGAGEMENT
TRANSPORT				
Electrify transit system	Markham Electric Vehicle Strategy	City of Markham	Infrastructure funding	Net zero engagement strategy
Increase/improve cycling & walking infrastructure	City of Markham			
Car free zones				
Electrify personal vehicles	Markham Electric Vehicle Strategy	City of Markham, businesses	Non-financial	
Electrify commercial vehicles				

A COMMUNICATIONS PLAN

The MEP is an ambitious plan that requires the City to significantly enhance its efforts in new and existing spheres of activity. Community engagement will be a critical element in ensuring support and participation in these activities.
An engagement effort has been designed to support the implementation of the MEP, including events, programs, pilot projects, online strategies and other aspects.

EVALUATING

Many of the policies and interventions in the MEP represent enhancement efforts in existing program areas. Tracking the effectiveness of these actions helps to manage the risk and uncertainty associated with these efforts, as well as external forces such as evolving senior government policy, and new technologies which can disrupt the energy system. Key motivations for monitoring and evaluation include the following:

- Identify unanticipated outcomes
- Adjust programs and policies based on their effectiveness
- Manage and adapt to the uncertainty of climate change
- Manage and adapt to emerging technologies

Specific activities which have been identified to support the implication of the MEP include an annual work plan and review, an annual indicator report, an update of the GHG inventory every two years and an update of the MEP every five years.

Table 4. Monitoring and evaluation activities.

ACTIVITY	PURPOSE	DESCRIPTION	FREQUENCY
1. ANNUAL WORK PLAN AND REVIEW	Review work to-date and set annual priority actions	Annual report with prioritized actions	Annual
2. ANNUAL INDICATOR REPORT	Track effectiveness of actions	Annual report on set of indicators with an analysis of the results.	Annual
3. INVENTORY	Update GHG emissions profile	Re-calculate the GHG emissions inventory	Every 2 years
4. UPDATE THE MEP	Update the MEP to reflect changing conditions	Work through each stage of the community energy and emissions planning process	Every 5 years

The MEP represents a detailed analysis of a pathway to achieve the net zero energy emissions target for the City of Markham. This pathway represents a transformation in the way in which energy is generated and used in the City, but the analysis demonstrates viable and realistic options. The pathway requires significant investment, particularly in the short term, but over the long-run results in financial benefits for households, businesses and the municipality. The actions and programs described require an enhanced effort by the City and new partnerships, building on efforts already underway.

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.

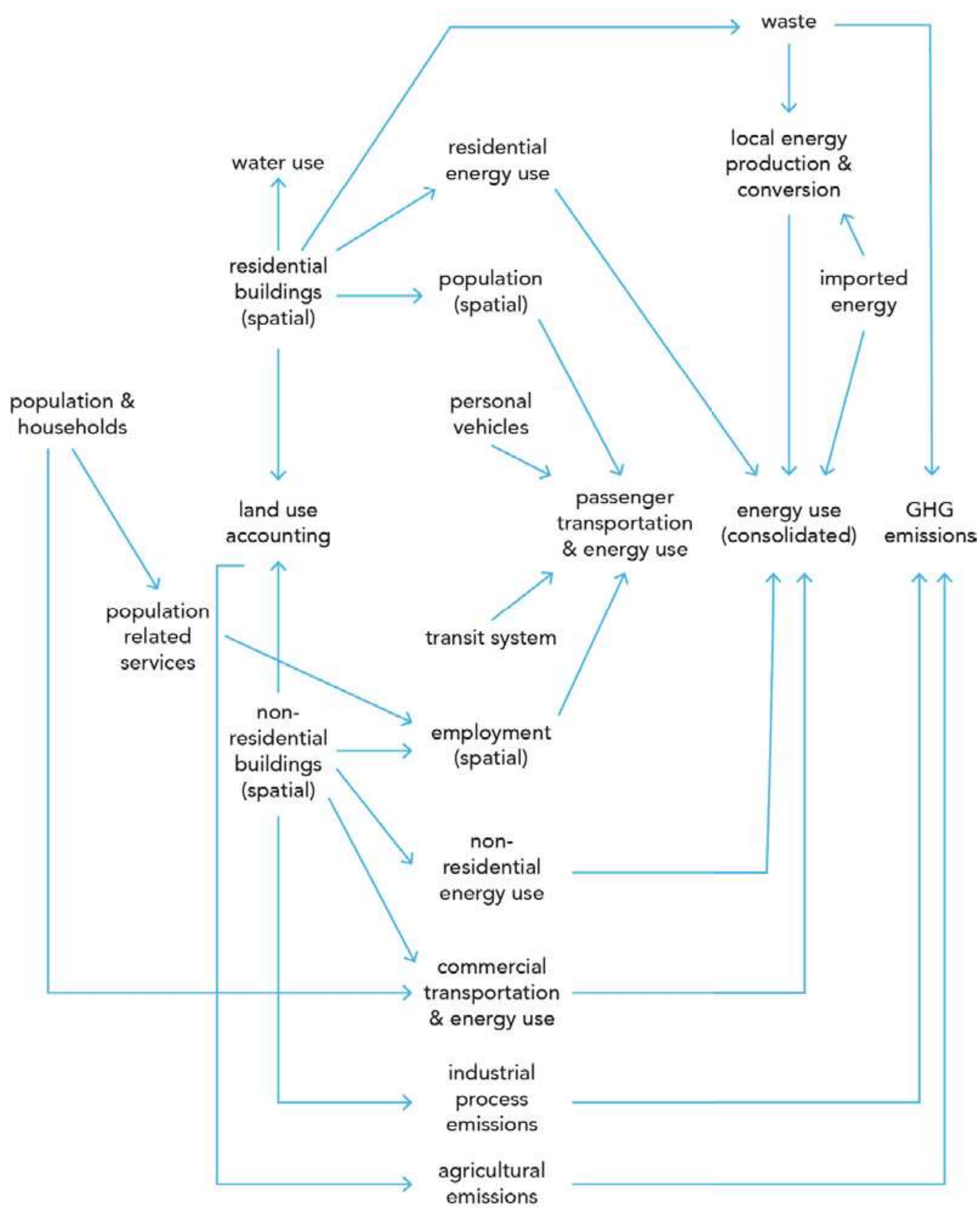


Figure 9. An illustration of municipal energy and emissions systems.

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

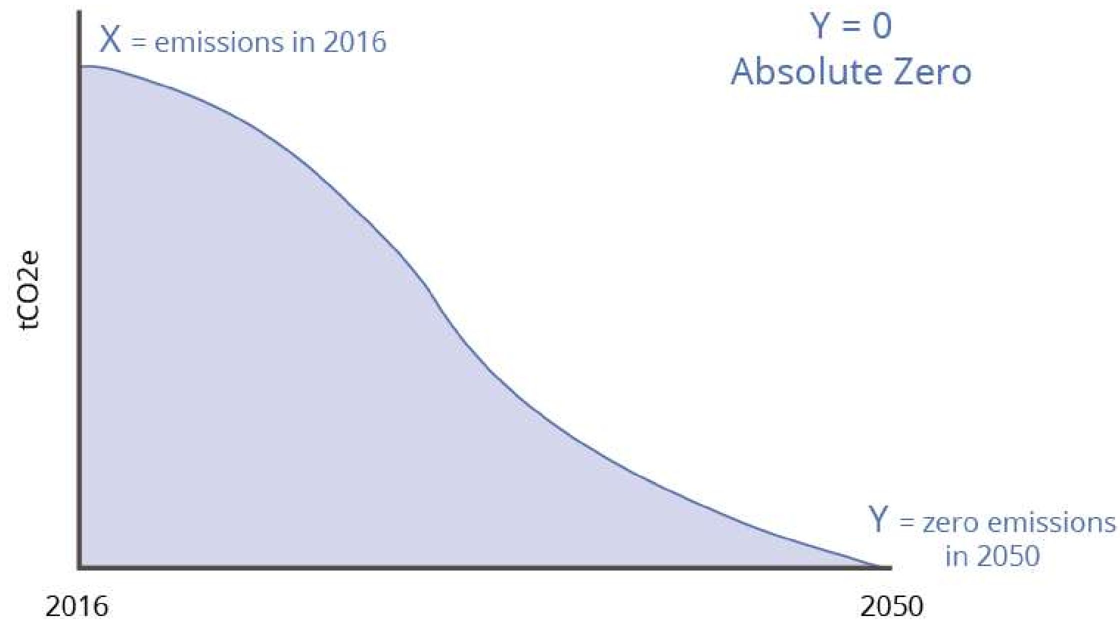


Figure 10. Sample projection of absolute zero in 2050. Achieving "absolute" zero by 2050 means that by 2050, or in the year 2050, there are zero emissions produced from any energy consuming activities. Y represents zero GHG emissions in 2050.

NET ZERO EMISSIONS TRAJECTORY

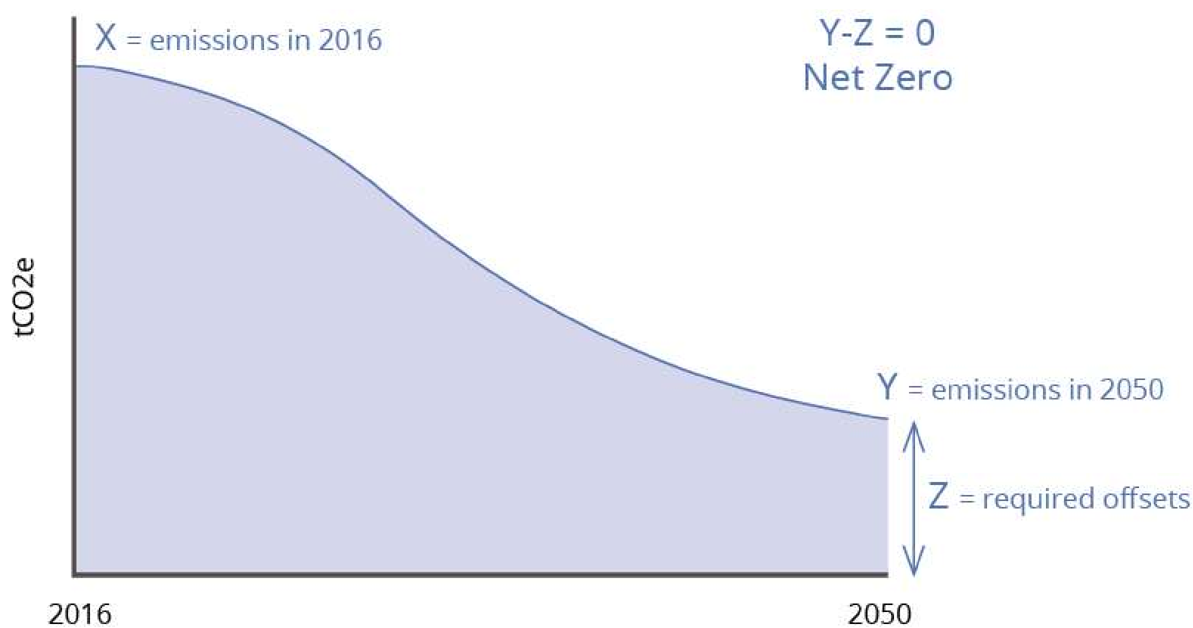


Figure 11. Sample projection of net zero using offsets in 2050. The offset (Z) is equal to the amount of GHG emissions produced in 2050 (Y), resulting in net zero emissions.

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

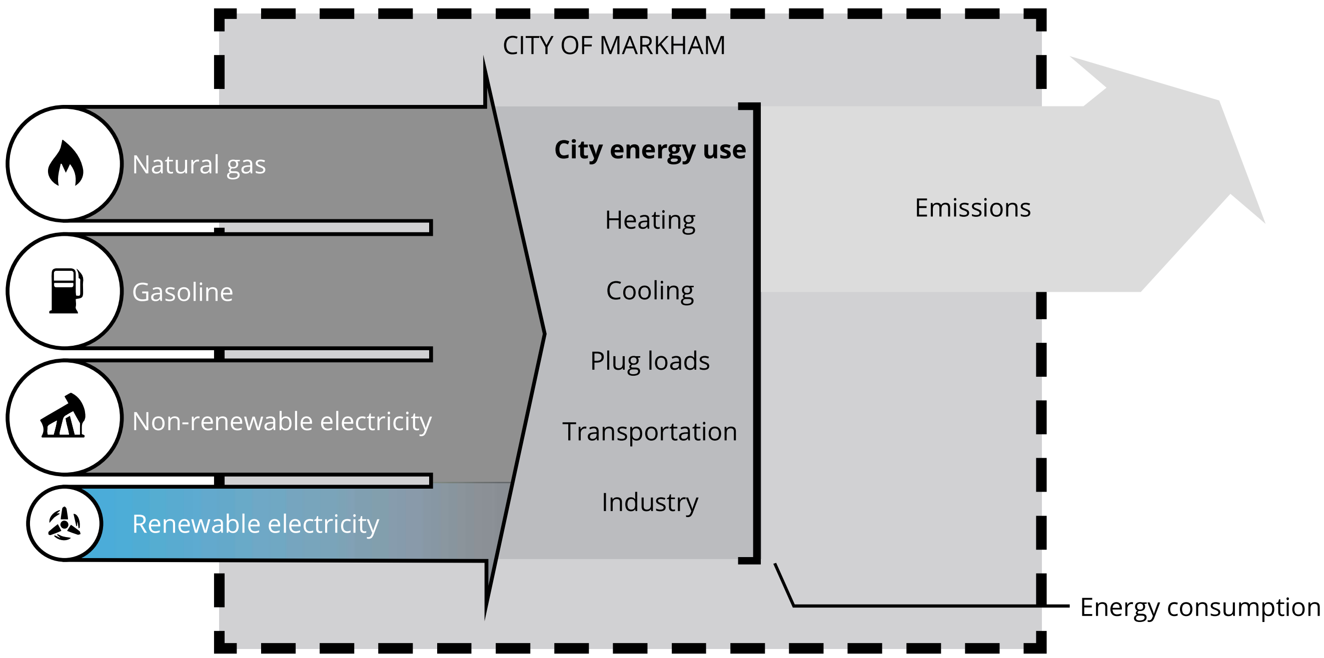
The long term vision to reach net zero by 2050 is guided by three main principles:

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)

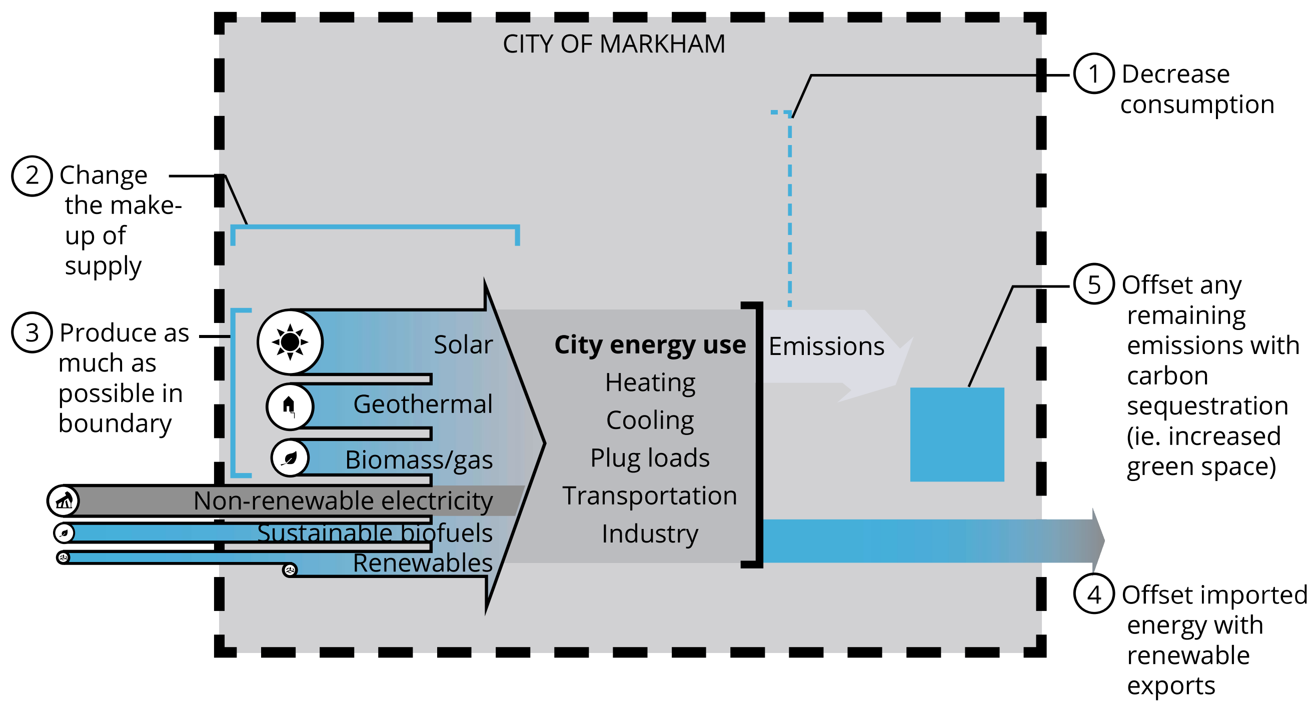


Figure 12. Illustration of the net zero principles to the City of Markham's energy system.

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.

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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.

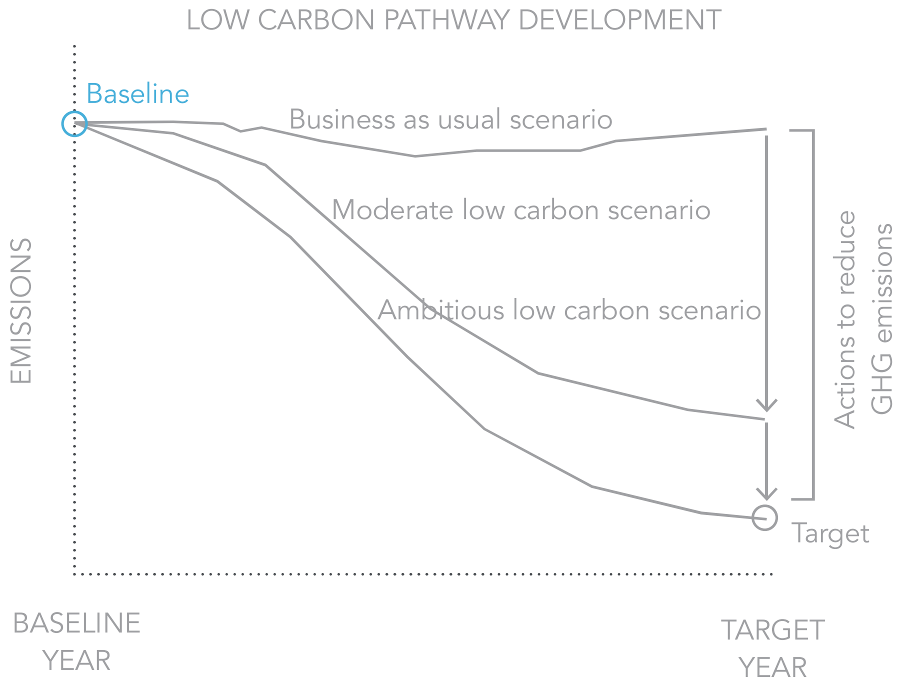

Figure 14. The development of low carbon scenarios, represented visually.

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).

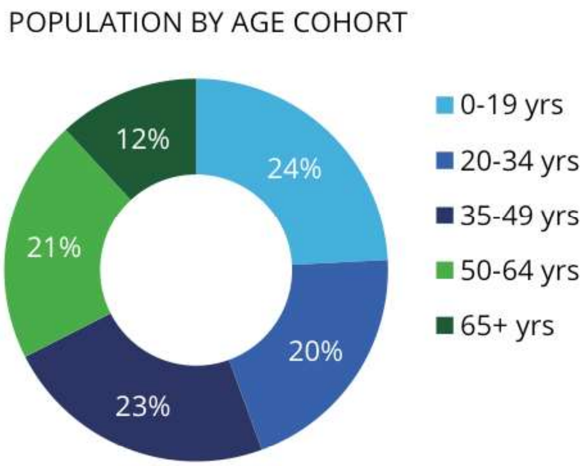

Figure 16. Markham population, 2011.

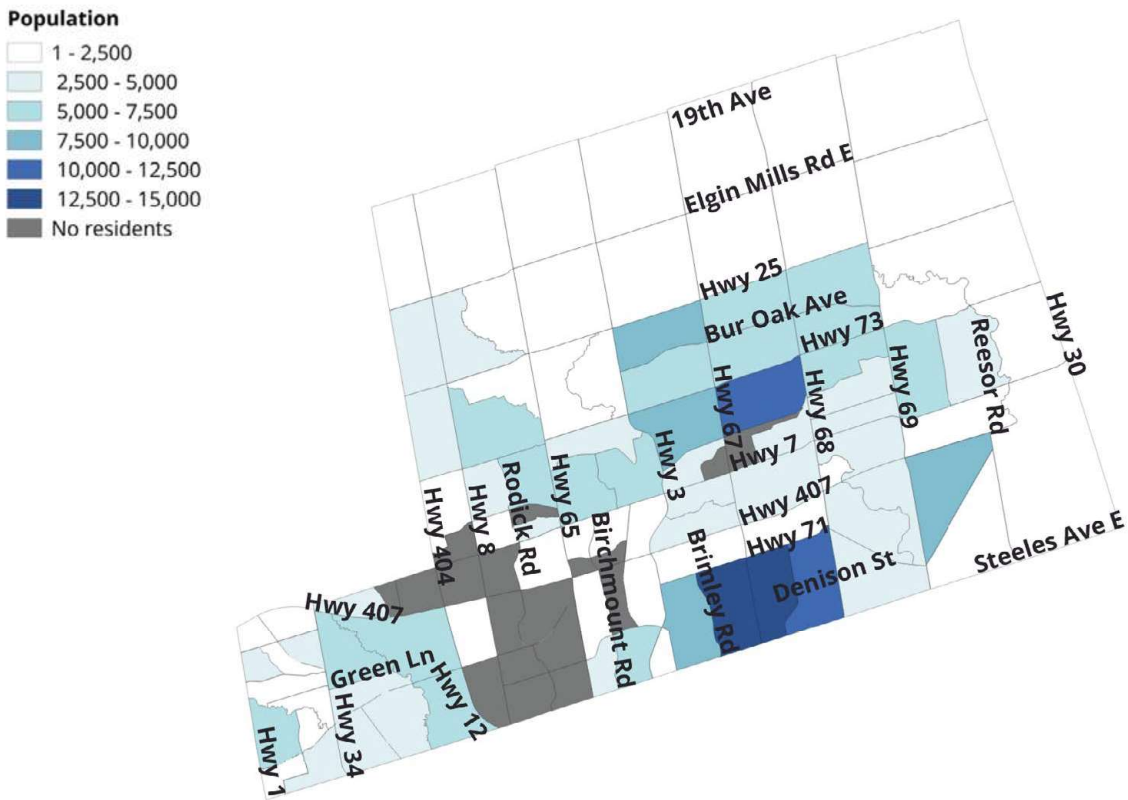

Figure 17. Markham resident distribution, 2011.

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

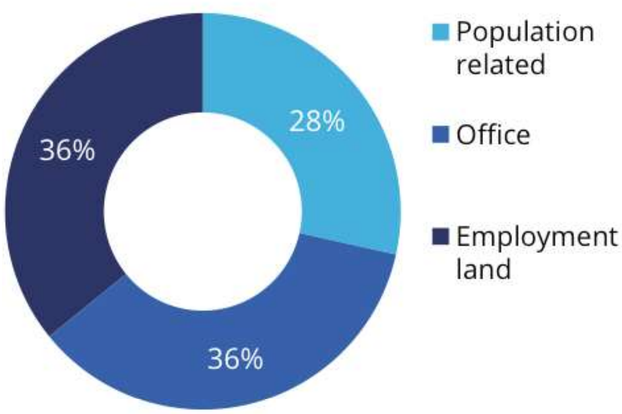

Figure 18. Markham employment, 2011.

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?

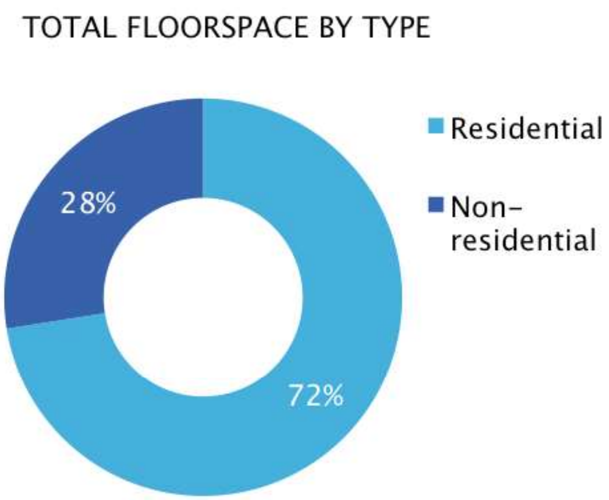

Figure 19. Total floorspace by type, 2011.

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.

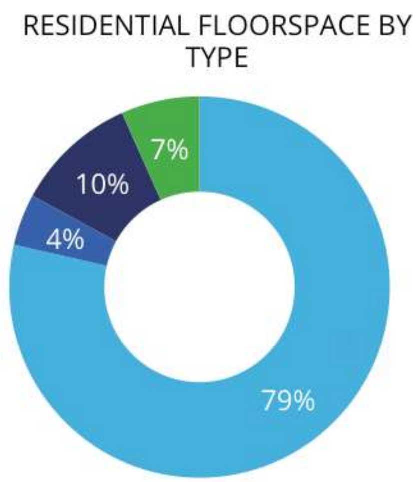

Figure 20. Residential floorspace by type, 2011.

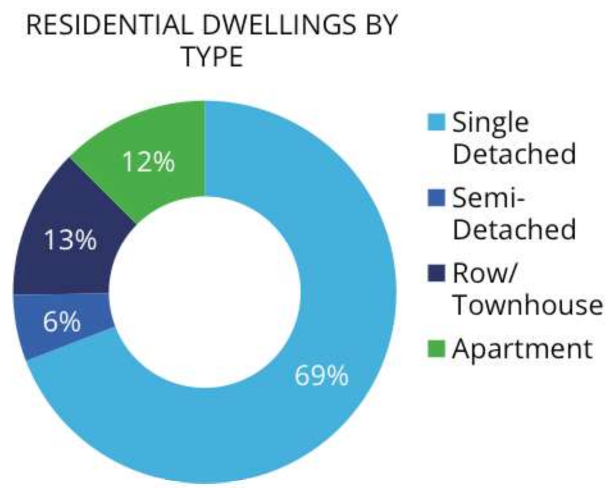

Figure 21. Residential dwellings by type, 2011.

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).

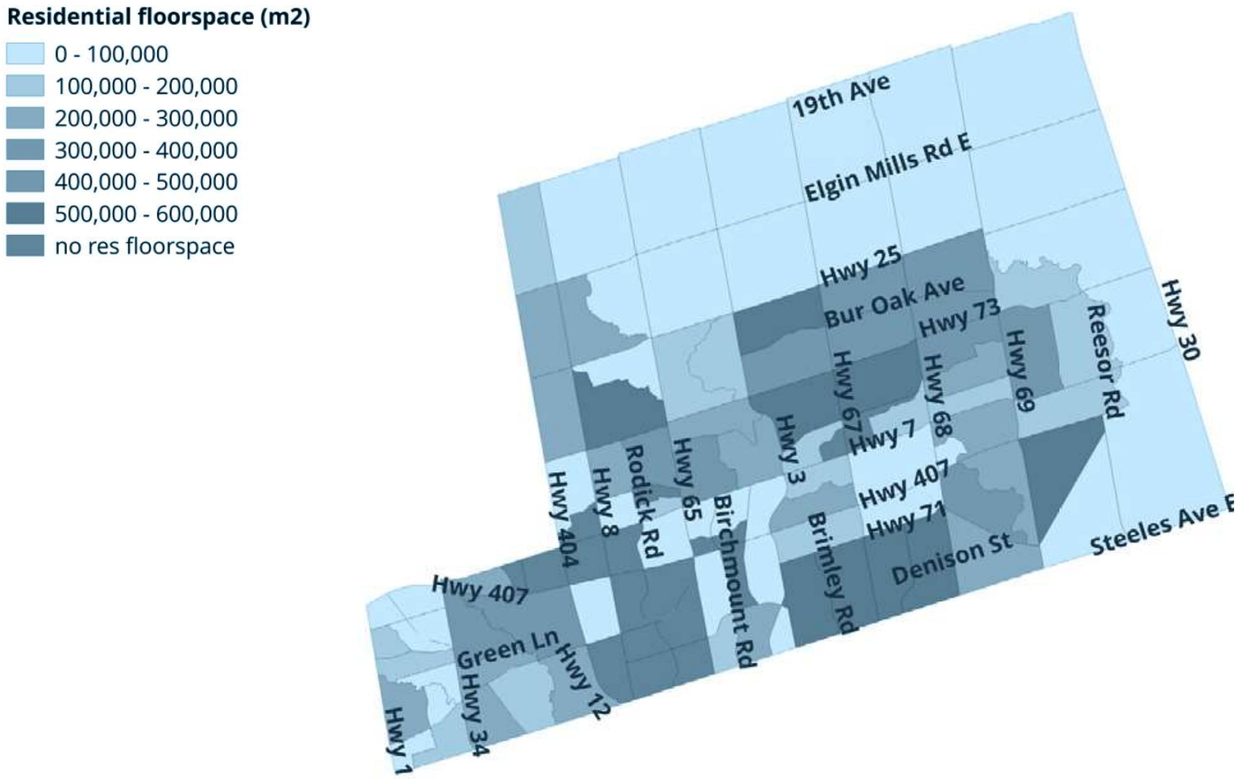

Figure 22. Residential floorspace distribution, 2011.

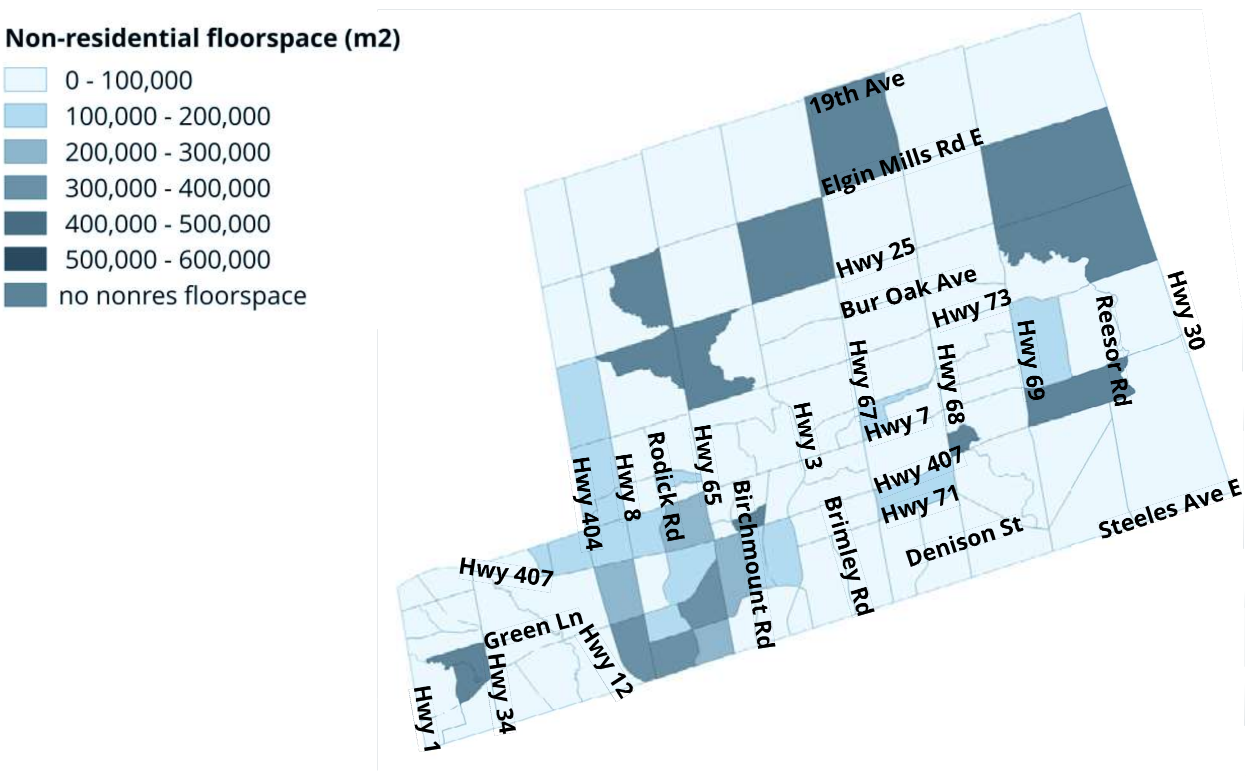

Figure 23. Non-residential floorspace distribution, 2011.

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.

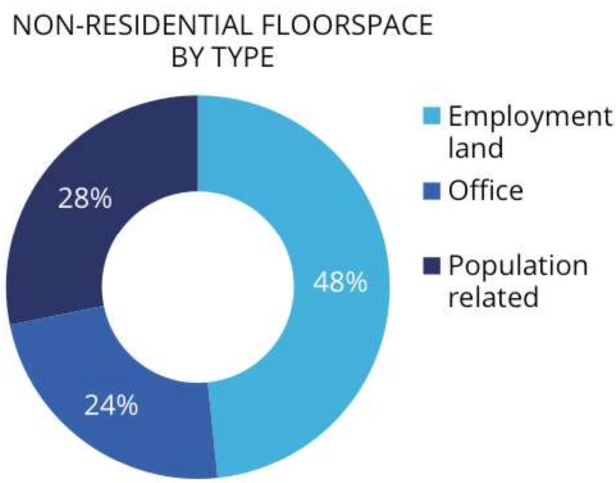

Figure 24. Non-residential floorspace by type, 2011: employment land (industrial and business parks), office (buildings larger than 20,000 sf), and population related (services such as schools and government offices).

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.

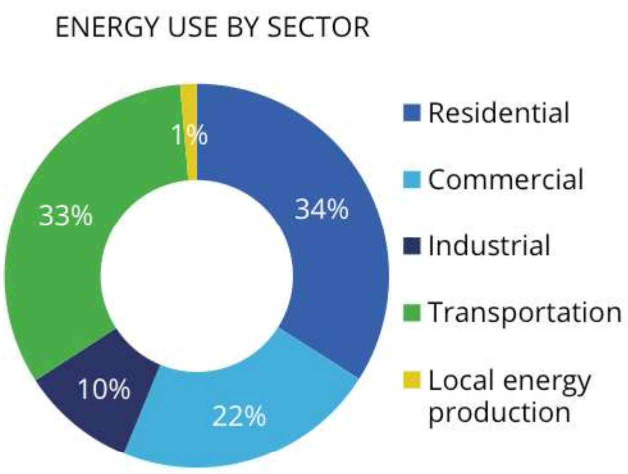

Figure 25. Energy use by sector, 2011

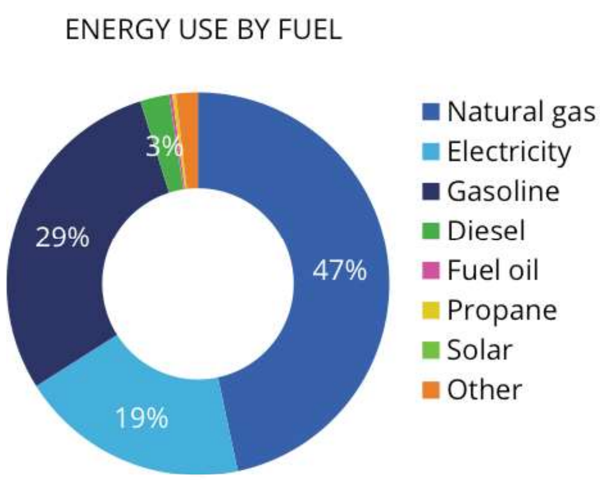

Figure 26. Energy use by fuel, 2011.

12 1PJ = 1 million GJ

ENERGY USE in Markham totalled

95 GJ per person.

ENERGY USE BY SECTOR AND FUEL TYPE

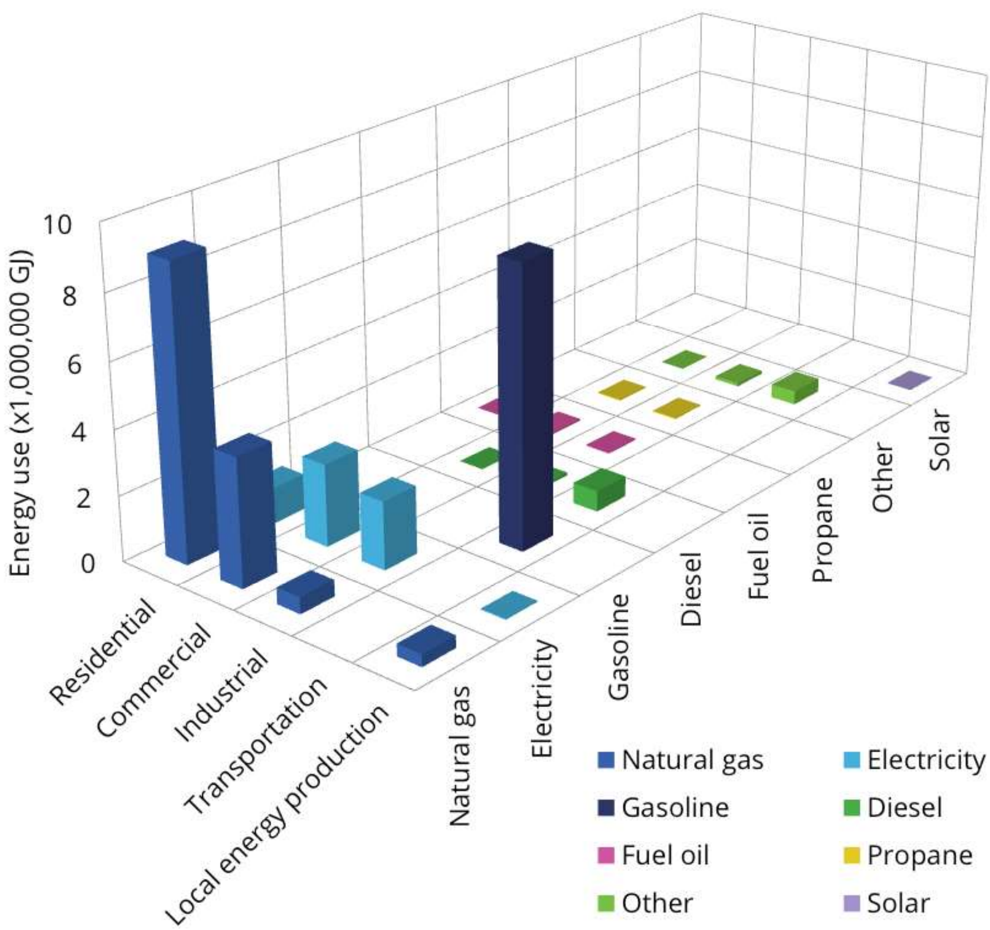

Figure 27. Energy use by sector and fuel, 2011.

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.

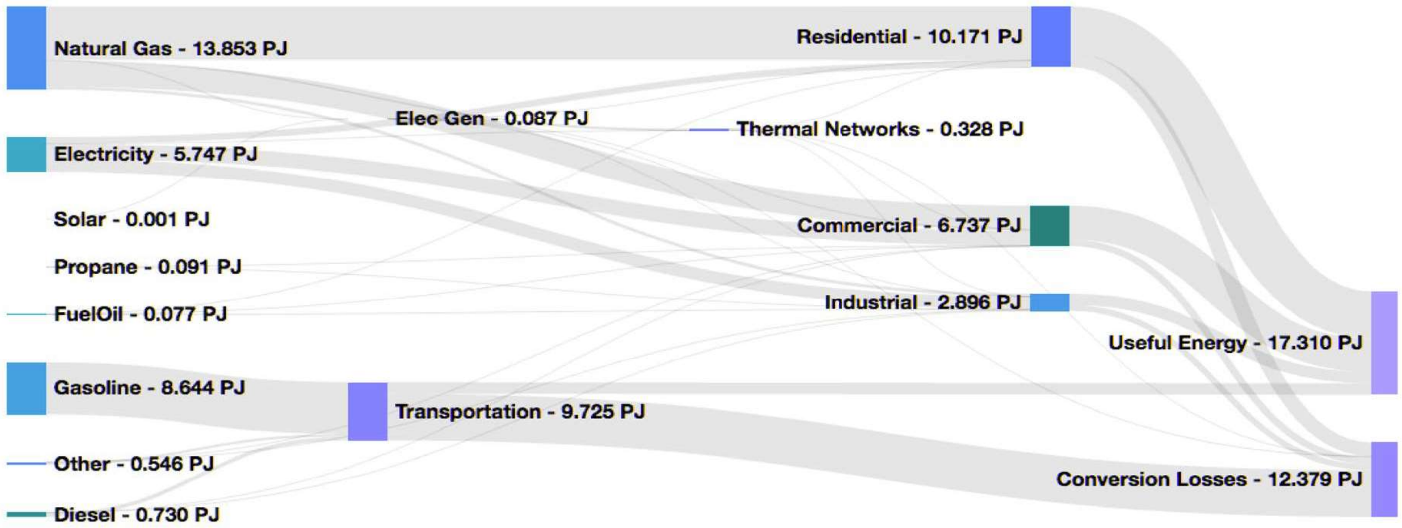

Figure 28. Energy flow, 2011.

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).

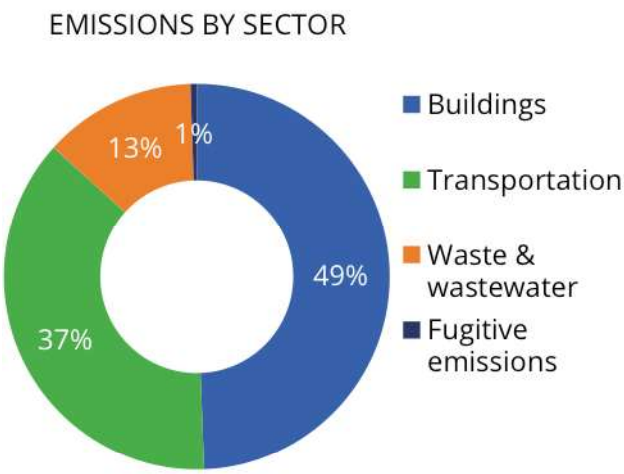

Figure 29. Markham emissions by sector, 2011.

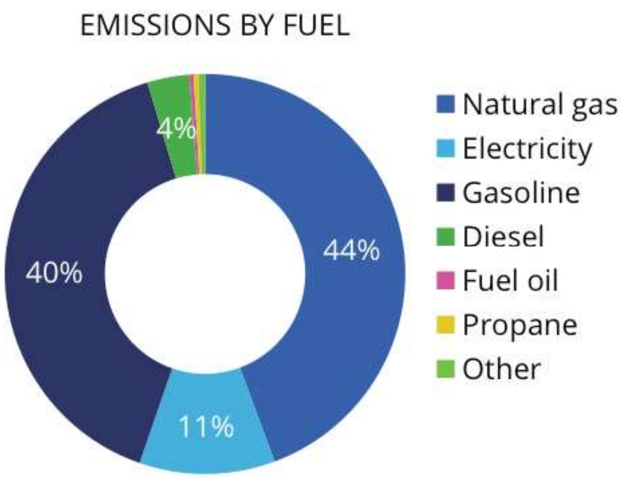

Figure 30. Markham emissions by fuel, 2011.

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

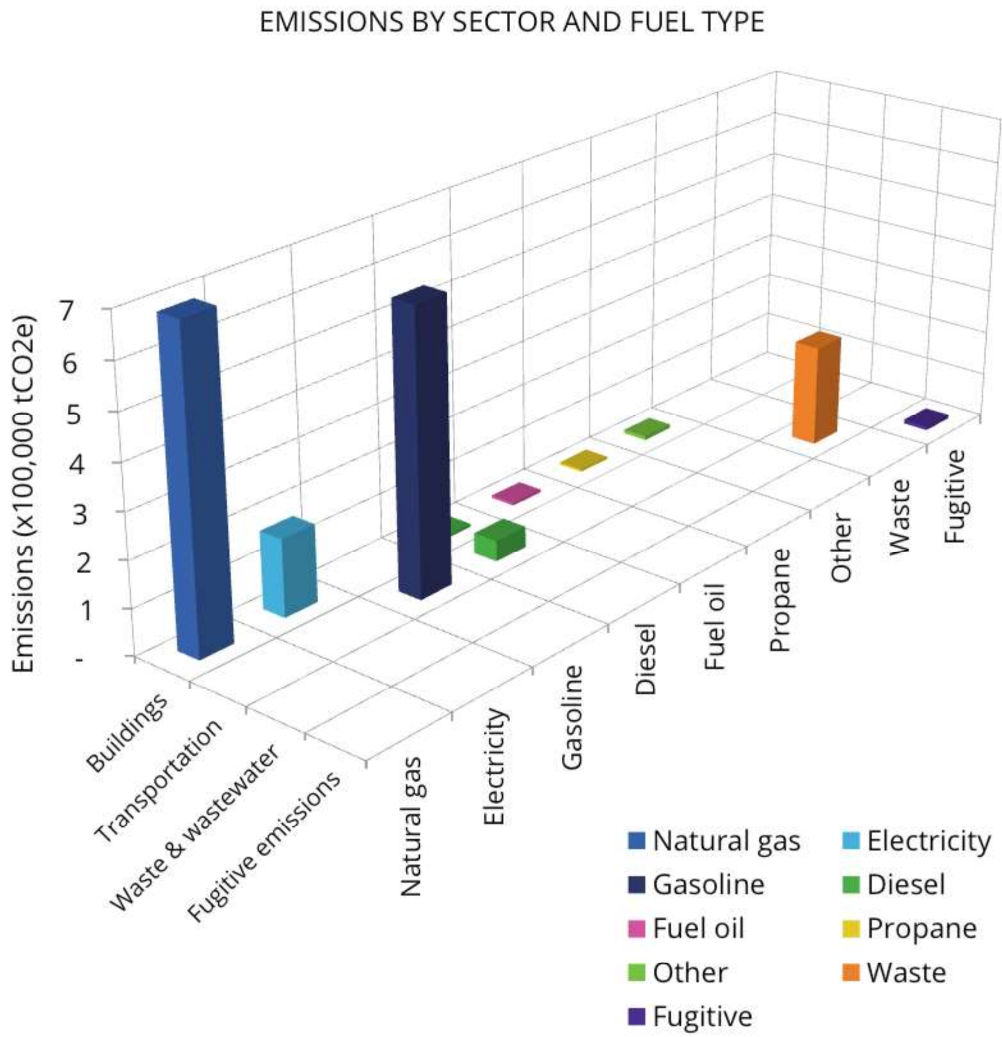

Figure 31. Markham emissions by sector and fuel, 2011.

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.

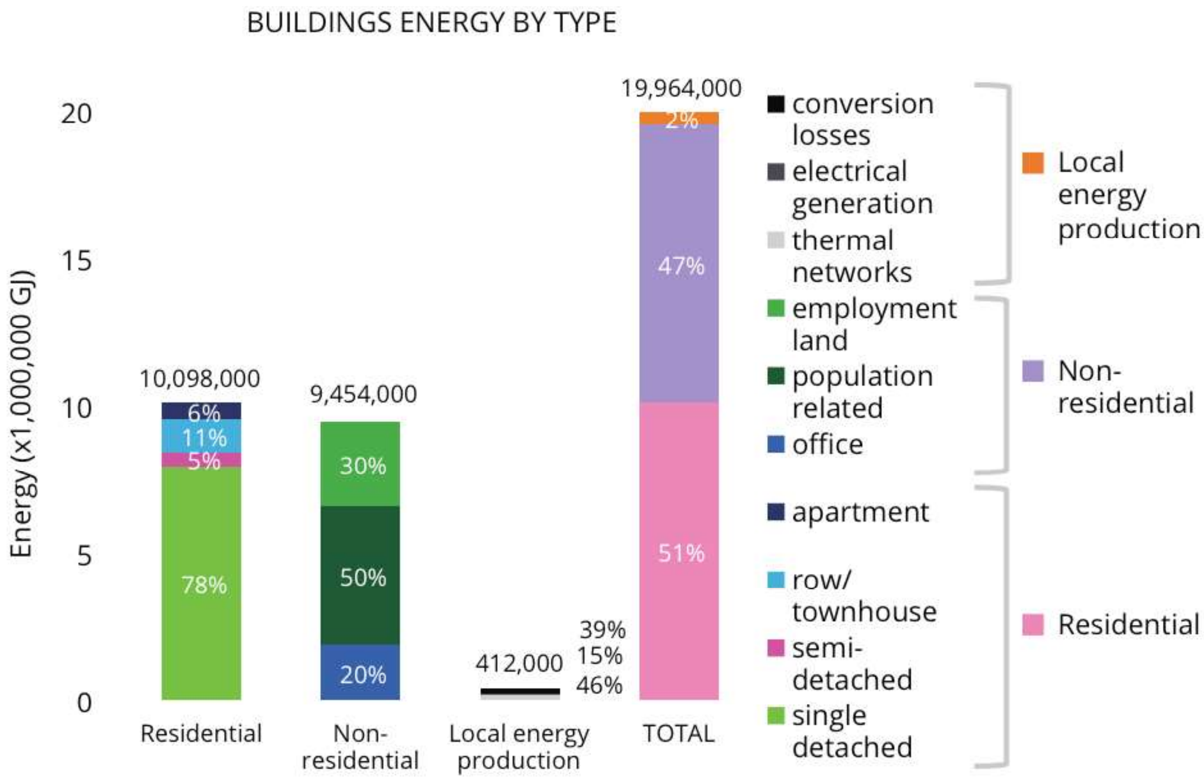

Figure 32. Buildings energy use by building type, 2011.[13]

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%).

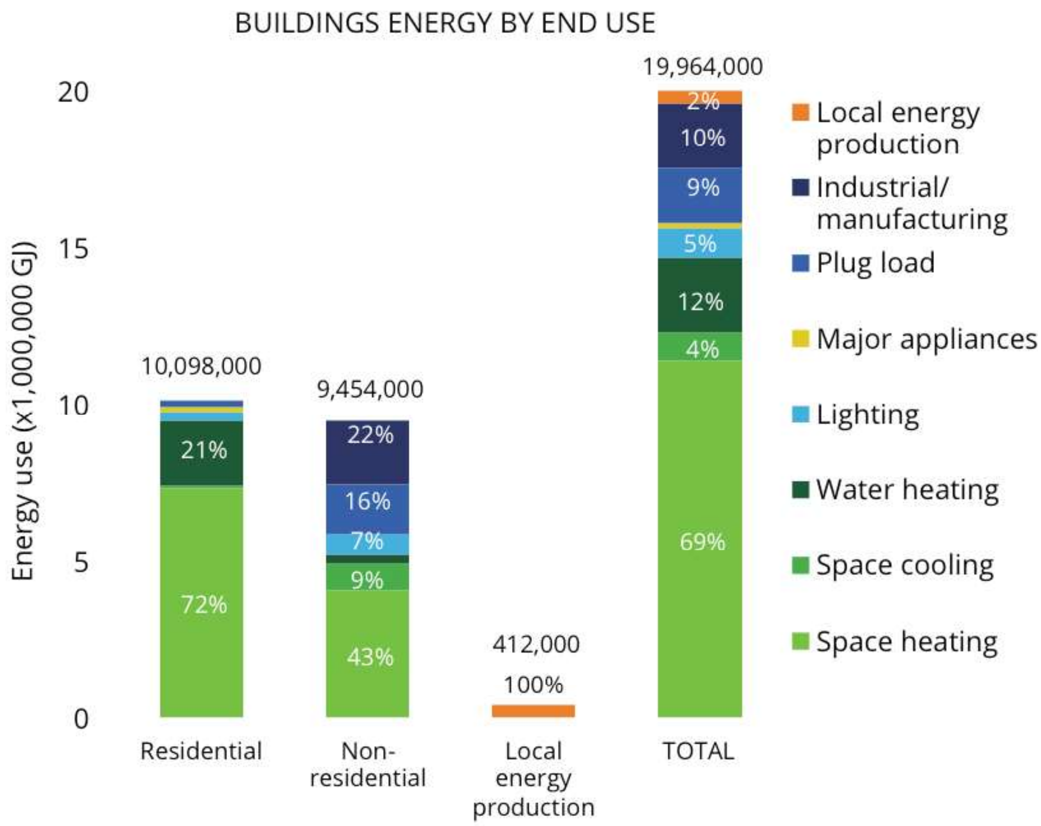

Figure 33. Buildings energy use by end use, 2011.

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.

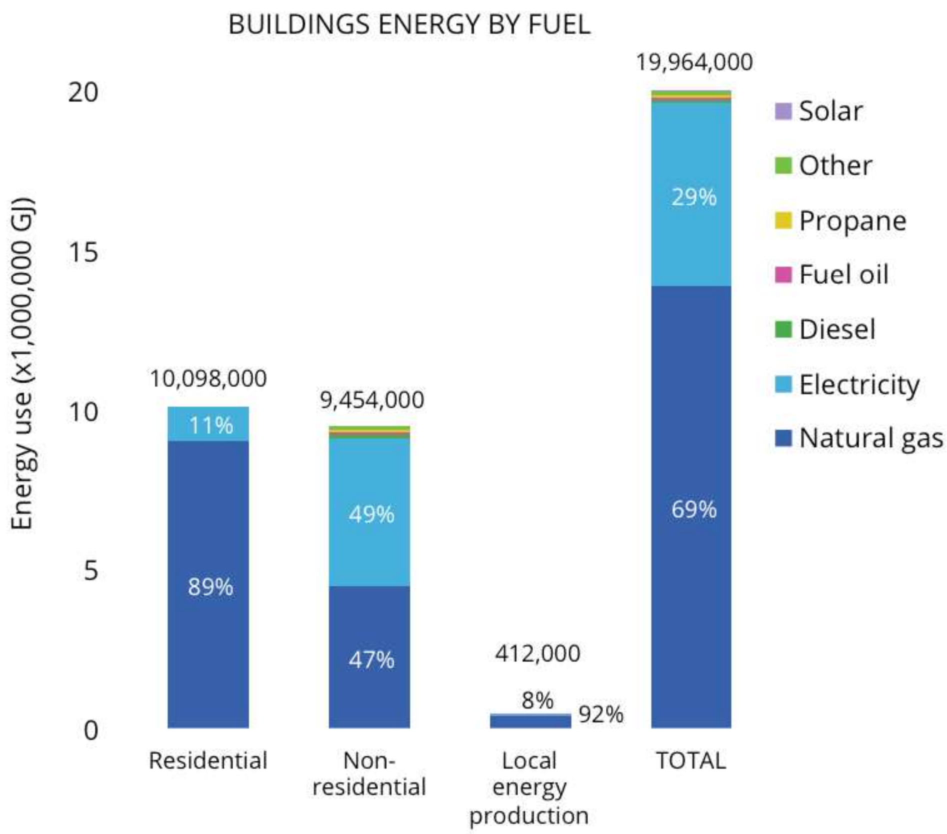

Figure 34. Buildings energy use by fuel, 2011.

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.

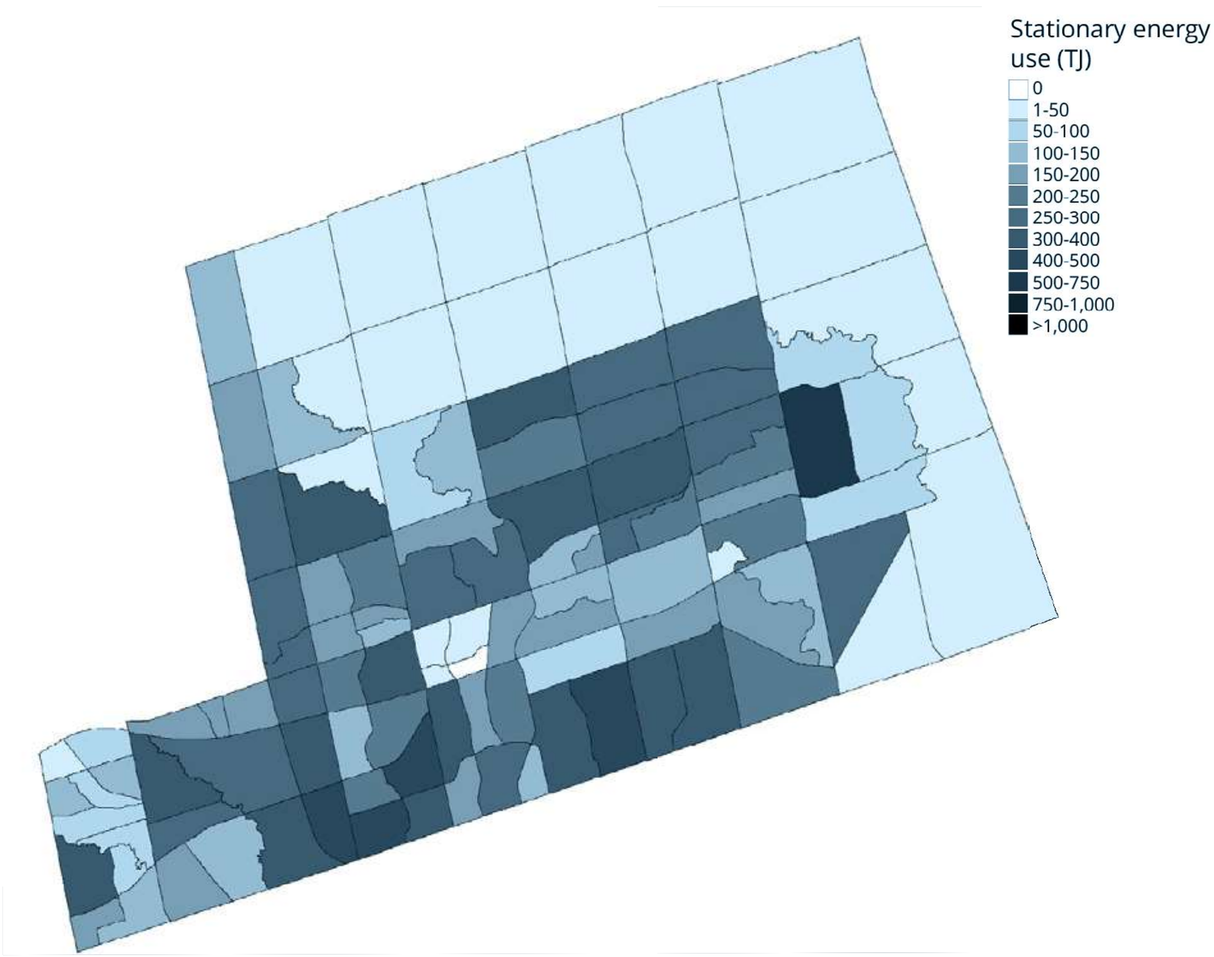

Figure 35. Total energy (TJ) by zone; all buildings, 2011.

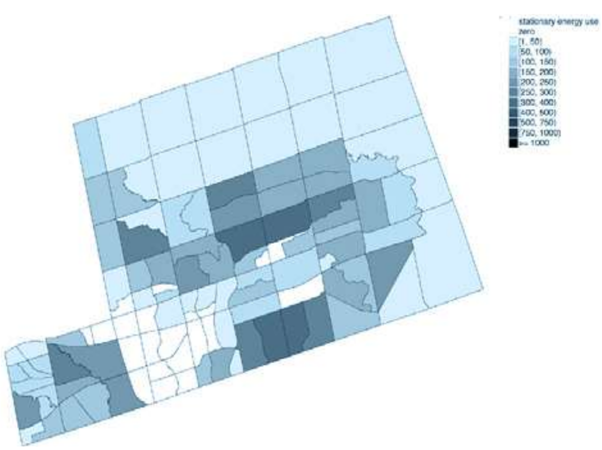

Figure 36. Total energy (TJ) by zone; residential buildings, 2011.

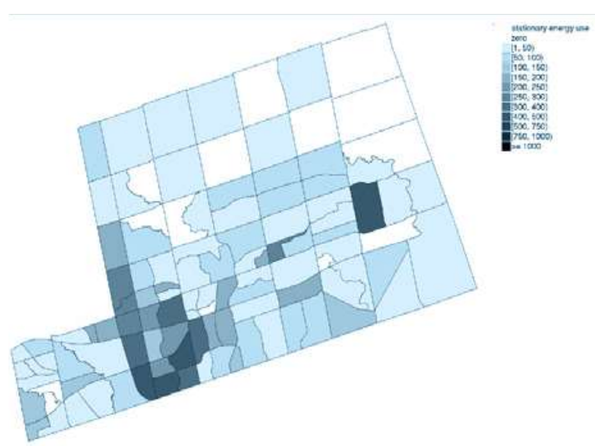

Figure 37. Total energy (TJ) by zone; non-residential buildings, 2011.

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.

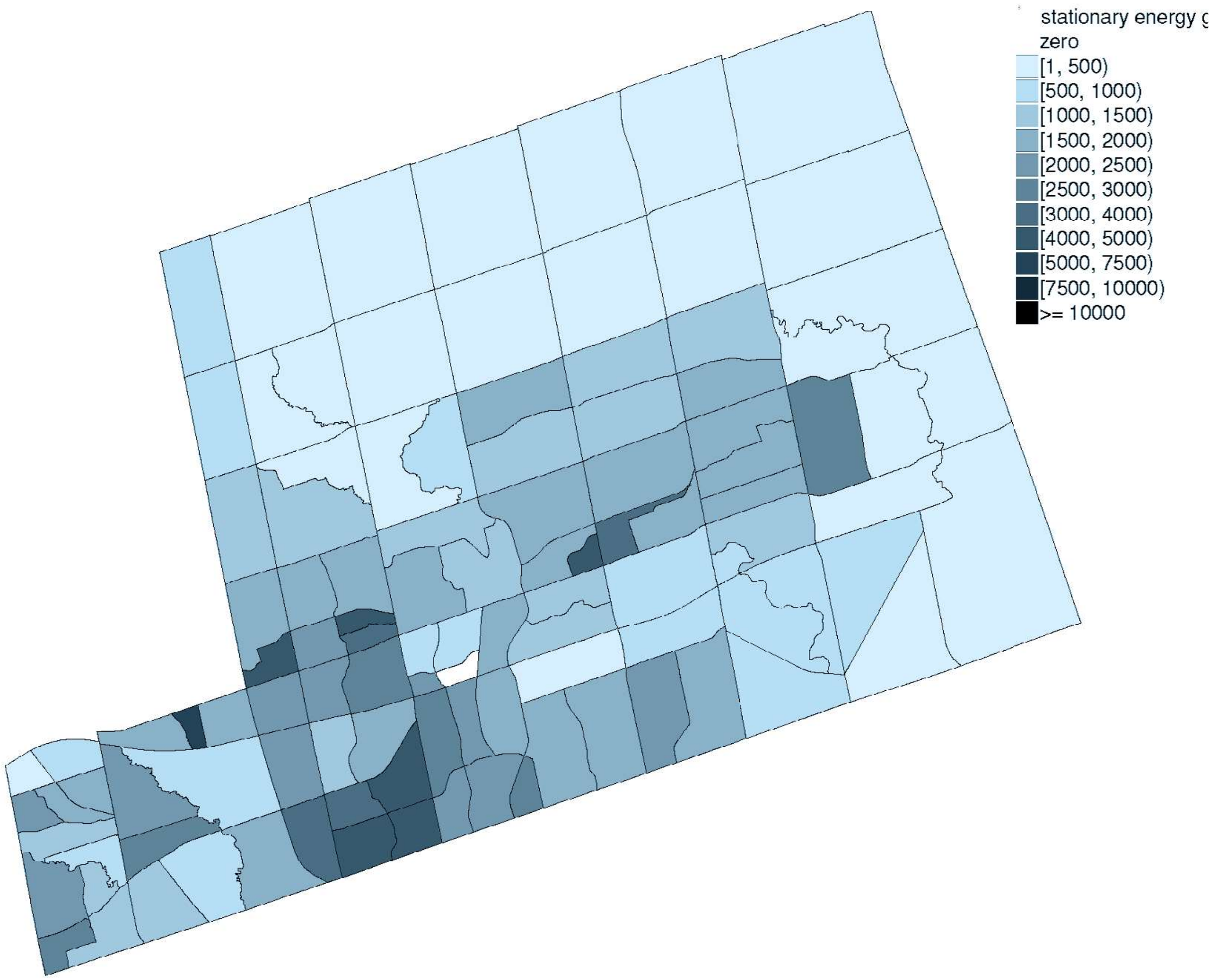

Figure 38. Energy density (GJ/ha) by zone; all buildings, 2011.

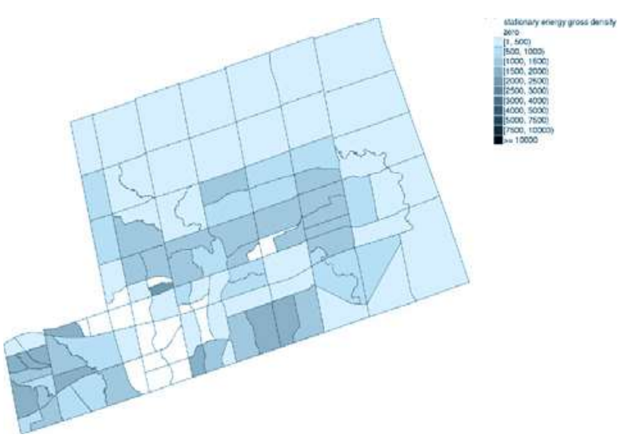

Figure 39. Energy density (GJ/ha) by zone; residential buildings, 2011.

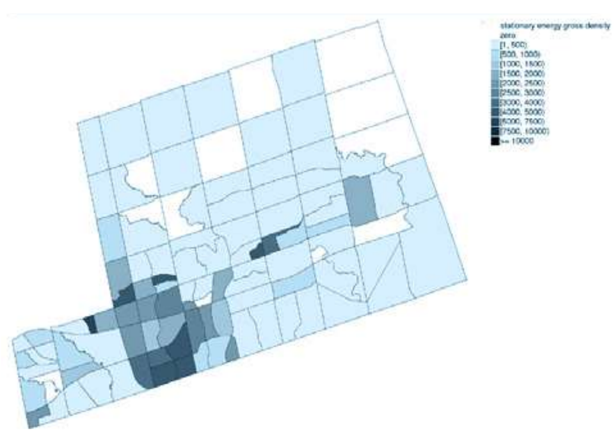

Figure 40. Energy density (GJ/ha) by zone; non-residential buildings, 2011.

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.

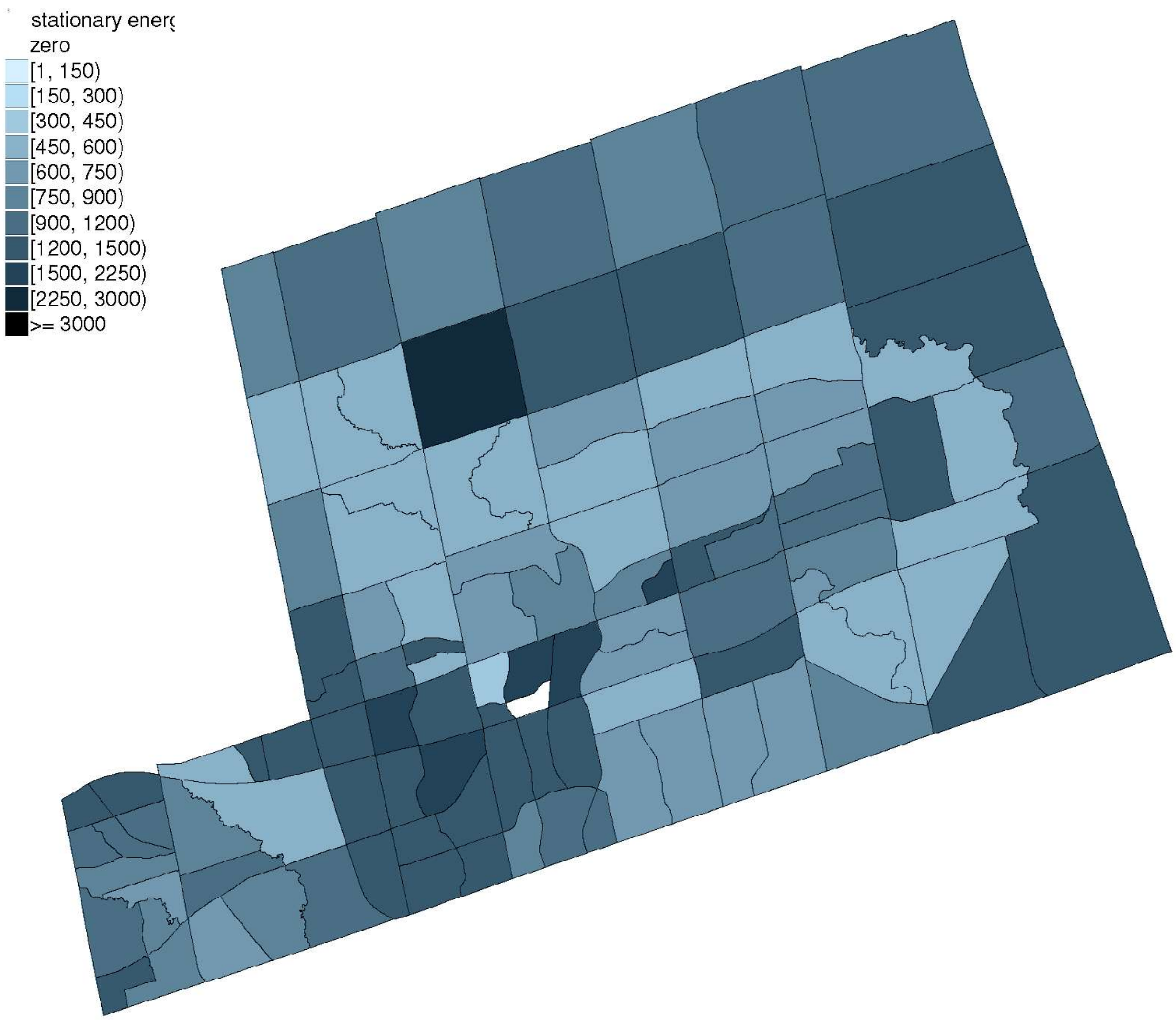

Figure 41. Energy intensity (MJ/m^2) by zone; all buildings, 2011.

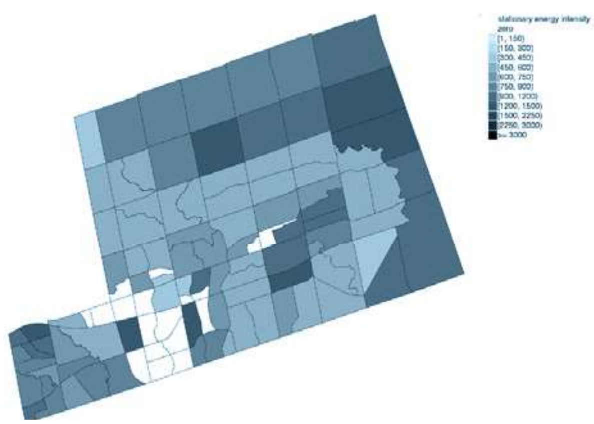

Figure 42. Energy intensity (MJ/m^2) by zone; residential buildings, 2011.

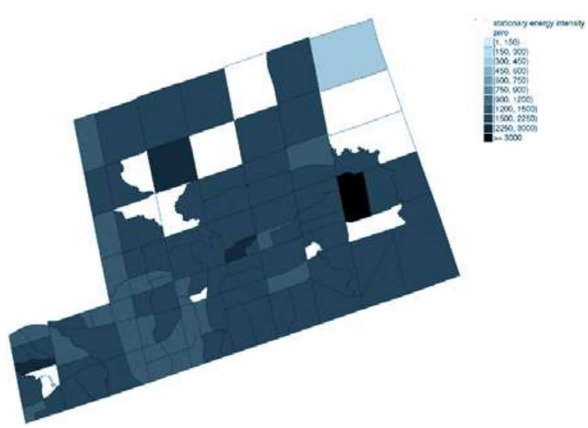

Figure 43. Energy intensity (MJ/m$^{2)}$ by zone; non-residential buildings, 2011.

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).

BUILDINGS EMISSIONS BY TYPE

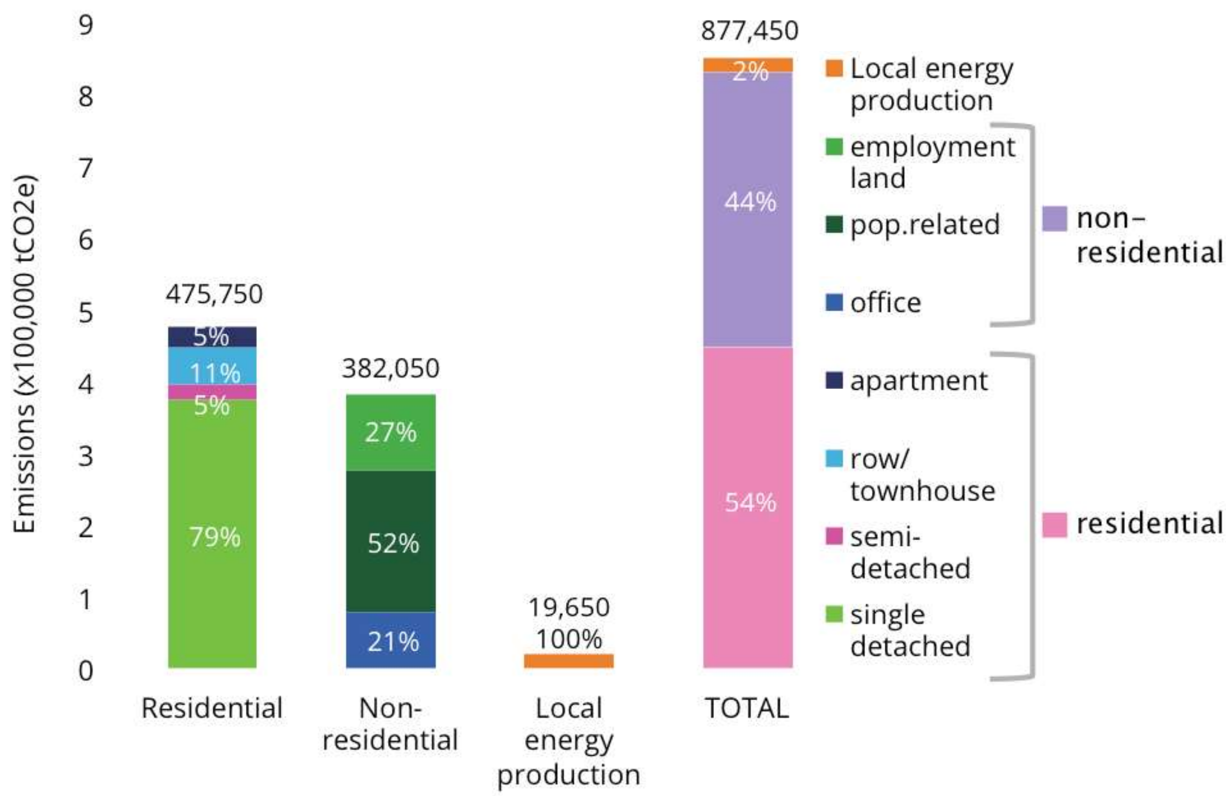

Figure 44. Buildings emissions use by building type, 2011.

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.

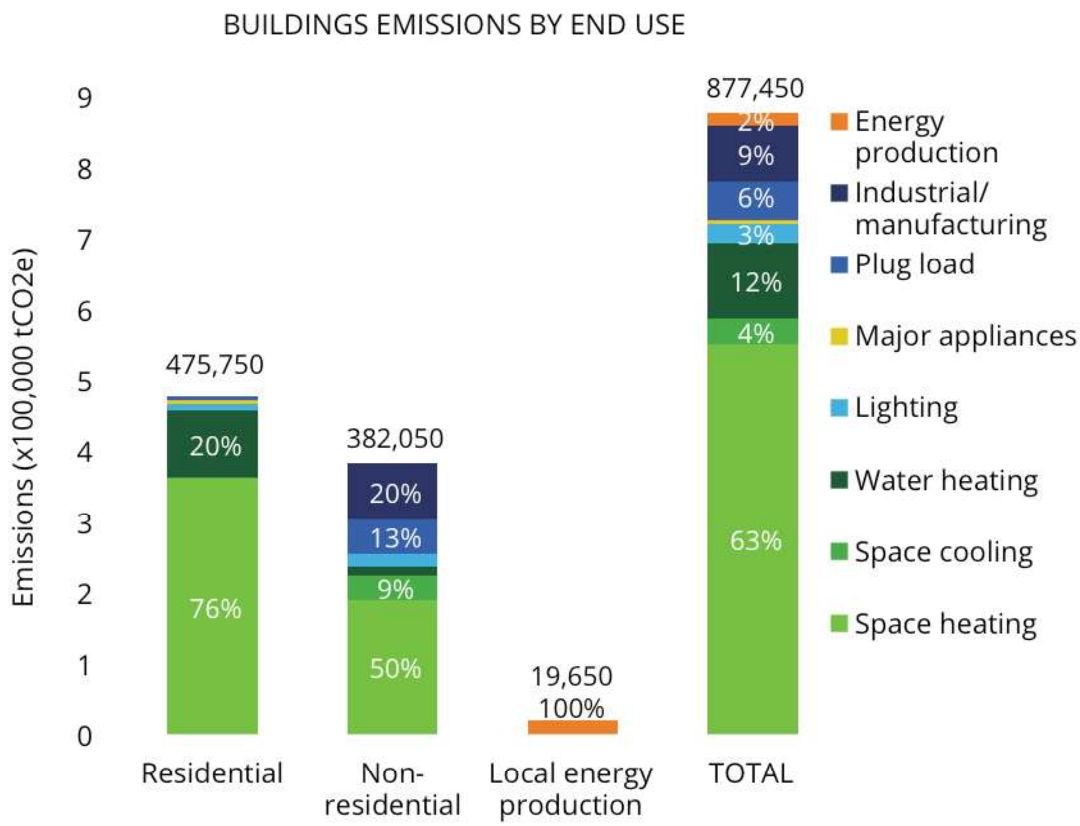

Figure 45. Buildings emissions use by end use, 2011.

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%).

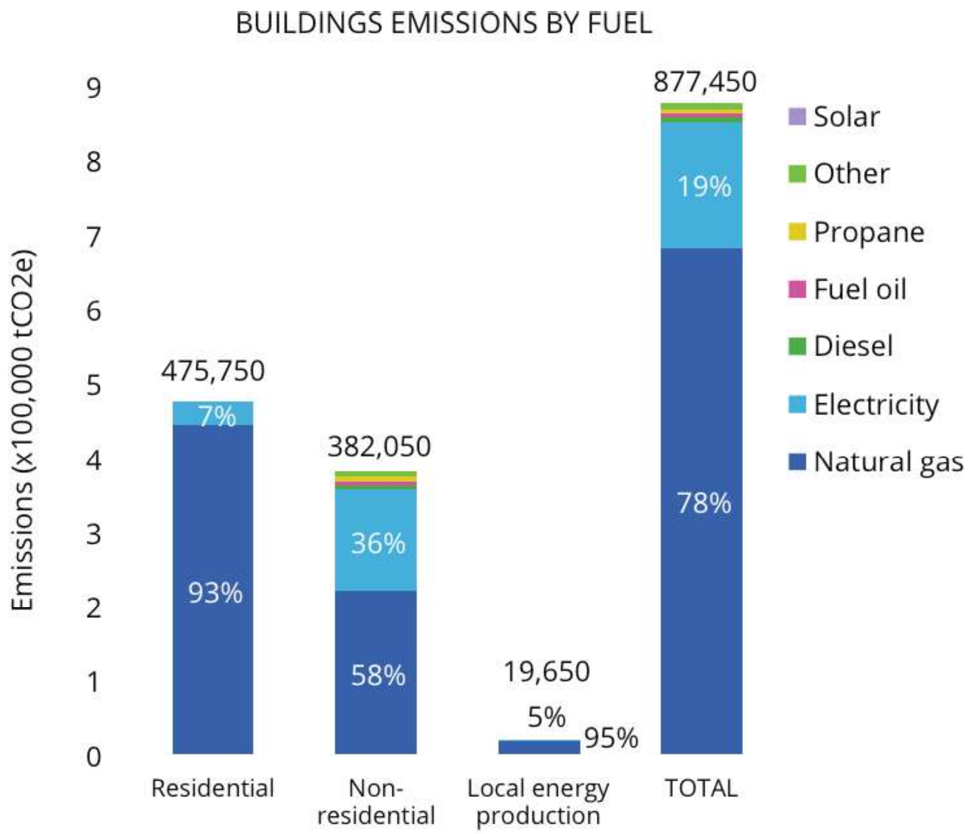

Figure 46. Buildings emissions by fuel, 2011.

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.

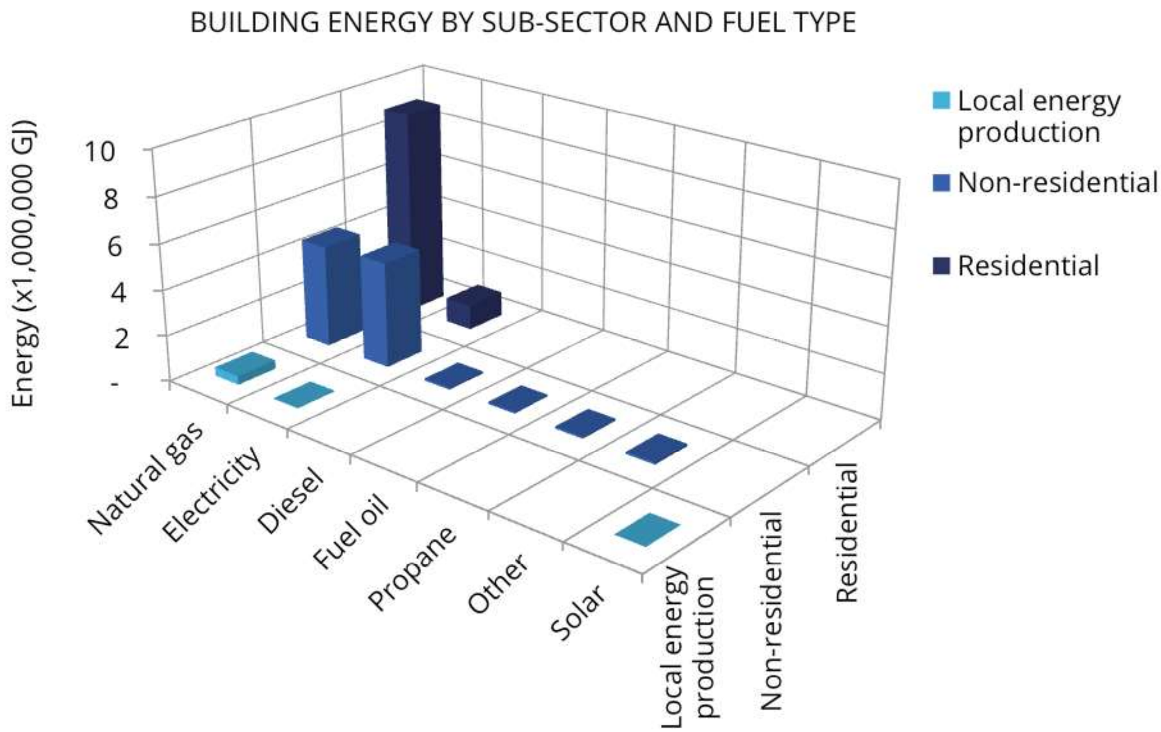

Figure 47. Buildings energy use by sub-sector and fuel type, 2011.

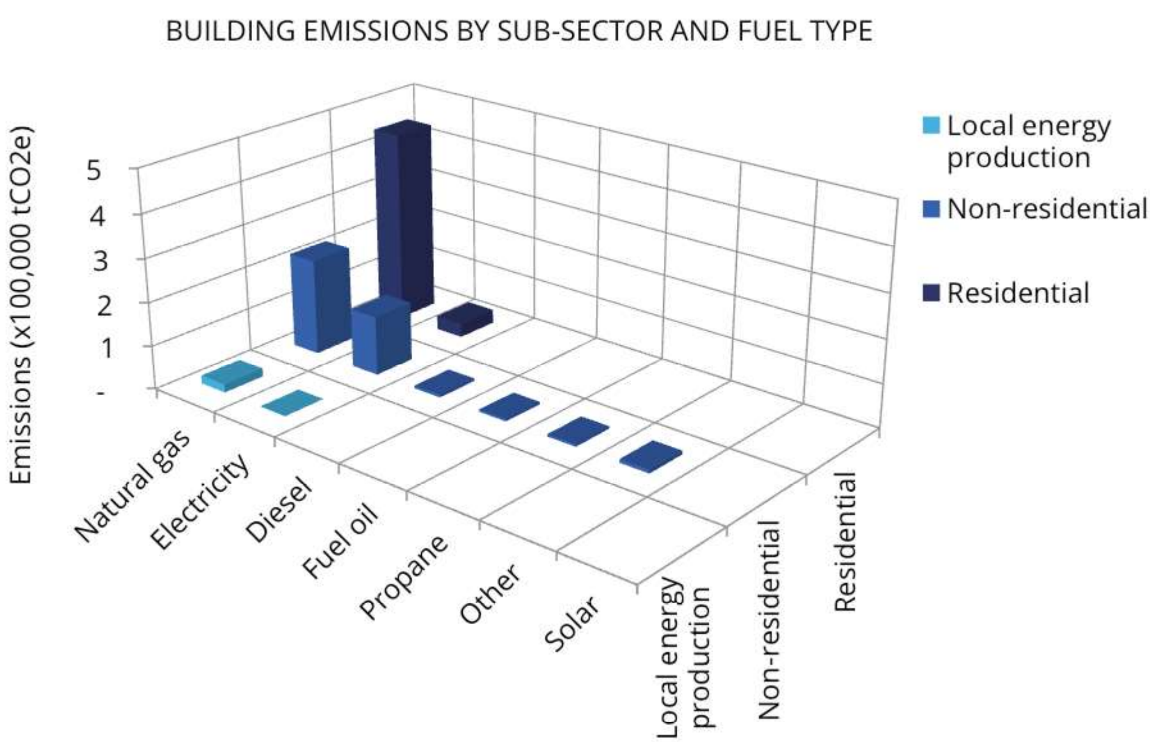

Figure 48. Buildings emissions by sub-sector and fuel type, 2011.

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.

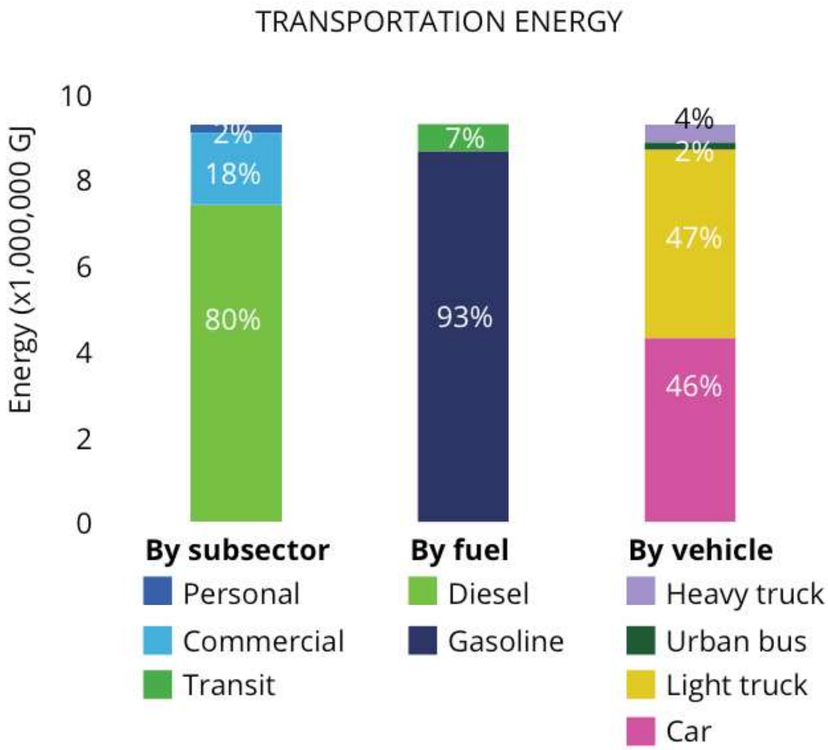

Figure 49. Transportation energy by subsector, fuel and vehicles type, 2011.

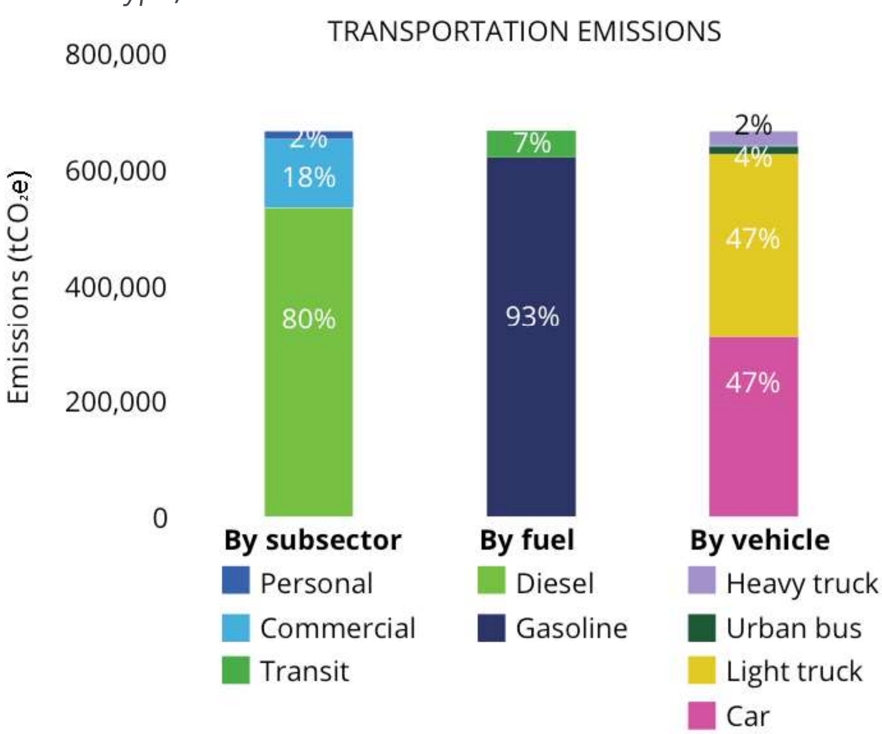

Figure 50. Transportation emissions by subsector, fuel and vehicle type, 2011.

TRIP TYPES

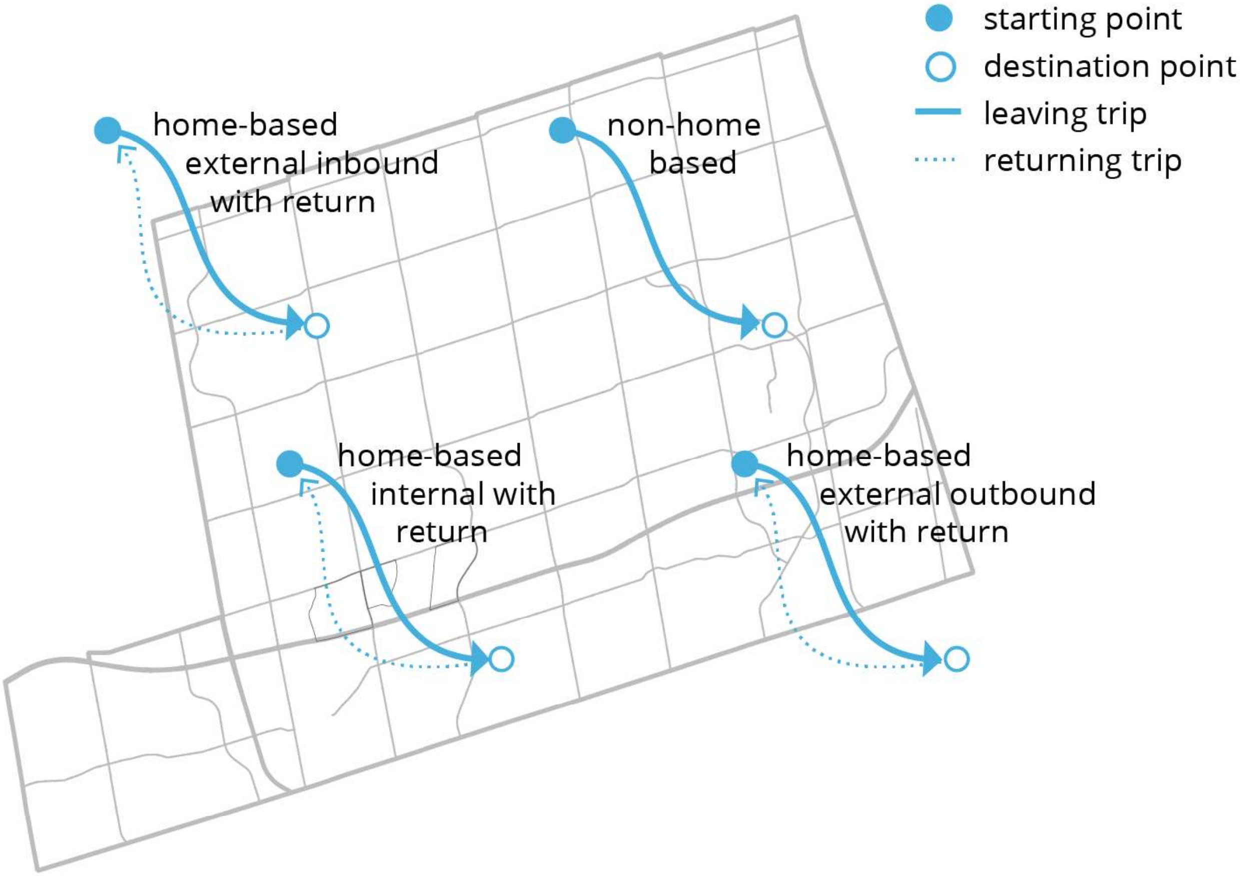

Figure 51. Conceptual diagram of trip categories. Home-based trip types include: work, school, and other.

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**.

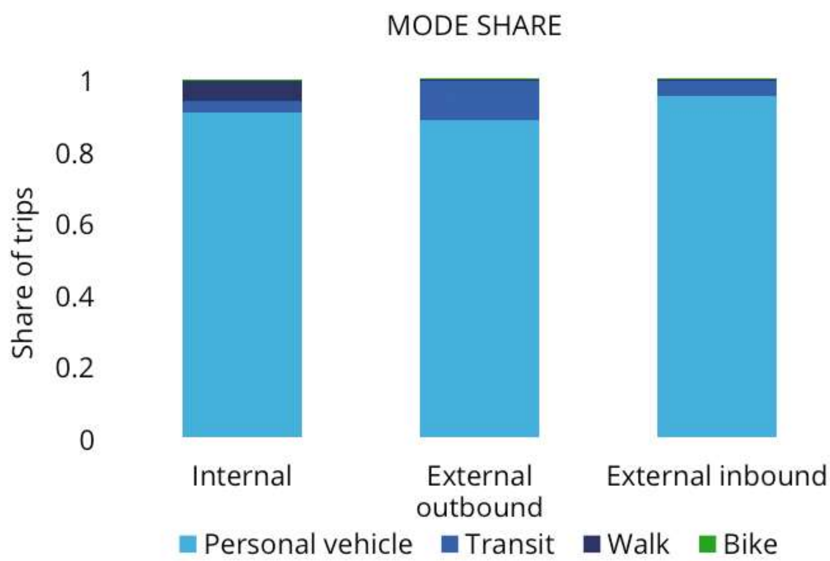

Figure 52. Mode share, 2011.

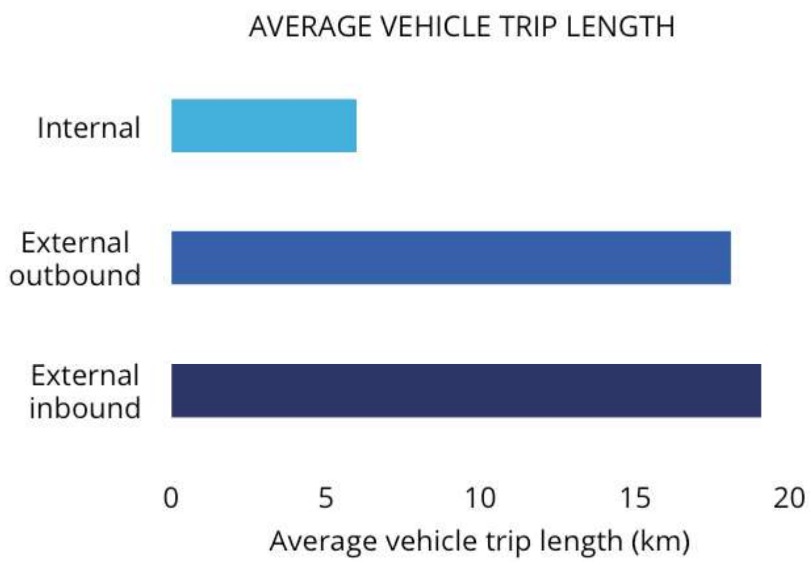

Figure 53. Average vehicle trip length, 2011.

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

12,000 km per year.

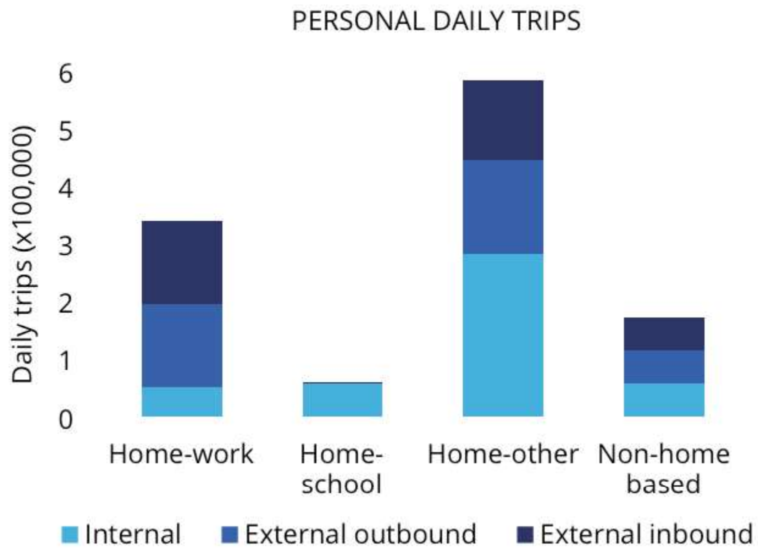

Figure 54. Personal daily trips, 2011.

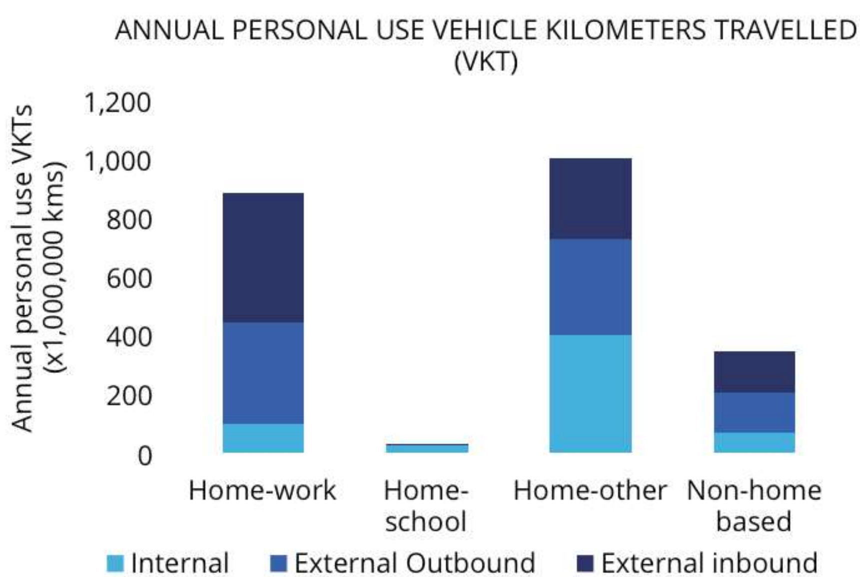

Figure 55. Annual personal use VKT, 2011.

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

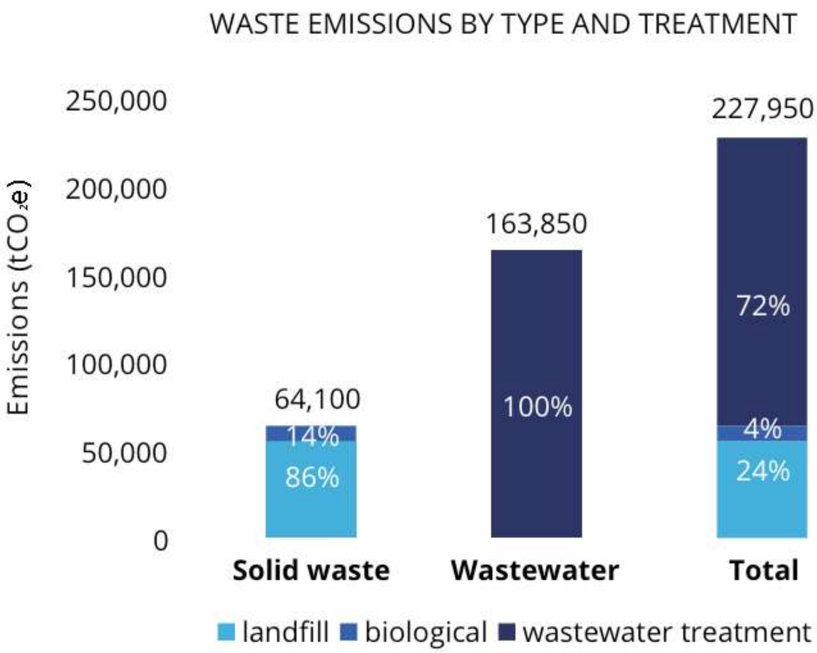

Figure 56. Waste emissions by type and treatment, 2011.

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).

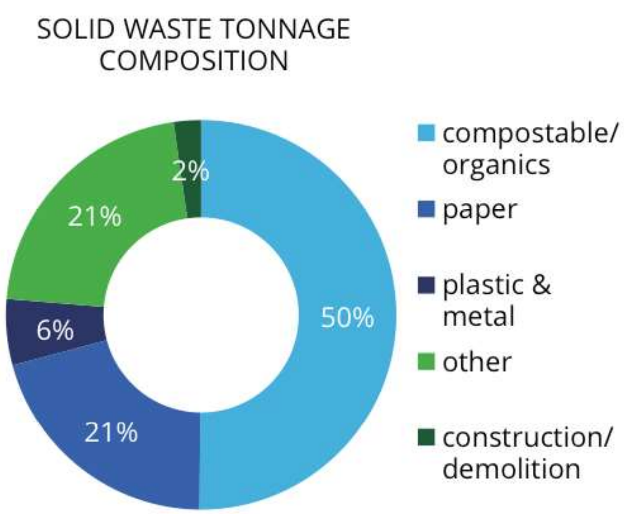

Figure 57. Waste tonnage composition, 2011.

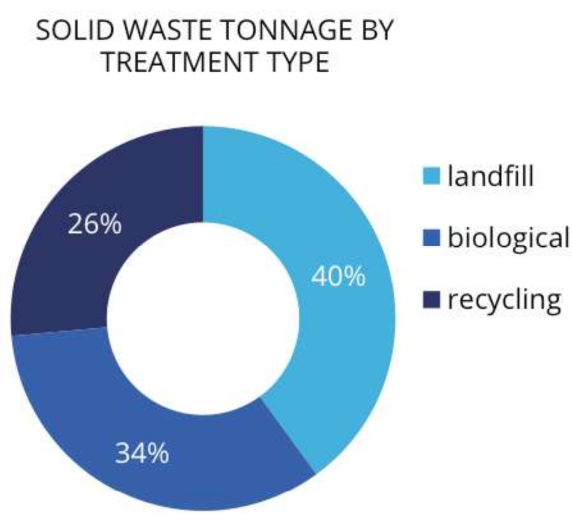

Figure 58. Waste tonnage by treatment type, 2011.

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?

3 Exploring the future

5 The current trajectory

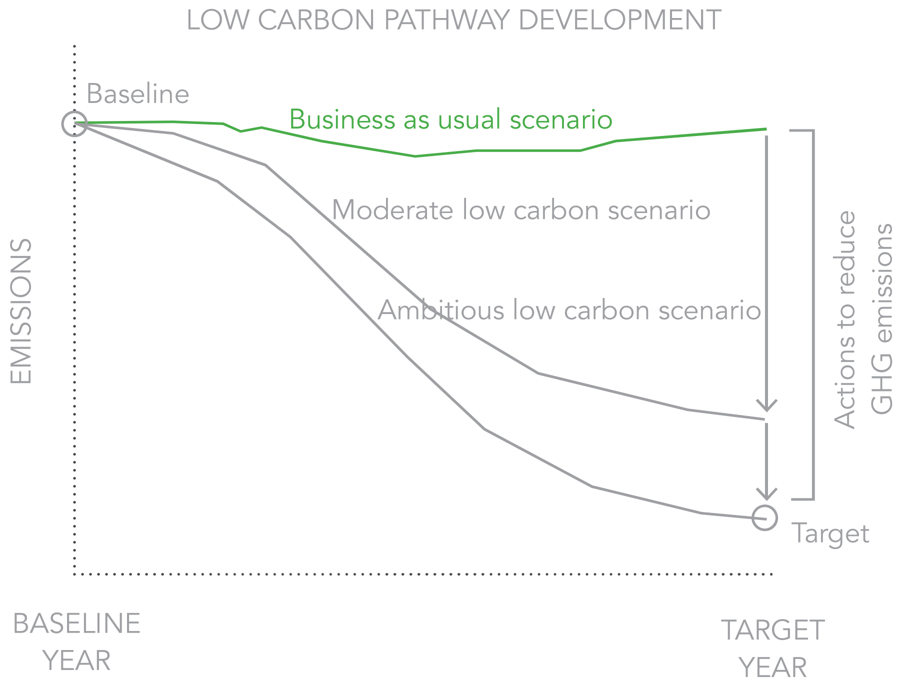

Figure 59. The BAU scenario.

The City of Markham's POPULATION is projected to almost double by 2050, from 311,500 in 2011 to 580,000 in 2050. The population will also age over the same period.

5.1 THE BUSINESS AS USUAL SCENARIO

Following the development of a comprehensive picture of current energy use in Markham, the next step is to explore potential future conditions, beginning with the Business as Usual (BAU) scenario. The BAU scenario is a projection out until 2050 designed to illustrate energy use and greenhouse gas emissions for the City of Markham. The BAU assumes that no additional policies, actions or strategies are implemented beyond those currently in place.

The BAU projection is one of many possible views of the future; it aims to be coherent in describing the relationships between different variables and reflects an evolution of current physical stocks such as buildings and vehicles.

The development of the BAU involved a review of city policies, identification of projections that have been developed for specific sectors such as transportation and population, and a review of regional, provincial and federal policies that may play a role in municipal energy and emissions.

5.1.1 How many people?

A population projection was provided by the Region of York based on the 2041 Preferred Growth Strategy, based on the Provincial Policy Statement. These projections were incorporated into CityInSight's cohort-survival population model, and extrapolated to 2050. The population of Markham in 2011 was 311,400 people and is projected to climb to 578,900 people by 2050, representing total growth of 86% over that period. Figure 60 indicates that while all age cohorts are increasing, the dominant increase is expected in the 65+ age cohort.

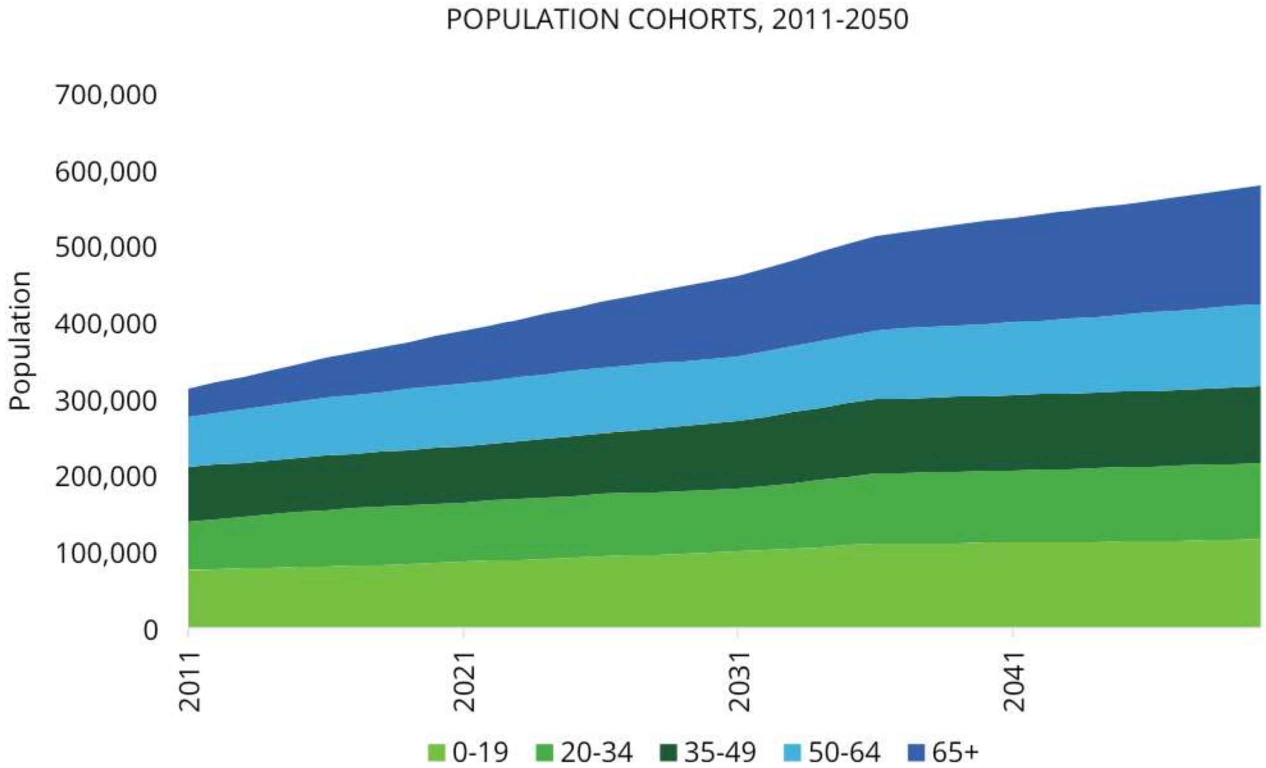

Figure 60. Population projection, 2011-2051.

5.1.2 What do people live in?

The Region of York's projections also include a projection of the types of dwellings that will be constructed in the City of Markham. The mix shifts towards apartments and row houses as illustrated in Figure 61; however, the number of dwellings in all four categories increases. Figure 62 indicates that the number of single family dwellings increases by 45%, to a total of 27,920 in 2051. Dwelling units in apartments show a nearly fourfold increase adding 41,430 dwellings over the 2011 number of 11,290.

Future construction will emphasize APARTMENTS and ROW HOUSES, not single family homes.

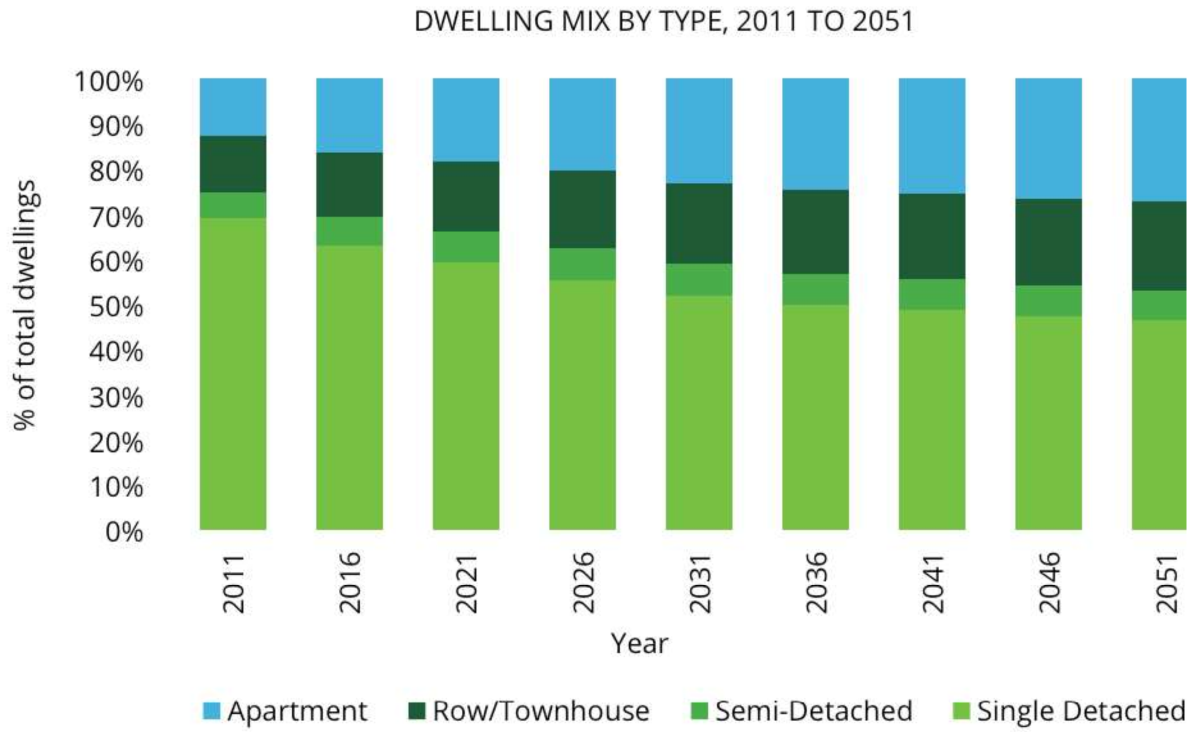

Figure 61. Dwelling mix projections , 2011-2051.

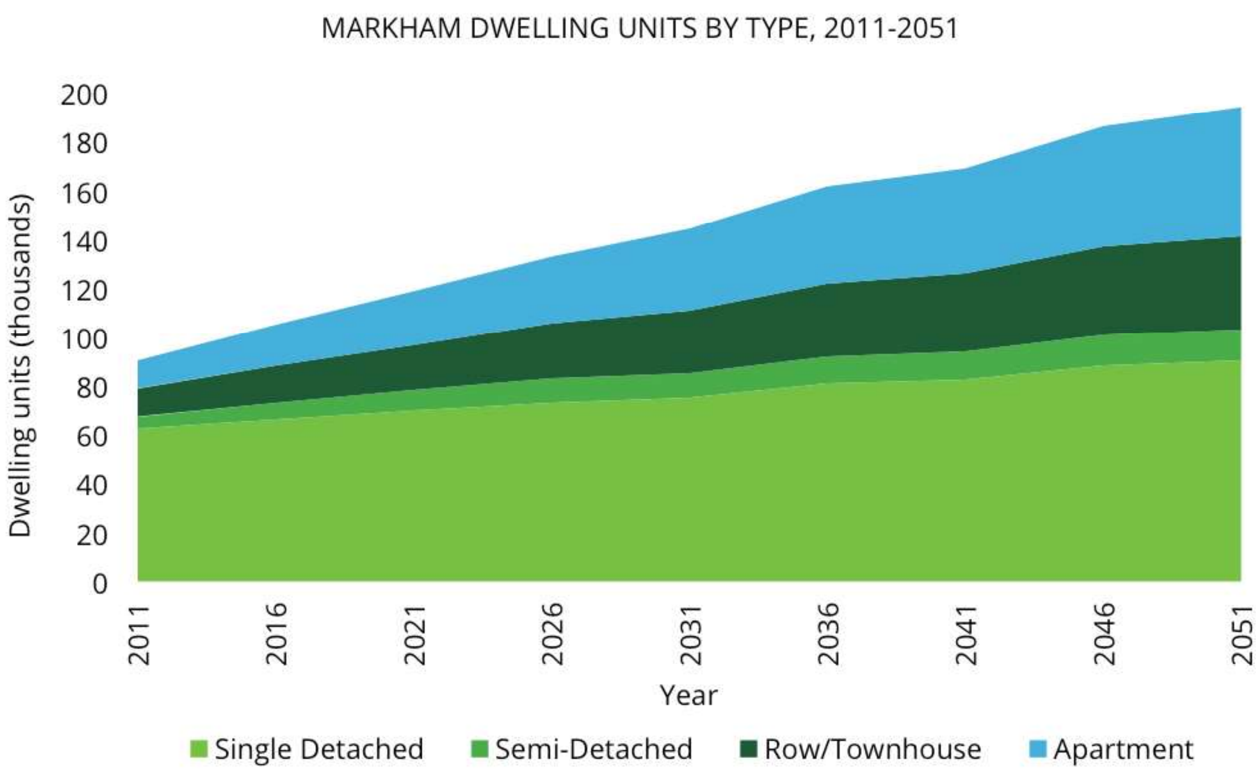

Figure 62. Dwelling projections, 2011-2051.

Total floorspace (residential and nonresidential) declines from 830 ft² (77 m²) per person in 2011 to 790 ft² (73 m²) per person in 2050.

The Preferred Growth Strategy also includes employment projections; these were assigned floor areas to generate projections for non-residential floorspace for the City. Of total floorspace, Markham is dominated by single family homes in 2011 at 60% of the floor area, but by 2051, this share has declined 45%. Non-residential floor space climbs by 60%, while residential space increases by 87%. Figure 63, illustrates the breakdown of floorspace by building category.

Total floorspace increases by 80% from approximately 24 million m^2 in 2011 to 42.5 million m^2 in 2051. Figure 64 illustrates the dominance of floorspace in single family dwellings over the entire period, even though future development is projected to shift away from this building form.

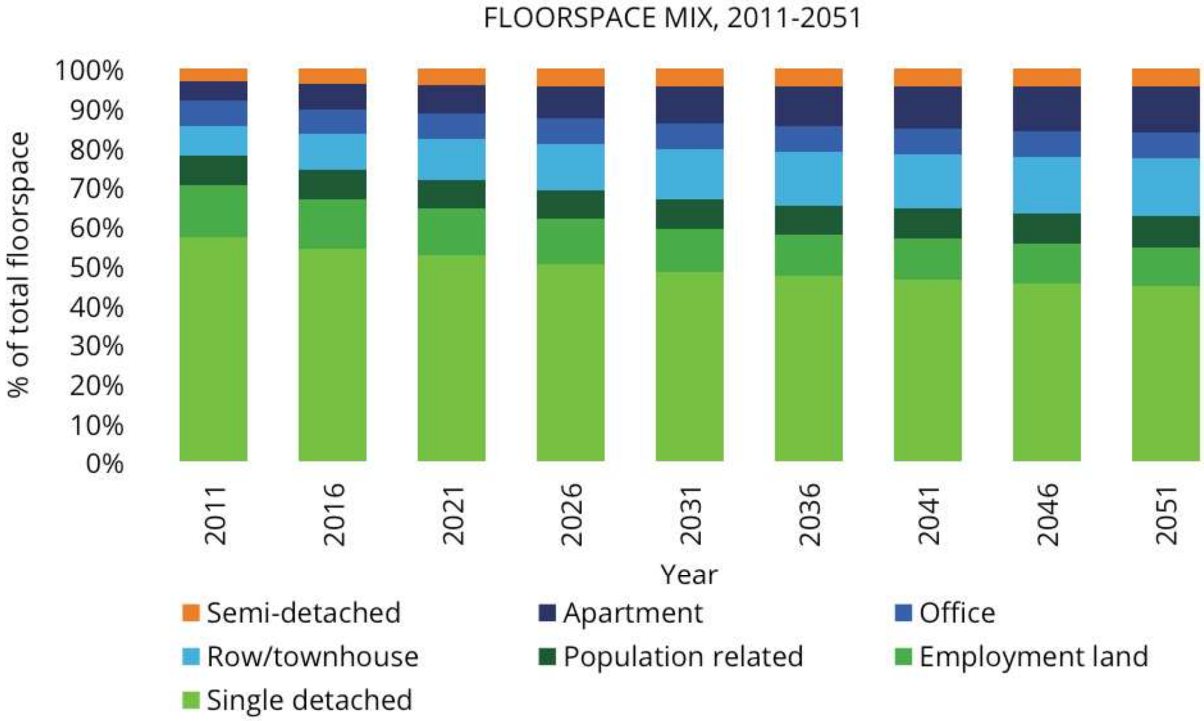

Figure 63. Total floorspace mix, 2011-2051.

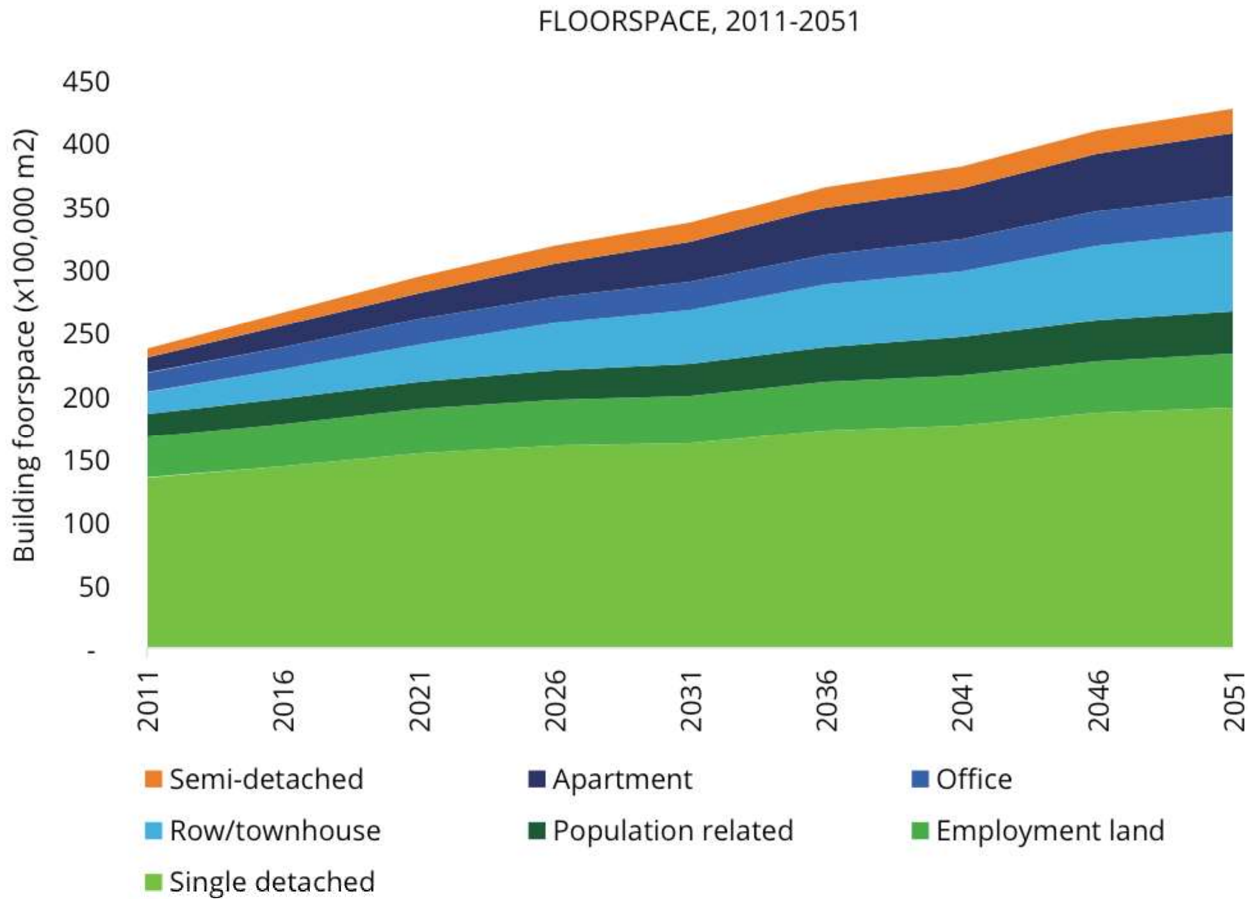

Figure 64. Total floorspace by category, 2011-2051.

5.1.3 How much energy will buildings use?

Energy performance of buildings is determined by the building form, but also by thermal performance and the equipment contained within. Each building type was calibrated against observed data for natural gas and electricity in order to identify performance characteristics. The calibrated level of performance was then held constant for all new buildings added to provide housing and workplaces for population increases out until 2050. A background rate of 1,000 dwelling units retrofit each year was also assumed, influencing the energy performance of the older building stock.

Figure 65 and Figure 66 illustrate total energy by end-use, with a notable decrease in share of space heating in both residential and non-residential buildings, and an increase in space cooling in non-residential buildings. The steps in the curve in Figure 66 occur because CityInSight tracks new floorspace in five-year increments; each step represents the addition of new floorspace over a five-year period.

Despite the population increase, total ENERGY USE is more or less flat, primarily due to decreased heating requirements from CLIMATE CHANGE.

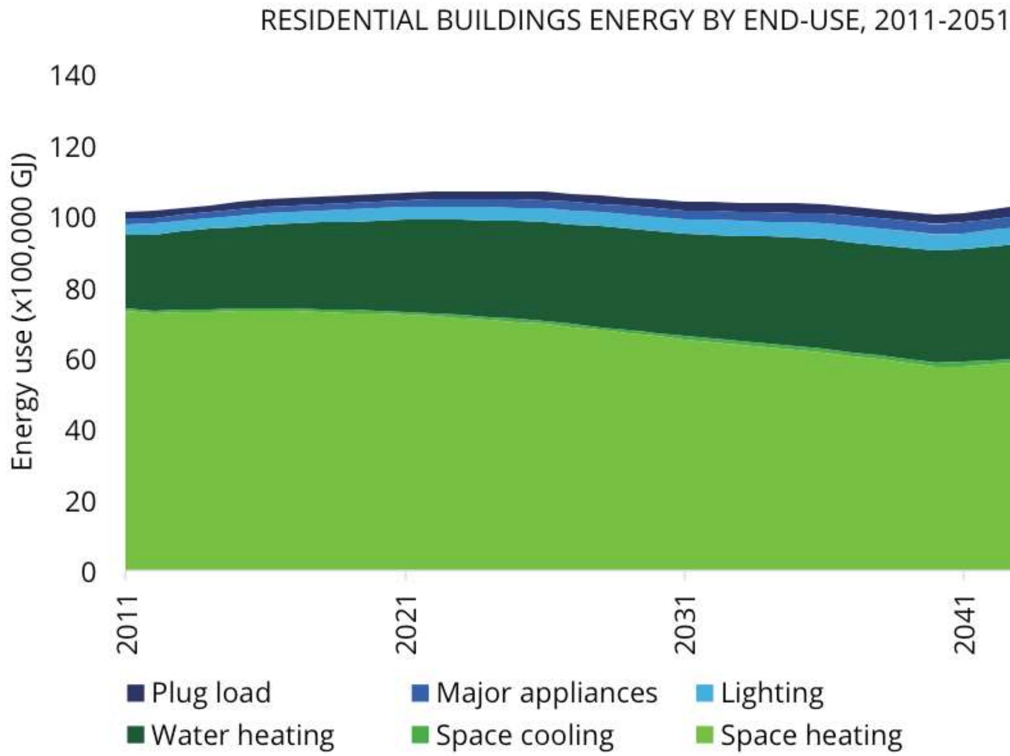

Figure 65. Energy consumption by end-use in residential buildings, 2011-2050.

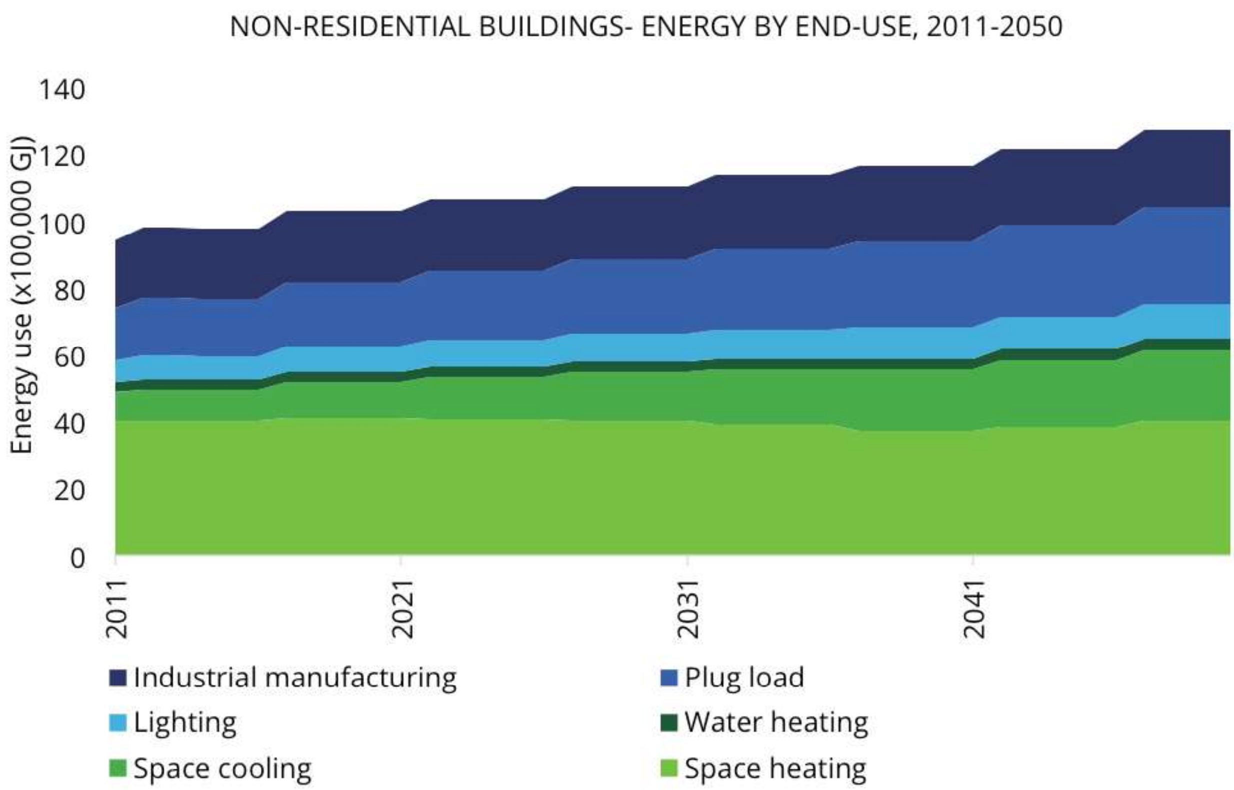

Figure 66. Energy consumption by end-use in non-residential buildings, 2011-2050.

5.1.3.1 MAJOR APPLIANCES, PLUG LOAD, LIGHTING AND SPACE CONDITIONING

Residential energy use was modelled by evolving the stocks of equipment that provide energy services including heating, cooling, cooking, lighting, other appliances and other plug loads. The stock data is obtained from Natural Resources Canada and includes the categories listed in Table 9.

Table 9. Stocks of equipment that consume energy.

MAJOR APPLIANCES	LIGHTING	PLUG LOAD
• Refrigerator • Freezer • Dishwasher • Clothes washer • Clothes dryer (electricity or natural gas) • Range (electricity, natural gas or propane)	• Incandescent • Compact fluorescent • Fluorescent • Halogen • LED	• Plug load (minor appliances)

SPACE HEATING		SPACE COOLING
• Oil furnace (normal, mid or high efficiency) • Gas (normal, mid or high efficiency) • Electric • Heat pump (electric or gas) • Geothermal • Wood	• Liquified Petroleum Gas (LPG) • Coal and other • Wood/electric • Wood/oil • Solar/electric • Solar/gas • Solar/oil • Gas/electric • Oil/electric	• Central • Heat pump • Room

Each stock was modelled by age and by Energy Star rating, or an energy consumption metric specified for that particular appliance or furnace. The detailed inventory of stocks enables the model to calculate the energy use by fuel type, and in the calibration process, the demand for the energy services is adjusted until energy use from all of the buildings matches the energy use in

Statistics Canada's Report on Supply and Demand (RESD).[1] Efficiencies of new technologies and energy consumption for appliances and heating and cooling equipment were held constant at 2011 levels for future projections.

5.1.3.2 THE INFLUENCE OF CLIMATE CHANGE

Energy use in Markham is significantly influenced by the coldness of the winter and to a lesser degree, the heat of the summer. To account for the influence of climate change, energy use was adjusted according to the number of heating and cooling degree days identified in a projection for the City of Toronto. Because the projection only includes the time periods of 2000–2009 and 2040–2049, a trend line was interpolated between those two periods[2] (Figure 67).

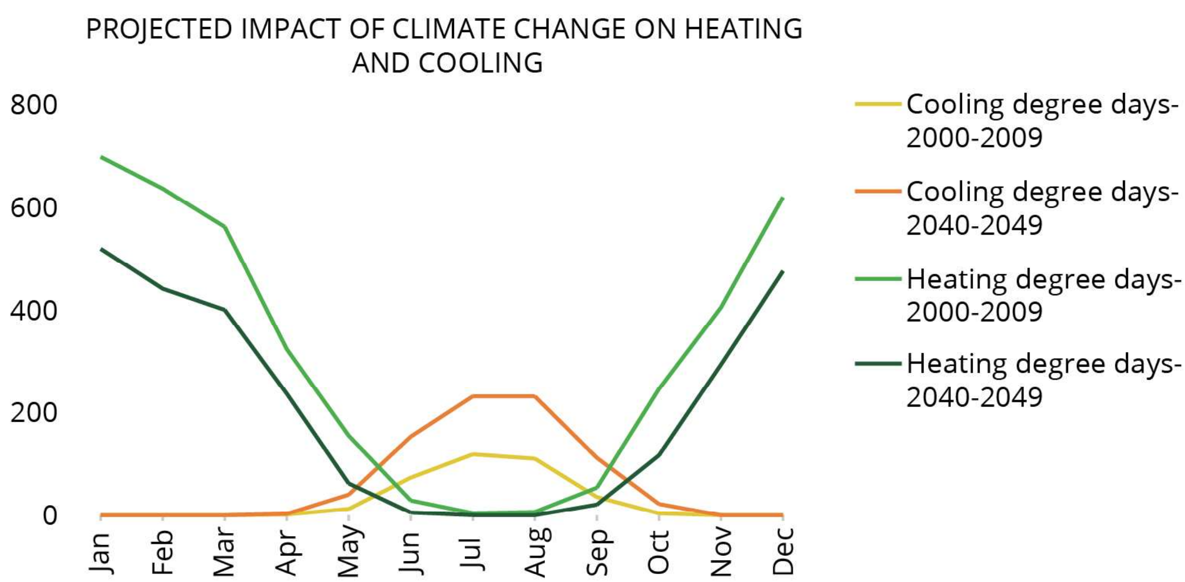

Figure 67. Heating and cooling degree days in 2000–2009 and 2040–2049.

1 Statistics Canada. (2016). Report on energy supply and demand in Canada (No. 57–003–X). Retrieved from http://www.statcan.gc.ca/pub/57-003-x/57-003-x2016002-eng.pdf

2 SENES Consultants Ltd. (2011). Toronto's future weather and climate driver study: Volume 2 – data tables (2000-2009 and 2040-2049). City of Toronto. Retrieved from http://www1.toronto.ca/city_of_toronto/environment_and_energy/key_priorities/files/pdf/tfwcds-volume2-datatables.pdf

Natural gas is projected to decline as heating requirements decrease due to CLIMATE CHANGE.

5.1.3.3 WHAT KIND OF ENERGY IS USED IN BUILDINGS?

Figure 68 shows that natural gas dominates in residential buildings, accounting for 89% of the fuel share in 2011, which declines to 83% by 2050; natural gas is used for the two major energy loads in residential buildings, space heating and water heating.

In non-residential buildings the share of natural gas consumption is projected to fall from 47% to 39% between 2011 and 2050, primarily due to decreasing heating requirements, with a proportionate gain in favour of electricity. Total energy consumption increases by 35% to 11.7 million GJ.

5.1.3.4 SPATIAL PATTERNS OF ENERGY USE

As buildings are located in transportation zones, stationary energy associated with these buildings can also be tracked by those zones. The following maps show the impact of projected energy consumption in buildings spatially, using the same representations as described in Section 3.5.

Figure 70 shows the northward expansion of the City into areas with very little or no development in 2011. Significant new energy consumption is projected in the northwest corner of Markham, including some intensification.

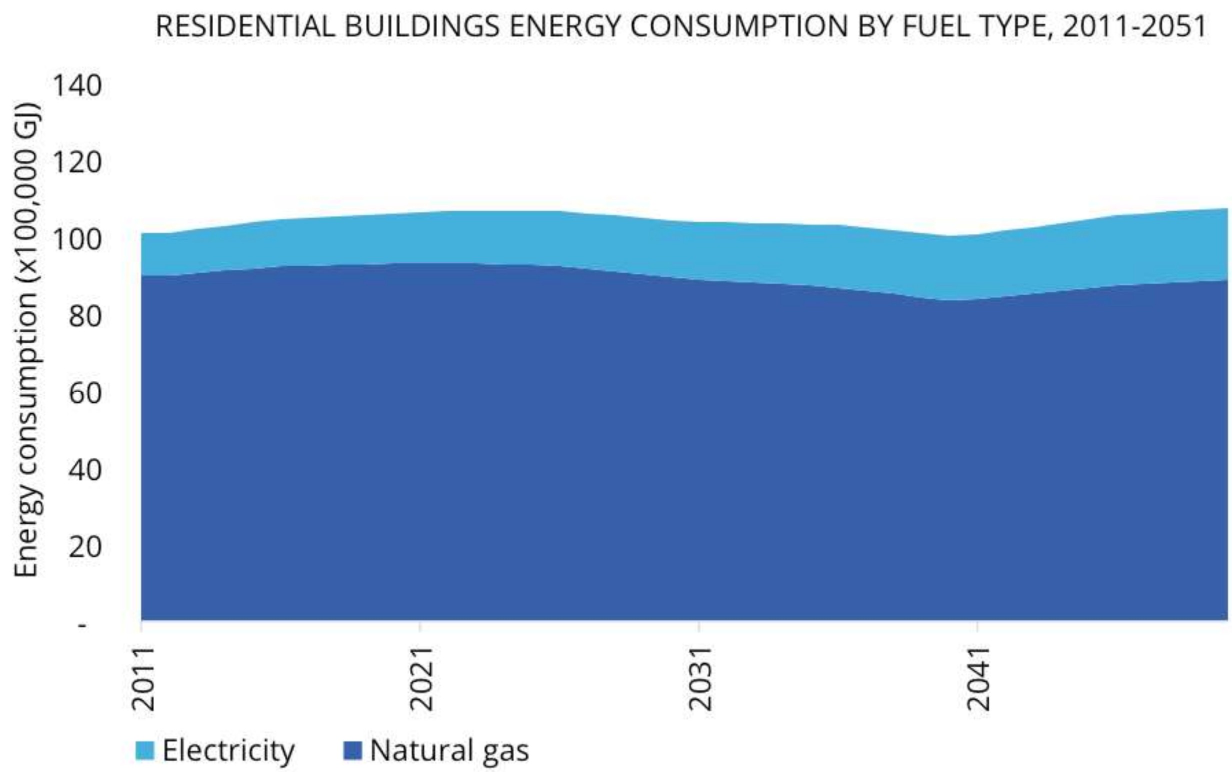

Figure 68. Energy use in residential buildings by fuel type, 2011–2051.

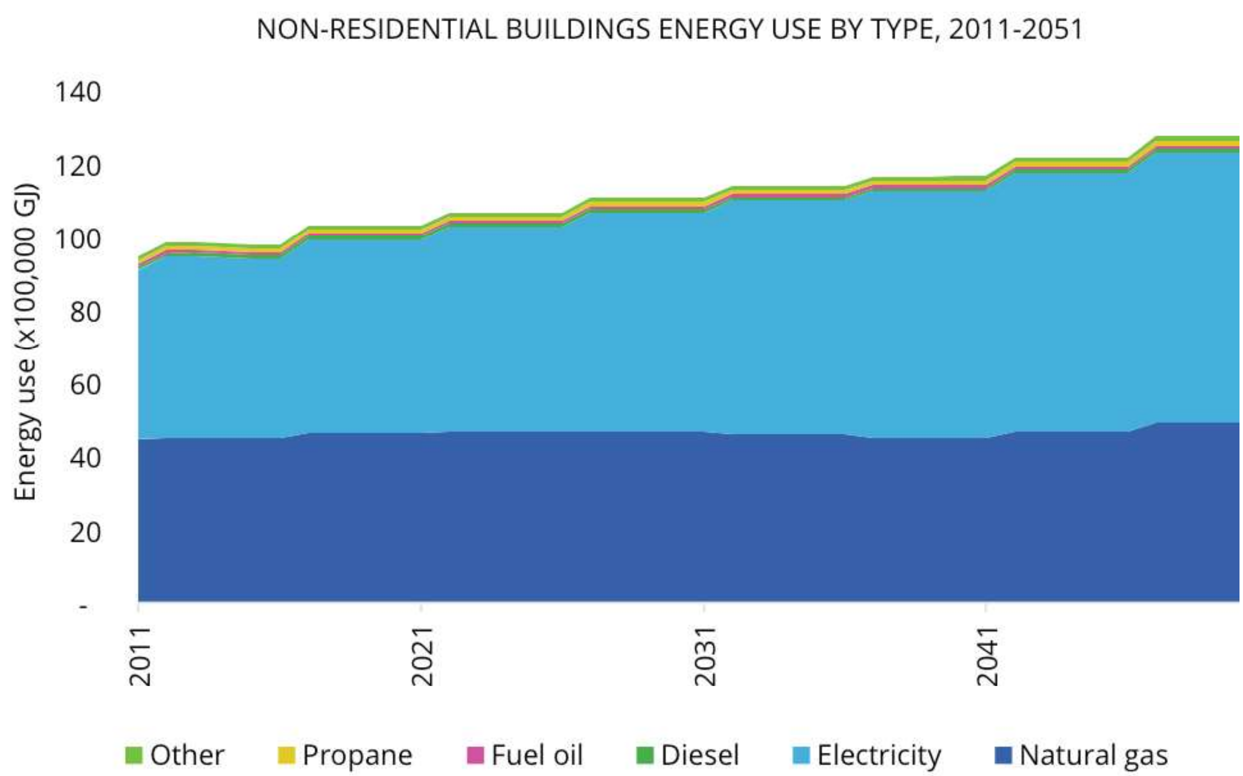

Figure 69. Energy use in non-residential buildings by fuel type, 2011–2051.

ENERGY CONSUMPTION expands northwards

Figure 70. Total energy (TJ) by zone; all buildings, 2011 and 2050.

Figure 71 indicates that residential buildings are a major contributor to the northwestern expansion, whereas non-residential building development, shown in Figure 72, develops in a corridor along the western edge. Note that these maps do not reflect the growth strategy of the City of Markham to 2031, rather they are based on projections developed by the Region of York out until 2041. New concentrations of energy consumption are evident, but some areas also experience a decline, due primarily to decreased heating requirements.

Figure 71. Total energy (TJ) by zone; residential buildings, 2011 and 2050.

Figure 72. Total energy (TJ) by zone; non-residential buildings, 2011 and 2050.

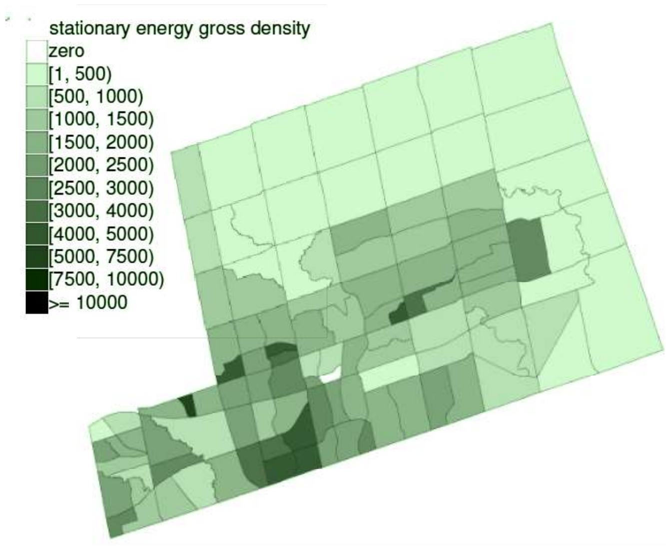

Figure 73. Energy density (GJ/ha) by zone; all buildings, 2011 and 2050.

The energy density maps (Figure 74 to Figure 76) indicate that the energy density concentrations found in the southwest in 2011 remain in 2041, with the highest concentration centred on non-residential buildings.

Figure 74. Energy density (GJ/ha) by zone; residential buildings, 2011 and 2050.

Figure 75. Energy density (GJ/ha) by zone; non-residential buildings, 2011 and 2050.

Energy intensity, which normalizes for the addition of new buildings, shows the impact of reduced heating loads in all building types (Figure 76 to Figure 78).

Figure 76. Energy intensity (MJ/m2) by zone; all buildings, 2011 and 2050.

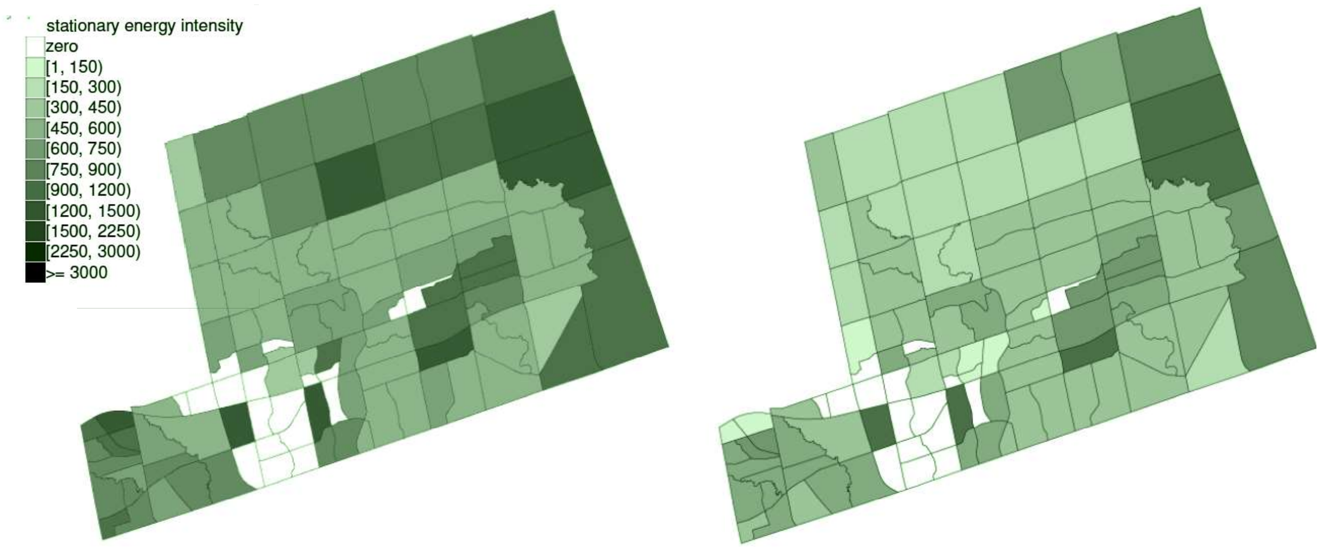

Figure 77. Energy intensity (MJ/m2) by zone; residential buildings, 2011 and 2050.

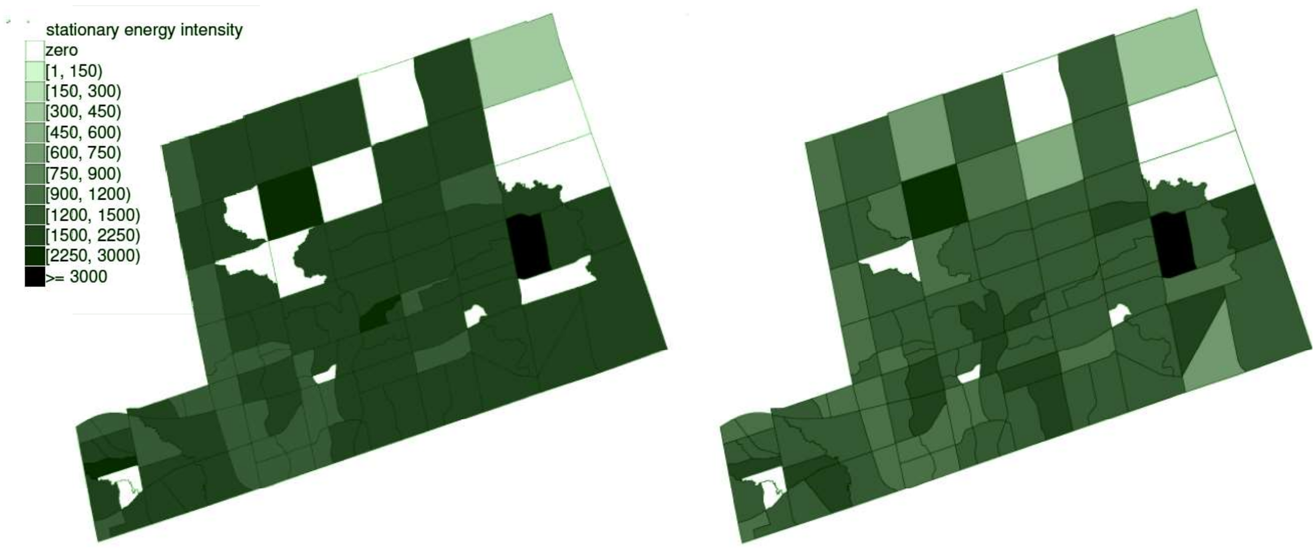

Figure 78. Energy intensity (MJ/m2) by zone; non-residential buildings, 2011 and 2050.

The PRIVATE VEHICLE continues to dominate until 2050.

5.1.4 How do people get around?

The Region of York provided modelled origin-destination matrices for each of the transportation zones, which describe how many trips start and end in each transportation zone by trip purpose and mode out until 2041, which were extrapolated to 2050.

Trip length for internal and external outbound and inbound trips, does not vary significantly, as illustrated in Figure 79. Internal trip length increased from 6 km to 6.9 km between 2011 and 2050, whereas external outbound trips declined from 18.1 km to 17.7 km over the same period. External inbound trips increase from 19.1km to 19.2 km in 2050.

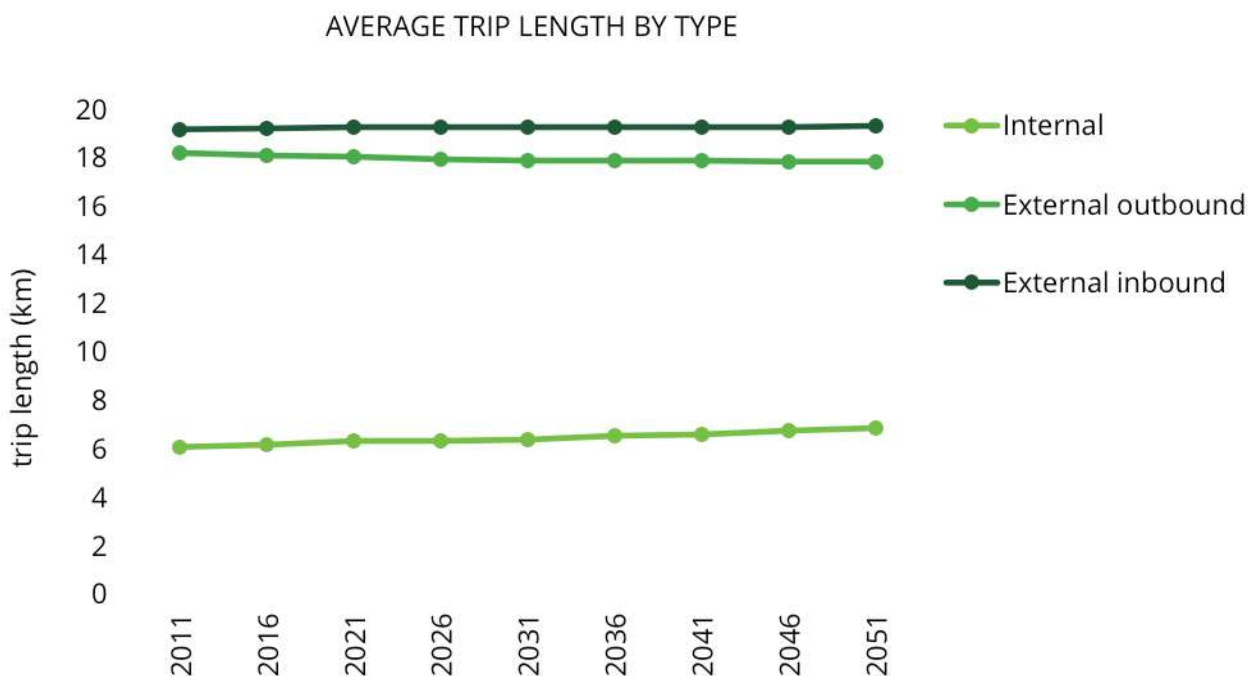

Figure 79. Average trip length, 2011–2050.

The dominant mode of transportation remains the private vehicle with slight gains in mode share for transit evident for the three trip types, as illustrated in Figure 80 to Figure 82.

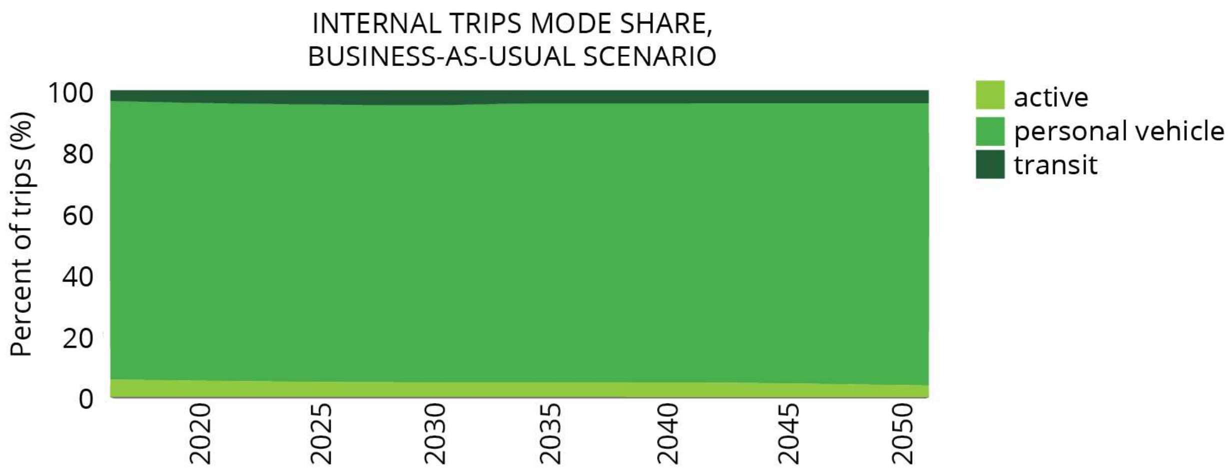

Figure 80. Mode share, internal trips, 2011–2050.

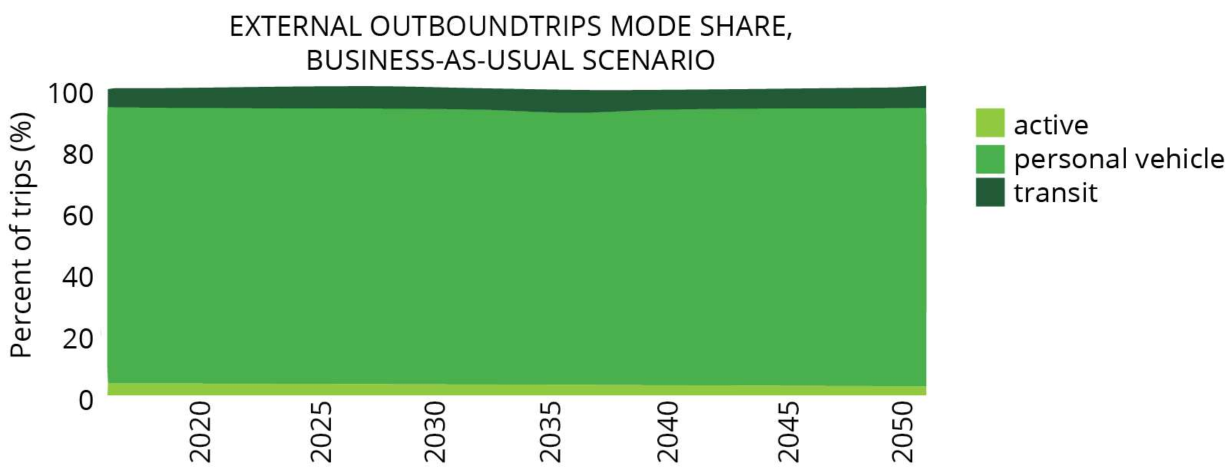

Figure 81. Mode share, external outbound trips, 2011–2050.

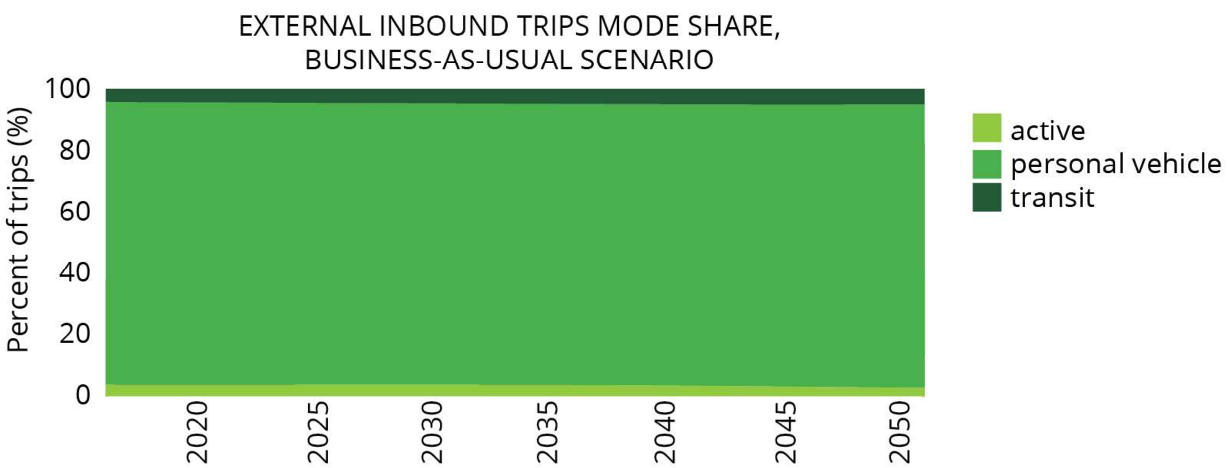

Figure 82. Mode share, external inbound trips, 2011–2050.

5.1.4.1 WHAT KIND OF VEHICLES DO PEOPLE HAVE?

The CityInsight model constructs a detailed representation of the stocks of vehicles by their age, including personal and commercial light duty, commercial medium duty, and commercial heavy duty road vehicles, using data on the stock composition from Statistics Canada and Natural Resources Canada's Demand and Policy Analysis Division[3], which are then scaled proportionately to Markham. The model simulates vehicle stock turnover and the introduction of new fuel types and technologies over time. Each vehicle is described in terms of its engine and fuel type; the light duty vehicle types are shown in Table 10.

Table 10. Vehicle types

PERSONAL LIGHT DUTY VEHICLES	PUBLIC TRANSIT VEHICLES	COMMERCIAL VEHICLES
CARS SUVS AND TRUCKS	• Buses • Subway/LRT • Commuter rail	• Light duty • Taxis • Delivery vehicles • Medium duty • “heavy duty” pickups and vans

Each of these vehicles types is then assigned an engine technology, which can be an internal combustion engine (ICE), a hybrid ICE, a fuel cell, a plug-in hybrid (PIHB), or an electric engine. Subsequently these power sources can be fuelled by gasoline, diesel, propane, hydrogen, compressed natural gas, liquid natural gas or electricity.

Fuel use for each of these vehicle types and engine/fuel combinations was calibrated with historic data in order to track with fuel use consumption reported by Statistics Canada's Report on Energy Supply and Demand (RESD). The BAU scenario incorporates the implementation of harmonized fuel efficiency standards that apply to Canada, including the Corporate Average Fuel Economy (CAFE) Standards for Light-

3 Natural Resources Canada. (n.d.). Energy Use in Canada: NEUD Publications. Retrieved September 15, 2016, from http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/publications.cfm?attr=0

Duty Vehicles (2022–2025)[4] and Phase 1 (2014–2018) and 2 (2018–2027) of Fuel Efficiency and GHG Emission Program for Medium- and Heavy-Duty Trucks.[5]

The impact of the fuel efficiency standards is evident in Figure 83, as total fuel consumption declines despite a significant increase in population and minimal changes in average trip length. Notably, total energy use by cars declines much more significantly than light trucks, which is relatively constant. Figure 84 illustrates that gasoline remains the dominant fuel with an emerging but narrow slice of electricity by 2050.

Federal fuel efficiency standards REDUCE FUEL USE despite an increasing population

For local energy generation, observed data from Markham District Energy was applied between 2011 and 2015, which showed a slight increase in generation over that period. For 2015 onwards, local energy generation capacity was held constant to 2050.

5.1.5.2 THE ELECTRICAL GRID

The historical data for the electrical grid is obtained from a variety of sources including Statistics Canada's Canadian Socio-Economic Information Management System (CANSIM) tables for total capacity and generation, along with Environment Canada's National Inventory Report (NIR) specifically for the years from 2011 to 2014.

For the BAU scenario, the electricity generation input variables were set on the basis of the National Energy Board's (NEB)

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4 EPA. (2012). EPA and NHTSA set standards to reduce greenhouse gases and improve fuel economy for model years 2017–2025 cars and light trucks. Retrieved from https://www3.epa.gov/otaq/climate/documents/420f12050.pdf

5 For detailed information on the fuel standards, see: http://www.nhtsa.gov/fuel-economy

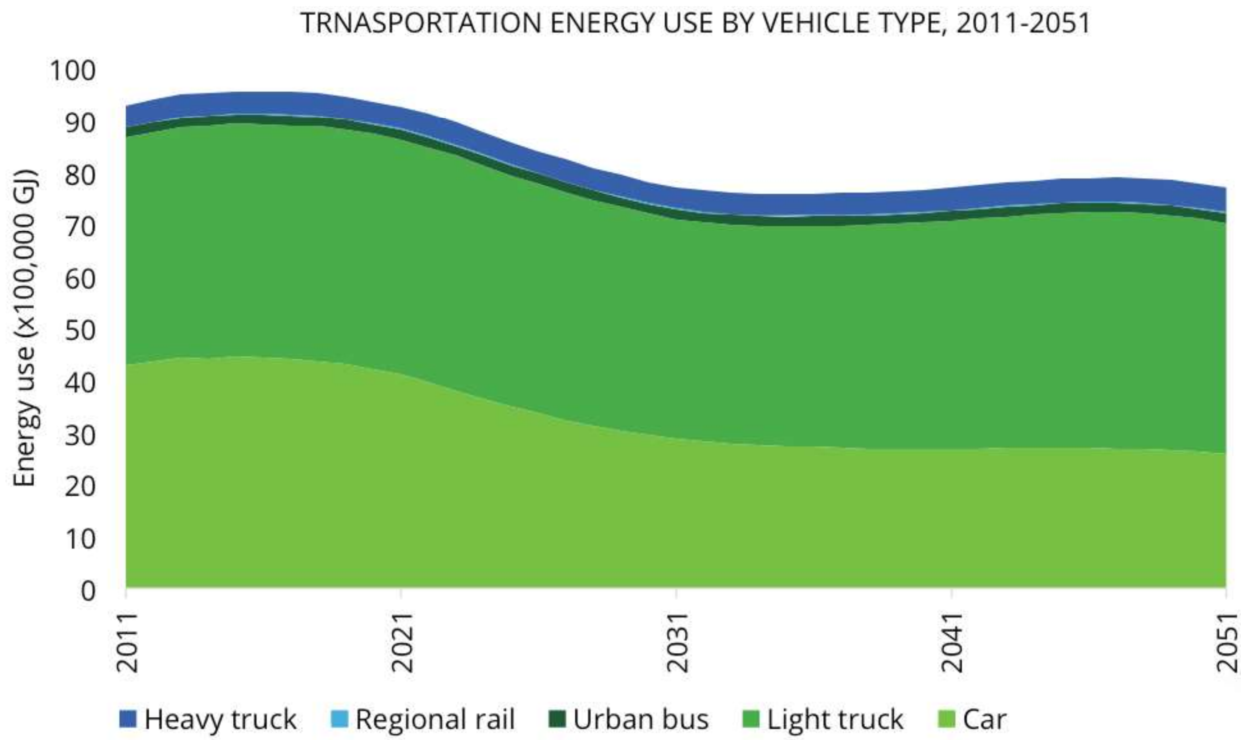


Figure 83. Transportation energy by vehicle type, 2011–2051.

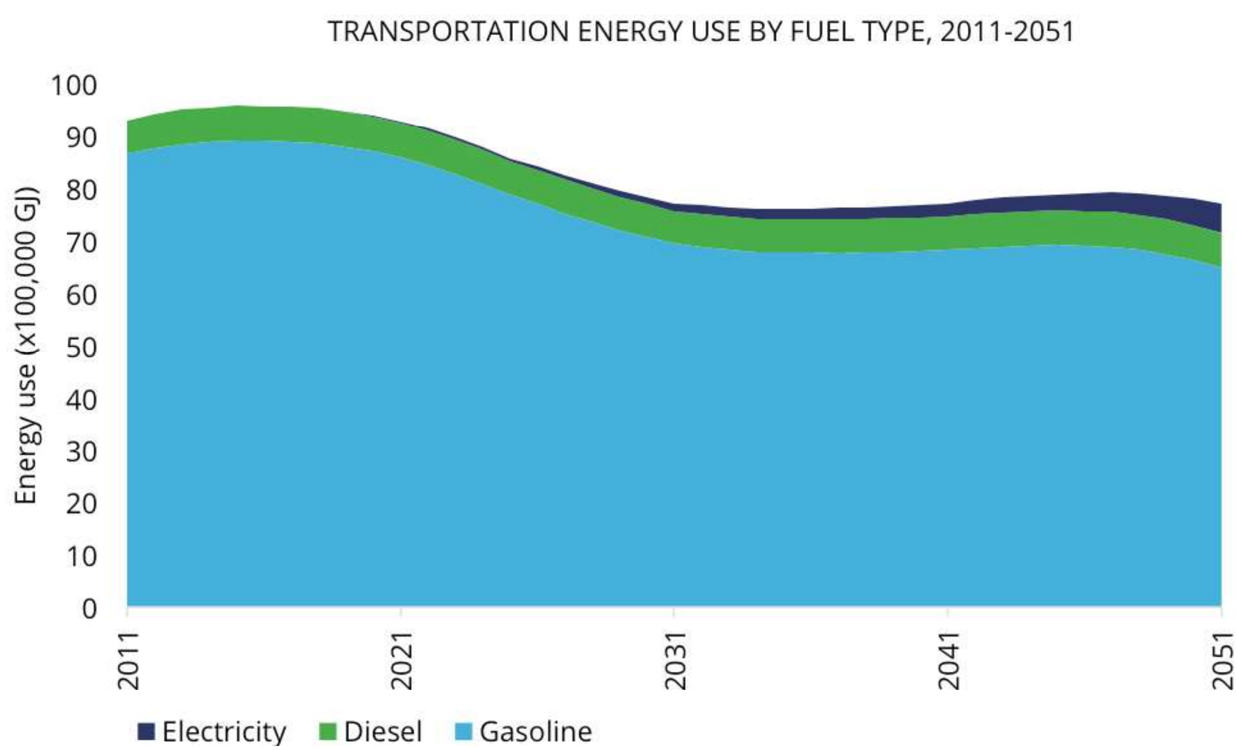


Figure 84. Transportation energy by fuel type, 2011–2051.

Energy Future 2016, beginning in 2015.[6] A subsequent comparison with electricity capacity data for each generation technology from IESO[7] showed a very good match for Ontario, although some decommissionings or added new generation capacity occurred one or two years earlier or later. Despite those minor differences, a comparison of CanESS with NIR (Table 11) shows that CanESS provides a good representation of the carbon intensity of the grid capacity in Ontario and was therefore used to develop carbon intensity projections for the Ontario grid.

Table 11. Emissions factor comparison between the National Inventory Report and CanESS.

YEAR / $kgCO_2e$/MWH	NIR	CANESS
2012	95	101
2013	66	70
2014	41	33

PROJECTED EMISSIONS FACTORS FOR ELECTRICITY GRID, ONTARIO (2011-2051)

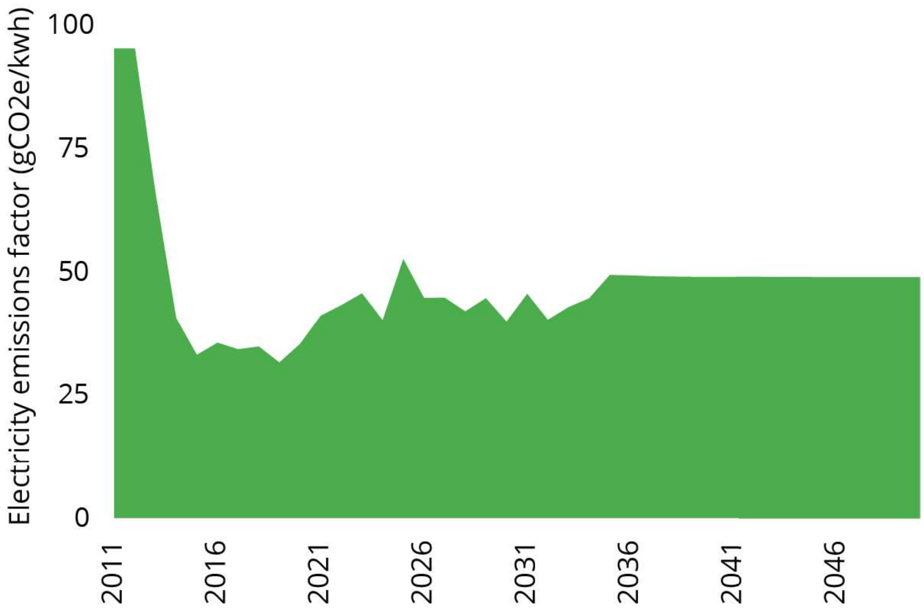


Figure 85. Projected emissions factors for electricity grid, Ontario (2011–2050).

6 National Energy Board. (2016). Canada's energy future 2016. Government of Canada. Retrieved from https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016pt/nrgyftrs_rprt-2016-eng.pdf

7 IESO (2016) MODULE 4: Supply Outlook. Retreived from http://ieso.ca/Documents/OPO/MODULE-4-Supply-Outlook-20160901.pptx

For current and future generation capacity, coal capacity was phased out in 2014, City of Pickering units are decommissioned between 2022 and 2024, while refurbishments of the remaining nuclear facilities mostly occurs in the 2020s. Wind, solar and natural gas show increases in capacity from 2016 to 2025, as projected by IESO. From 2015 onwards there is a slight increase in carbon intensity as nuclear loses some of its share. Post 2035 it is assumed that fossil fuel based electricity generation (natural gas) is maintained at 2035 levels, and all increases in capacity, required due to increases in demand, is non-fossil fuel based. As a result the carbon intensity post 2035 remains constant. Figure 85 illustrates the projected emissions factor for the electricity grid in Ontario.

5.1.6 The trajectory of waste production

Waste diversion targets were provided by the Region of York as well as Markham's Roadmap to 80% Diversion. Total waste increases from 114,000 tonnes in 2011 to 209,000 tonnes in 2051, driven by the population increase.

A drop in solid waste going to the landfill is apparent between 2011 and 2015, when the mass of waste going to the landfill declined from 46,000 tonnes in 2011 to 9,900 tonnes in 2015. By 2050, just under 8% of solid waste is anticipated to be directed to landfill.

By 2050, just under 8% of solid waste is anticipated to be directed to landfill.

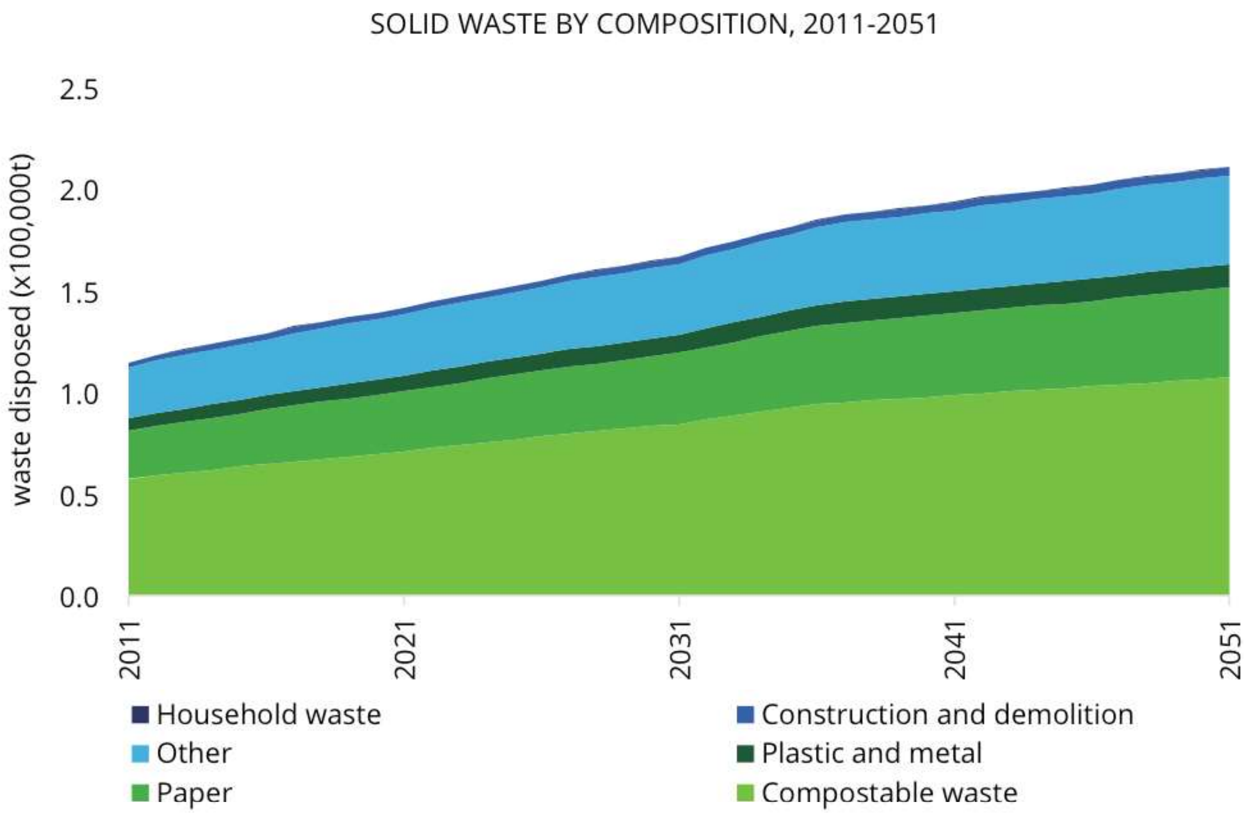


Figure 86. Solid waste by composition (2011–2051).

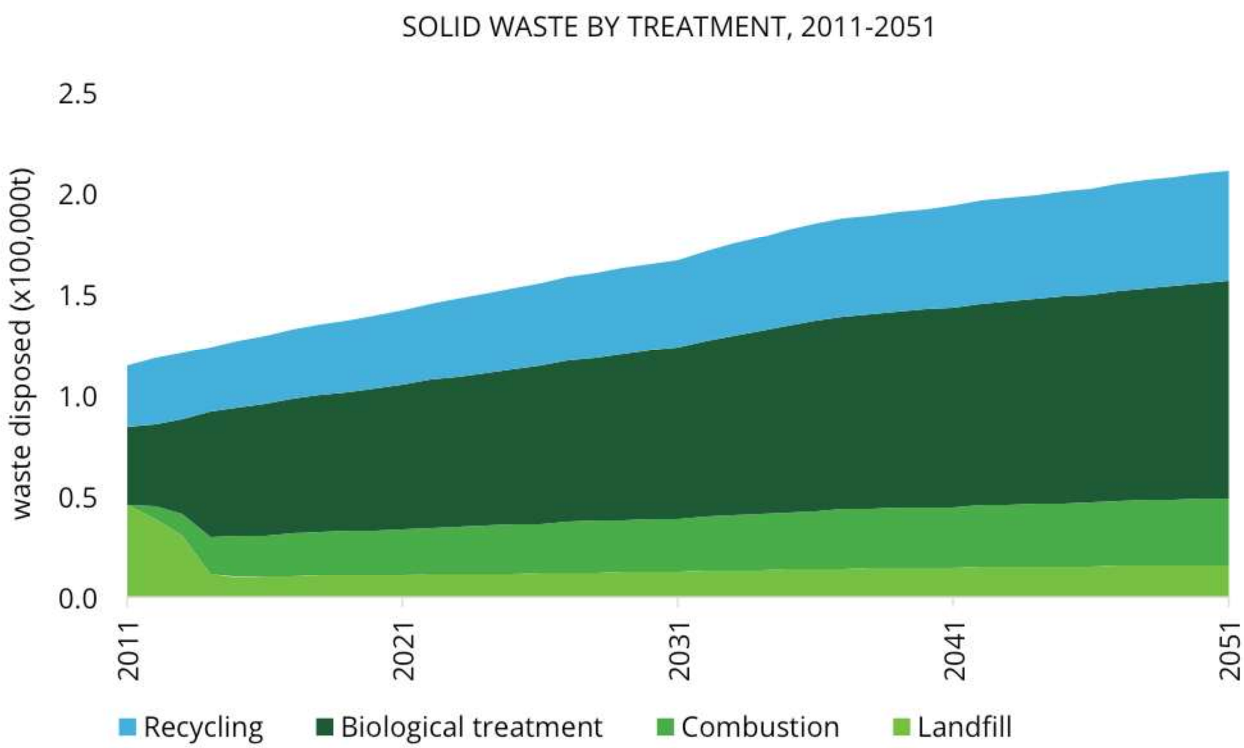


Figure 87. Solid waste by treatment type (2011–2051).

5.1.7 GHG emissions in the BAU scenario

Total GHG emissions decline very slightly from 1.78 $MtCO_2e$ in 2011, to 1.75 $MtCO_2e$ by 2050, a **1.78%** decrease.

In terms of fuels, there is a noticeable decline in gasoline consumption. Though the overall decrease in emissions is not significant, when the population increase is considered, there is a decline in per capita emissions, decreasing from approximately 5.7 tCO_2e/capita in 2011 to 3 tCO_2e/capita in 2050.

As illustrated in Figure 88, the major source of this decline in the transportation sector is due to fuel efficiency standards. In the buildings sector, Figure 89 shows a significant decline in heating energy due to the decreased number of heating degree days; however, natural gas remains the most significant contributor to emissions, both in the buildings sector and emissions overall.

In the BAU, GHG emissions decline by just under 2% primarily as a result of climate change and fuel efficiency standards.

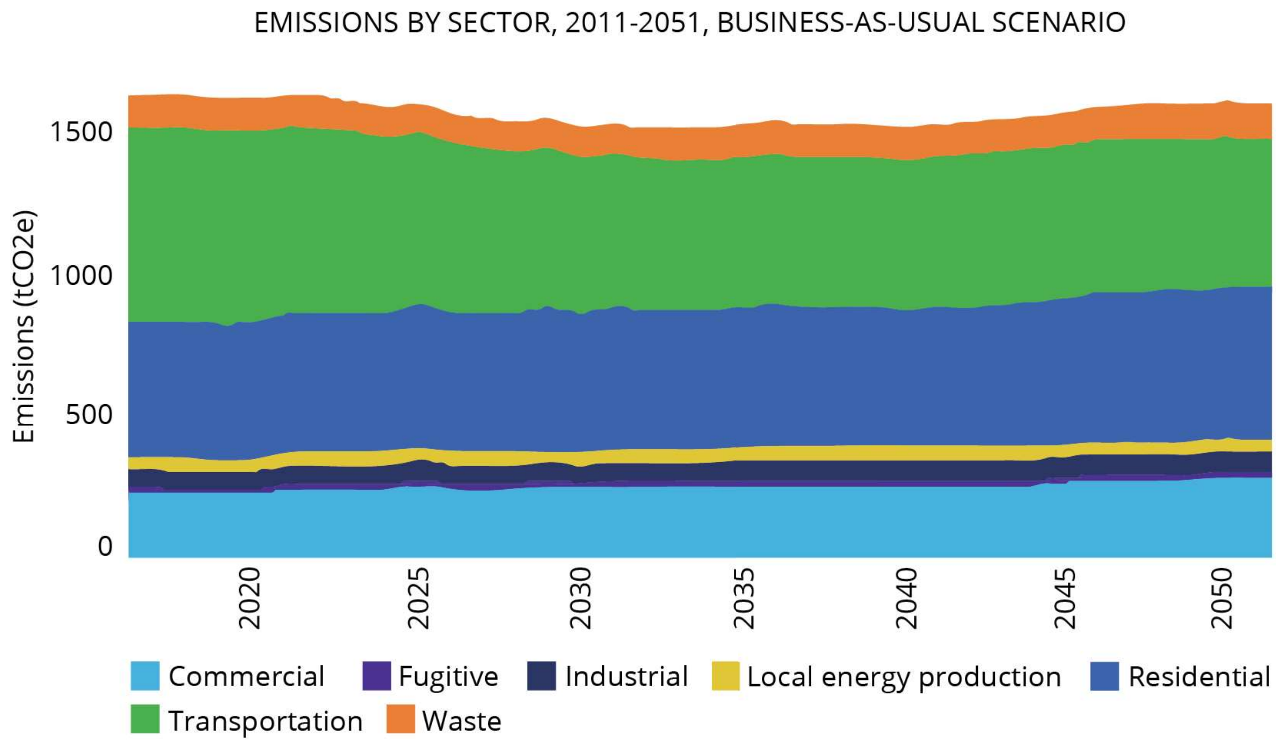


Figure 88. Total GHG emissions by sector (2011–2050).

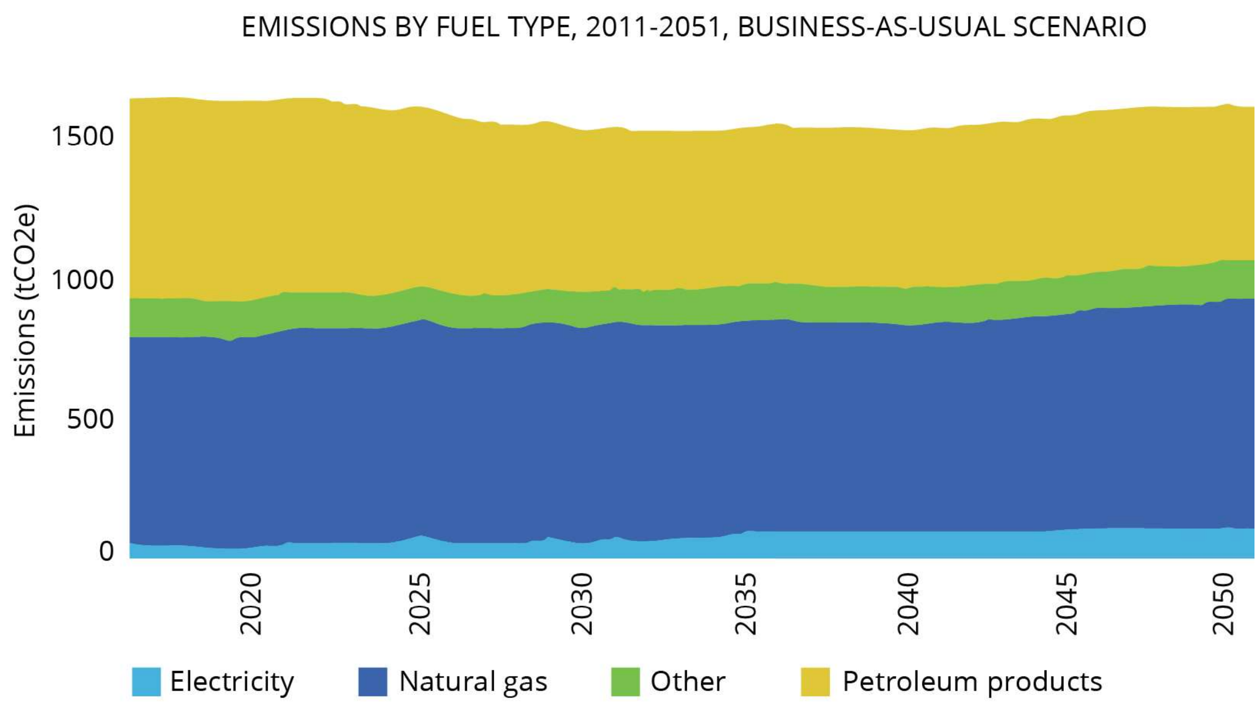


Figure 89. Total GHG emissions by fuel type (2011–2050).

5.2 INSIGHTS FROM THE BAU

The population of Markham is expected to grow to just under 580,000 by 2050. This growth in population is accompanied by increases in residential dwellings and nonresidential space.

While population continues to grow, the BAU projections indicate that emissions have a decreasing trajectory, amounting to 1.75 $MtCO_2e$ in 2050.

The primary drivers for this reduction are:

Continued decline of grid electricity emissions factor

Coal capacity was phased out in 2014; wind, solar and natural gas show increases in capacity from 2016 to 2025; refurbishments of the remaining nuclear facilities mostly occurs in the 2020s; post 2035, fossil fuel based electricity generation (natural gas) is maintained at 2035 levels (natural gas maintains its share of the generation mix), and all increases in capacity, required due to increases in demand, are non-fossil fuel based. As a result, the carbon intensity of the Ontario grid remains constant post 2035 where electricity is generated by a mix of nuclear, natural gas, hydropower, bionenergy, wind, and solar.

Improving vehicle fuel efficiency standards

The fuel economy of cars, light trucks, and medium- and heavy-duty trucks increases through the implementation of harmonized fuel efficiency standards that reduces energy consumption to 2050.

Emissions are decreasing over time towards 2050, but only slightly.

Decrease in heating degree days (due to a warming climate), partially offset by a small increase in cooling degree days

The number of heating degree days (the number of degrees that a day's average temperature is below 18° Celsius, at which buildings need to be heated) decreases as the climate continues to warm. This results in a reduction in the amount of energy required for space heating, which is predominantly supplied by natural gas, resulting in a reduction in emissions. This increase is partially offset by an increase in the number of cooling days (the temperature at which buildings start to use air conditioning for cooling), which results in an increase in energy usage, supplied by electricity.

Increase in energy retrofits of existing buildings

An incremental increase in energy retrofits in existing buildings results in a reduction in energy consumption in existing building stock.

Increasing numbers of electric vehicles in overall stock of vehicles

A higher proportion of the electric vehicle stock results in a reduction in emissions as vehicles switch from carbon intensive gasoline and diesel to increasingly cleaner electricity, with accompanying efficiency gains.

5.3 CONCLUSIONS FROM THE BAU

Switching to electricity provides a significant emissions reduction opportunity

The emissions factor for the provincial grid (electricity) continues to decline. This creates an emissions reduction opportunity for fuel switching for vehicles (private and transit) away from carbon intensive gasoline to increasingly cleaner electricity.

Out of all fuel sources, natural gas is the most significant source of emissions; this creates an emissions reduction opportunity for fuel switching to electricity for space heating, as the emissions factor for electricity continues to decline and technologies such as heat pumps to support this transition are available.

New electricity generation capacity from renewables will be needed

Significant efforts to fuel switch to electricity will require new generation capacity with renewables to ensure that the emissions factor for electricity continues to decline, as well as ensuring sufficient electrical capacity is available.

New construction standards and retrofitting are key

Improved performance standards will be needed for new construction in order to lessen the upward pressure of an increasing population on the GHG curve. However, existing buildings (pre-2011) have a major impact on GHG emissions, and an ambitious retrofit program will be critical.

Vehicle mode share and trip length remain high

Vehicular mode share and trip lengths are not projected to decline. A focus on the provision of transit infrastructure and transit-oriented development will be critical to influence a shift. Efforts to support active transportation through the provision of infrastructure and behaviour change efforts are also important.

Diversion rates are not keeping up with waste generation

Despite increases in diversion rates, solid waste emissions increase slightly, as more waste is generated from a growing population.

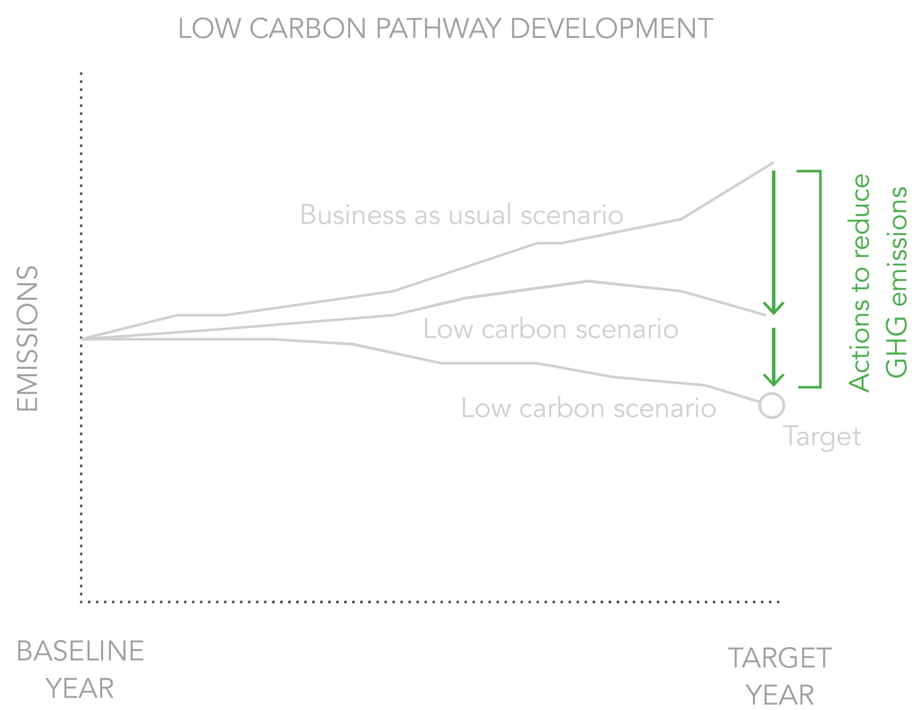
The city has benefitted from provincial policy and standards

The City has benefitted significantly from the greening of the provincial grid and vehicle fuel efficiency standards, both of which have being implemented at the provincial level, and have not been driven by the City itself.

Significant effort will be required to reach the 2050 target

The BAU projections indicate that while there is a slight decrease in emissions to 2050 (whereby the City has benefitted from the provincial policy and standards mentioned above), the target of net-zero energy emissions by 2050 represents a significant challenge as the remaining major opportunities are more intransigent and challenging at the municipal level.

6 Exploring the low carbon future



6.1 THE FUTURE OF ENERGY

Energy and emissions planning is about change – the transformation of a system powered by fossil fuels to a system characterized by energy efficiency and renewable energy. There is a tendency to postpone transformative actions and investments, as society is often resistant to change. There are two consequences of delay, however: more drastic and costly emissions reductions will likely be required in the future, and the community will forfeit economic, health and other benefits associated with low carbon investments and actions.

INFRASTRUCTURE REPLACEMENT OPPORTUNITIES FOR SELECTED EQUIPMENT AND FACILITIES BETWEEN 2015 AND 2050

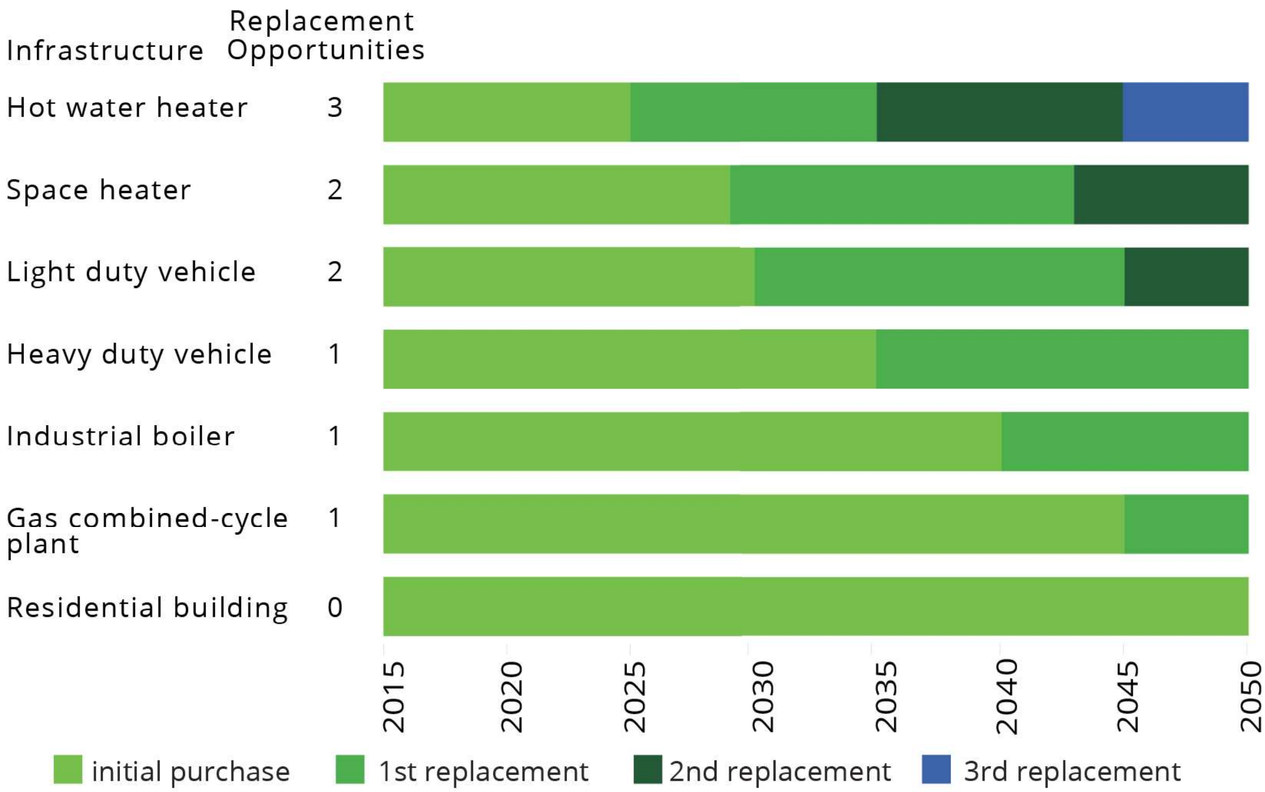


Figure 90. Example of turnover of key stocks.[8]

8 Adapted from: Duane, T., Koomey, J., Belu, K., & Hausker, K. (2017). From risk to return: Investing in a clean energy economy. Retrieved from http://riskybusiness.org/site/assets/uploads/sites/5/2016/10/RBP-FromRiskToReturn-WEB.pdf

A key consideration in identifying actions is the number of opportunities that exist to replace infrastructure as part of the natural transition at the end of that infrastructure's serviceable life, between now and 2050. Different types of infrastructure have different degrees of longevity (Figure 90).

For example, hot water heaters will turn over three times between now and 2050, providing three opportunities to upgrade the efficiency or switch to different fuel types. Residential buildings built today, however, will still be around in 2050; decisions on shape, size and energy performance for buildings today therefore have direct implications on long term GHG reductions. Interventions can be made midway through the lifetime of an investment, but the societal cost, in terms of finances, materials and energy will be higher. Assets which need to be replaced prior to the end of their useful life are defined as stranded assets.

The most durable decision of all is the result of land-use planning, which determines patterns of investment in roads, infrastructure, community services, and buildings that can last one hundred or more years. From a carbon perspective, the inertia of the built environment generates both positive and negative feedback cycles. A municipality that is compact will have lower GHG emissions and energy demand as people are more likely to walk and cycle, for example. Transit investments are more financially feasible in this context, with more people having easy access; when transit is built, new development is attracted to the transit corridor and the city continues to densify, with carbon emissions declining further and further.

District energy systems also tend to be more financially feasible in a compact city context, as higher energy loads are in closer proximity to each other and to the district energy heating source (plant), driving down the cost of district energy, and resulting in a further decline in emissions. A virtuous cycle reigns. In the opposite case, many of the low carbon solutions are confronting an uphill battle; the financial case is limited or non-existent, preventing meaningful uptake of low carbon solutions.

6.2 THE ACTIONS

The first part of the actions development process involved extensive research of low carbon actions and best practices to reduce emissions at the city scale. The initial list was reviewed with City staff, and a filtering process was undertaken to identify actions that were explicitly not relevant or applicable to the context of the City, or that the City was already undertaking. This initial list of actions was completed prior to the baseline and BAU emissions modelling and was agnostic as to whether the implementation of the action would have a significant impact on emissions reduction in the City context or not; this approach was intentional so that no action was left off the initial list.

6.2.1 Reduce, improve, switch

This approach, which we have adapted from similar approaches such as the well-known Reduce-Reuse-Recycle (from the waste sector), and Avoid-Shift-Improve[9] (from the transportation sector), seeks to look at the energy system as a whole in all sectors. It focusses on the concept of reducing energy consumption and improving the efficiency of the energy system (supply and demand), and then fuel switching to low carbon or zero carbon renewable sources.

The energy system is complex, and the linear application of reduce-improve-switch is not simple; neither should it be the only approach considered. Many actions have cross-cutting impacts. 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 PV could be installed on the roof, facilitating a switch to a zero carbon renewable source. In general, whether it be buildings, transport or waste, the idea is to first reduce the amount of energy needed by as much as possible through reduced consumption and efficiencies, and then to fuel switch to supply low or zero carbon fuel sources to supply the remainder of the demand.

9 GIZ. (2011). Sustainable urban transport: Avoid-shift-improve. Retrieved from http://www.sutp.org/files/contents/documents/resources/E_Fact-Sheets-and-Policy-Briefs/SUTP_GIZ_FS_Avoid-Shift-Improve_EN.pdf

6.2.2 Community energy planning (CEP)

A key principle of community energy planning includes prioritizing interventions in terms of a hierarchy based on what lasts longest.[10] The first priority is land use planning and infrastructure, including density, mix of land uses, energy supply infrastructure and transportation infrastructure. The second is major production processes, transportation modes and buildings, including industrial process, choice of transportation modes, and building and site design. The final priority is energy-using equipment including transit vehicles, motors, appliances and heating, ventilation and cooling (HVAC) systems.

This hierarchy explicitly concentrates the efforts on spheres of influence where there are fewer options to intervene, and it decreases the emphasis on the easier interventions which are likely to have greater short term returns. The World Bank defines this consideration as urgency,[11] posing the question: Is the option associated with high economic inertia such as a risk of costly lock-in, irreversibility, or higher costs, if action is delayed? If the answer is yes, then action is urgent; if not, it can be postponed. From this perspective, land-use planning is likely the more urgent mitigation option.

The concepts and approaches of reduce-improve-switch, turnover inertia, and community energy planning described above guided the analysis and identification of a final list of actions for modelling, as well as the sequencing of actions in modelling. The stocks and flows logic underpinning CityInSight embeds consideration of inertia into the analysis.

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10 Jaccard, M., Failing, L., & Berry, T. (1997). From equipment to infrastructure: community energy management and greenhouse gas emission reduction. Energy Policy, 25(13), 1065–1074.

11 Fay, M., Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Narloch, U., & Kerr, T. M. (2015). Decarbonizing development: three steps to a zero-carbon future. Washington, DC: World Bank Group.

The net zero target is applied to all new residential dwellings (including buildings with < 5 units) with implementation increasing incrementally up to 100% of new homes by 2030.

6.3 THE MODERATE LOW CARBON SCENARIO (LC-MOD)

The LC-mod scenario represents a significant level of effort to reduce emissions in the City of Markham. While referred to as "moderate" for the purposes of this report, the scenario is by no means moderate in terms of ambition; reducing emissions in this scenario relies on a major and sustained effort by the City, the private sector, higher levels of government, and citizens. LC-mod requires significantly scaling up many activities that the City already has underway, and introduces many new ones. LC-amb is an ambitious version of LC-mod, with the same set of actions but more aggressive targets in order to achieve an outcome closer to the objective of net zero energy emissions.

6.3.1 Buildings

Two distinct sets of actions target the buildings sector: those for existing buildings and those for future buildings. A summary of each is provided in Figure 91. Existing buildings are considered to be any buildings built before 2016.

6.3.1.1 NEW CONSTRUCTION

The primary focus for the new building stock is to achieve energy efficiency through improved building performance standards, and providing the remaining energy from renewable sources.

The net zero target is applied to all new residential dwellings (including buildings with < 5 units) with implementation increasing incrementally up to 100% of new homes by 2030. For all multi-residential and commercial buildings, implementation of PassiveHouse levels of performance also increases incrementally up to 100% of new buildings by 2030.

PassiveHouse levels of performance require energy consumption for space heating to be less than 15kWh/m^2/year, and total primary energy consumption to be less than 120 kWh/m^2/year; a significant improvement over current (2016) multi-residential buildings in Markham, which have an average space heating consumption of 92 kWh/m^2/year.

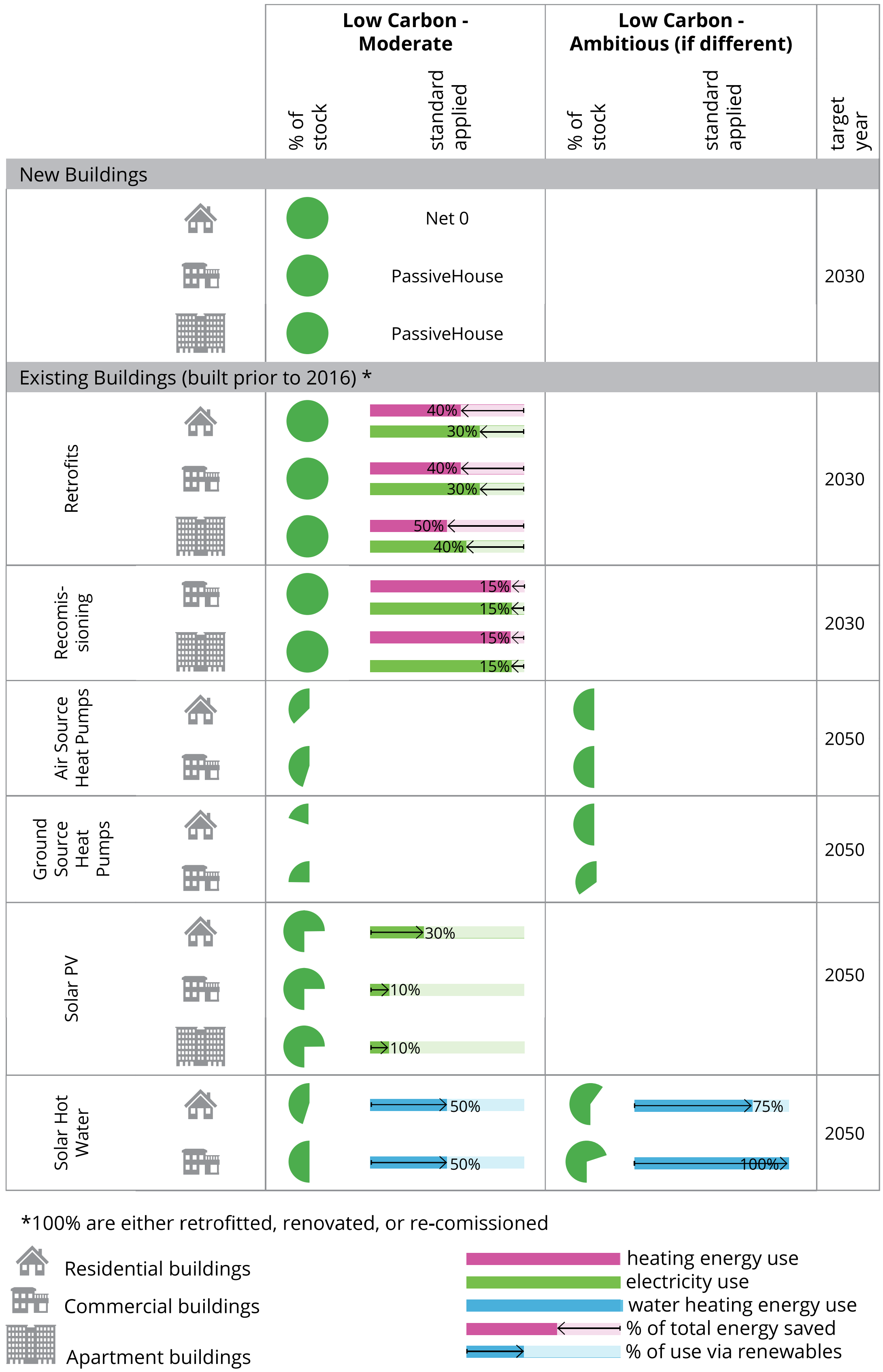

Figure 91. Summary of actions in the low carbon scenarios.

By 2050, all of the buildings constructed prior to 2016 are either retrofitted, renovated, or re-commissioned without overlap.

Additionally, for buildings which are not net zero energy, solar photovoltaic systems are installed targeting 25% of the annual electricity requirement in a net metering arrangement, for an increasing increment of new construction.

6.3.1.2 EXISTING BUILDINGS

The primary focus for the existing building stock is to upgrade the energy efficiency of the buildings through retrofit programs, renovations and re-commissioning. All of the buildings constructed prior to 2016 are either retrofitted, renovated, or re-commissioned without overlap.

Retrofits were applied to existing buildings according to their age and structure. Thermal energy savings of 40% and electrical savings of 30% were applied to single family homes and commercial buildings. Apartment buildings were retrofit to 50% savings for thermal energy and 40% savings for electricity.

A process of recommissioning was also implemented that resulted in 15% savings, split between thermal energy and electricity savings, applied to 5% of commercial buildings and multi-unit residential buildings per year.

The final action for existing buildings involved applying the energy performance requirements for new construction as buildings undergo major renovations.

6.3.1.3 BUILDING SCALE RENEWABLE ENERGY

Fuel switching from natural gas to electricity is critical for reducing emissions, particularly in the case of thermal energy. Heat pumps are used to efficiently harvest heat, and are a primary option.

Air source heat pumps are incrementally introduced into 30% of residential buildings and 40% of commercial buildings by 2050. Separately, ground source heat pumps were installed in 20% of residential buildings and 25% of commercial buildings, again by 2050.

Solar photovoltaic systems were installed on 75% of the buildings by 2050, and using a net metering arrangement, the solar photovoltaic systems were sized to provide 30% of the electricity consumption for buildings of less than 5 storeys and 10% of the electrical load for apartments and commercial buildings. Solar hot water systems were installed on 40% of the residential buildings and 50% of the commercial buildings by 2050, supplying 50% of hot water requirements for both residential and non-residential buildings.

6.3.2 Energy generation

6.3.2.1 GROUND MOUNT SOLAR PHOTOVOLTAIC

As electrification occurs in the transportation and building sectors, additional electricity capacity will be needed. In Markham, there is a preference for local, renewable energy generation, a principle discussed in Section 2.3.3. This action models the addition of 2 MW per year of ground mounted solar PV between 2018 and 2050, which can be added to surface parking lots, vacant land or other appropriate locations.

2 MW

per year of

ground mounted solar PV are added between

2018 and 2050

6.3.2.2 ENERGY STORAGE

Energy storage bridges the temporal gap between when renewable energy is generated and when there is a demand for the energy, increasing the percentage of energy that can be used, and decreasing the reliance on fossil fuel-based peaking plants. For this reason, in modelling, energy storage is assumed to increase the capacity factor for renewable energy. The action assumes a capacity factor of 20% for installed storage. For Markham, a target of 10 MW was identified for 2025, scaling up to 100 MW of storage by 2050, as increasing renewable capacity comes online from other actions.

6.3.3 Transportation

6.3.3.1 ACTIVE TRANSPORTATION

INCREASED CYCLING MODE SHARE

The Transportation and Land-use Planning Research Laboratory at Ryerson University completed a project that considered the potential for cycling in the Greater Toronto

All new vehicles in Ontario after 2030 will be electric, including personal light duty vehicles.

Region.[12] Approximately one third of the total trips in the Region are potentially cyclable, which is defined as a trip that is not currently taken on foot or using a bicycle, is between 1 and 5 km, and does not facilitate the travel of other passengers. The action assumes that 50% of trips with a length of between 1 and 5 km shift to cycling by 2040.

INCREASED WALKING MODE SHARE

The approach to walking was similar to the cycling analysis described above. In this case, 50% of the potential walking trips or trips that are not already walking, that were less than 2 km, and were not supporting the travel of another passenger, were shifted to walking by 2050.

6.3.3.2 CAR FREE ZONES

Car free areas are implemented incrementally in certain zones, whereby the vehicular mode share declines linearly from 2030 to 2050, reaching zero to and from those zones. These zones were identified for areas that, by 2050, had densities of higher than 150 people and jobs per hectare (with a fairly even split of jobs to people), and are in close proximity to transit – conditions amenable to pedestrian-only areas. Figure 92 illustrates the potential car free zones for Markham.

6.3.3.3 ELECTRIFYING VEHICLES & TRANSIT

VEHICLE TECHNOLOGIES

The principle of "*switching to low carbon renewable sources of energy*" indicates that the primary intervention in the transportation sector is to electrify the vehicle and transit fleet. Electrifying the transit fleet (action 18) includes incrementally transitioning buses in Markham, starting in 2020, so that the fleet is fully electric by 2040.

For personal vehicles, the action assumes all new vehicles in Ontario after 2030 will be electric, including personal light-duty vehicles; an action which is consistent with commitments

12 Mitra, R., Smith Lea, N., Cantello, I., & Hanson, G. (2016). Cycling behaviour and potential in the greater Toronto and Hamilton area. Retrieved from http://transformlab.ryerson.ca/wp-content/uploads/2016/10/Cycling-potential-in-GTHA-final-report-2016.pdf

announced by Germany[13] and Norway.[14] For commercial vehicles, electric vehicle uptake is increased incrementally from 2020 to 2050, whereby 90% of commercial vehicle activity in Markham will be electric by 2050. Note that other zero carbon transportation technologies or fuels, such as hydrogen, would have a similar impact on the City of Markham's low carbon scenarios.

Included in the electrifying of personal vehicles (action 21), is an assumption around the uptake and impact of autonomous vehicles (AV). Based on a scenario developed by the Rocky Mountain Institute,[15] the action assumes that personal vehicle ownership declines by 50% by 2050 but personal vehicle kilometres travelled (VKT) increases by 20%.[16] The increase in VKT results as new cohorts of the population (young and elderly, for example) have access to vehicles, and the convenience of private vehicles increases, with the cost of travel decreasing.[17]

As there is an expected increase in VKT associated with AV, emissions are expected to increase; however, in this action, AV's follow the same rate of EV adoption as all other vehicle stocks, which scales up to 100% EV by 2030. The net result is a decrease in emissions as personal vehicles are electrified.

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13 Schmitt, B. (2016). Germany's Bundesrat resolves end of internal combustion engine. Retrieved January 3, 2017, from http://www.forbes.com/sites/bertelschmitt/2016/10/08/germanys-bundesrat-resolves-end-of-internal-combustion-engine/#b1c666a31d95

14 Staufenberg, J. (2016). Norway to "completely ban petrol powered cars by 2025." Retrieved January 3, 2017, from http://www.independent.co.uk/environment/climate-change/norway-to-ban-the-sale-of-all-fossil-fuel-based-cars-by-2025-and-replace-with-electric-vehicles-a7065616.html

15 Johnson, C., & Walker, J. (2016). Peak car ownership: The market opportunity of electricity automated mobility services. Rocky Mountain Institute. Retrieved from https://rmi.org/Content/Files/CWRRMI_POVdefection_FullReport_L12.pdf

16 Horl, S., Ciari, F., & Axhausen, K. (2016). Recent perspectives on the impact of autonomous vehicles. Retrieved from https://www.ethz.ch/content/dam/ethz/special-interest/baug/ivt/ivt-dam/vpl/reports/2016/ab1216.pdf

17 Ticoll, D. (2015). Driving changes: Automated vehicles in Toronto. Retrieved from https://www1.toronto.ca/City%20Of%20Toronto/Transportation%20Services/TS%20Publications/Reports/Driving%20Changes%20(Ticoll%202015).pdf

Figure 92. Proposed car free areas.

6.4 AN AMBITIOUS LOW CARBON SCENARIO (LC-AMB)

In the Low Carbon Ambitious (LC-amb) scenario, emissions are further reduced as the rate of deployment of solar heating/hot water, and air and ground source heat pumps are scaled up in the residential and commercial sectors; and all natural gas is replaced with Renewable Natural Gas (RNG). LC-amb reduces emissions further compared with Low Carbon Moderate (LC-mod) scenario, but does not result in net zero emissions.

6.4.1 Buildings

Heat pumps

The LC-amb increases the penetration of air and ground source heat pumps in the residential and commercial building stock. For residential, 50% of buildings are assumed to have air source heat pumps and 50% have ground source heat pumps by 2050, increased from 30% and 20% respectively in LC-mod. For commercial, 50% of the buildings have air source heat pumps and 35% have ground source heat pumps, increased from 40% and 25% respectively in LC-mod.

Solar hot water

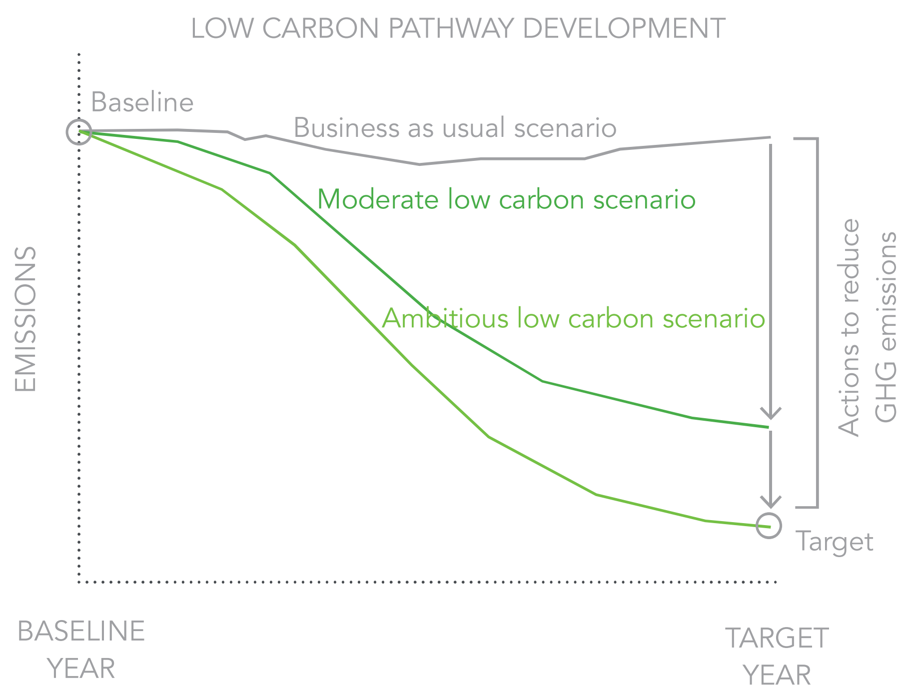
LC-amb increases solar hot water deployment, scaling up to 60% of the residential building stock by 2050 and 70% of commercial stock. Solar hot water supplies 75% of residential and 100% of commercial hot water requirements.

6.4.2 Energy generation

Renewable natural gas

Renewable natural gas scales up to replace any conventional natural gas usage by 2050 after introducing additional heat pumps and solar hot water as noted above, resulting in an additional decrease of 282,000 tCO_2e in 2050.

7 The results of the low carbon scenarios



The ambitious low carbon scenario achieves GHG emissions reductions from energy sources of **90%** by **2050** over **2011** levels.

LC-amb results in 90% savings in annual GHG emissions from energy sources over the 2011 baseline year; note that GHG emissions from waste have been excluded from this analysis. On a per capita basis the GHG emissions reductions are even steeper, at -94% by 2050.

The emissions descent pathways of the two low carbon scenarios over time are illustrated relative to the BAU scenario in Figure 93.

The remaining emissions in LC-amb, totalling 161 ktCO_2e, are the result of imported electricity coming from the provincial grid[18], and fossil fuel consumption in the industrial sector. Options to eliminate the remaining emissions in LC-amb in order to achieve the net zero target are further explored in the next section.

Table 12. Summary results of the scenarios[19]

SCENARIO	2050 (ktCO_2e)	% CHANGE OVER 2011	2050 (tCO_2e/ CAPITA)	% CHANGE OVER 2011
BAU	1,478	-5%	2.55	-49%
LC-mod	501	-68%	0.87	-83%
LC-amb	161	-90%	0.28	-94%

18 While the Ontario grid electricity emissions factor has declined significantly since 2011, the grid electricity emissions factor is not expected to be zero by 2050.

19 Because of the focus of the net zero definition on GHG emissions from energy sources, GHG emissions from waste have been removed from these calculations.

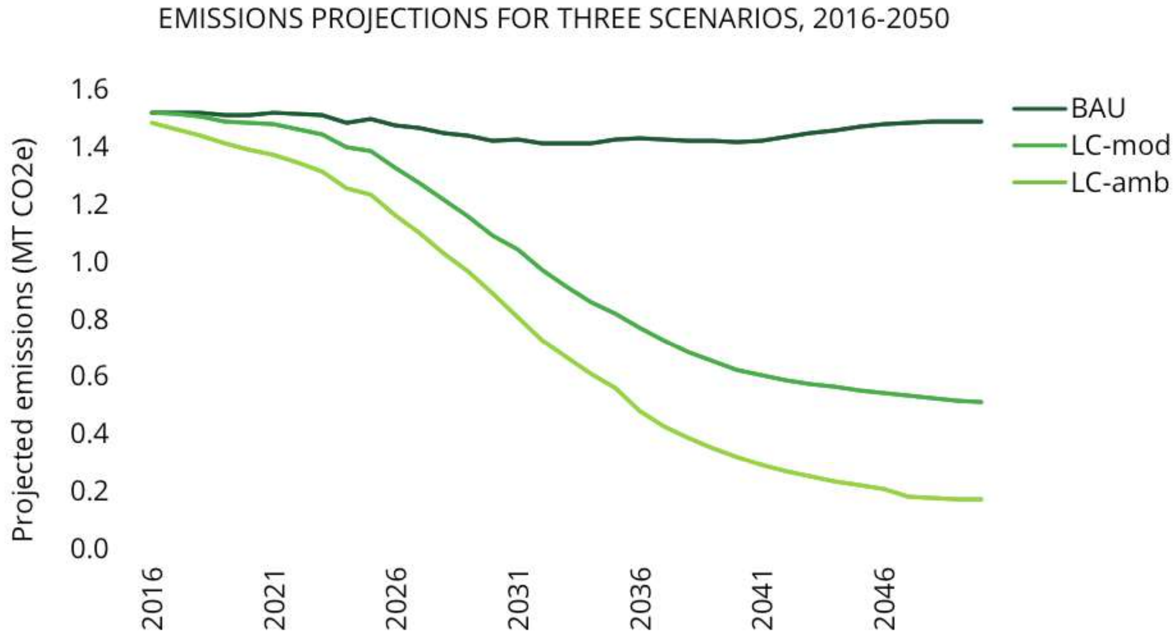


Figure 93. BAU, LC-mod and LC-amb projections, 2016–2050.

7.1 WEDGES DIAGRAMS

The emissions reduction impact of each of the actions quantified and evaluated against the BAU scenario and then all the actions are modelled together in the form of an integrated scenario. Once the results of the integrated scenario are calculated, the proportionate reductions from each action are distributed on a year over year basis to generate a wedge diagram, illustrated in Figure 94 for the LC-mod scenario, and Figure 95 for the LC-amb scenario.

The wedge diagram shows the contribution of each action to the overall emissions reduction trajectory. As there are dependencies and feedback cycles between the actions, which are captured by the model, the wedge diagram represents a simplified representation of the results.

Electrification of all personal vehicles reduces GHG emissions by 260,000 tCO_2e by 2050, almost 20% of the total emissions.

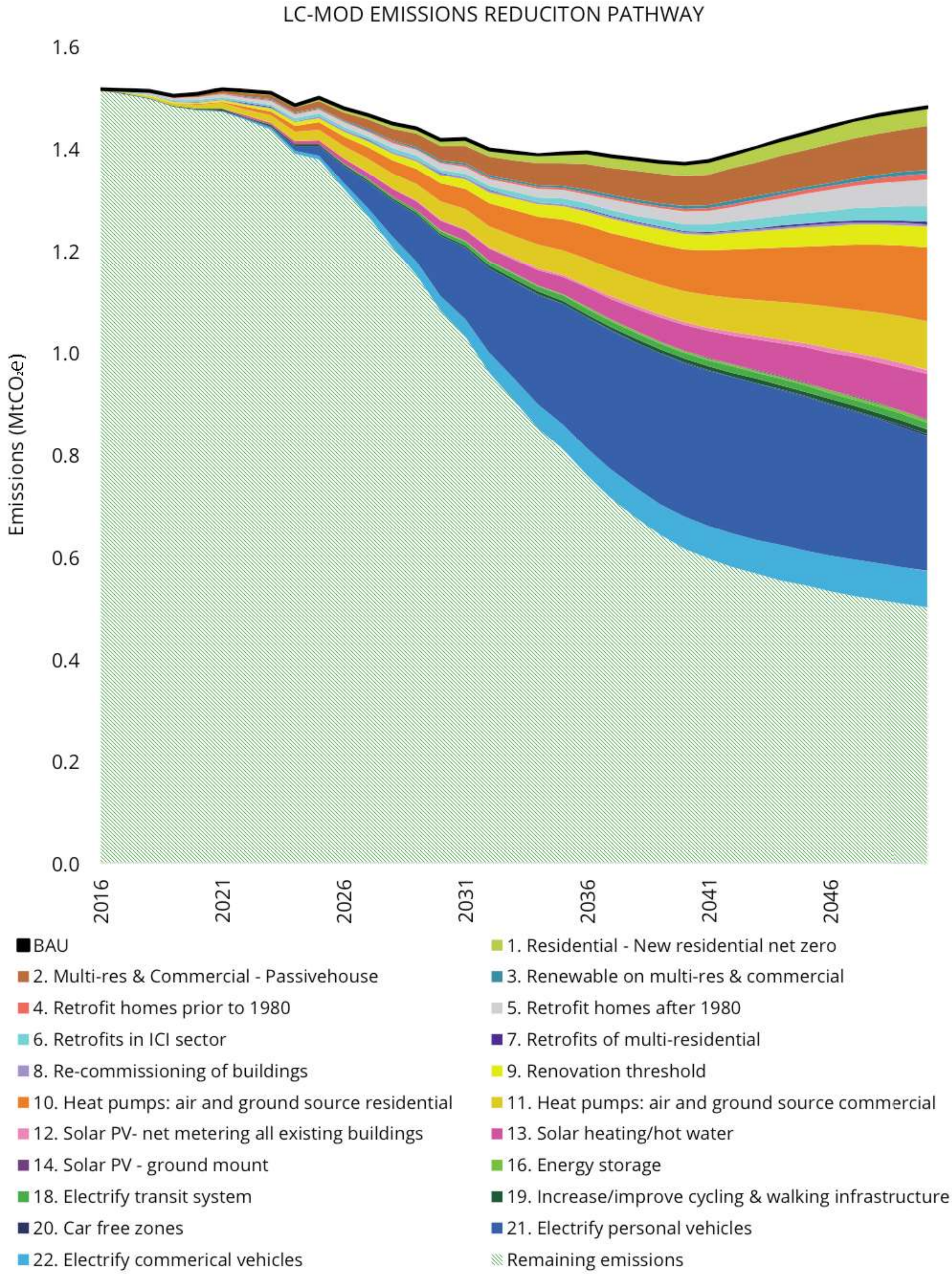


Figure 94. LC-mod emissions reductions, 2016–2050.

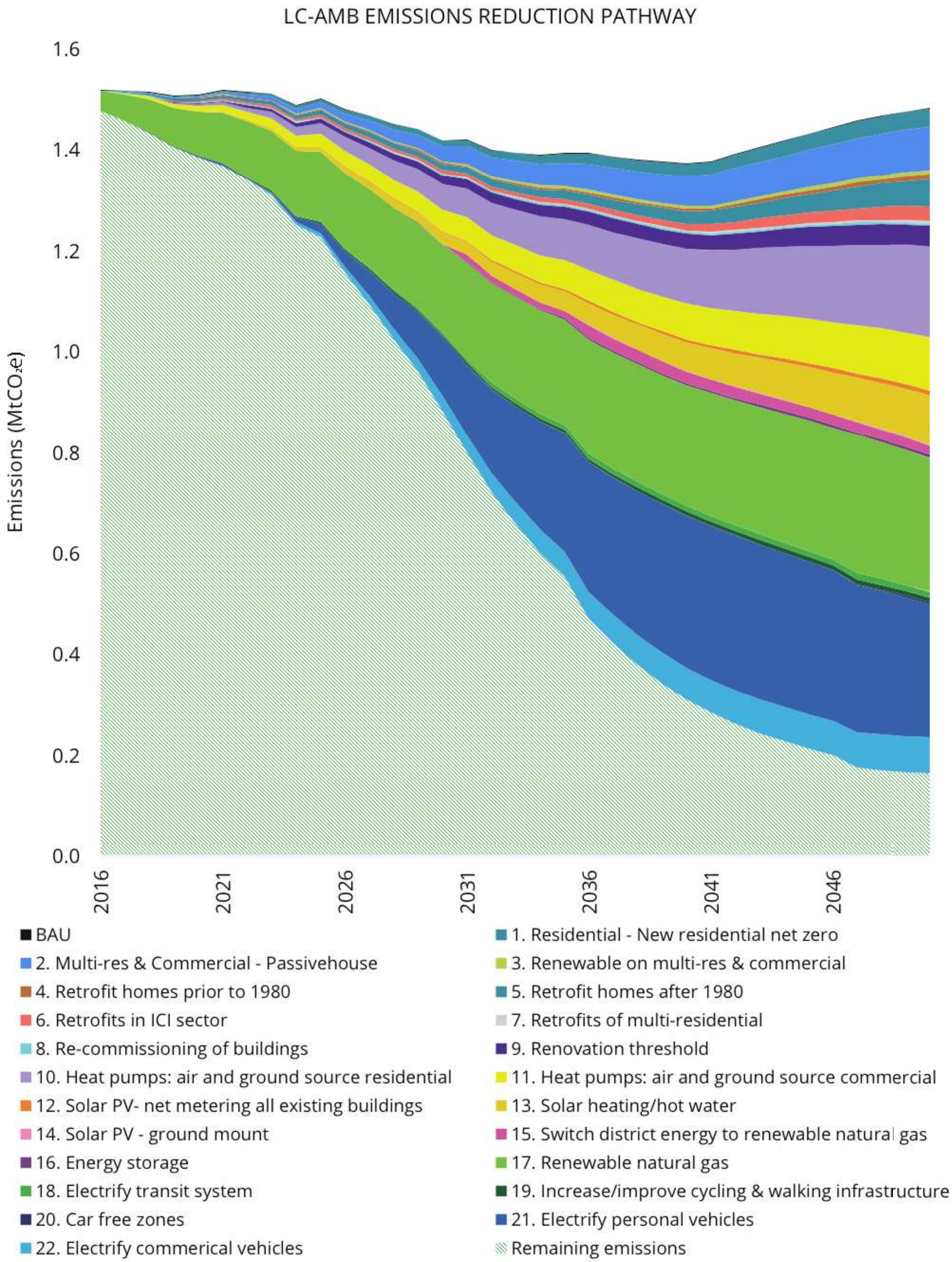


Figure 95. LC-amb emissions reductions, 2016–2050.

Table 13 describes the GHG emissions reductions associated with each of the actions for the two scenarios. For detailed assumptions associated with the actions, see Appendix 1.

Table 13. Emissions reduction results of actions for LC-mod and LC-amb, $ktCO_2e$ in 2050.

BUILDINGS		$ktCO_2e$ (2050) LC-MOD	LC-AMB
NEW BUILDINGS - BUILDING CODES & STANDARDS			
1	Residential - New residential housing development targets net zero, including solar PV	36.2	36.2
2	Multi-residential (incl. condominiums) & commercial and institutional - Passivehouse standard applied to multi-unit residential, commercial and institutional buildings	86.2	86.2
3	Renewable energy installation requirements or incentives on multi-res, commercial and institutional buildings	7.4	7.4
EXISTING BUILDINGS - RETROFITTING			
4	Retrofit homes prior to 1980	10.4	10.4
5	Retrofit homes after 1980	52.9	52.9
6	Retrofits in ICI sector	30.0	30.0
7	Retrofits of multi-residential	4.4	4.4
8	Re-commissioning of buildings	4.1	4.1
9	Renovation threshold requirement to meet codes and standard	41.4	41.4
RENEWABLE ENERGY GENERATION (ON-SITE, BUILDING SCALE)			
10	Installation of heat pumps: air and ground source residential	144.8	179.5
11	Installation of heat pumps: air and ground source commercial	94.7	106.6
12	Solar PV - Net metering all existing buildings	8.9	8.9
13	Solar heating/hot water	87.9	98.0
ENERGY GENERATION		LC-MOD	LC-AMB
LOW OR ZERO CARBON ENERGY GENERATION (COMMUNITY SCALE)			
14	Solar PV - ground mount	1.3	1.3

			ktCO$_2$e (2050)
15	Switch district energy to renewable natural gas	-	17.6
16	Energy storage	6.3	6.3
17	Renewable natural gas	-	264.9
TRANSPORT		LC-MOD	LC-AMB
TRANSIT			
18	Electrify transit system	11.9	11.9
ACTIVE			
19	Increase/improve cycling & walking infrastructure	9.6	9.6
20	Car free zones	4.1	4.1
PRIVATE/PERSONAL USE			
21	Electrify personal vehicles	263.4	263.4
22	Electrify commercial vehicles	71.6	71.6
TOTAL		**977.5**	**1316.8**

7.2 THE IMPACT OF THE LOW CARBON SCENARIOS ON THE ENERGY SYSTEM

The sankey diagrams (Figure 96) depict the energy flow by fuel and sector through Markham in 2050, in the BAU, LC-mod, and LC-amb scenarios respectively.

Overall, energy decreases significantly in the LC-mod and LC-amb scenarios. Additionally, and more significantly perhaps, is the reduction in conversion losses; the ratio of useful energy to conversion losses in BAU 2050 is 1.7:1, compared with 3.7:1 in LC-mod and 4.6:1in LC-amb. The LC-mod and LC-amb represent a more efficient energy system, indicating significant financial savings. Energy consumption in the transportation sector declines significantly, primarily due to the increased efficiency of electric vehicles over internal combustion engines.

Total electricity consumption in the low carbon scenarios is similar to the BAU despite electrification of transportation and heating.

The LC-mod sankey diagram indicates that overall consumption of electricity decreases slightly compared with BAU despite major emphasis on fuel switching to electricity, particularly in the transport sector. This reduction is a result of the increased efficiencies in the building stock, which exceeds the addition of new electricity consumption from vehicles and the addition of heat pumps. In contrast, however, the LC-amb sankey diagram indicates an increase in electricity, resulting from a more ambitious switch to this energy source. A consideration is that the electrification of vehicles in particular would require investments in the grid to support new electrical loads, and partnerships with Alectra and IESO.

The LC-mod and LC-amb sankey diagrams demonstrate that the energy system in Markham becomes more complex by 2050, with a greater diversity of fuels and generation technologies gaining prominence, especially in LC-amb, as illustrated by the number of lines and the thickness of the lines.

Total energy consumption in 2050 is ONE THIRD LESS in the low carbon scenarios than in the BAU.

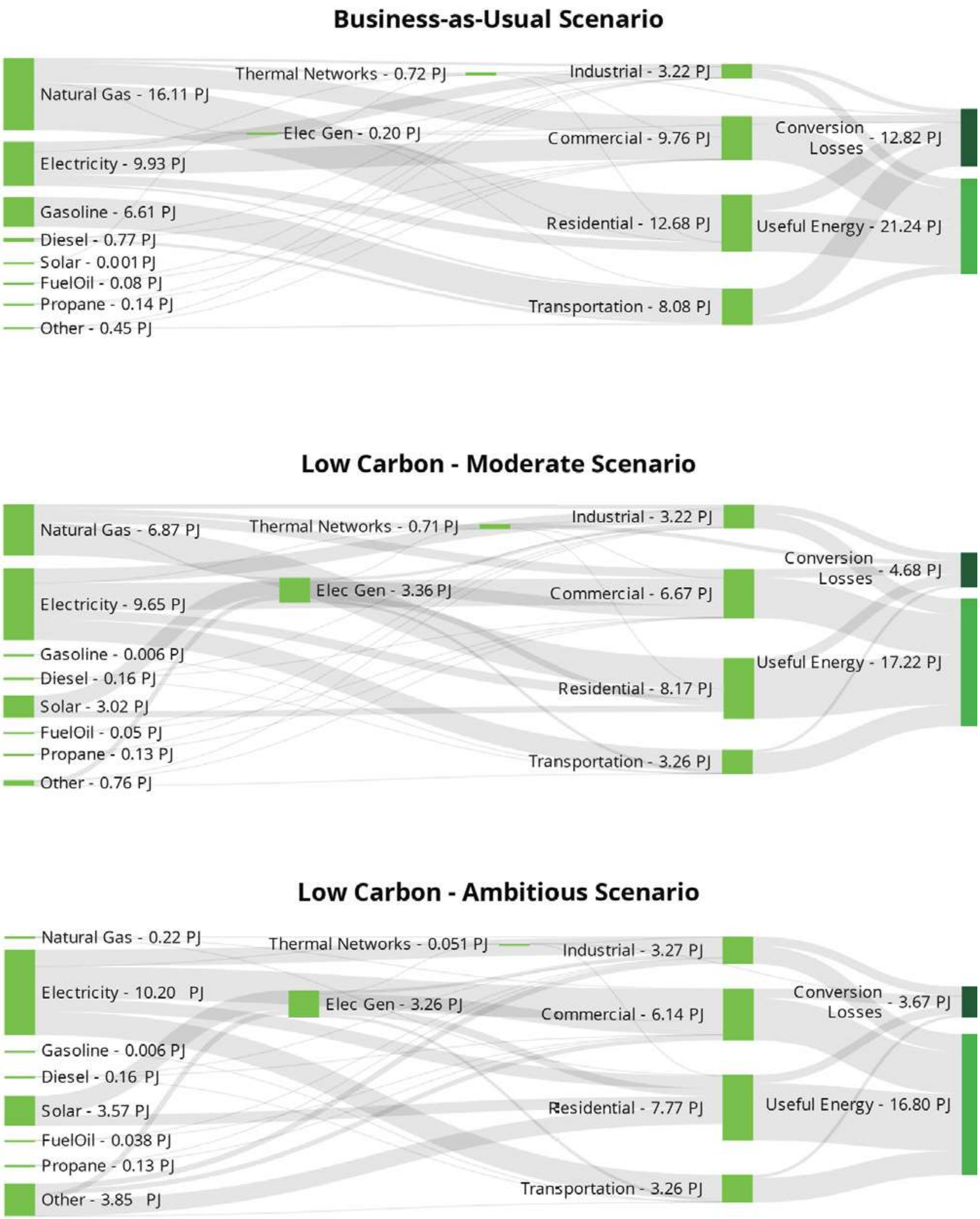


Figure 96. Energy flow sankey diagrams, 2050.

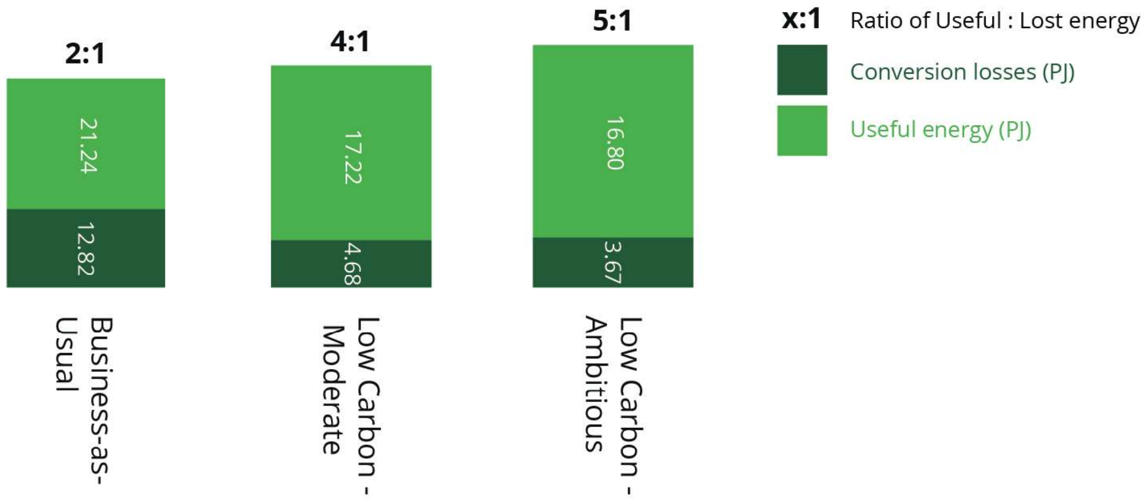


Figure 97. *Ratio of useful to lost energy.*

7.3 ENERGY RESULTS

The LC-mod scenario sees a gradual decrease in overall energy consumption to 2050, with significant decreases in the transportation sector (Figure 98) as gasoline and diesel consumption declines significantly to 2050 (Figure 99). Increases in electricity and renewable sources, in particular solar, are evident as fuel shifting in the buildings and transport sectors away from fossil fuels increases to 2050.

The LC-amb scenario also sees a gradual decrease in overall energy consumption to 2050, to a slightly greater extent than LC-mod. Significant decreases are also evident in the transportation sector (Figure 100). Electricity, solar and renewable natural gas (biogas) become the main sources of energy by 2050; natural gas is replaced entirely with RNG (Figure 101).

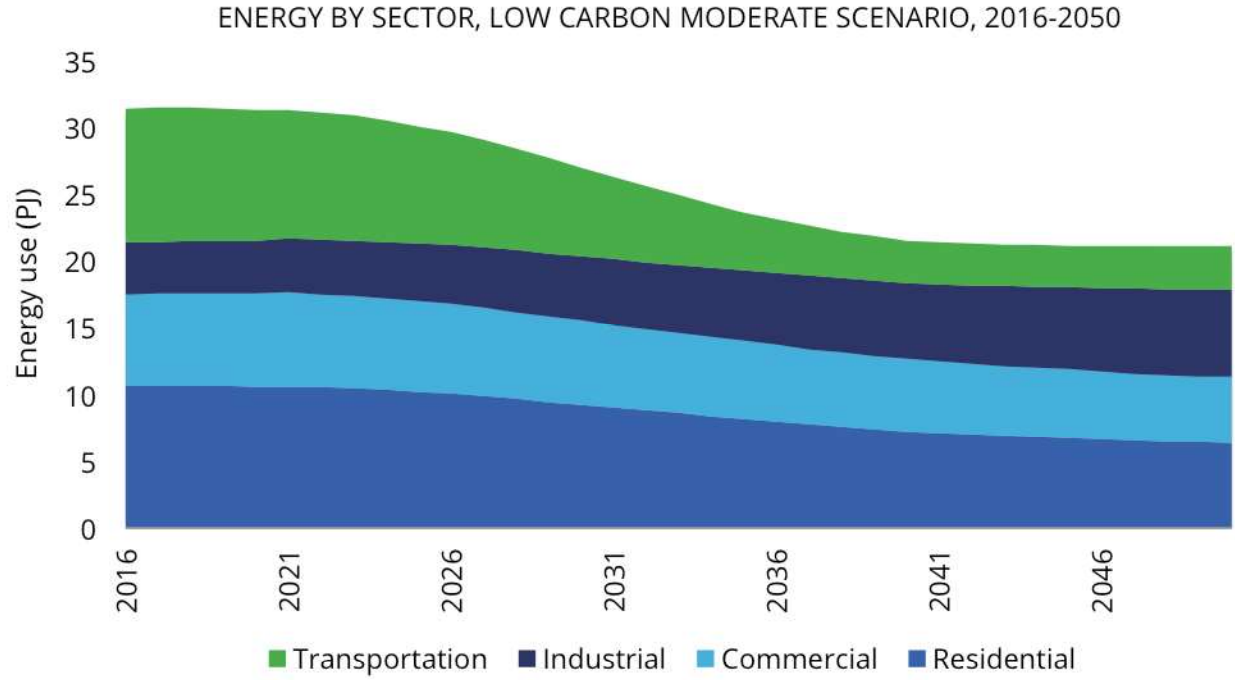


Figure 98. Energy by sector, LC-mod, 2016–2050.

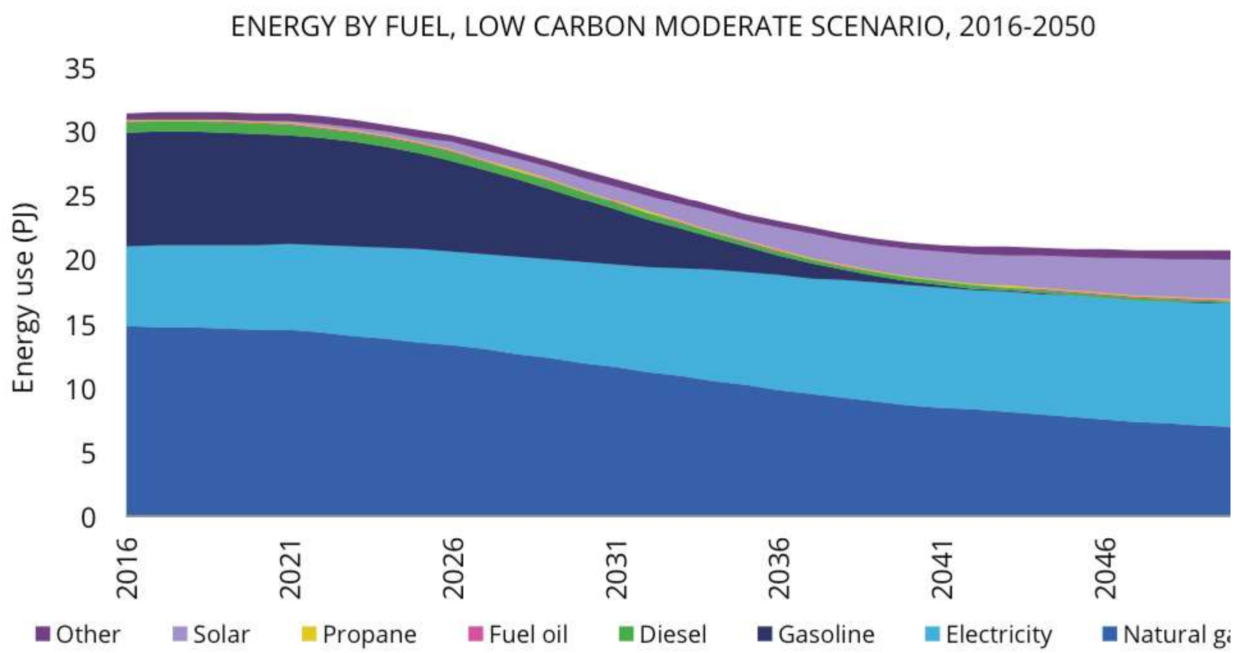


Figure 99. Energy by fuel, LC-mod, 2016–2050.

Solar PV and renewable natural gas become significant sources of energy in the low carbon scenario.

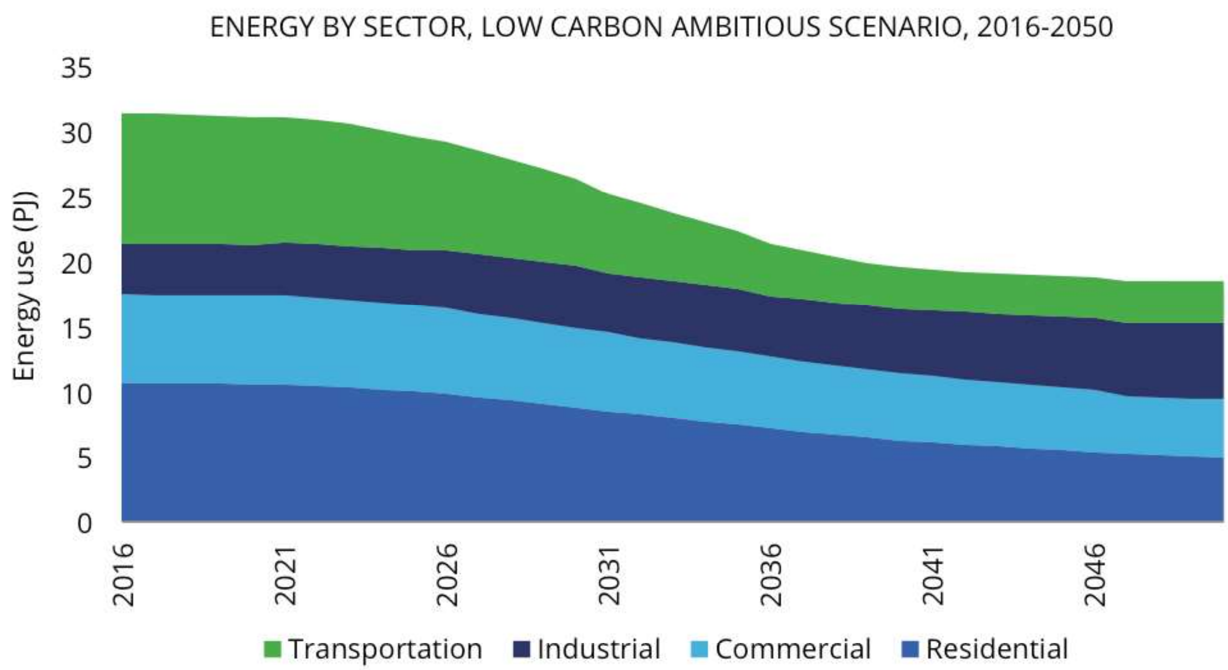


Figure 100. Energy by sector, LC-amb, 2016–2050.

Natural gas is phased out by 2050 in the ambitious low carbon scenario, replaced by renewable natural gas and heat pumps.

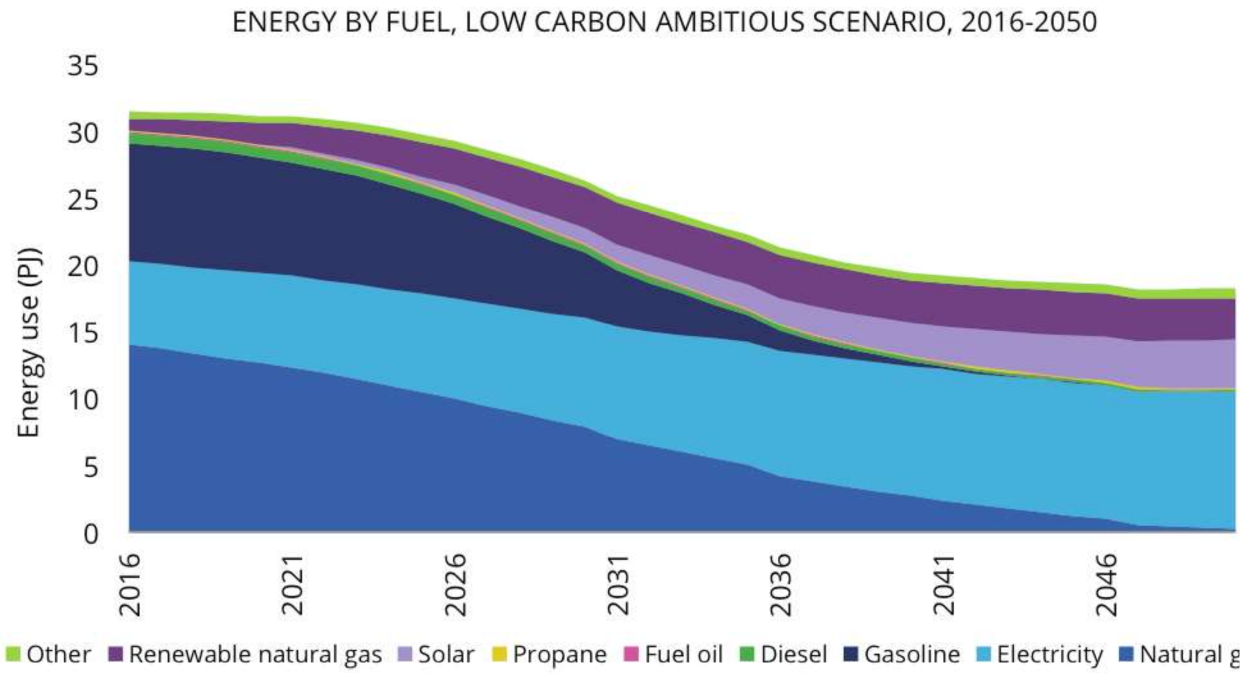


Figure 101. Energy by fuel, LC-amb, 2016–2050.

7.4 GHG EMISSIONS

In the low carbon scenario, emissions decline steadily between 2017 to around 2040, whereafter reductions taper off more gradually to 2050 (Figure 102). A significant contributor of the emissions reduction to 2040 is the decrease in gasoline and diesel use (Figure 103). By 2050, there are approximately 500 $ktCO_2e$ of emissions, the majority of which come from the use of natural gas.

Diesel and gasoline consumption are phased out by 2050 as ELECTRICITY takes over.

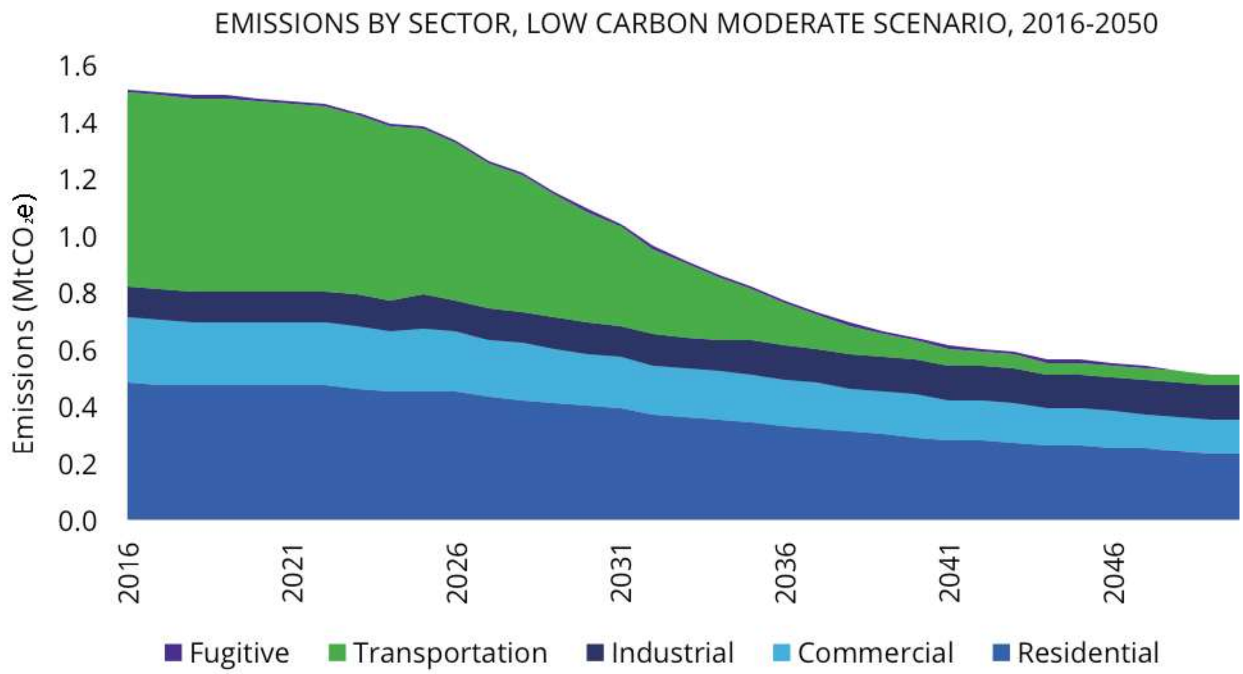


Figure 102. Emissions by sector, LC-mod, 2016–2050.

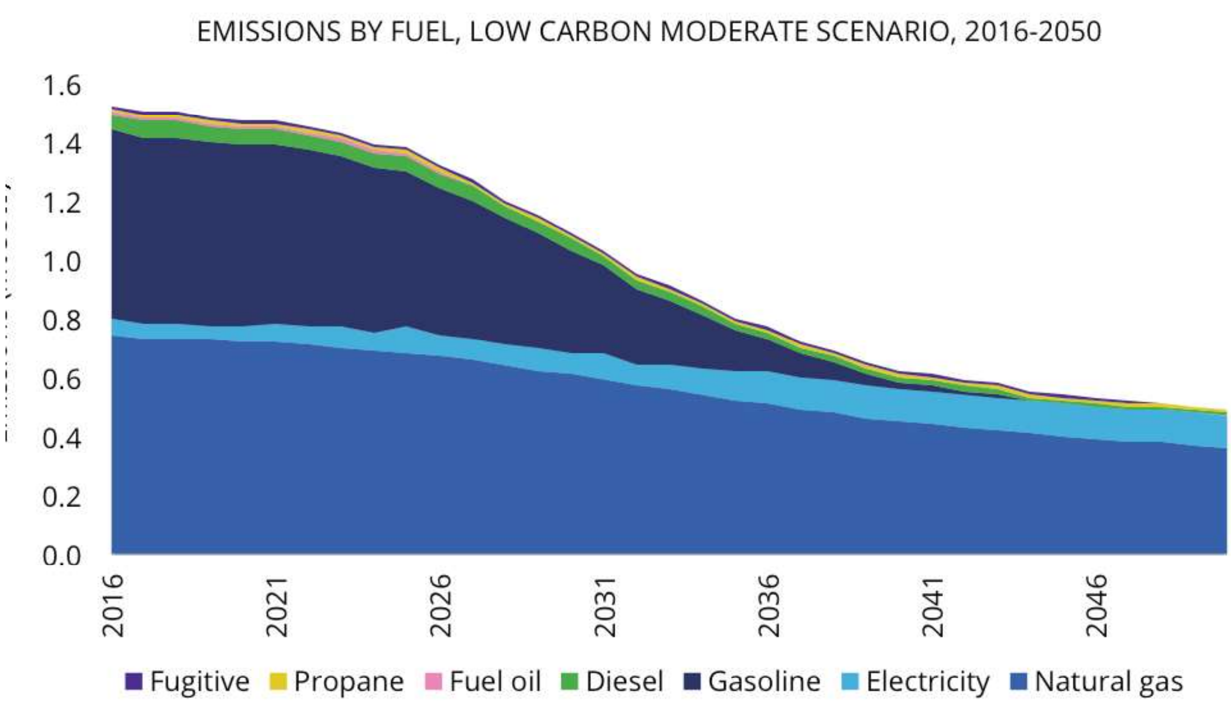


Figure 103. Emissions by fuel, LC-mod, 2016-2050.

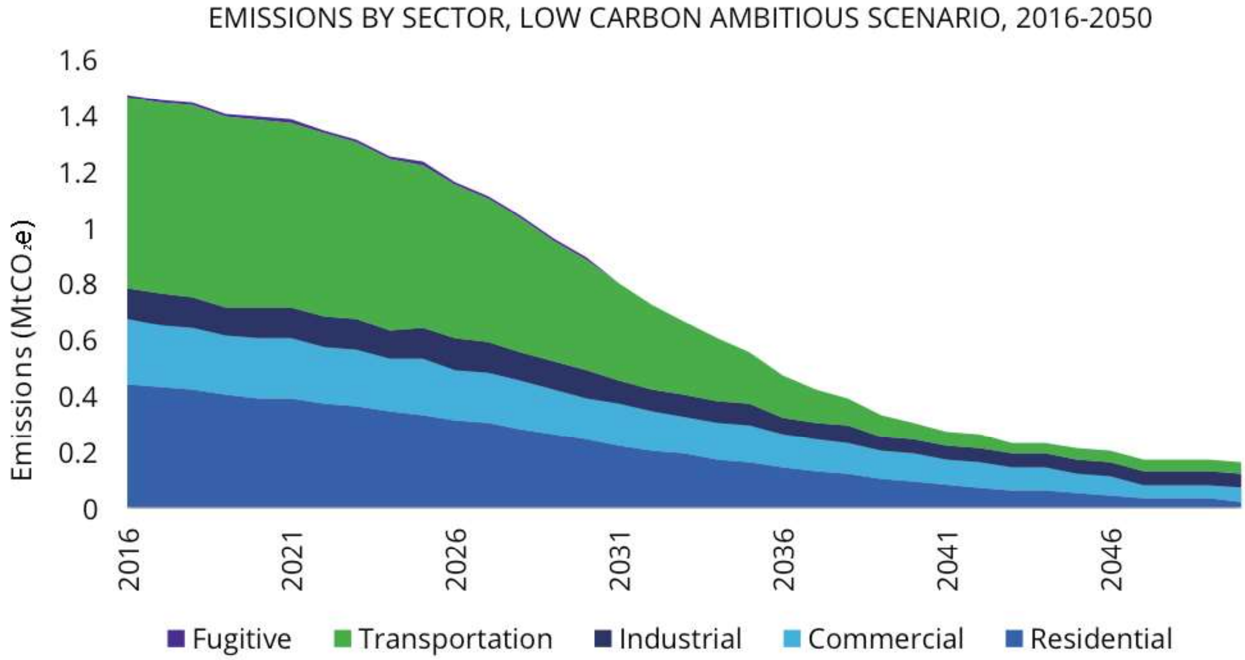


Figure 104. Emissions by sector, LC-amb, 2016–2050.

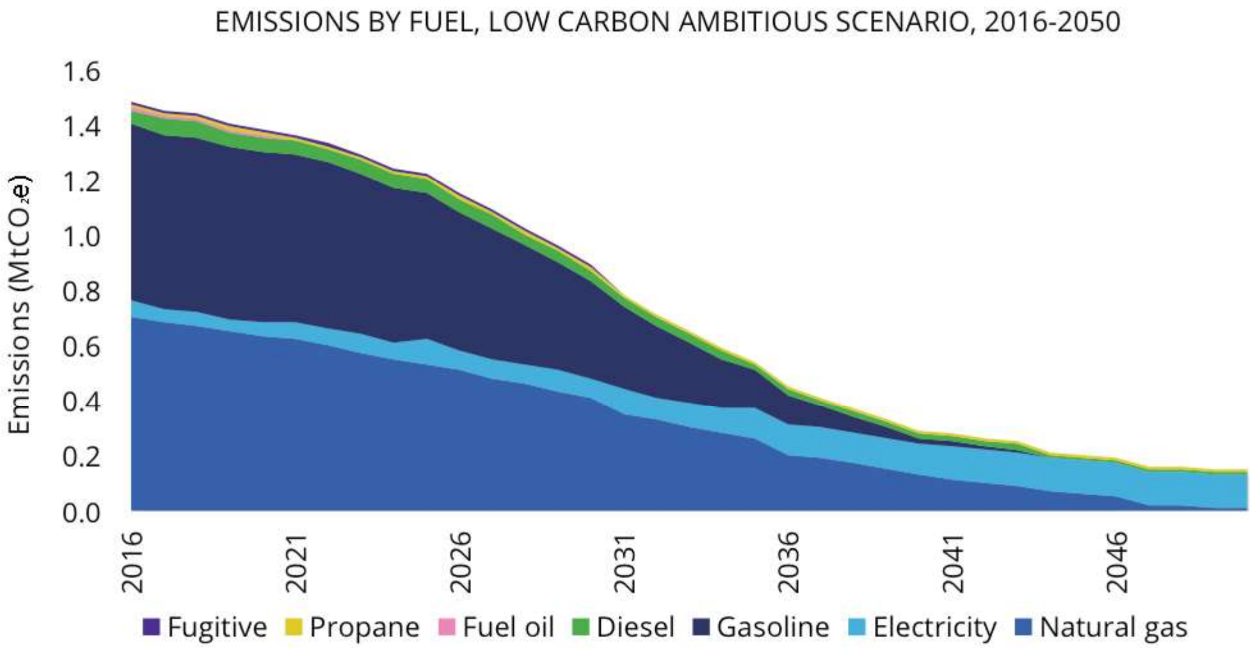


Figure 105. Emissions by fuel, LC-amb, 2016–2050.

In the ambitious scenario, emissions decline more rapidly to 2040 compared with LC-mod, whereafter reductions also taper off more gradually to 2050 (Figure 104). Similar to LC-amb, significant reductions are attributed to the decrease of gasoline and diesel use in the transportation sector.

In LC-amb, a significant decrease in emissions results from the reduction in natural gas consumption (Figure 105), as natural gas is replaced with RNG by 2050. Increases in renewable energy capacity and fuel switching to electricity also serve to decrease emissions, however, approximately 0.16 $MtCO_2e$ remain in 2050. The majority of these emissions are attributed to imported grid electricity.

While the Ontario grid electricity emissions factor has declined significantly since 2011, the grid electricity emissions factor is not expected to be zero by 2050.

7.5 BUILDINGS

Energy consumption in buildings decreases significantly by 2050 in both low carbon scenarios, with residential buildings consuming approximately 40% (LC-mod) and 54% (LC-amb) less energy compared with 2016 (Figure 106). Commercial buildings use 29% (LC-mod) and 35% (LC-amb) less energy compared with 2016.

Emissions reductions in residential buildings in LC-mod result predominantly from decreases in consumption; the share of natural gas relative to electricity and renewables remains fairly high in 2050. In LC-amb, decreases in emissions result from both a decrease in consumption of energy, but more significantly, as a result of switching to electricity, and replacing natural gas with RNG. Residential emissions decrease by 54% in LC-mod, and 96% in LC-amb, compared with 2016.

Similarly, emissions reductions in commercial and institutional buildings result predominantly from decreases in consumption in LC-mod, followed by a significant shift to electricity in LC-amb.

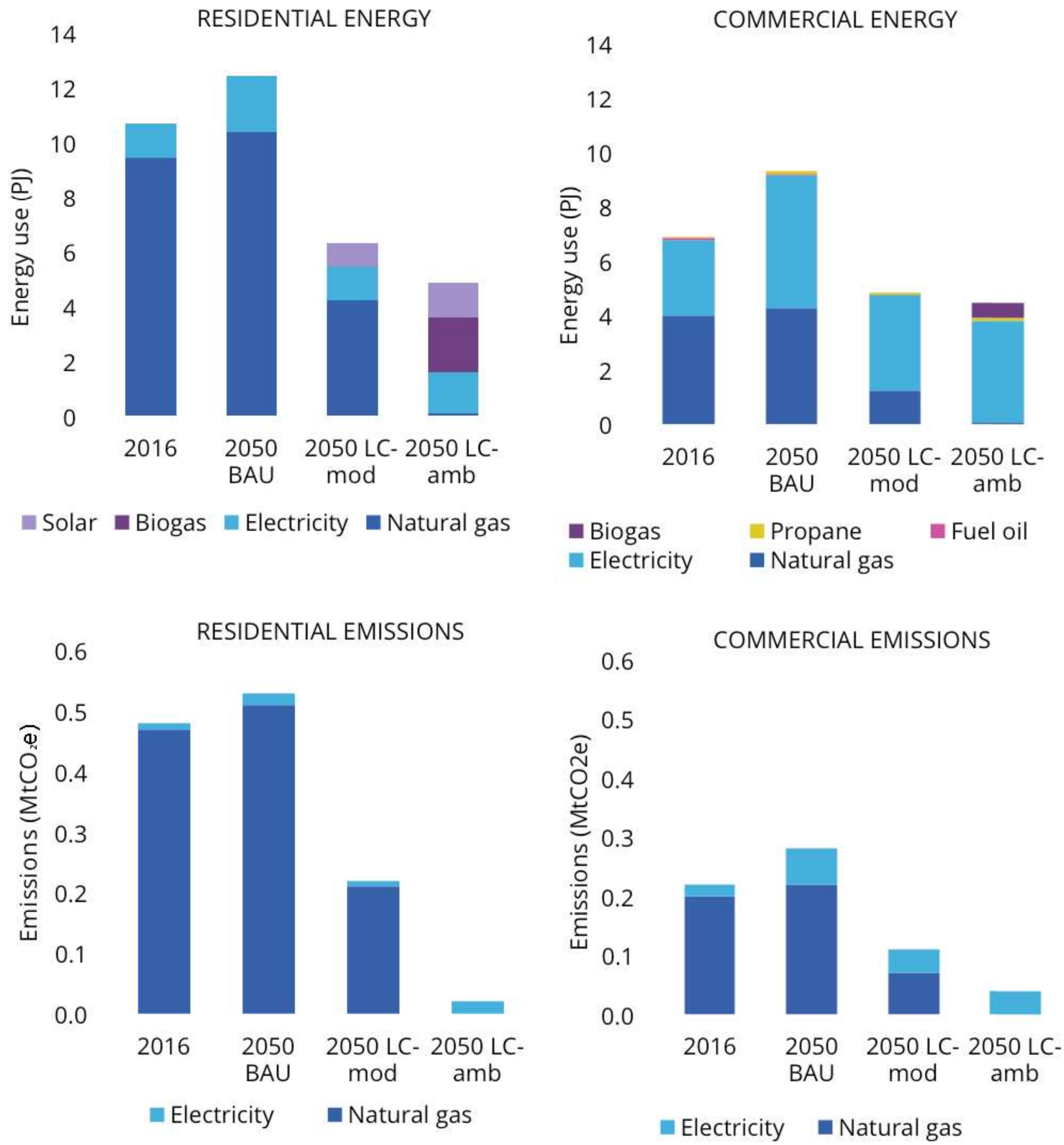


Figure 106. Residential, commercial (includes institutional) buildings energy and emissions by fuel.

Commercial and institutional emissions decrease by 45% in LC-mod, and 77% in LC-amb, compared with 2016.

Figure 107 and Figure 108 show energy intensity (EUI) by zone for the BAU and LC-mod scenarios in 2050 respectively. The maps show that there is a general decrease in building energy use intensities geographically across the City.

Energy consumption in dwellings declines by half between the base year and 2050.

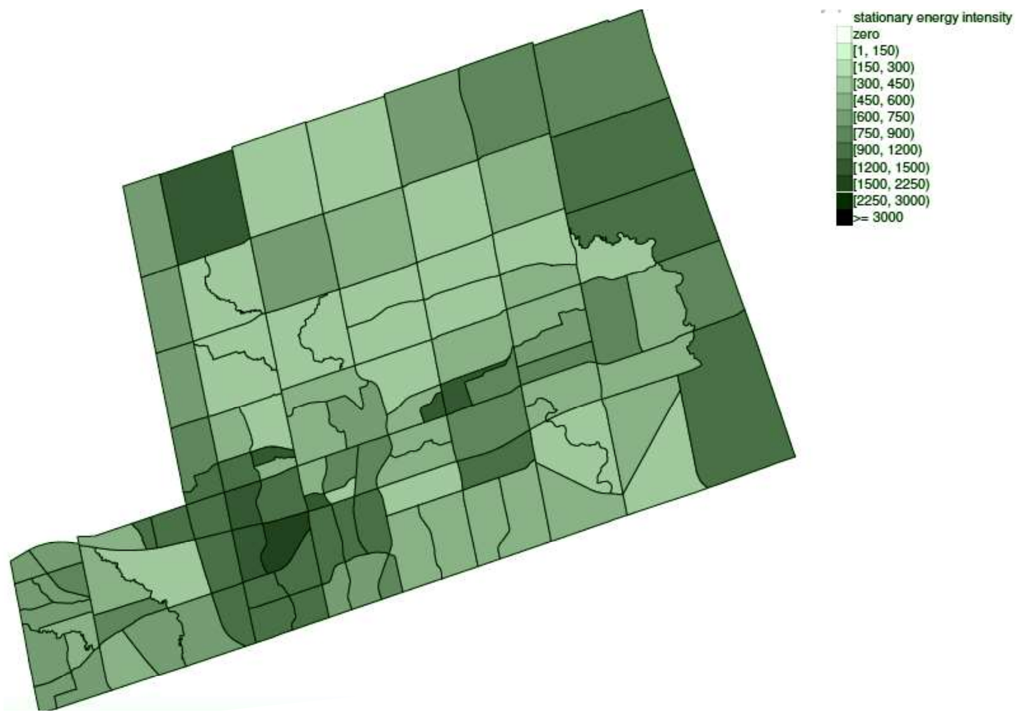


Figure 107. Building energy intensity (MJ/m2 by zone), BAU 2050.

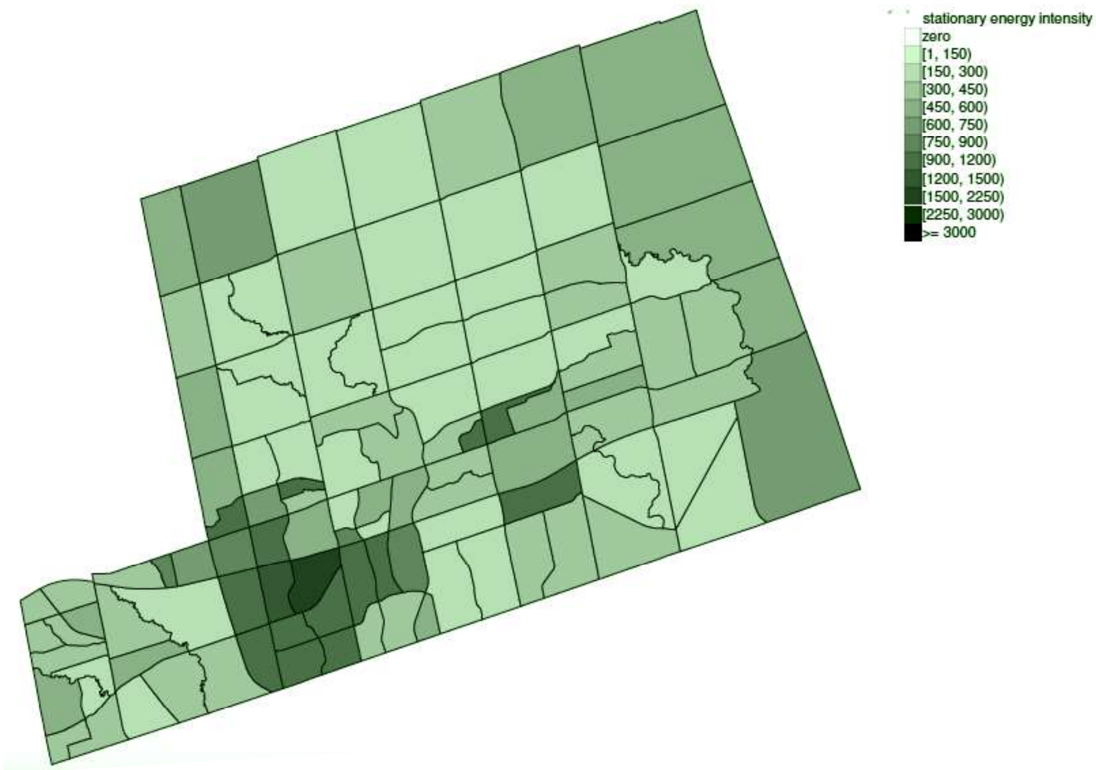


Figure 108. Building energy intensity (MJ/m2 by zone), LC-mod 2050.

The majority of trips within the City of Markham are less than 10km in length

7.6 TRANSPORT

7.6.1 Person Trips

The majority of trips within the City of Markham are less than 10 km in length, creating a significant opportunity for mode shifting to walking and cycling.

Figure 109 and Figure 110 illustrate the number of trips in the City by mode and by trip length. Each coloured bar represents the number of trips. There were no additional actions related to transportation in LC-amb versus in LC-mod; the transportation results are therefore the same for both scenarios. The results of the low carbon scenario (Figure 110) show a significant increase in short trips by bicycle (red bar) compared with the BAU (Figure 109). An increase in walking trips is also evident in the blue bar, particularly for very short trips. The decline in vehicle trips, particularly for shorter trips, is apparent in the decreased green bar, particularly for those of a distance of 5 km or less.

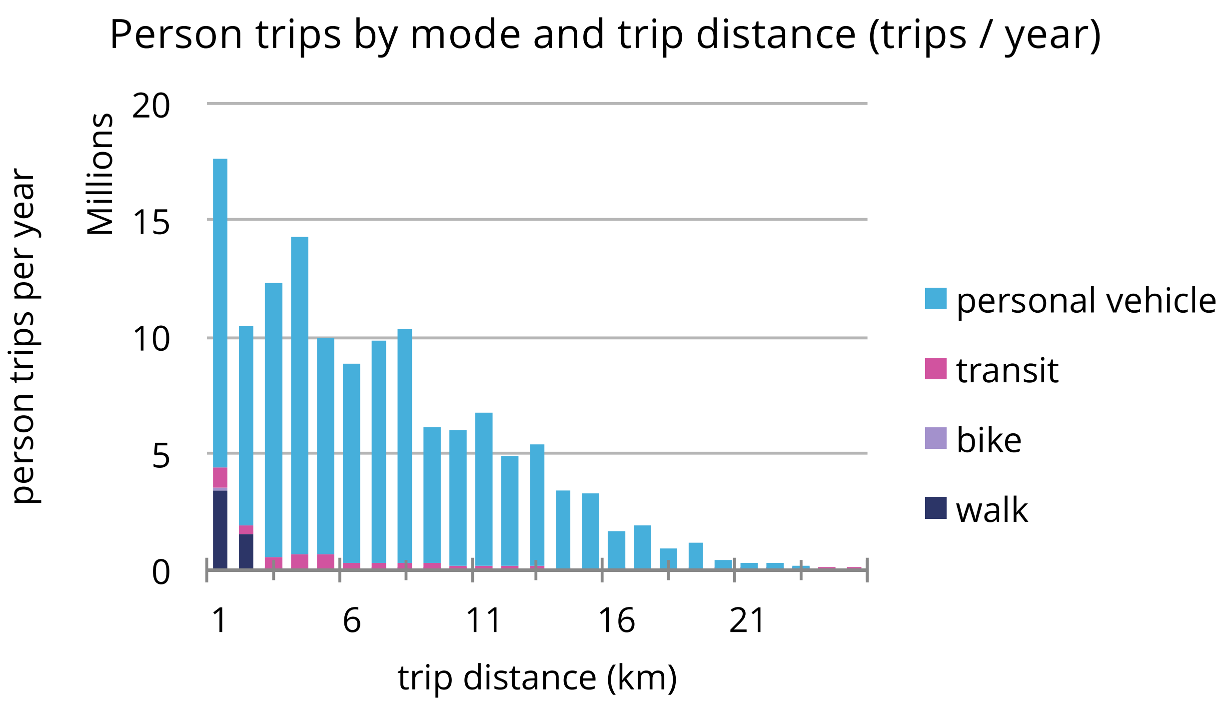


Figure 109. Person trips by mode and distance, BAU 2050.

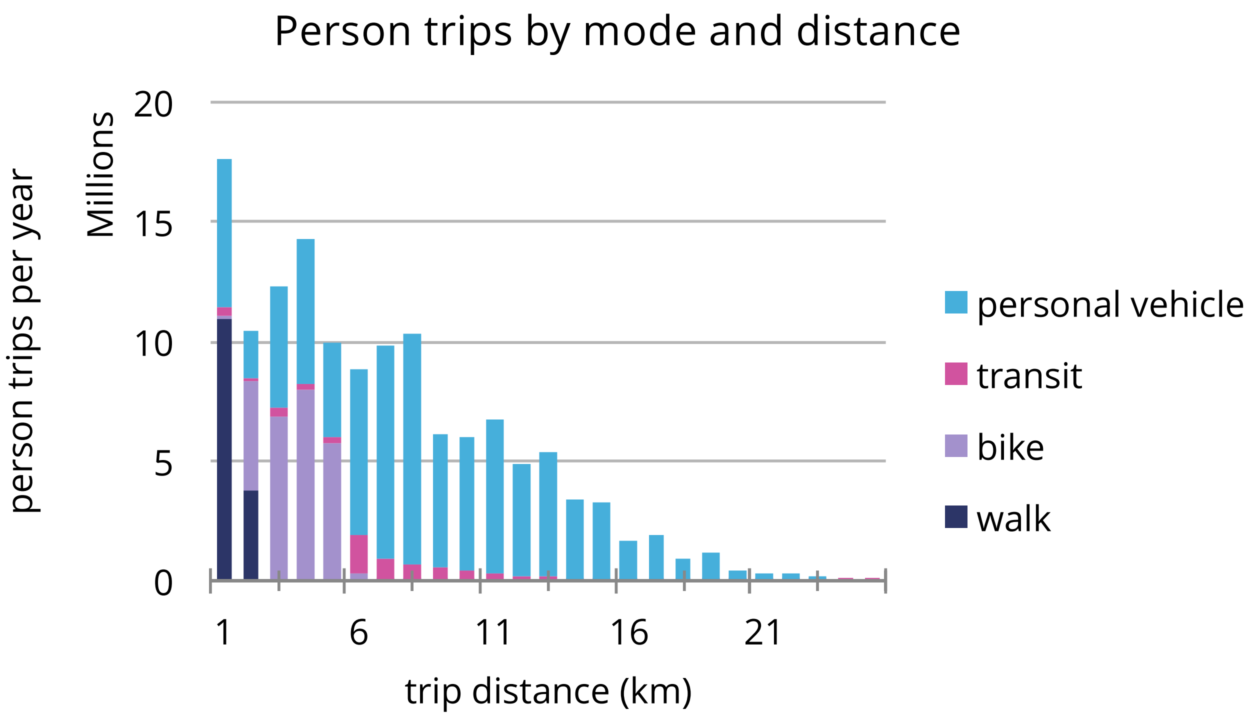


Figure 110. Person trips by mode and distance, LC-mod 2050.

7.6.2 Person kilometres travelled

Figure 111 and Figure 112 illustrate the total person kilometres associated with each mode, according to the colour of shading for mode, and by trip length, for the BAU and low carbon scenarios respectively.[20] The x-axis illustrates how distance travelled is distributed by trip length.

In the low carbon scenario (Figure 112), there is a sharp increase in trips of less than 5 km that are travelled by bicycle, as highlighted by the red bars, and a corresponding decrease in kilometres travelled by vehicle for the same trip length categories as represented by the green bars.

The person distance in auto mode is only partially reduced by switching the short trips to active modes because the longer trips, greater than 5 km, are more stubborn, and are difficult to shift to active modes.

20 There are no differences between the transportation assumptions modelled for LC-mod and LC-amb, and transportation results in this section represent those of both LC-mod and LC-amb, but are labelled as LC-mod for brevity.

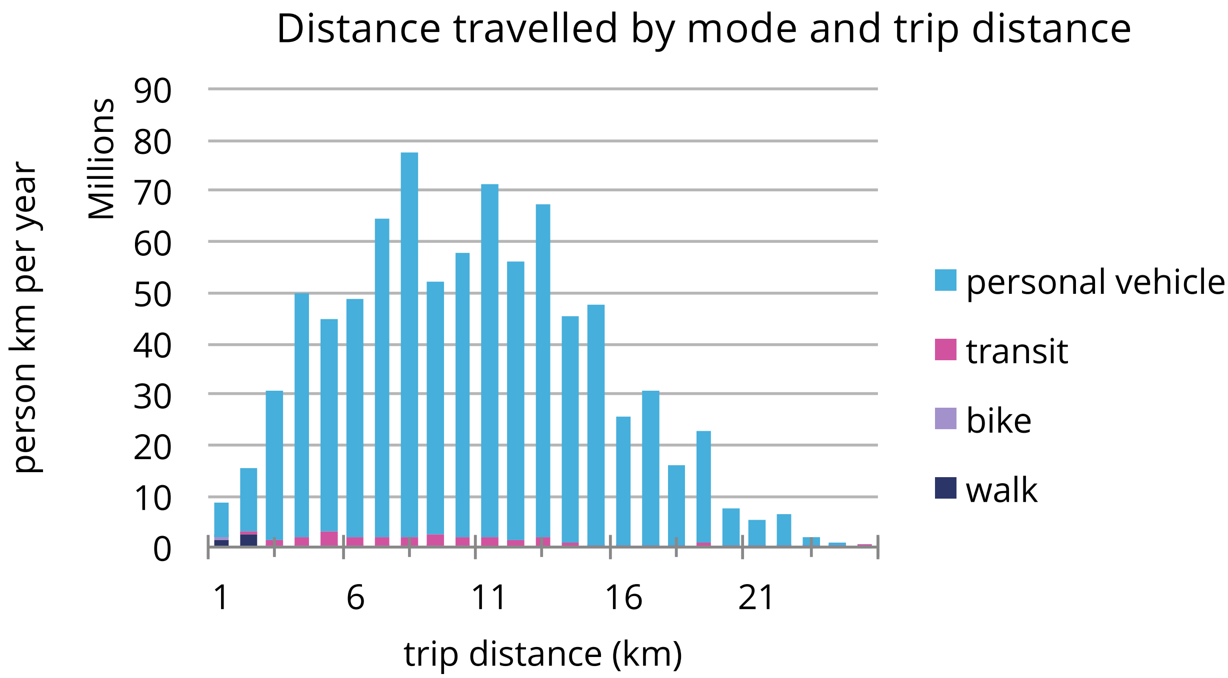


Figure 111. Distance travelled by mode and trip distance, BAU 2050.

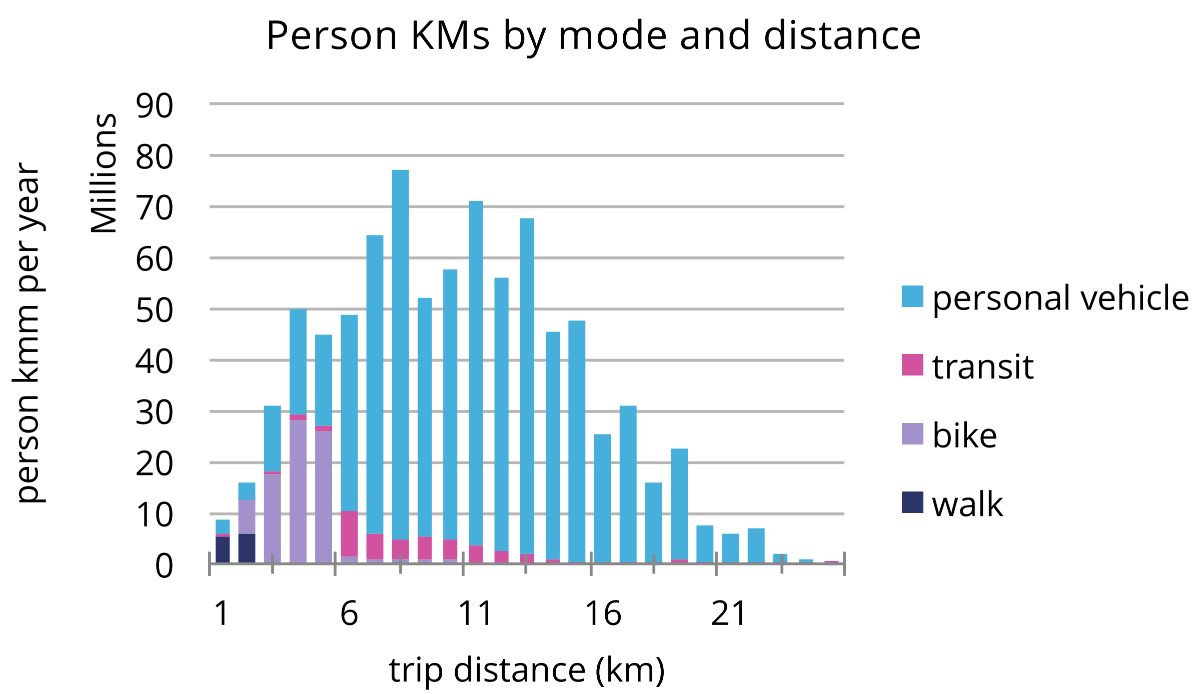


Figure 112. Distance travelled by mode and trip distance, LC-mod 2050.

7.6.3 Mode share

Walking and cycling modes experience gains in the low carbon scenario over the BAU, particularly for shorter trips. Figure 113 and Figure 114 illustrate mode share by trip length as a percentage of the total for BAU and the low carbon scenario respectively. In BAU (Figure 113), active trips decline to 0% when the trip length reaches 3 km, compared with the low carbon scenario (Figure 114), where the share of walking and cycling trips for short trips increases significantly for trips less than 5 km; personal vehicle trips also decrease significantly for shorter trips. Longer trips, however, are still dominated by personal vehicles.

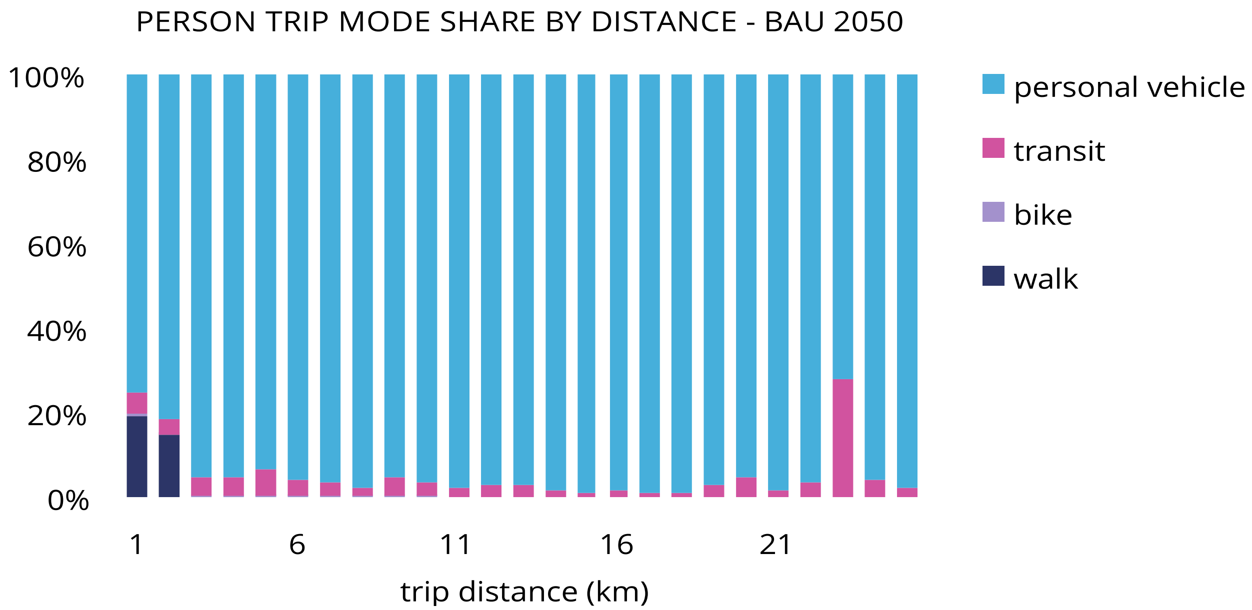


Figure 113. Person trip mode share by distance, BAU 2050.

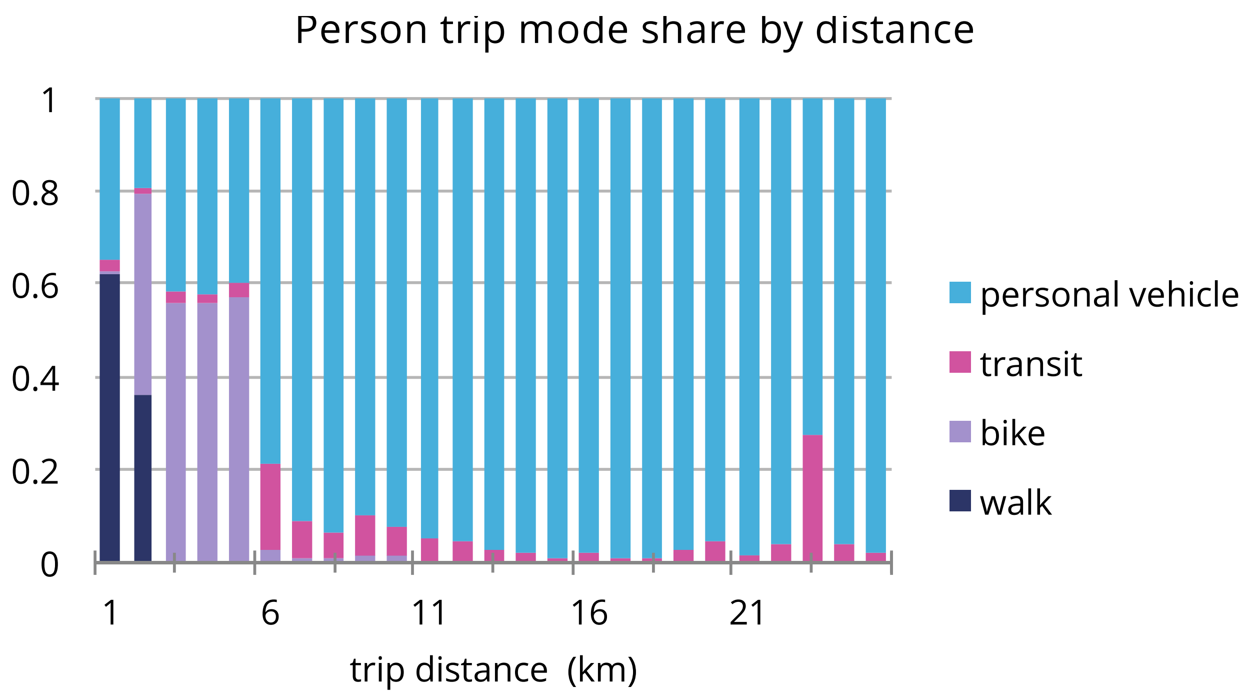


Figure 114. Person trip mode share by distance, LC-mod 2050.

7.6.4 Personal use VKT and average vehicle trip length

For internal trips, personal use VKT increases slightly in the low carbon scenario compared with BAU (Figure 115), along with a slightly steeper increase in average vehicle trip length (Figure 116). This is partially due to the introduction of autonomous vehicles which increases VKT as discussed in section 7.6.5, but also as a result of mode shifting shorter trips to active modes. In the low carbon scenario, there is a significant shift to active modes for internal trips between 0-5 km; however, for internal trips longer than 5 km, vehicle use is still predominant. So while residents use more active modes for shorter trips, when they do drive, they are generally making longer trips (>5 km), resulting in a higher average vehicle trip length compared with BAU.

External inbound and outbound VKT and average vehicle trip length continue to climb; this is driven primarily by the introduction of autonomous vehicles.

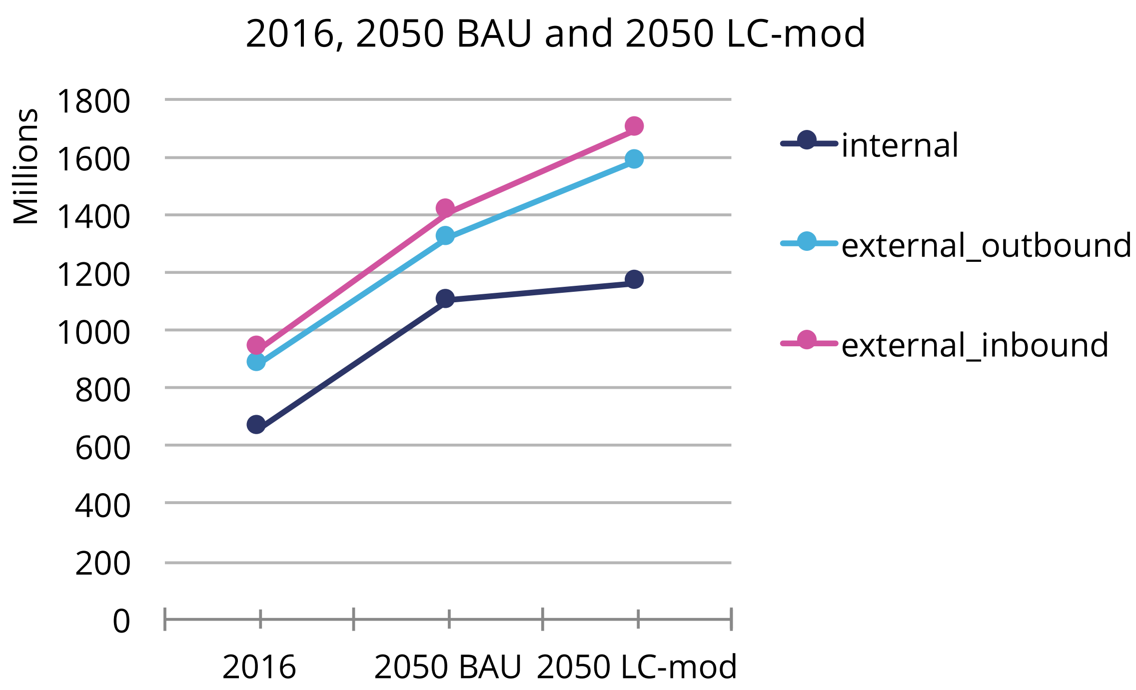


Figure 115. Personal use VKT.

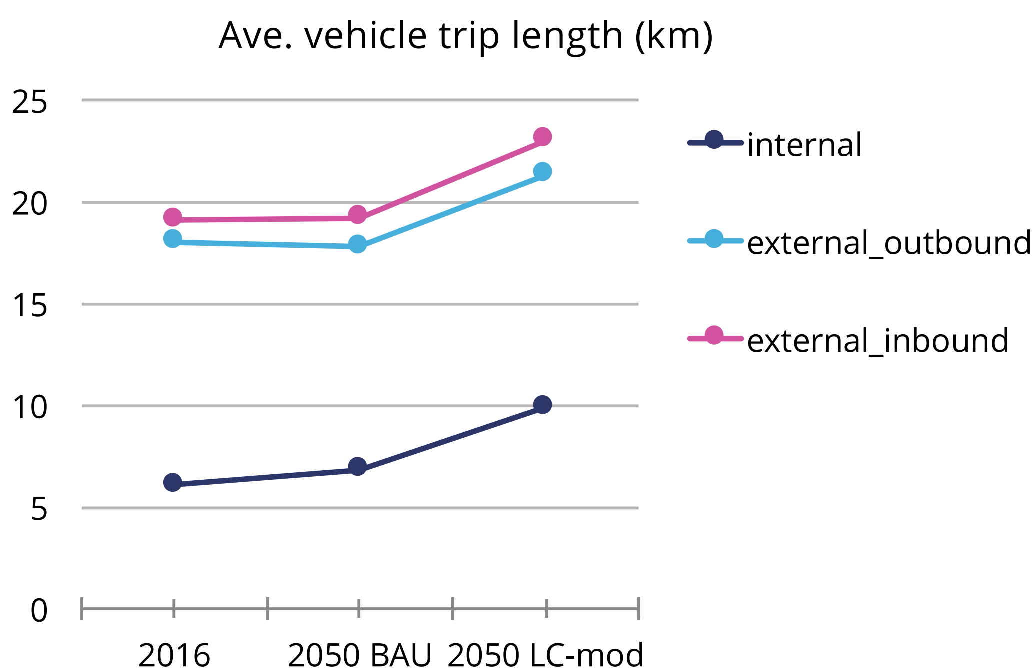


Figure 116. Average vehicle trip length.

7.6.5 Autonomous vehicles and electric vehicles

The introduction of AVs increases GHG emissions as a result of an increase in vehicle kilometres travelled, which in turn leads to an increase in electricity consumption. Electricity still has some associated emissions in 2050 and therefore emissions increase. Autonomous vehicles are assumed to follow the same rate of EV adoption as all other vehicle stocks, which scales up to 100% EV by 2030. The switch from gasoline to electricity across all vehicle stocks by 2030, including AVs, results in a net decrease in emissions.

8 Achieving net zero

LC-mod achieves an emissions reduction of 0.98 $MtCO_2e$ by 2050. The remaining 0.5 $MtCO_2e$ remaining represents a 68% reduction over the 2011 baseline of 1.56 $MtCO_2e$. LC-amb achieves a reduction of 1.32 $MtCO_2e$ by 2050, with 0.16 $MtCO_2e$ remaining, representing a 90% reduction over the 2011 baseline. Both scenarios represent a significant level of ambition for the City, and both achieve significant emissions reductions over the BAU.

The remaining GHG emissions in the LC-amb result from the consumption of electricity from the provincial grid and fossil fuel usage in the industrial sector.

LC-amb represents a significant shift towards electrification on the demand side, as well as increases in the production of local renewable energy on the supply side. Additionally, all remaining conventional natural gas use is switched to renewable natural gas (RNG). The remaining 0.16 $MtCO_2e$ consists of emissions associated with imported electricity coming into the City from the provincial grid[21] and fossil fuel

21 While the Ontario grid electricity emissions factor has declined significantly since 2011, the grid electricity emissions factor is not expected to be zero by 2050.

usage in the industrial sector.[22]

In order to achieve the net zero target by 2050, all fuel consumed in the City will need to be carbon free. As represented by LC-amb, all conventional natural gas use (after a major shift to electrification) will need to be switched to carbon free RNG. The remaining emissions associated with imported grid electricity could be eliminated if the City were to source only carbon free electricity.

8.1 TRANSIT, DISTRICT ENERGY AND LAND USE

In order to explore the expansion of transit as an action (in LC-mod and LC-amb) to further reduce emissions, a spatial analysis was conducted to identify zones with population and employment density thresholds appropriate to support additional and/or higher order transit service, zones that were not currently or projected to be served in the BAU.

Zones were considered appropriate for transit if sufficient density was found to support a higher level of transit than what is currently provided to the zone. Thresholds developed for Places to Grow[23] were used including 200–400 people and jobs per hectare to support bus rapid transit (BRT)/light rail transit (LRT), and 400+ people and jobs per hectare to support subway.

No opportunities for additional transit and district energy, beyond what is currently planned, were identified.

22 Other fossil fuels used in industry that have not been switched to RNG (eg. propane).

23 Higgins, C. D. (2016). Benchmarking, planning, and promoting transit-oriented intensification in rapid transit station areas. Retrieved from https://macsphere.mcmaster.ca/handle/11375/20228

A GIS layer of the proposed transit network was prepared and overlaid on a spatial analysis of projected population and employment densities in the City. This analysis indicated that there are no zones with densities meriting rapid transit and as a result, no additional transit (beyond BAU), was added.

Similarly, options to expand district energy, over and above BAU, were explored. An analysis was conducted to identify zones with heating density thresholds appropriate to support district energy. Zones would be considered appropriate if they demonstrated heating density thresholds of 140 MJ/m^2 or higher. A major study in the European Union indicates that between 100 and 300 MJ/m^2 is currently feasible for district heating and that 30–100 MJ/m^2 has potential for fourth generation district heating. Due to the lower costs of energy in Canada, a conservative threshold of 140 MJ/m^2 was used for the district energy scan of Markham.[24]

Prior to conducting the heating density threshold analysis, reduced heating degree days, the energy efficiency standards, and retrofits and renovation actions were applied first in order to ensure that potential district energy expansion would not be oversized.

There were no zones identified that exceeded the 140 MJ/m^2 heating density threshold for district energy and therefore no additional district energy (beyond BAU) was added. This analysis highlights the dynamic relationship between higher performing buildings and the potential for district energy to 2050, as more efficient buildings use less energy in the future.

In some cases it may make sense to deploy heat pumps using district energy, when space is limited for geothermal energy or when waste heat recovery is possible. The design of district energy is evolving to address the decreasing energy requirements of buildings. For example, fourth generation district energy systems integrate electrical and thermal grids, distribute low temperature heat and integrate different types of generating and storage technologies.[25] In the future, these

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24 Moller, B., & Werner, S. (2016). Quantifying the potential for district heating and cooling in EU member states. Retrieved from http://www.heatroadmap.eu/resources/STRATEGO%20WP2%20-%20Background%20Report%206%20-%20Mapping%20Potenital%20for%20DHC.pdf

25 Lund, H., Werner, S., Wiltshire, R., Svendsen, S., Thorsen, J. E., Hvelplund, F., & Mathiesen, B. V. (2014). 4th Generation District Heating (4GDH). Energy, 68, 1–11. https://doi.org/10.1016/j.energy.2014.02.089

Concentrating future development at higher densities increases the opportunity for district energy, walking and cycling and enhanced transit.

systems will likely be viable at heat densities below 100 MJ/m^2.[26] There are likely additional opportunities for district energy beyond those which were identified, as the scan relied on a heat density threshold. Anchor loads or high density greenfield developments merit additional analysis, particularly as low temperature district energy systems become more common.

Land-use patterns are widely recognized as one of the city-scale interventions in reducing GHG emissions that have cascading effects. As an example, increasing building densities increases the feasibility of district energy, enhanced transit and the likelihood that people will walk and cycle. In comparison, any future development that results in new floorspace that is not accessible to transit or district energy increases GHG emissions and energy requirements. Concentrating future development in the form of intensification, and at higher densities, increases the opportunity for district energy; increases walking and cycling (as more trips are shorter as a result of the concentration of future development, creating more opportunities to shift to walking and cycling trips); and supports a shift towards, and opportunities for, enhanced transit.

The 2014 Official Plan emphasizes intensification within the built-up area and limiting outward growth to future urban area land. Supporting this direction is the focus of new development in regional and local centres and corridors. However, a large portion of projected future development is not oriented towards intensification.

26 Moller, B., & Werner, S. (2016). Quantifying the potential for district heating and cooling in EU member states. Retrieved from http://www.heatroadmap.eu/resources/STRATEGO%20WP2%20-%20Background%20Report%206%20-%20Mapping%20Potenital%20for%20DHC.pdf

The growth projections for the Region of York 2041 Preferred Growth Strategy indicate approximately 54% of total new dwellings units (between 2011 and 2041) are located outside of “intensification areas”:

More than half of Markham’s projected dwelling unit growth is expected to take place in areas currently not served by higher order transit.

- 18% of new dwellings are in areas shown as future urban;
- 14% of new dwellings are in areas shown as rural; and,
- 22% of new dwellings are in existing low density areas of Markham (areas not shown as a regional and/or centre or corridor, or key development area)

According to the Region’s PGS, more than half of Markham’s projected dwelling unit growth is expected to take place in areas currently not served by higher order transit. Additionally, this new growth is expected to be low density: within the future urban area, 51% of new dwellings are shown as single family, with 32% rowhouse; in the rural areas, 57% of new dwellings are shown as single family, with 36% rowhouse. These densities are unlikely to support higher order transit or meet district energy heating density thresholds.

The development of the future urban area to 2030, in terms the area’s location relative Markham, is essentially locked in.[27] However, opportunities to use land-use as a lever for emissions reductions are still at hand, in particular the location of uses within the FUA, and the building densities of these uses. The careful location and mix of uses within walking distance will enable people to walk and cycle more readily and this in turn supports healthier and more active lifestyles.

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27 Locked in, in this context, means that decisions about location have already been made and are unlikely to change.

Transit supportive densities will be essential forplanned higher order transit.

Conversely, single use low density neighbourhoods will require people to drive, resulting in increased emissions and traffic congestion. Even as personal vehicles are electrified, additional electricity generation will be required. The electrification of vehicles in this instance functions more as a technological fix in reducing emissions; whereas reducing the amount of trips, decreasing trip distance, and shifting to more active modes through the appropriate use of building densities and locations serves to reduce energy demand overall (a driving principle of getting to zero), with the benefit of reducing congestion and supporting healthier communities and active lifestyles.

For development post 2030, there remains potential to focus new growth in intensification zones and/or existing built-up areas. Critical to this approach is the provision of commercial and community services, and employment opportunities. A large proportion of new dwelling units post 2030 will be constructed in rural areas; these dwellings could be shifted to areas that are already supported by higher order transit, or have potential for higher densities that will further support existing or expanded transit. Additionally, shifting development to existing areas can also increase the heat density of a zone or neighbourhood so that it surpasses the threshold at which district energy makes sense, tipping the balance. In this way, shifting a small percentage of buildings can be used as a lever to enable district energy for a large number of buildings, an example of how a small action can have a much larger impact. A similar approach can be applied for transit infrastructure. If new growth is not focused on intensification, costlier and more complex solutions may be required in the future to reduce emissions associated with transportation and buildings.

> New development in existing areas can also increase the heat density of a zone or neighbourhood so that it surpasses the threshold at which district energy makes sense, tipping the balance.

NEW DWELLINGS UNITS BY AREA TYPE

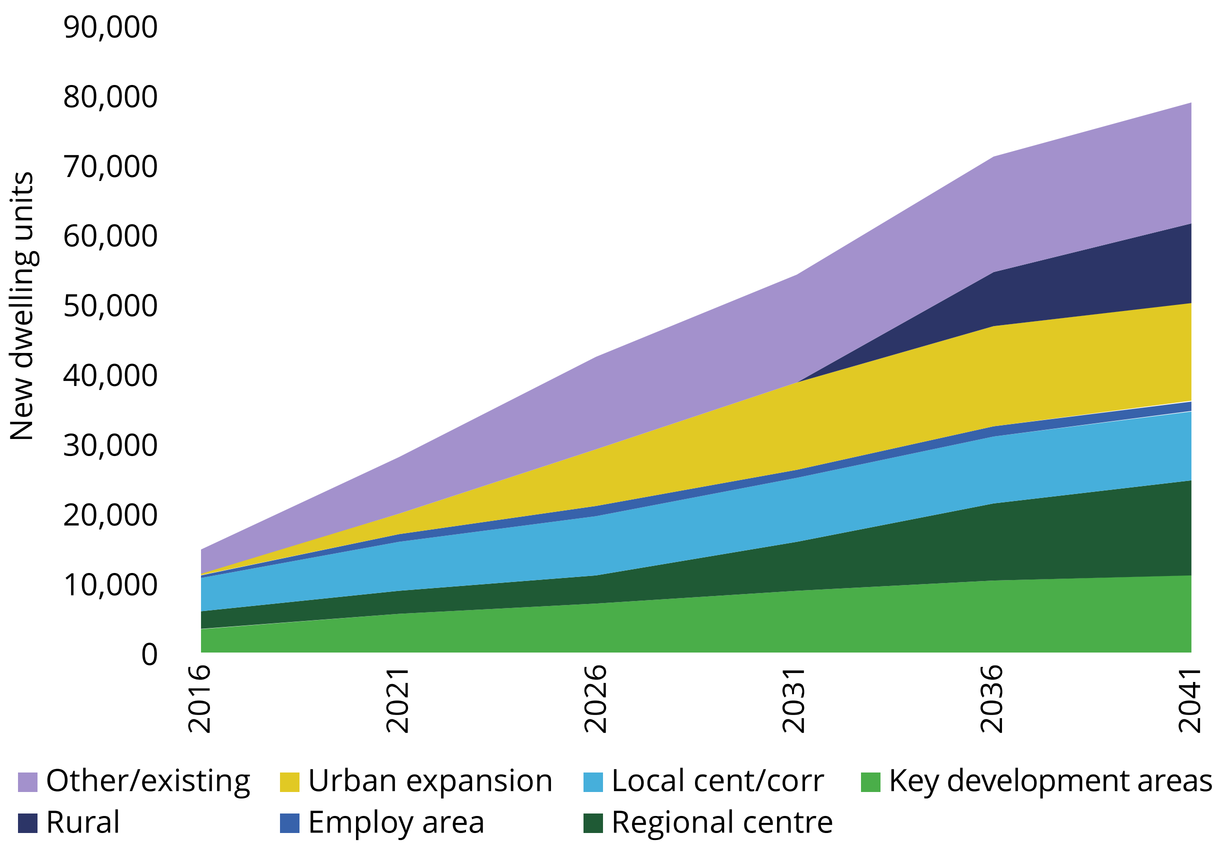

Figure 117. Projected new dwelling units for Markham, 2016-2041, from Region of York 2041 Preferred Growth Strategy.

8.2 RENEWABLE NATURAL GAS

The growth projections for the Region of York 2041 Preferred Growth Strategy (PGS) (Figure 117), indicate that in the near-term, "the potential Ontario generation of 1,372 million cubic meters per year of RNG from biogas supplies can account for about 6% of the residential, commercial and industrial use of Natural Gas". Enbridge notes that "for Enbridge Gas Distribution's customer base, this 6% represents approximately 720 million m^3/yr of renewable pipeline fuel"; and that "approximately 80% of this renewable resource exists within Enbridge's own gas distribution franchise, and the balance can be secured in and around Enbridge's gas storage operations in southwestern Ontario."

The consultancy ICF projects renewable natural gas supply to climb from 267 million m^3 to 4,265 million m^3 by 2030 in Ontario.[28] Using a per capita allocation based on the City of Markham's population relative to that of the province (2%), 5.5 million m^3 to 85.5 million m^3 of this could be available for the City.

At the time of writing the MEP, it is unclear what volume, and from where, the sources (biomass or otherwise) to produce the volumes of RNG noted above will come from, or how the RNG produced might be allocated. Irrespective of these concerns, Enbridge's Scenario Illustration for Renewable Gas Supplies and Conservation[29] indicates that by 2037, at least half of the fuel in the pipeline remains conventional natural gas.

In the LC-amb scenario, approximately 3.1 PJ of energy in 2050 is supplied by RNG. As the emissions factor for RNG is assumed to be zero for modelling (RNG is not mixed with conventional natural gas), there are no emissions associated with RNG in LC-amb.

Based on a conversion rate of 27 m3/GJ[30], 3.1 PJ amounts to roughly 84 million m3 of RNG. To enable the switch to 100% RNG in Markham, it is likely that the City will need to produce RNG in addition to what may come from Enbridge or other suppliers.

It is worth noting, however, that there is a significant reduction in energy consumption in LC-amb (through retrofits for example), as well as a switching to electricity, through solar PV, and the use of heat pumps. If these actions were not implemented, a significantly larger amount of RNG would be required, a volume likely exceeding what could be produced. In contrast, further efforts in reducing demand would result in lower requirements for RNG in 2050.

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28 See ICF material in this presentation: Klippensteins. (2016). Cross-examination material – Environmental Defence cross-examination of Enbridge.

29 Enbridge. (2016). Chart 1, pg 3.

30 Conversion factor for conventional natural gas per Natural Resources Canada. (http://www.nrcan.gc.ca/energy/natural-gas/5641). It is unconfirmed at the time of writing whether RNG has, or will have, the same conversion factor; as such, the same factor is used here for illustrative purposes.

The pathway to net zero energy emissions focuses on three main aspects:

1) the efficiency of buildings;

2) electrification of transportation; and,

3) generation and/or purchase of renewable electricity and renewable natural gas.

9 Insights from the net zero pathway

The target of net zero energy emissions for the City of Markham focuses on three main aspects: the efficiency of buildings; electrification of transportation; and, generation and/or purchase of renewable electricity and renewable natural gas.

One of the most significant challenges that the City of Markham faces is the ongoing pattern of low density development.

One of the most significant challenges that the City of Markham faces is the ongoing pattern of low density development, a form of development which is associated with high per capita energy and emissions. Much of the projected development is locked in as a result of existing planning and investment decisions. Were it possible to direct future development to support intensification, the additional development could be used as a lever to increase heat density (to support district energy), increase the density of people and jobs (increasing the viability of rapid transit), improve walking and cycling infrastructure (increasing the walking and cycling mode share), preserve green space and build more efficient buildings.

COMMUNITY RENEWABLE ENERGY PURCHASING

Palo Alto

The City of Palo Alto's utility purchased renewable electricity for the entire community with a retail rate impact cap of $0.005/kWh in 2016.[1] A parallel effort has been approved for natural gas with a limit on the financial impact of $0.1/therm[2], targeting carbon neutrality by 2018.[3]

San Francisco

San Francisco's CleanPowerSF is a community choice aggregation program that automatically enrolls customers in a program with a higher percentage of renewables, with an optional upgrade to 100% renewables for an additional $0.02/kWh.[4]

1 For more information, see http://www.cityofpaloalto.org/gov/depts/utl/residents/resources/pcm/carbon_neutral_portfolio.asp

2 Therm is a non-SI unit of heat energy equal to approximately the energy equivalent of burning 2.83 cubic metres of natural gas.

3 For more information, see http://www.cityofpaloalto.org/civicax/filebank/documents/54160bullfrog

4 For more information, see http://sfwater.org/index.aspx?page=959

In addition to consideration of the patterns and use of land, and the implications for energy and GHG emissions, the City should consider designing incentives that reflect the costs and benefits of different development patterns as a strategy to unlock this opportunity.

After land-use, the design of buildings has the second longest implications, lasting forty or more years prior to replacement. The cost of future retrofits can be avoided by making an upfront investment in designing for net zero when the building is constructed. Additionally, high levels of efficiency maximize the benefit of avoided energy consumption and energy costs over the lifetime of the building using existing technologies.

The City of Markham is unlikely to be able to generate sufficient green electricity or renewable natural gas within City boundaries to achieve the net zero target. The City will likely need to undertake bulk purchases of green energy and renewable natural gas, or develop its own green energy projects outside of its boundaries. The approach of purchasing renewable energy on behalf of the community is gaining traction in the US (see side bar).

Aside from efficiency improvements in buildings, and fuel switching away from fossil fuels, opportunities for efficiency gains and GHG emissions reductions from the industrial sector were not analyzed in detail, as the municipality has limited levers over this sector. Additional analysis in this sector could result in opportunities for energy savings and GHG emissions.

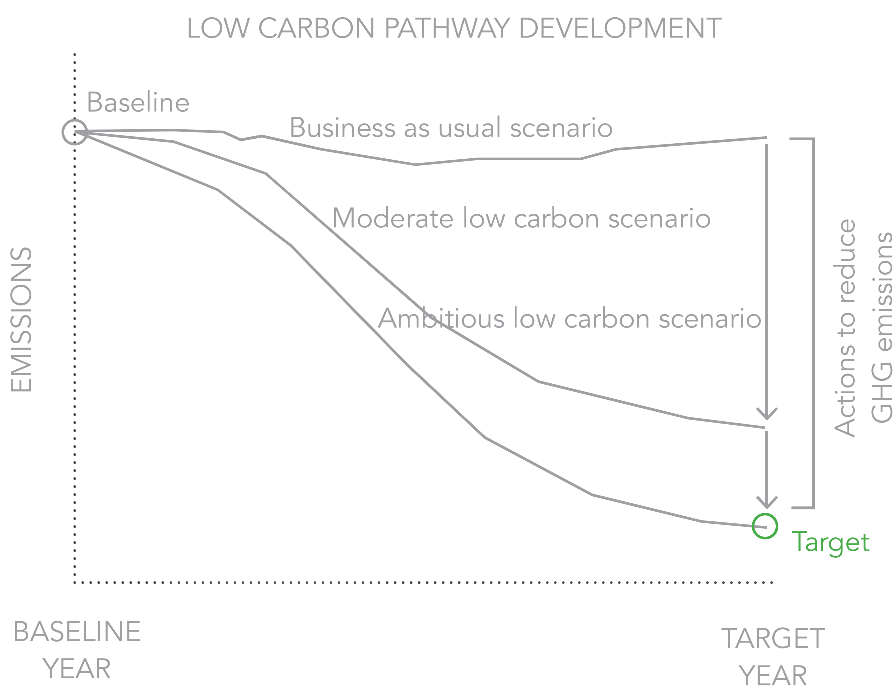
The aging population may have additional impacts on energy use, as the cohorts of 65+ population are likely to drive less than during their working years, whereas the modelling assumed that VKT rates are not influenced by demographic characteristics. As a result, energy use and GHG emissions may decrease as the population ages beyond what was modelled in the low carbon scenarios. On the other hand, the introduction of autonomous vehicles, may stimulate additional travel by the elderly as the barrier to travel decreases.

Another aspect which was not accounted for is the life cycle GHG impacts of the City of Markham's recycling efforts, which were not included in the scope of emissions associated with energy. The GHG emissions reductions that result from the recycling of energy intensive materials such as paper, metals, steel, aluminum, plastic and glass do not occur within the boundaries of Markham but rather in displaced energy and emissions required for raw material extraction and manufacturing. For example if 50,000 tonnes of metals and papers are recycled this could result in upstream emissions reductions of between 50,000 and 150,000 tCO_2e.[31] Protocols to account for and validate these GHG emissions reductions are not yet available.

There are likely additional opportunities for district energy beyond those which were identified, as the scan relied on a heat density threshold. Anchor loads or high density greenfield developments merit additional analysis, particularly as low temperature district energy systems become more common.

31 Torrie Smith Associates, Sonnevera International Corp., & Kelleher Environmental. (2015). Greenhouse gas emission and the Ontario Waste Management Industry. Retrieved from http://www.owma.org/Portals/2/Cover_Page_Image/OWMA%20GHG%20Report%20December%202015.pdf

10 The targets



The City of Markham's GHG target declines steeply between 2020 and 2040.

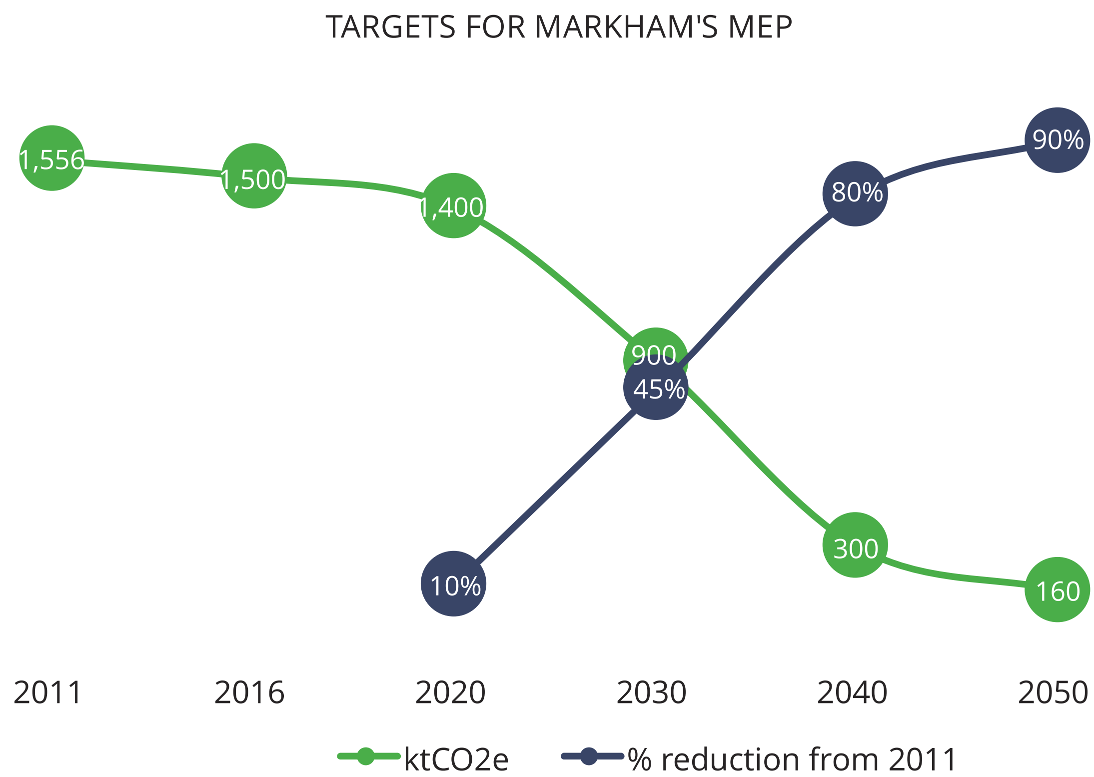
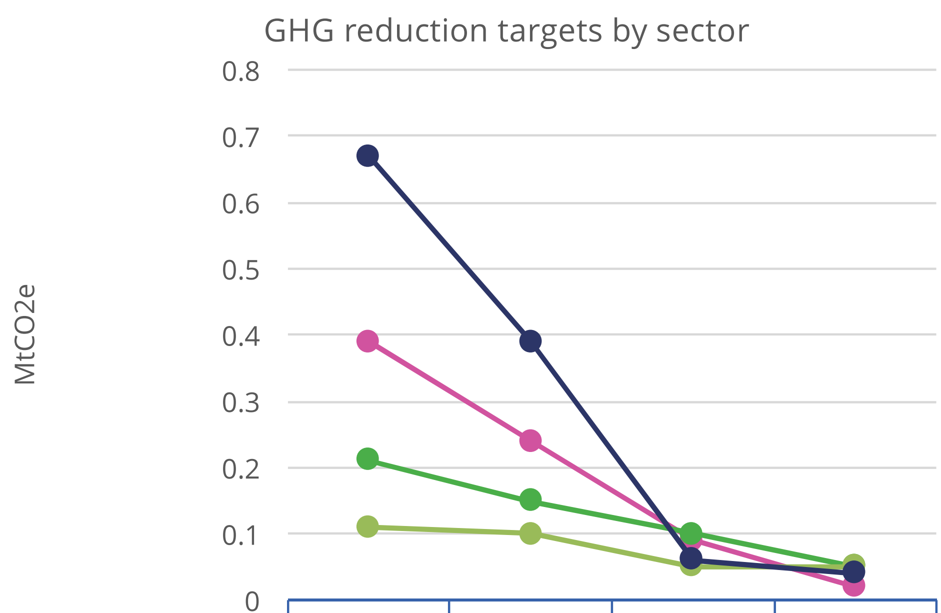


Figure 118. GHG reductions targets for the MEP.

The target of net zero energy emissions requires a downward trajectory in emissions and the modelling results provide specific targets between 2017 and 2050. Figure 118 shows the total GHG emissions for 2020, 2030, 2040 and 2050, as well as the percentage reduction associated with each period. These targets allow the City to track progress over time against the low carbon scenarios.

In addition to the overall GHG targets, sector specific GHG targets have been identified, in order to facilitate the development of sector specific strategies as part of the broader MEP implementation process.

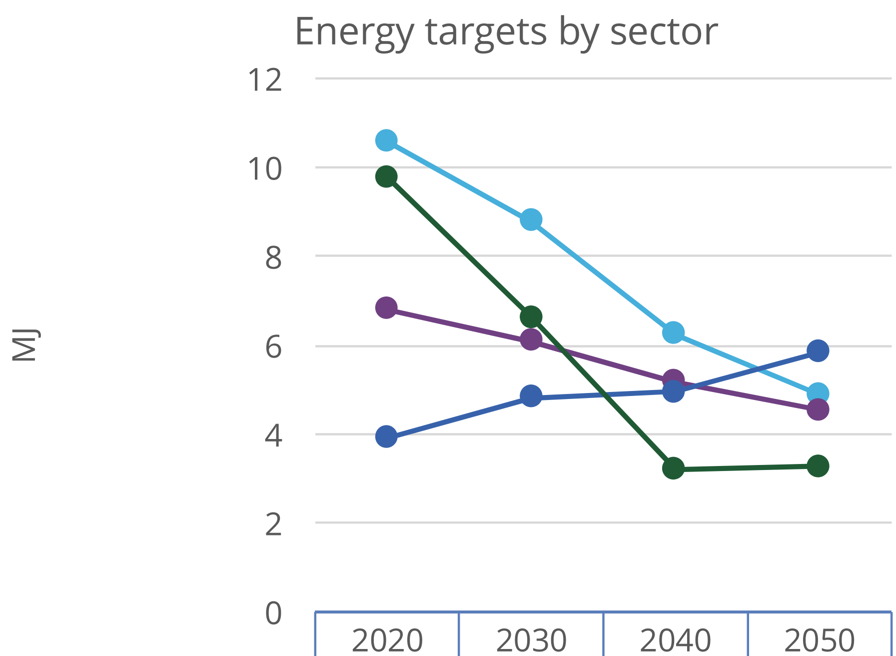
The most significant GHG emissions reductions are in the transportation sector.



	2020	2030	2040	2050
Residential	0.39	0.24	0.09	0.02
Commercial	0.21	0.15	0.1	0.05
Industrial	0.11	0.1	0.05	0.05
Transportation	0.67	0.39	0.06	0.04

Figure 119. GHG reduction targets by sector.

Achieving energy efficiency objectives is key to ensuring the financial outcomes associated with the MEP. In order to achieve these objectives, energy consumption targets have been identified for each sector, again on a ten-year timeline.



	2020	2030	2040	2050
Residential	10.6	8.8	6.2	4.9
Commercial	6.8	6.1	5.2	4.5
Industrial	3.9	4.8	4.9	5.8
Transportation	9.8	6.6	3.2	3.3

Figure 120. Energy targets by sector.

Finally, carbon budgets have been identified for each sector. The carbon budget represents the total GHG emissions for the sector that can be emitted between 2017 and 2050 in order to achieve LC-amb. The total carbon budget for the City of Markham over that period is 28.62 MtCO_2e.

The total carbon budget for the City between 2017 and 2050 is 28.6 $MtCO_2e$.

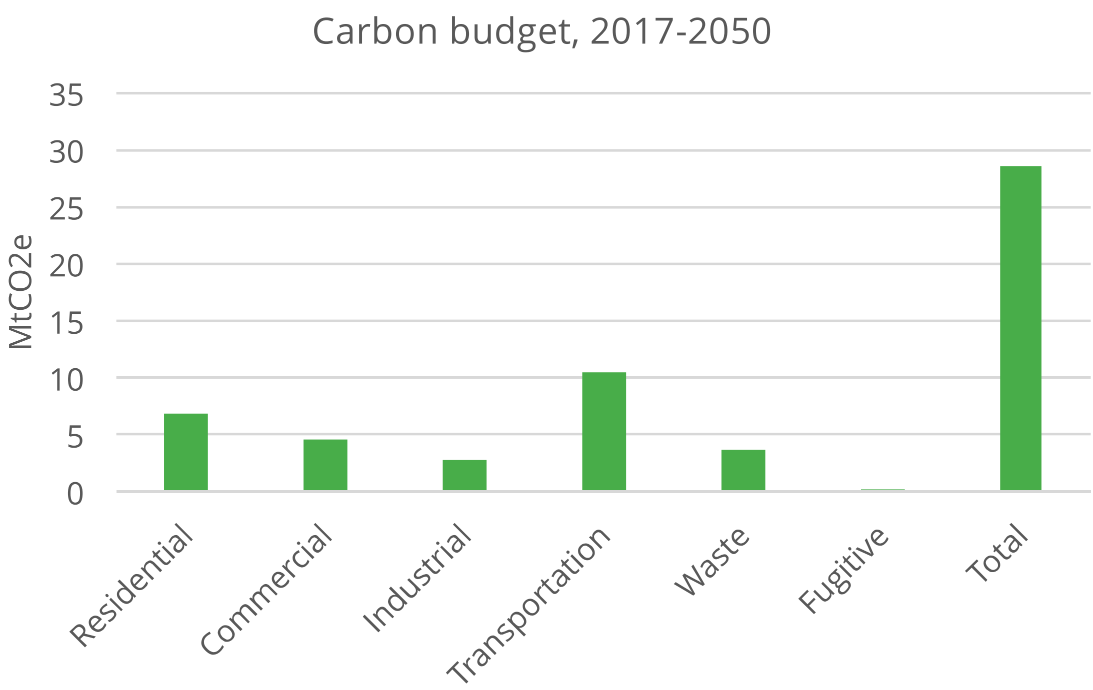


Figure 121. Carbon budget for each sector, 2017–2050.

11 Managing uncertainty

11.1 WHAT DOES SENSITIVITY ANALYSIS TELL US?

The low carbon scenarios illustrate the emissions reductions of potential pathways for the City of Markham and are built on the assumptions as described in Sections 2-6 of this report. Sensitivity analysis involves the process of adjusting certain selected variables within the model in order to identify variables that have the most significant impact on the model outcomes of a scenario. It is not a process of "scenario analysis", as the variables tested do not represent internationally consistent scenarios. The approach to sensitivity analysis is to adjust those variables that were identified as having a higher potential to "move the curve", (ie. the factors that appear to be contributing significantly to the LC scenario), in order to be better informed about the implications of future options.

The process used applies a judgement-based "one-at-a-time"[32] exploration of variables within a scenario. The results should not be viewed as an evaluation of fully considered alternative

32 One-factor-at-a-time (OFAT or OAT) involves changing only one variable at a time to see what effect it produces on the output; generally involves changing one input variable while keeping others at their baseline (nominal) values, then returning the variable to its nominal value, and repeating for each of the other inputs in the same way. Sensitivity is then measured by monitoring changes in the output.

futures, rather, it is an exploration revealing how a selected output (i.e. emissions) responds to changes in selected inputs (e.g. # residential units).

11.2 VARIABLES AND RESULTS

Sensitivity analysis was applied to the LC-mod scenario. Several variables were identified for sensitivity analysis; the assumptions and results of each are described in Section 6.1, and depicted in Figure 122. The impact (expressed in $MtCO_2e$) shows the absolute emissions difference relative to the LC-mod in 2050.

Table 14. Sensitivity analysis variables and results.

CATEGORY	VARIABLE ADJUSTMENT	ENERGY IMPACT: RELATIVE TO LC-MOD (21.04 PJ)		EMISSIONS IMPACT: RELATIVE TO LC-MOD (0.5 $MtCO_2e$)	
		+/- GJ	+/- %	+/- $ktCO_2e$	+/- %
BUILT FORM					
Decrease population & employment	-10% dwelling units with reduced population -10% NR floorspace with reduced employment	-1,734,000	-13.3%	-38	-3.9%
Increase population & employment	++10% dwelling units with increased population +10% NR floorspace with increased employment	1,734,000	13.3%	38	3.9%
HEATING DEGREE DAYS (HDD)					
Hold HDD fixed	Keep number of heating degree days fixed at baseline value.	3,347,700	25.7%	130	13.3%

CATEGORY	VARIABLE ADJUSTMENT	ENERGY IMPACT: RELATIVE TO LC-MOD (21.04 PJ)		EMISSIONS IMPACT: RELATIVE TO LC-MOD (0.5 $MtCO_2e$)	
		+/- GJ	+/- %	+/- $ktCO_2e$	+/- %
Decrease HDD	Decrease number of heating degree days for 2040 and later by 10%. Linearly interpolate for 2012–2039.	-778,800	-6.0%	-30	-3.1%
GRID ELECTRICITY EMISSIONS FACTOR (EF)					
Decrease EF	Natural gas (NG) is considered a transition fuel towards a clean grid. Post 2020 all NG turbines get decommissioned at end of life (20 years) and replaced by carbon free sources; 1.59 gCO_2e/kWh in 2050 (BAU 37.4 gCO_2e/kWh in 2050)	0	0.0%	-108	-11.1%
Increase EF	National Energy Board data derived capacity factors that use less nuclear and hydro and more natural gas; 76 gCO_2e/kWh in 2050 (BAU 37.4 gCO_2e/kWh in 2050)	0	0.0%	115	11.7%
RETROFITS					
Decrease residential retrofits (Actions 5,6,8, 10)	LC scenario with -25% residential retrofits (# units retrofitted to 2050 in actions 5,6,8 and 10).	2,421,800	18.6%	175	17.9%

CATEGORY	VARIABLE ADJUSTMENT	ENERGY IMPACT: RELATIVE TO LC-MOD (21.04 PJ)		EMISSIONS IMPACT: RELATIVE TO LC-MOD (0.5 $MtCO_2e$)	
		+/- GJ	+/- %	+/- $ktCO_2e$	+/- %
ELECTRIC VEHICLE (EV) ADOPTION					
Decrease in EV uptake in all vehicle stocks	Reduce 2050 EV share of light-duty vehicle stocks by 62%, compared to LC (100%) and BAU (22%). For 2050 non-residential vehicle activity reduce EV share to 45% compared to LC (90%) and BAU (~0%).	2,849,300	21.9%	260	26.6%
VEHICLE KILOMETRES TRAVELLED (VKT)					
Increase VKT	Gradual increase in passenger vehicle VKT by 20% in 2050.	533,400	4.1%	6	0.60
Decrease VKT	Gradual decrease in passenger vehicle VKT by 20% in 2050.	-533,400	-4.1%	-6	-0.6%

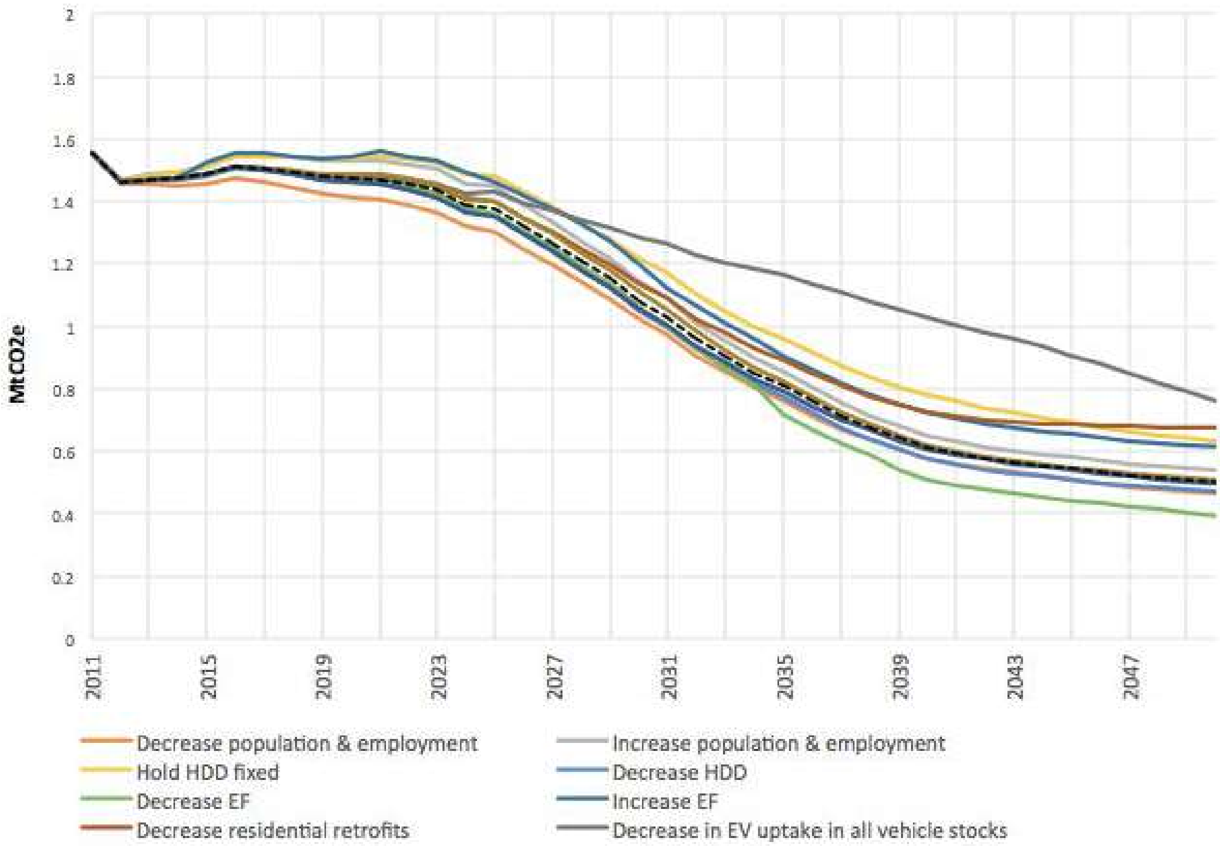


Figure 122. Change in LC-mod projection for modelled variables.

For energy, changes in assumptions for heating degree days (HDD), uptake of electric vehicles, and rate of residential retrofits have the most significant impact on energy consumption. Those variables with the least impact include changes in VKT and grid electricity emissions factor.

Similarly, for emissions, changes in assumptions for HDD, uptake of electric vehicles, and rate of residential retrofits, as well as the grid electricity emissions factor, have the most significant impact on the GHG emissions trajectory. Variables with a lesser impact include changes in VKT, and population and employment.

Heating degree days appear to be muting the impact of increasing population growth on emissions in LC-mod. For sensitivity, if it is assumed that HDD are constant over the time period (i.e. the climate does not change, and winters do not become warmer), the results indicate an increase in energy (+25.7%) and emissions (+13.3%); the impact of population growth becomes more apparent.

EV uptake in the LC-mod plays a major role in the decrease of energy and emissions in the transport sector. Reducing the share of EVs in the vehicle stock to 62% in 2050 (compared with 100% in LC-mod) results in an increase in energy of 2,849,300 GJ, and an increase in emissions of 260 ktCO_2e, which is 26.6% higher than the projected 2050 emissions of the LC-mod scenario.

Changes in the grid electricity emissions factor has an important influence for emissions; as there is a major shift towards electricity in the LC-mod scenario, it is fundamental that the EF of new capacity remain low, or the electrification approach is at risk from a greenhouse gas emissions perspective. Increased fossil fuel generation in the provincial electricity grid poses a major risk, as it would jeopardize the emissions reduction value of fuel switching efforts in the building and transportation sectors. This risk is difficult to mitigate, unless the City embarks on massive city-owned renewable energy projects to displace the impact of increased emissions from the grid. If the emissions factor of the grid is maintained or decreased, the next most significant risk is if the uptake in electric vehicles is slower than modelled. In this case, the City should focus its efforts on reducing emissions by reducing VKT, that is, shifting to other modes.

12 What are the financial impacts of the low carbon pathway?

SYNOPSIS

In the BAU scenario, total spending on buildings, vehicles and energy will be $120 billion between 2017 and 2050, ranging between $3 and $4 billion per year. The LC-amb scenario will save approximately $7 billion over that period, after an initial increase in spending of $700 million over the period of 2017 and 2028. The incremental increase in expenditures in LC-amb over the BAU for the initial 11 years ranges from less than 1 to 5% per year.

A low carbon City is also a lower cost City. By 2050, per capita vehicle costs (excluding energy) will decline by two thirds over 2016, as a result of a shared, electric vehicle fleet, which requires fewer vehicles and reduced maintenance. Household energy costs for transportation and homes will decline by 60%, again on a per capita basis as a result of significant efficiency gains.

The analysis indicates that most of the actions in LC-amb represent investment opportunities for businesses, the City or residents with varying financial returns. Seven actions require either subsidies or bundling with more lucrative actions to justify financially.

There are also new opportunities for employment that emerge, more than offsetting declines in sectors such as maintenance of gasoline vehicles. The increase is the result primarily of increases in labour intensive activities such as retrofits and the capture of more energy dollars locally.

12.1 INTRODUCTION

Detailed financial modelling of the actions and the three scenarios – BAU, LC-amb, LC-mod – was completed. This analysis involved identifying projections of capital, operating and maintenance costs of vehicles, buildings, infrastructure and energy systems. A comprehensive financial data library is used for assumptions, drawing from sources including the National Energy Board, US Energy Information Agency, several specific data sources for particular stocks, and in some cases expert opinion.

Financial values are represented as either constant dollars or current dollars in this section.

Constant dollars assumes that a dollar now is a dollar in the future, in other words there is no change in value. If no qualifying term is used, the dollar value refers to constant dollars.

Current dollars are calculated by translating the value of future dollars into present (2017) value, using discounting. Present value was calculated by applying a discounting rate of 3% to outflows and inflows beyond 2017. The discounting rate of 3% is recommended by the Government of Canada in circumstances where environmental and human health impacts are involved.[33]

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33 Environment and Climate Change Canada. (2016). *Technical update to Environment and Climate Change Canada's social cost of greenhouse gas estimates*. Retrieved from http://ec.gc.ca/cc/BE705779-0495-4C53-BC29-6A055C7542B7/Technical%20Update%20to%20Environment%20and%20Climate%20Change%20Canadas%20Social%20Cost%20of%20Greenhouse%20Gas%20Estimates.pdf

12.2 FINANCIAL ANALYSIS OF THE ACTIONS

12.2.1 Many of the actions save money

The investment and return of each action was evaluated against the BAU scenario separately. The net present value (NPV) was calculated as the difference between the present value of cash inflows (financial returns) and the present value of cash outflows (investments). In this analysis, a positive NPV represents a cost to the City and a negative NPV represents savings; in other words, the more negative the NPV, the better the investment.

The majority of the actions generate financial returns (the inflow is greater than the outflow) and therefore can be undertaken on their financial merits alone. The attractiveness of the investment, however, will vary according to the investment return expectations of the organisation or business making the investment. A key future step is matching investment opportunities with prospective investors, whether they be households, businesses, the municipality or other entities.

Note that the NPV analysis for each action does not capture the feedback between the actions, which is captured in the analysis of the integrated scenarios, described in a subsequent section.

On a stand-alone basis, **many of the actions generate financial returns** over the lifetime of the action.

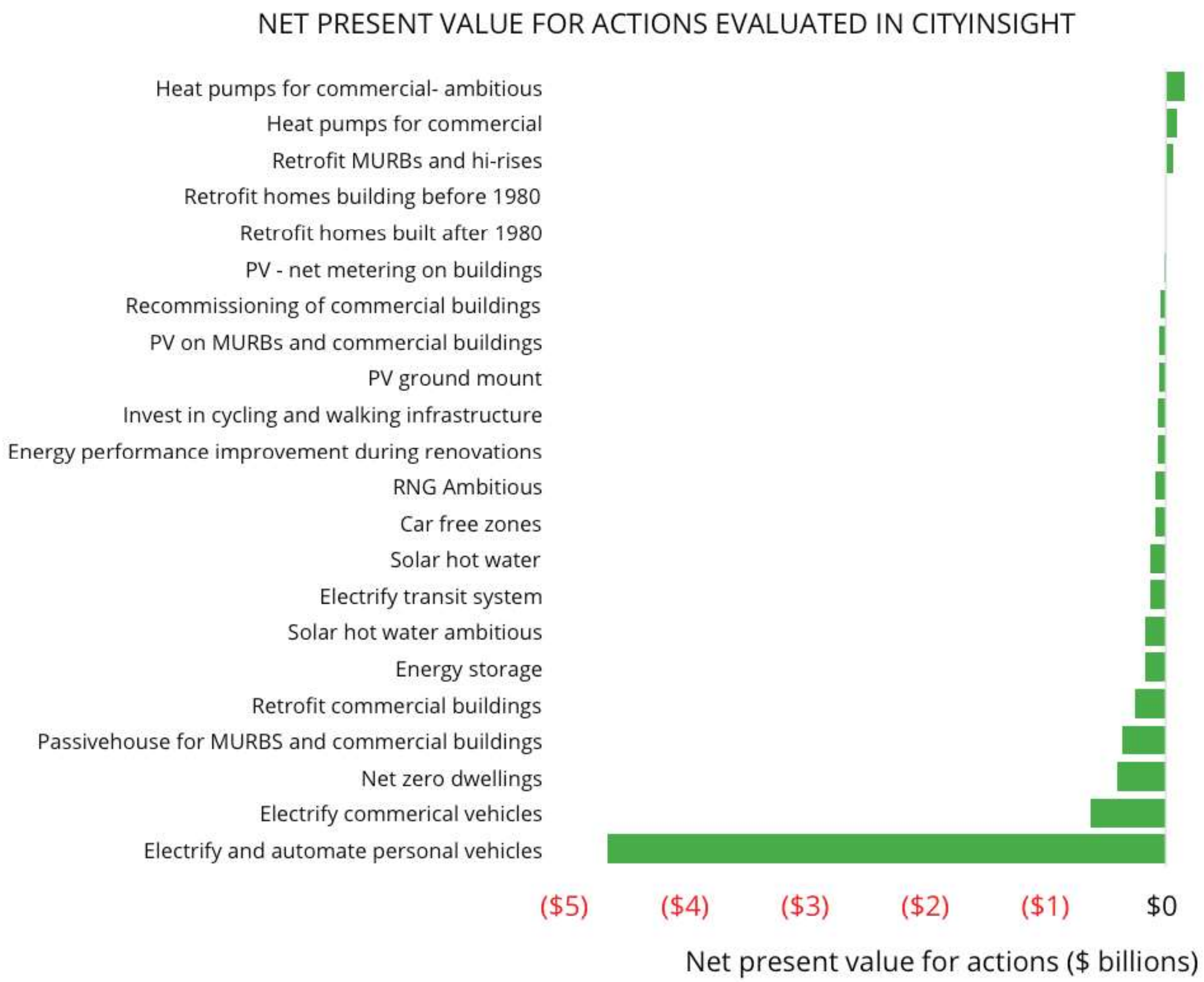


Figure 123. Net present value for each of the actions.

The most notable financial savings result from shifting to a shared, autonomous vehicle fleet. Sharing vehicles reduces the capital and operating cost requirements for the vehicle fleet as fewer vehicles need to be purchased. Additional benefits results from the reduced maintenance costs of electric vehicles and lower fuel costs due to the efficiency of electric engines.

Seven of the actions have net costs over the period considered and therefore can be targeted for subsidies or grants and/or bundled with more lucrative actions, in particular the actions related to heat pumps. Notably the economics of fuel switching from natural gas to electric heat pumps is financially challenging primarily as a result of the low cost of natural gas relative to electricity. The projection for future natural gas costs is conservative and if natural gas costs increase beyond the projections, these investments will become more favourable. Another approach is to bundle actions, for example if commercial retrofits and commercial heat pumps are bundled together, the collective return on investment is positive.

Table 15 summarises the total costs and savings for the actions over the lifetime of that action in current dollars. The return on investment illustrates the financial return associated with the actions. For example, if an action costs $100 to implement and generates $100 in savings, the return would be 0%. If that action generates $150, than the return is $150-$100, or $50. The return on investment is then $50/$100 or 50%.

Table 15. Return on investment.

ACTIONS	COSTS	SAVINGS	RETURN ON INVESTMENT
	CURRENT (2017) $		
1. Residential- New residential housing developments target net zero, including solar PV	$230,663,310	$639,777,283	177%
2. Multi-residential (incl. condominiums) & commercial and institutional - Passivehouse standard applied to multi-unit residential, commercial and institutional buildings	$163,456,507	$527,177,319	223%
3. Renewable energy installation requirements or incentives on multi-res, commercial and institutional buildings	$294,563,714	$351,936,623	19%
4. Retrofit homes prior to 1980	$53,368,699	$49,915,154	-6%
5. Retrofit homes after 1980	$262,879,060	$259,540,341	-1%
6. Retrofits in ICI sector	$83,163,820	$341,609,072	311%
7. Retrofits of multi-residential	$72,627,526	$9,142,911	-87%
8. Re-commissioning of buildings	$19,275,480	$61,794,108	221%

ACTIONS	COSTS	SAVINGS	RETURN ON INVESTMENT
	CURRENT (2017) $		
9. Renovation threshold requirement to meet codes and standard	$173,553,750	$243,198,350	40%
10 Installation of heat pumps: air and ground source residential	$974,733,041	$126,375,102	-87%
10.a Installation of heat pumps: air and ground source residential ambitious	$2,365,260,309	$210,662,250	-91%
11. Installation of heat pumps: air and ground source commercial	$155,138,196	$65,268,901	-58%
11.a Installation of heat pumps: air and ground source commercial-ambitious	$246,265,304	$87,313,228	-65%
12. Solar PV - net metering all existing buildings	$241,403,127	$249,002,178	3%
13. Solar heating/hot water	$109,234,716	$234,892,677	115%
13.a Solar heating/hot water ambitious	$142,005,170	$310,884,774	119%
14. Solar PV - ground mount	$63,302,224	$122,686,931	94%
16. Energy storage	$185,967,803	$356,210,110	92%
17. Renewable natural gas	$410,208,589	$493,107,090	20%
18. Electrify transit system	$39,609,974	$166,763,892	321%
19. Increase/improve cycling & walking infrastructure	$113,325,520	$182,061,835	61%
20. Car free zones	$0	$89,256,711	0%
21. Electrify and automate personal vehicles	$226,545,345	$4,873,278,919	2051%
22. Electrify commercial vehicles	$71,438,068	$699,289,569	879%

12.2.2 For many actions, reducing GHG emissions also saves money.

The marginal abatement cost (MAC) is a measure of the cost or savings of reducing GHG emissions for a particular action. The MAC divides the total costs or savings of the action, as represented by the NPV, by the total GHG emissions reductions associated with that action over its lifetime. The result is a cost or savings per tonne of GHG emissions reduced. An action with a high cost/tonne is an expensive GHG emissions reduction, whereas an action that results in savings indicates that money is saved for every tonne of GHG emissions reduced.

There is a general perception that reducing GHG emissions costs money, and this is true in many sectors of the economy. In the context of Markham, however, all but seven of the actions analysed result in financial savings, up to $4,000 per tonne of GHG emissions reduced. Actions which generate both financial savings and GHG emissions reductions are no-loss opportunities. The implementation of these actions is likely currently constrained by legal, logistical or other barriers. A key focus on the MEP is unlocking those opportunities so that the City and its residents can both save money and reduce GHG emissions.

There is a general perception that reducing GHG emissions costs money, and this is true in many sectors of the economy. In the context of Markham, however, all but seven of the actions analysed result in financial savings

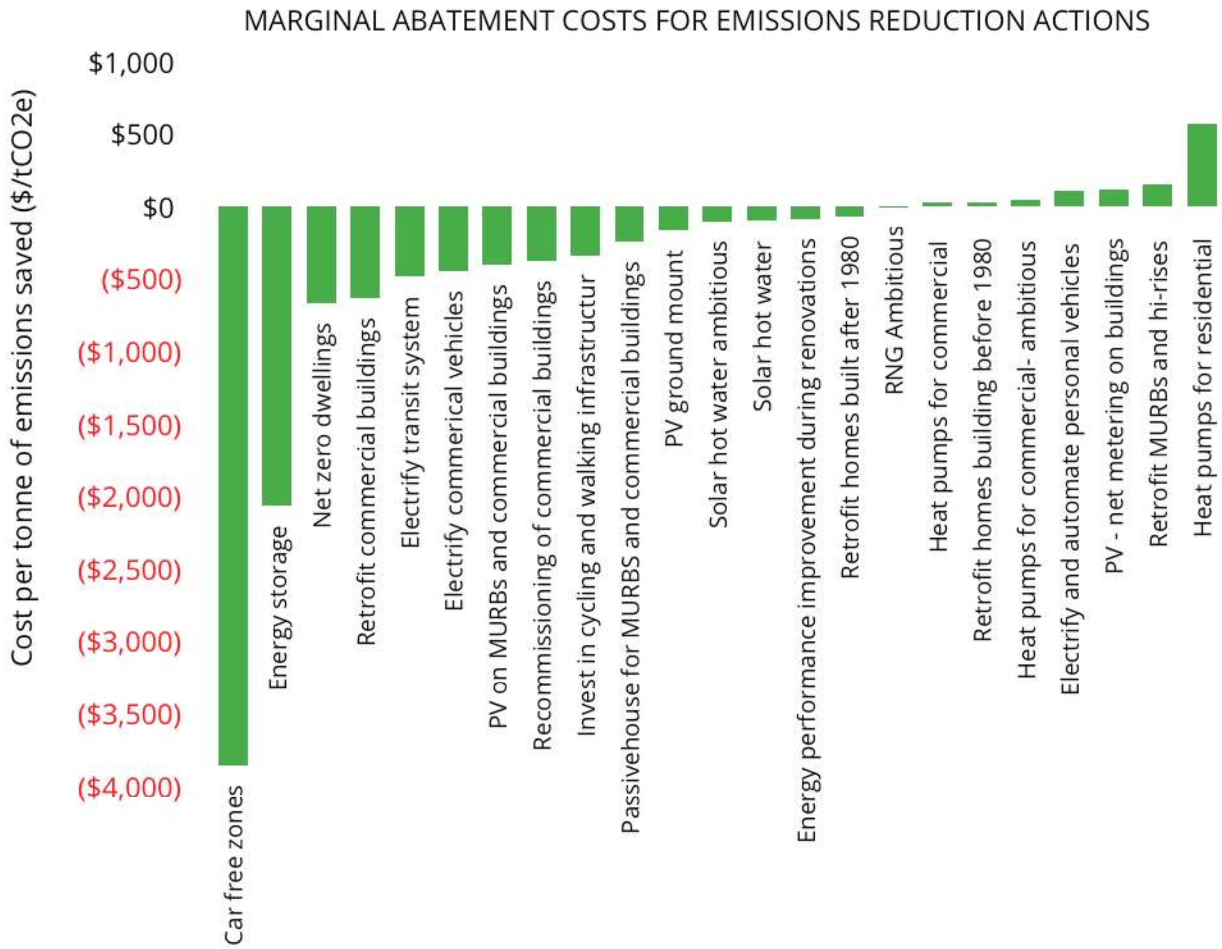


Figure 124. Marginal abatement costs.

12.3 FINANCIAL ANALYSIS OF THE SCENARIOS

The financial analysis of the two low carbon scenarios illustrates the overall impact of the combination of actions on the City, including interactions between the actions. For example, the completion of retrofits prior to heat pumps reduces the need for heating and therefore reduces the cost of heat pumps.

Financial impacts were evaluated by calculating the total capital and operating expenditures of the BAU and low carbon scenarios separately. The results for each of the low carbon scenarios were then compared with the results of the BAU.

12.3.1 Capital expenditures

The incremental capital expenditures of LC-amb over the BAU scenario is represented in Figure 125. In some sectors the capital expenditures are lower, in particular as a result of the transition to a shared autonomous fleet of vehicles. Fewer vehicles are purchased which offsets the increased capital cost of electric vehicles. Decreased capital expenditures on vehicles exceeds additional capital investment in retrofits, renewable energy and electric vehicle deployment, and high performance buildings.

Over the long run, the **low carbon scenarios require less investment than the BAU**. The total additional investment over BAU is -$0.5 billion dollars between 2016 and 2050 for LC-amb versus $-2.4 billion for LC-mod.

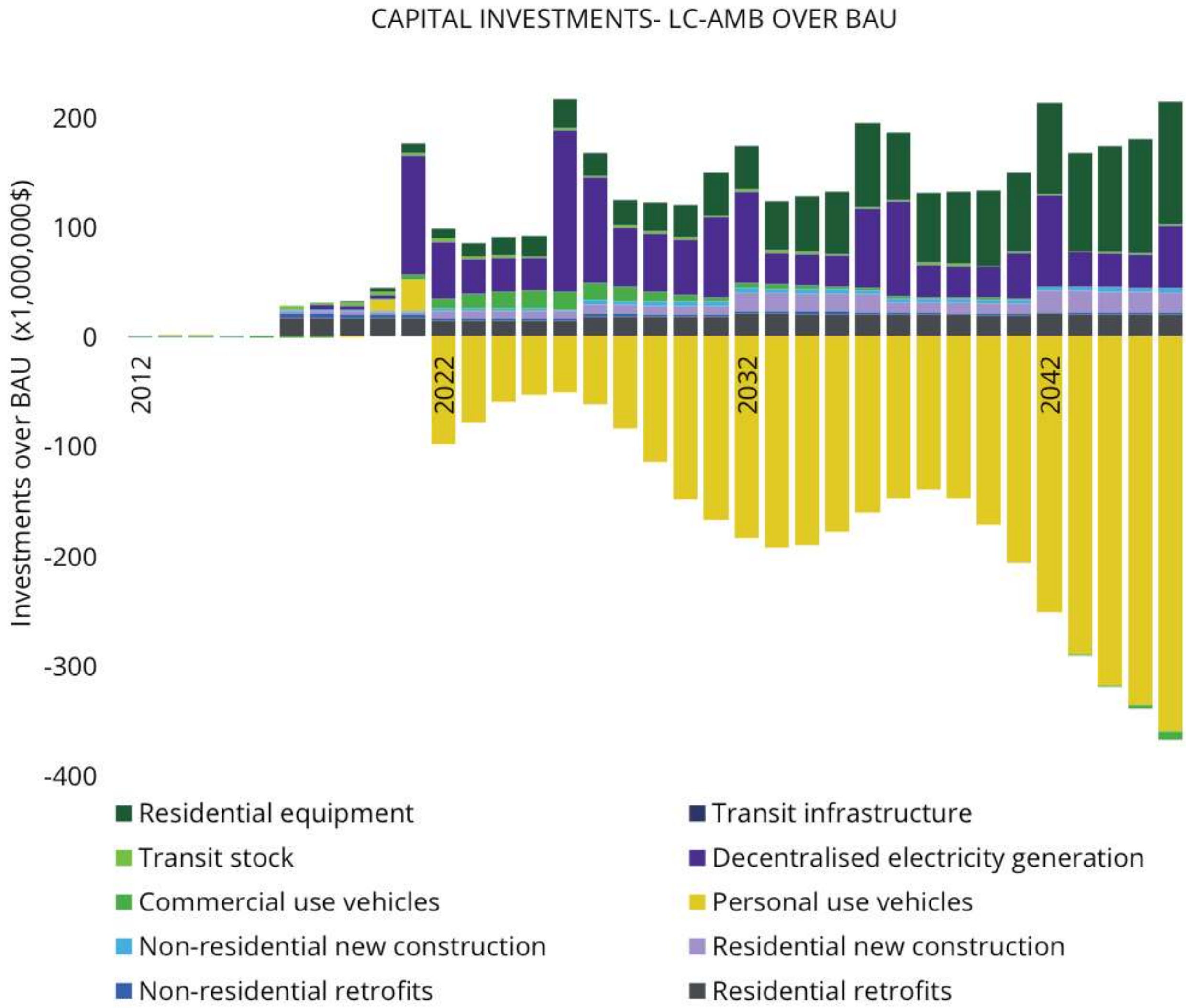


Figure 125. Incremental investment in LC-amb over BAU.

12.3.2 Additional capital is required in the short term for the low carbon scenario.

Figure 126 illustrates the cumulative investment associated with the LC-amb in constant dollars; essentially the sum of the prior years' investments. For example, cumulative investment in year 12 would be the investments in year 11 + year 10 + year 9 and so on. For the later part of the time period LC-amb and LC-mod result in a negative investment – in other words the LC-amb requires less capital than the BAU scenario, in part because the costs of solar PV and electric vehicles decline below their fossil fuel alternatives, but primarily because of the decreased capital costs of shared autonomous vehicles. Increased investments in heat pumps in LC-amb offset some of the capital reductions associated with shared autonomous vehicles. The total additional investment over BAU is -$0.5 billion dollars between 2016 and 2050 for LC-amb versus $-2.4 billion for LC-mod.

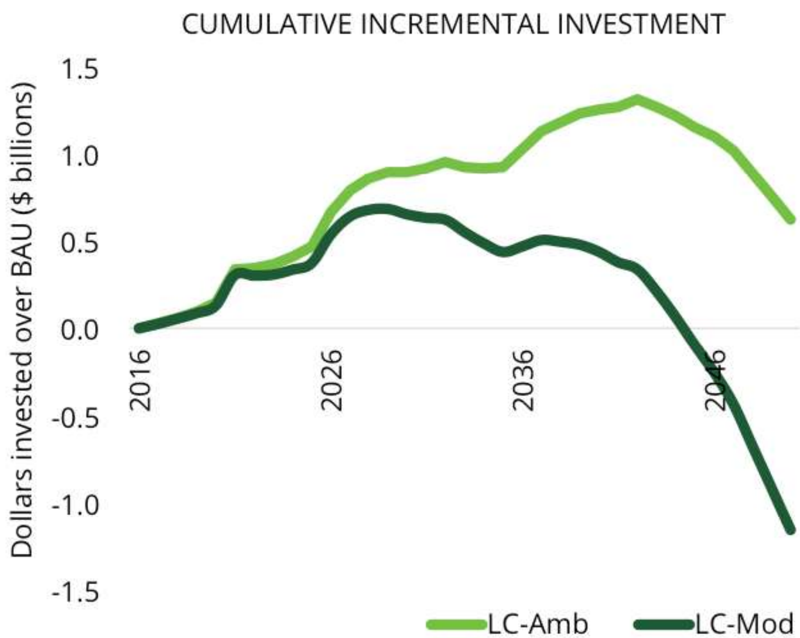


Figure 126. Total cumulative investment for Low Carbon Scenarios over BAU, 2017 dollars.

Initial investments of $700 million in the first decade are required for LC-amb in 2017 dollars. In subsequent decades, the investment in LC-amb is lower than BAU, primarily because of the lower capital requirements for shared autonomous vehicles.

12.3 SPENDING ON ENERGY

12.3.1 Spending on energy declines in the low carbon scenario

Energy expenditures were analyzed for each of the three scenarios, using energy price projections from the reference scenario of the National Energy Board (NEB)'s Energy Futures report. The LC-amb results in significant avoided energy expenditures over the BAU scenario, as illustrated in Figure 127, and avoided carbon price expenditures, as illustrated in Figure 128. In the BAU scenario, both energy expenditures and carbon price expenditures demonstrate an upward trend to 2050, whereas the low carbon scenarios result in the stabilization and decline of these expenditures, as energy consumption is reduced due the implementation of the low carbon actions.

LC-amb results in annual avoided energy and carbon expenditures of nearly half a billion dollars per year by 2050.

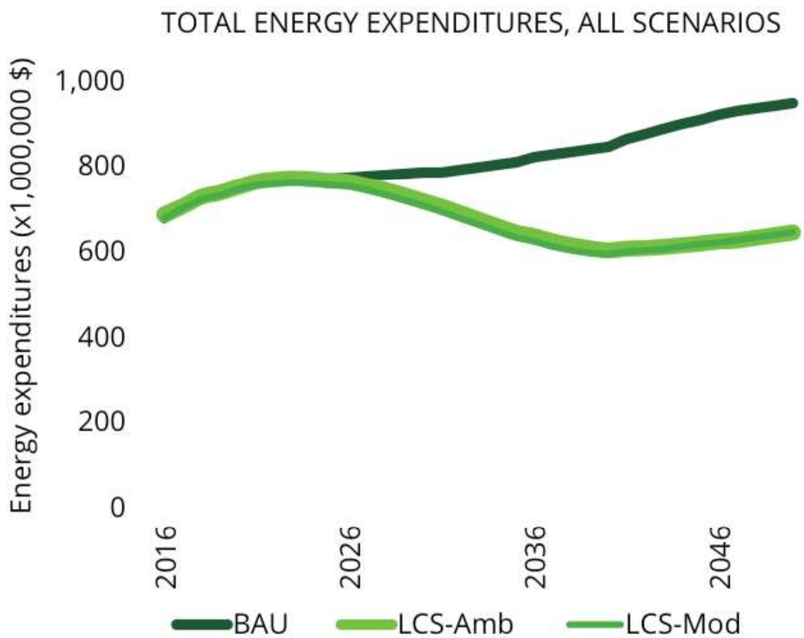


Figure 127. Total energy expenditures, all scenarios.

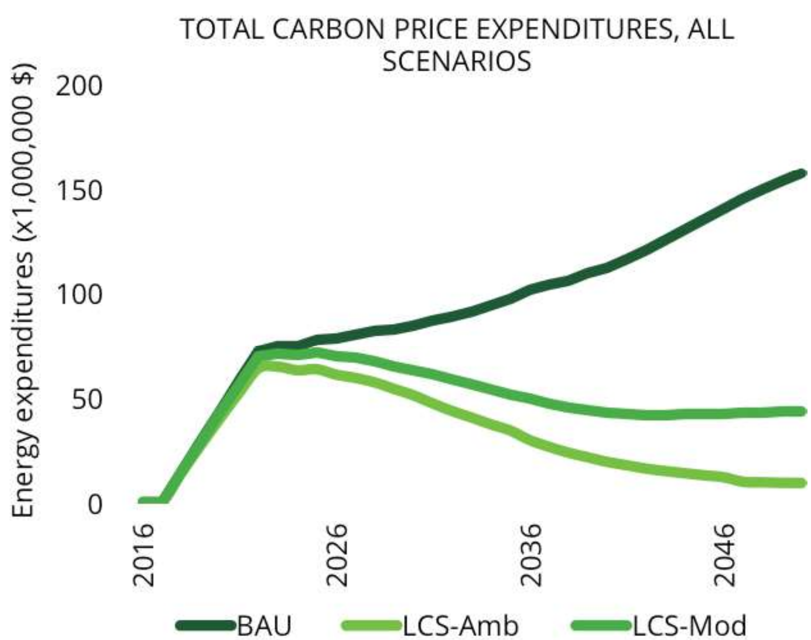


Figure 128. Total carbon price expenditures, all scenarios.

12.3.2 The most significant reductions in energy spending occur in the residential sector

The majority of the reduced spending on energy and carbon price in LC-amb occurs in the residential sector, as illustrated in Figure 129 and Figure 130. By 2050, annual overall spending on energy is over $300 million less in LC-amb than in the BAU.

Reduced spending on carbon price totals $150 million per year by 2050, as illustrated in Figure 130. This savings reflects the reduction in GHG emissions and the commensurate reduction in the cost associated with a price on carbon.

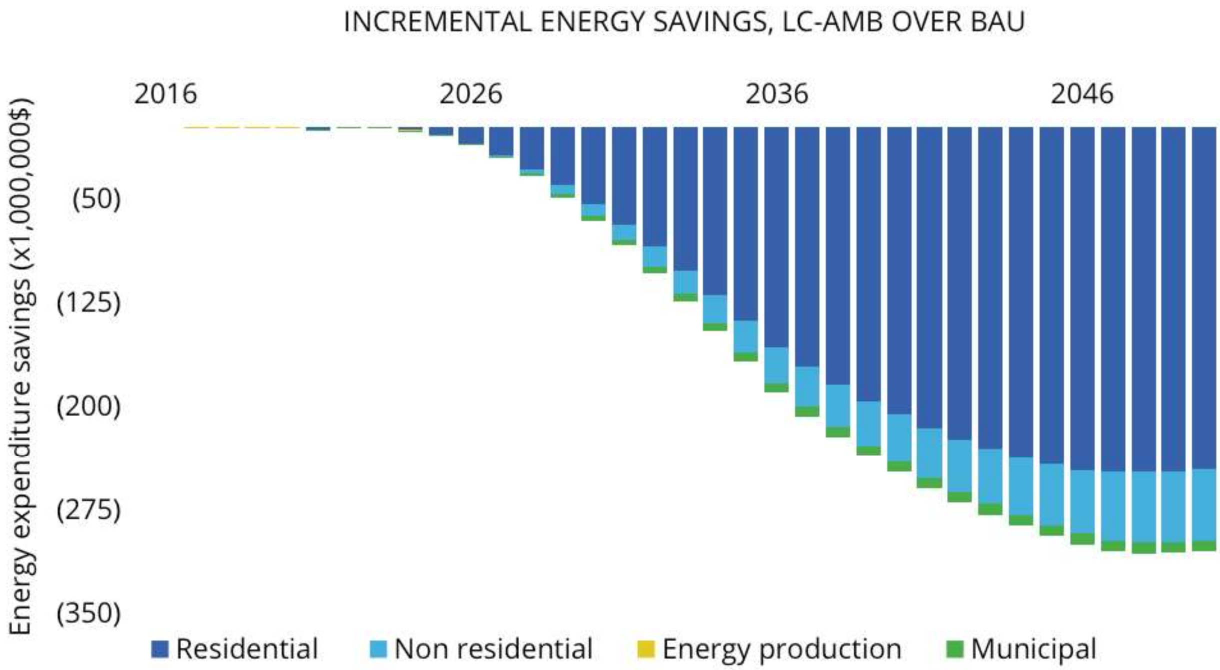


Figure 129. Avoided energy spending, constant $, LC-amb over BAU.

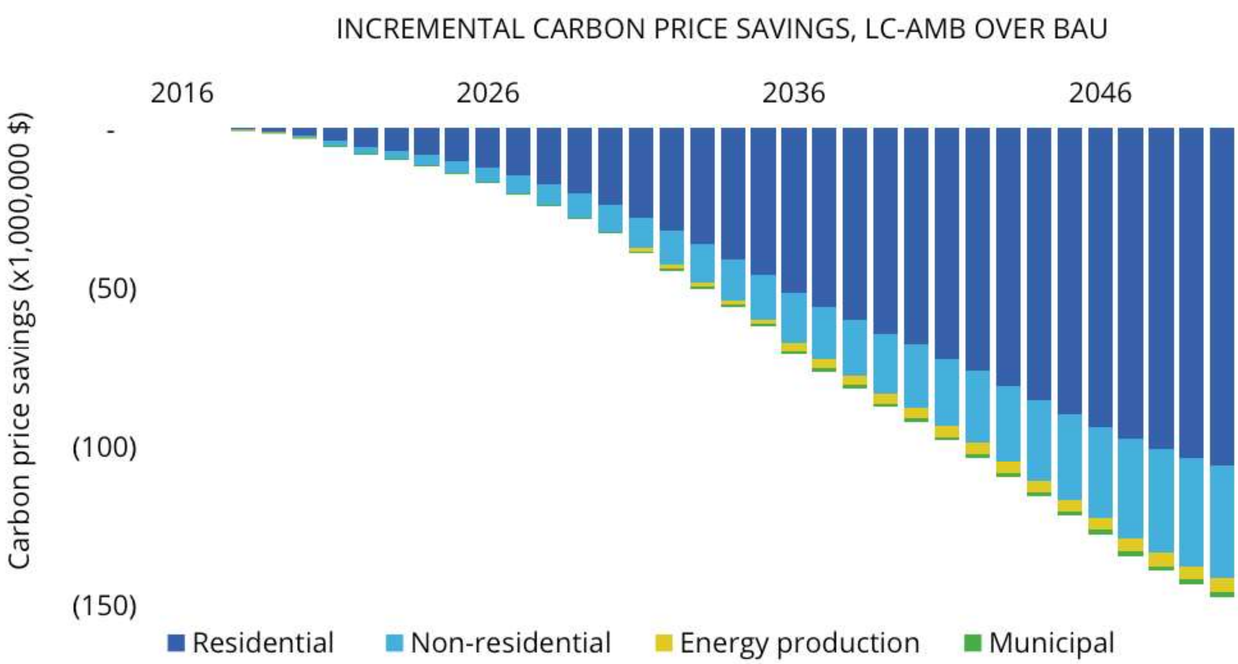


Figure 130. Avoided carbon price spending, constant $, LC-amb over BAU.

12.3.3 Total energy and carbon price savings accumulate

The cumulative savings resulting from avoided energy and carbon price expenditures are represented in Figure 131; in total the avoided expenditures climb to just under $8 billion by 2050 in constant dollars. When discounted at 3%, the cumulative savings represent a present value of $3.2 billion (2017 dollars).

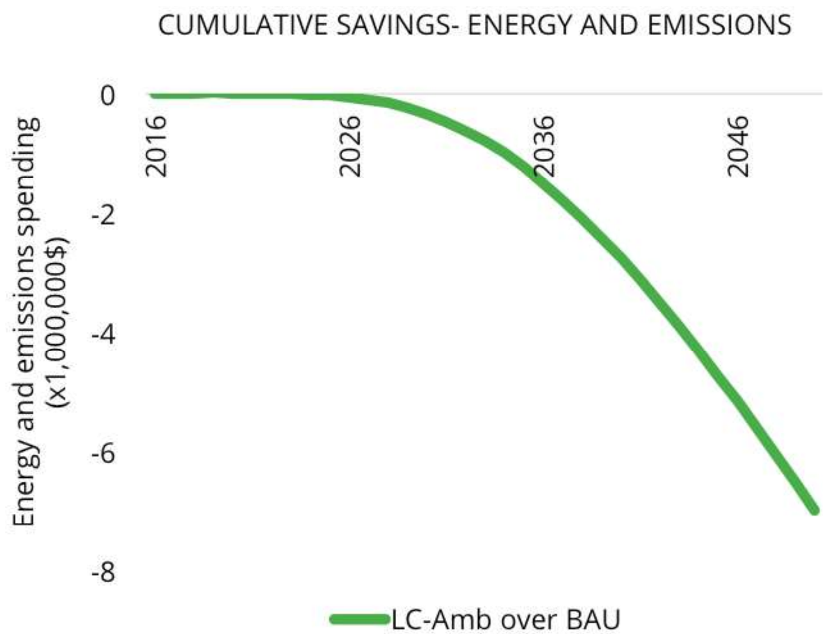


Figure 131. Cumulative savings from reduced spending on energy and carbon price in constant dollars, LC-amb over BAU.

Reduced spending on energy and carbon price totals

$8 billion between 2017 and 2050 in LC-amb.

12.3.4 The low carbon scenarios reduce the exposure to fluctuating energy prices

Recognising the uncertainty of future energy prices, low and high energy price projections were modelled to compare against the reference case. Like the reference case, the low and high projections were based on the National Energy Board (NEB) Energy Futures projections for natural gas, electricity, oil and gasoline and were supplemented with projections for biogas, biodiesel, biomass and propane from the Ontario Energy Board. Three different cost curves for the price of carbon were also created, climbing from $10/tonne of carbon to $100-$196/tonne by 2050.

Figure 132 illustrates the energy and carbon costs of the BAU and the LC-amb for the low, reference and high cost scenarios. By 2050, spending on energy in the highest cost assumption of the BAU exceeds $1.3 billion per year; more than double the annual expenditures on energy in the LC-amb. The spread of the total energy and emissions costs for the three cases under the BAU scenario varies by $400 million, indicating much more uncertainty than the spread for the LC-amb, which varies by less than $30 million. LC-amb therefore reduces exposure to future energy price increases for the City.

The ambitious low carbon scenario reduces the risks associated with fluctuating energy prices.

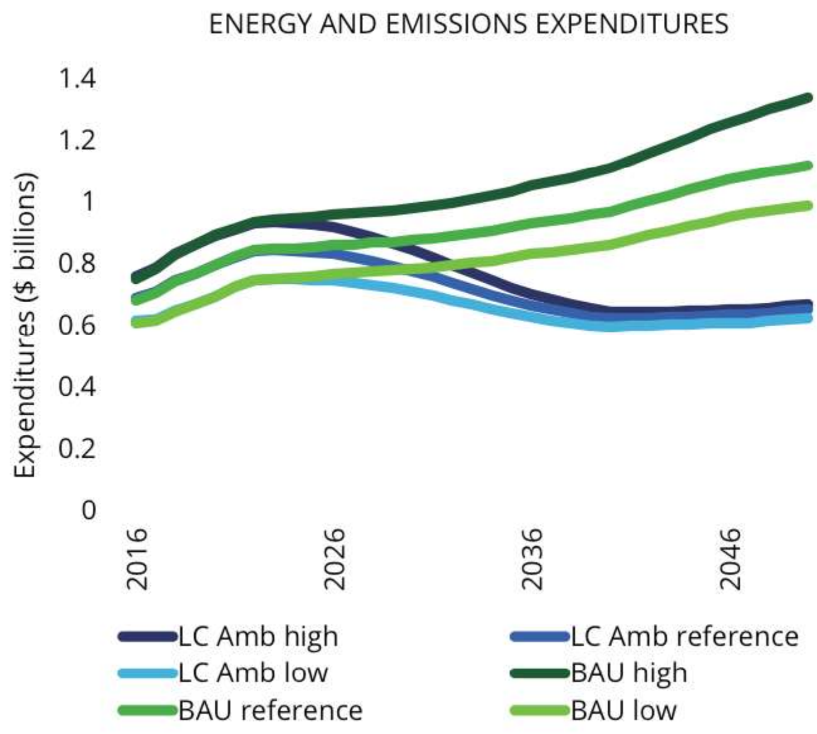


Figure 132. Total projected fuel costs and carbon costs for LC-amb and BAU using three cost scenarios.

The reduction in risks associated with exposure to fluctuating energy costs is also illustrated in the decline of the ratio of the cost of energy relative to other costs. The ratio of energy costs to other expenditures for the two scenarios is illustrated in Figure 133. The share of energy costs relative to total capital and operating expenditures declines from 30% in the BAU scenario in 2050 to 20% in 2050 in LC-amb.

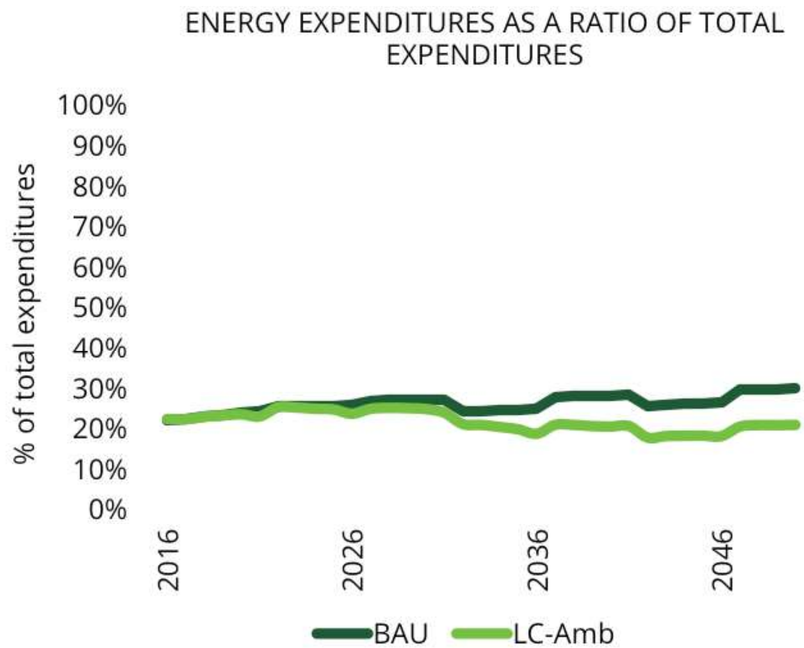


Figure 133. Total cumulative savings from fuel costs and carbon tax for LC-amb.

12.4 THE BIG PICTURE

This section of the financial analysis describes total expenditures for the relevant sectors, bringing together the results of the previous sections. Revenues are also included where relevant, for example, for transit and the sale of energy from district energy systems.

Table 16. Categories of expenditures tracked

SECTOR	CATEGORIES
HOUSEHOLDS	• Personal vehicles (capital and maintenance expenditures) • Dwellings (capital and maintenance expenditures) • Equipment in dwellings (appliances, heating systems, lighting) (capital and maintenance expenditures) • Energy costs • Carbon price costs

SECTOR	CATEGORIES
NON-RESIDENTIAL (institutional, commercial and industrial)	• Vehicles (capital and maintenance expenditures) • Buildings (capital and maintenance expenditures) • Equipment in buildings (appliances, heating systems, lighting) (capital and maintenance expenditures) • Energy costs • Carbon price costs
MUNICIPAL FLEET AND TRANSIT	• Capital and maintenance expenditures • Transit revenues • Carbon price • Energy expenditures
LOCAL ENERGY PRODUCTION	• Capital and maintenance • Energy sales revenues • Carbon price • Energy expenditures

In the case of the City of Markham, the transit system is owned and operated by the regional government, however, because of the structure of the financial analysis, it has been bundled with the City fleet.

Annual expenditures in these sectors are projected to range from $3 to $4 billion per year in the City of Markham, representing primarily the addition of new buildings and vehicles to service an increasing population, as well as the replacement of aging buildings and vehicles. Figure 134 illustrates the annual expenditures in the City of Markham for these sectors in the BAU. Vehicles represent the most significant source of expenditures, including capital and maintenance.

In 2016 the community of Markham spend spent approximately $1.25 billion on new vehicles and maintenance of existing vehicles, $1.1 billion on new and existing buildings and $700 million on energy for buildings and fuel for vehicles.

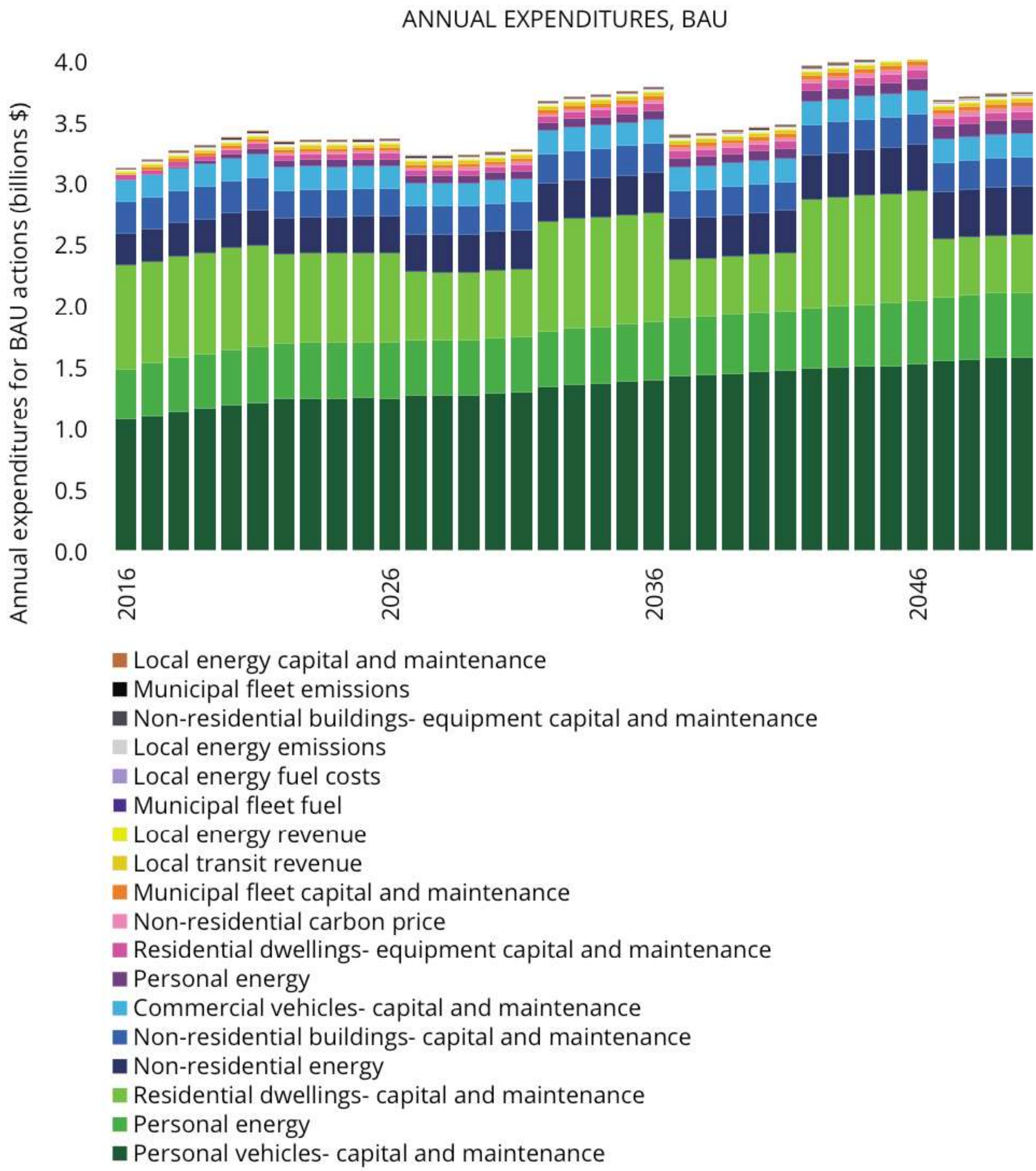


Figure 134. Annual expenditures by sector for BAU, constant $.

The difference in annual expenditures for the three scenarios is illustrated in Figure 135. The low carbon scenarios initially represent a slight increase in total expenditures over the BAU, representing the incremental cost of higher performance buildings and electric vehicles. Around 2030, however, the low carbon scenarios decline below the BAU scenario around 2030 as technology costs decrease and autonomous vehicles come online.

Annual expenditures in LC-amb and LC-mod are very similar, as the additional investments in LC-amb are relatively small in comparison with total expenditures. The steps in the curves are the result of investments in residential building stock, which is modelled in five-year steps. Every five years additional dwellings are added to accommodate the population increase over that period.

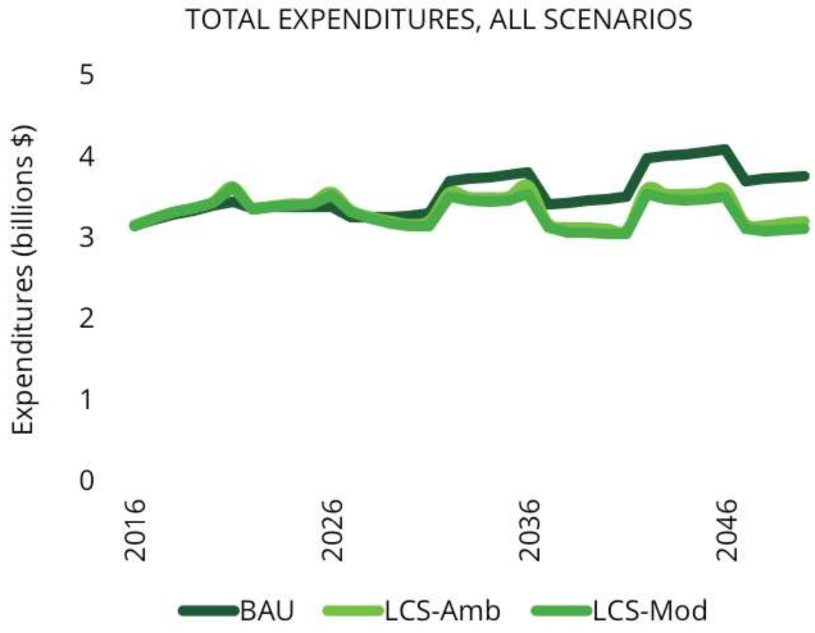
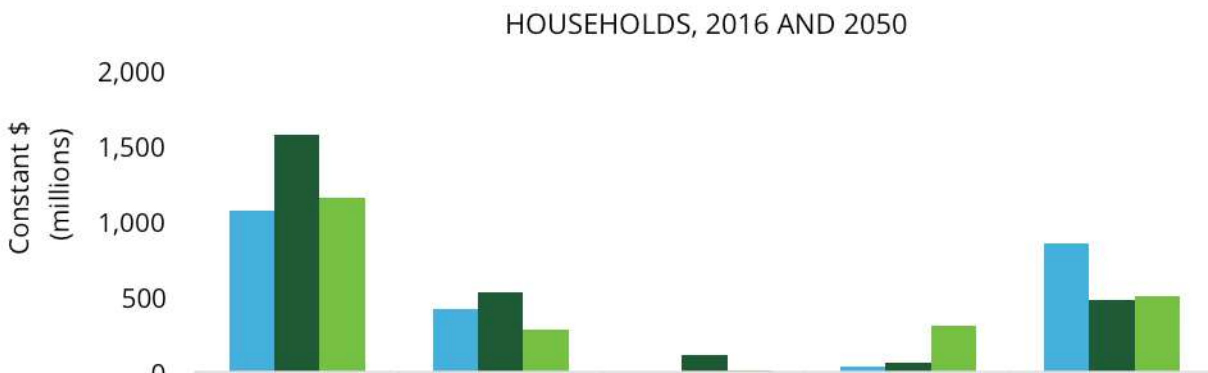


Figure 135. Annual total expenditures for the three scenarios, constant $.

The majority of these expenditures occur with the normal turnover of stocks, irrespective of the low carbon pathway. For example, people will purchase cars in the future, regardless of whether they are electric or not, implying ongoing capital investment in cars. Similarly, buildings will be built to service the population increases, irrespective of their energy performance. In other words, the majority of the capital will be deployed whether or not the actions in the low carbon scenarios occur.

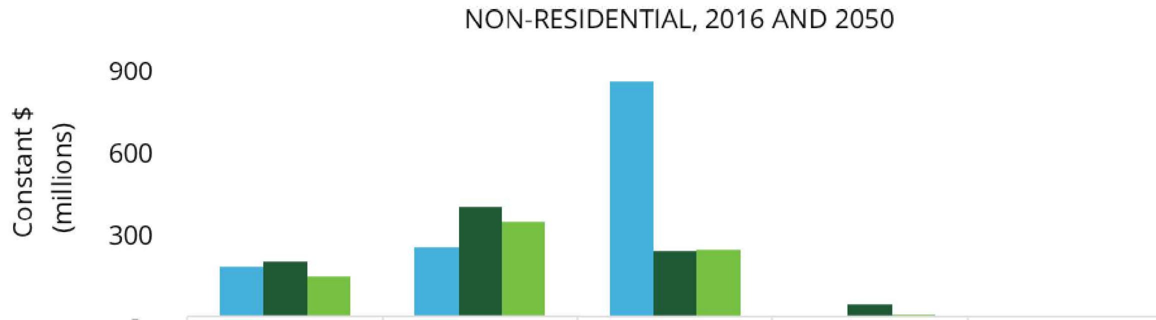
12.4.1 Annual expenditures decline in the low carbon scenarios in many categories of expenditures

Figure 136 to Figure 139 compare annual expenditures by spending category for 2016 and then 2050 for the BAU and LC-amb scenarios. Note that there was no carbon price applied in 2016. In most categories spending in LC-amb in 2050 is less than in 2016 and than in the BAU in 2050. The primary exception is greater investment in local energy generation in 2050 in LC-amb (capital and maintenance).



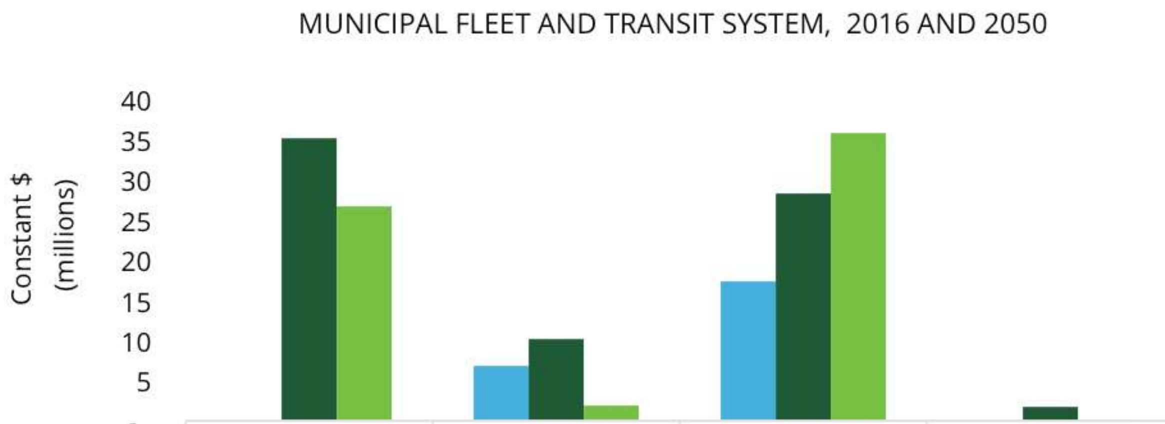
	Personal vehicles- capital and maintenance	Personal energy	Personal carbon price expenditures	Residential dwellings- equipment capital and maintenance	Residential dwellings- capital and maintenance
2016	1,067,454,985	417,916,438	-	40,402,668	852,520,865
BAU- 2050	1,569,993,873	527,020,629	109,265,740	63,883,721	473,754,995
LC-amb- 2050	1,154,207,886	279,781,861	2,556,845	304,831,543	499,536,334

Figure 136. Household ependitures by spending category.



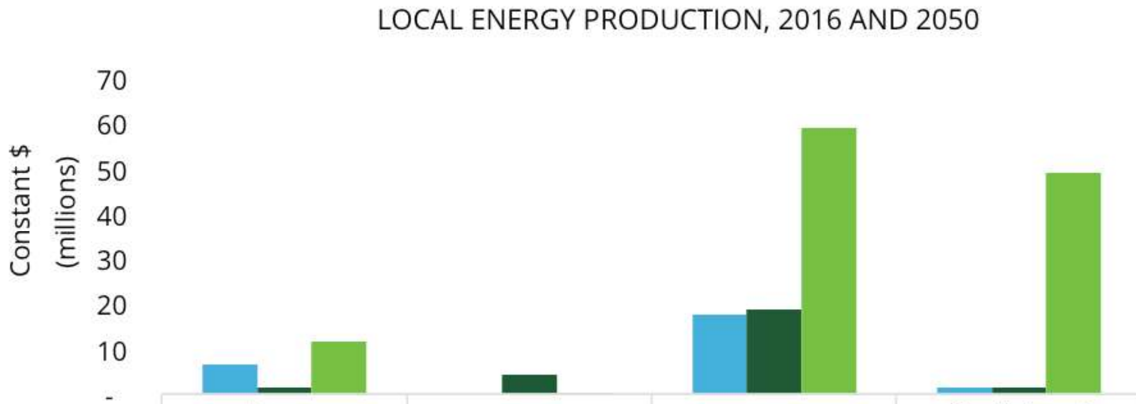
	Commercial vehicles- capital and maintenance	Non-residential energy	Non-residential buildings- capital and maintenance	Non-residential carbon price	Non-residential buildings- equipment capital and maintenance
2016	181,057,660	249,327,848	852,520,865	-	712,448
BAU- 2050	198,597,225	396,182,786	237,236,699	41,867,931	2,272,104
LC-amb- 2050	145,648,418	344,302,080	241,811,887	6,403,808	2,272,104

Figure 137. Non-residential ependitures by spending category.



	Capital and maintenance expend	Energy expenditures	Transit revenue	Carbon price
2016	-	6,813,807	17,393,053	-
BAU- 2050	35,192,864	10,084,360	28,235,430	1,663,507
LC-amb- 2050	26,651,140	1,953,586	35,718,844	173,712

Figure 138. Fleet and transit system expenditures by spending category.



	Energy expenditures	Carbon price	Revenues	Capital and maintenance
2016	6,461,330	-	17,716,127	1,481,541
BAU- 2050	1,369,135	4,319,017	18,712,797	1,369,135
LC-amb- 2050	11,637,129	46,203	59,093,732	48,985,562

Figure 139. Local energy production expenditures by spending category.

12.4.2 The low carbon scenarios result in significant financial savings for the City

Figure 140 illustrates that investments (positive numbers) are weighted more heavily in the near term (green bars labelled 'capital'), whereas the savings (negative numbers) accumulate towards the end of the time period considered (light and dark blue bars). Savings from fuel costs and avoided cost of carbon increase incrementally, totalling $660 million per year by 2050.

More investments are required early on and the savings increase from 2030 onwards.

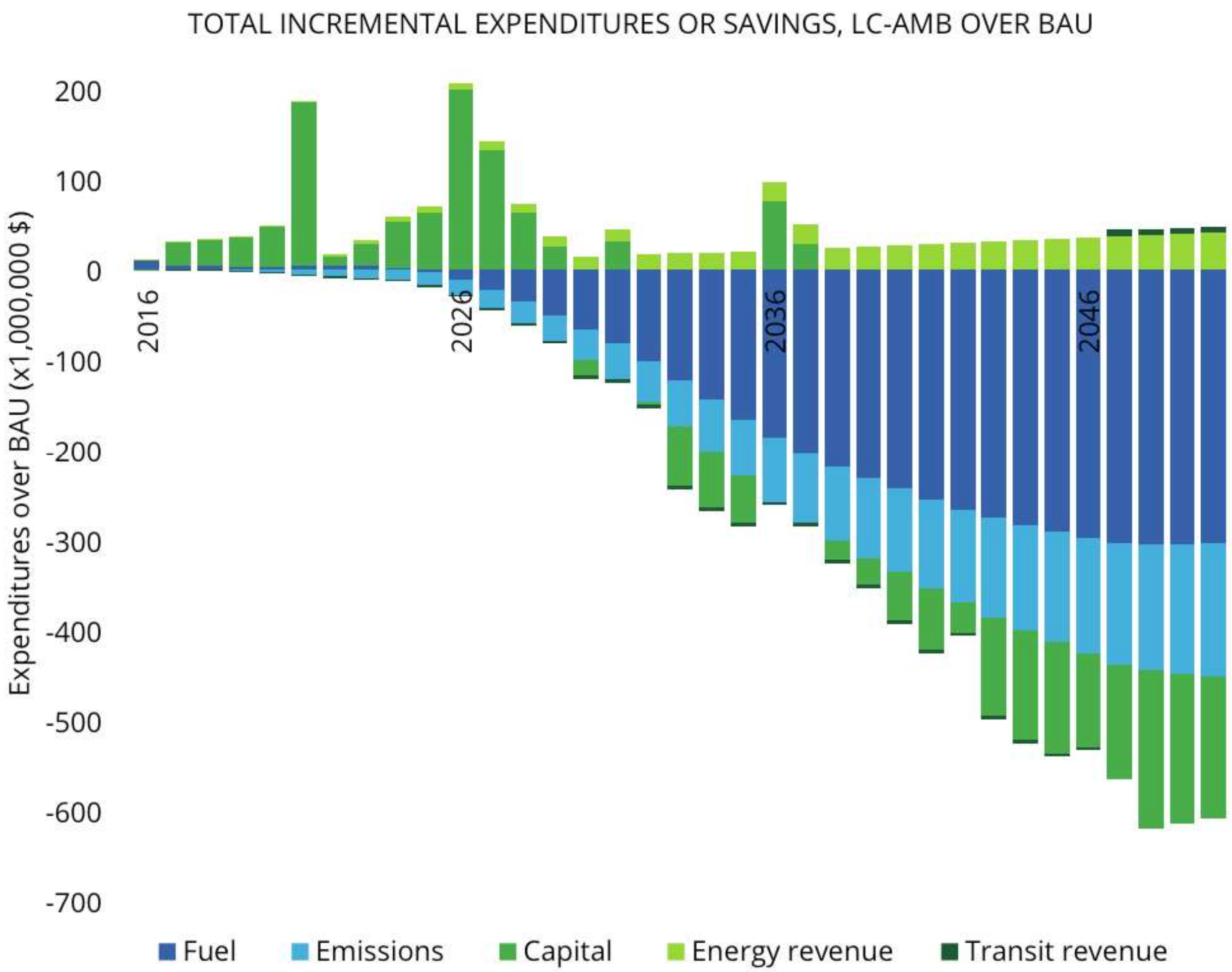


Figure 140. Total incremental investment in LC-amb over BAU, constant $.

Total expenditures between 2017 and 2050 are $120 billion. The LCS-amb results in savings of $7 billion in constant dollars (not discounted). In LC-mod the savings are $8.3 billion over the same period.

Table 17. Total expenditures between 2017 and 2050

SCENARIO	TOTAL EXPENDITURES ($)	SAVINGS ($)
BAU	119,811,440,782	
LCS-AMB	113,046,409,998	6,765,030,785
LCS-MOD	111,437,516,187	8,373,924,595

Figure 141 illustrates the accumulation of reduced spending in the low carbon scenarios over the BAU after 2028, increasing to nearly $7 billion in LC-amb and $8 billion in LC-mod by 2050. The savings will continue to increase post 2050 as illustrated by the trajectory of the curve.

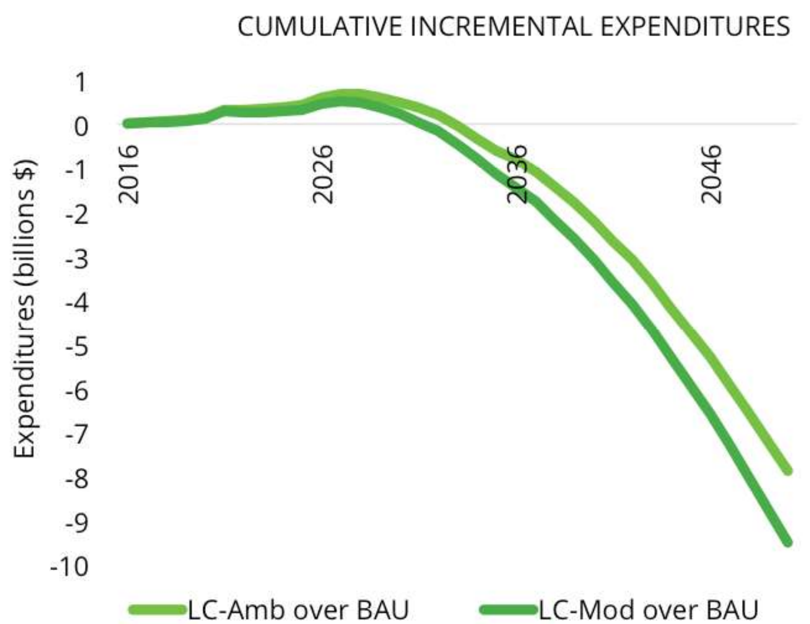


Figure 141. Trajectory of savings versus investments for the low carbon scenarios, constant $.

LC-amb shifts from incremental costs to savings over BAU in 2028.

12.5 EMPLOYMENT IMPACTS

The employment impact of the investments is represented in Figure 142, generated by applying a multiplier for direct employment to the investments in each category. Total additional person-years peaks at 2,000 in 2036 as a result of the additional investments in the LC-amb. In total, an additional 35,400 person-years of employment are generated between 2018 and 2050 in LC-amb and 19,5000 in LC-mod.

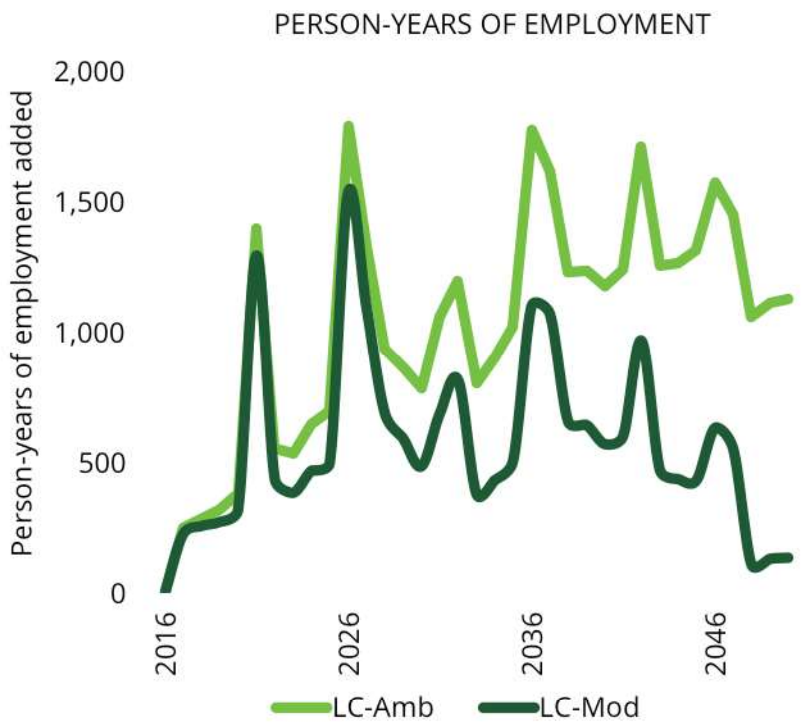


Figure 142. Net person-years of employment.

The investments associated with LC-amb result in 35,000 person years of employment over the period of 2018 to 2050.

Figure 143 illustrates the source of the person-years of employment. In some cases, employment declines in certain sectors, for example in the construction and maintenance of personal vehicles, as the overall size of the fleet is reduced due to vehicle sharing. The dark blue bars represent employment that is associated with manufacturing and maintaining vehicles; most of these job losses are anticipated to be outside of Markham, but as vehicles become increasingly technology oriented, Markham may be able to attract new jobs in this sector. Employment in retrofits and high performance homes and buildings is by definition located in Markham, as is employment in decentralized energy; these are the primary opportunities for new employment.

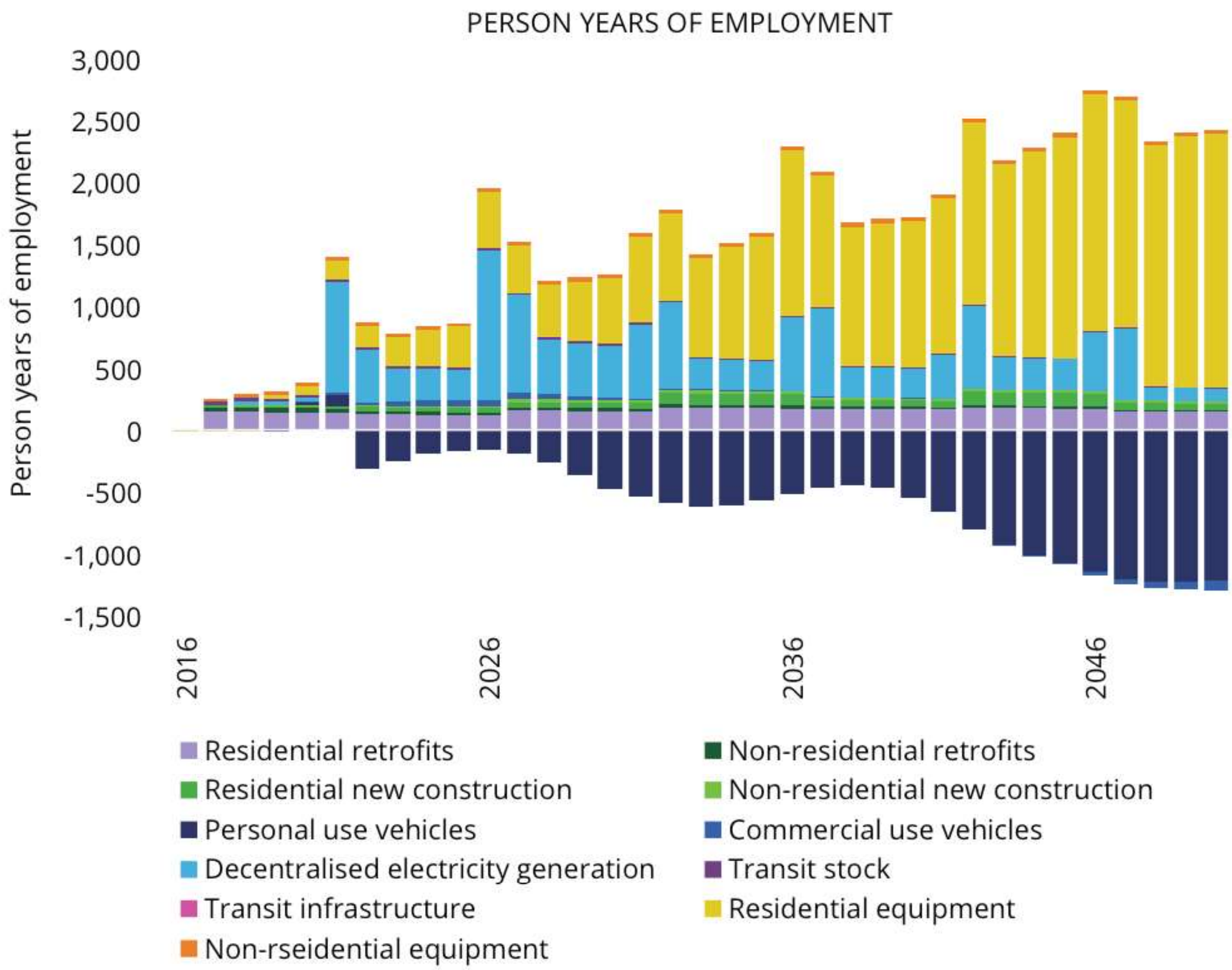


Figure 143. Employment by sector.

12.6 GETTING ALL THE WAY TO NET ZERO HAS ADDITIONAL COSTS

In LC-amb, there is 10.211 PJ of electricity being consumed from the grid, resulting in the remaining wedge of emissions. There are two options for achieving net zero – purchasing carbon offsets or purchasing zero carbon or green energy. The purchase of green energy requires a purchase of 10.211 PJ of green energy to ensure there are no GHG emissions associated with electricity consumption.

Assuming that the net zero target would not actually be achieved until 2050, the following costs would be involved for each of these strategies.

Table 18. The additional cost of net zero.

STRATEGY	COST PER UNIT	NUMBER OF UNITS	TOTAL COST IN 2050
CARBON OFFSETS	$20[35]	160,000 tCO2e	$3.2 million per year
GREEN ENERGY	$0.03/kWh[36]	2,834 MWh (10.211 PJ)	$85 million per year

The approach of purchasing green electricity to displace electricity consumed from the grid is significantly more expensive. This cost is higher than purchasing offsets because electricity is relatively clean, so the GHG emissions associated with each unit of electricity are low, so the offsets required are disproportionately small.

The City of Markham also has the option of purchasing offsets prior to 2050, but the cost would be higher, as the GHG emissions are higher. Purchasing green energy, on the other hand, would not completely eliminate GHG emissions prior to 2050, as some natural gas is still consumed.

Both the purchase of offsets and the purchase of green energy require the development of specific criteria and careful evaluation to ensure that the approach is credible and ethical.

34 This is an average cost in 2017; offset costs range from $17 to $40/tonne.

35 This is a premium for green energy: https://www.economics.utoronto.ca/public/workingPapers/tecipa-478.pdf.

4 Implementation

IMPLEMENTATION FRAMEWORK FOR BUILDINGS AND RENEWABLE ENERGY

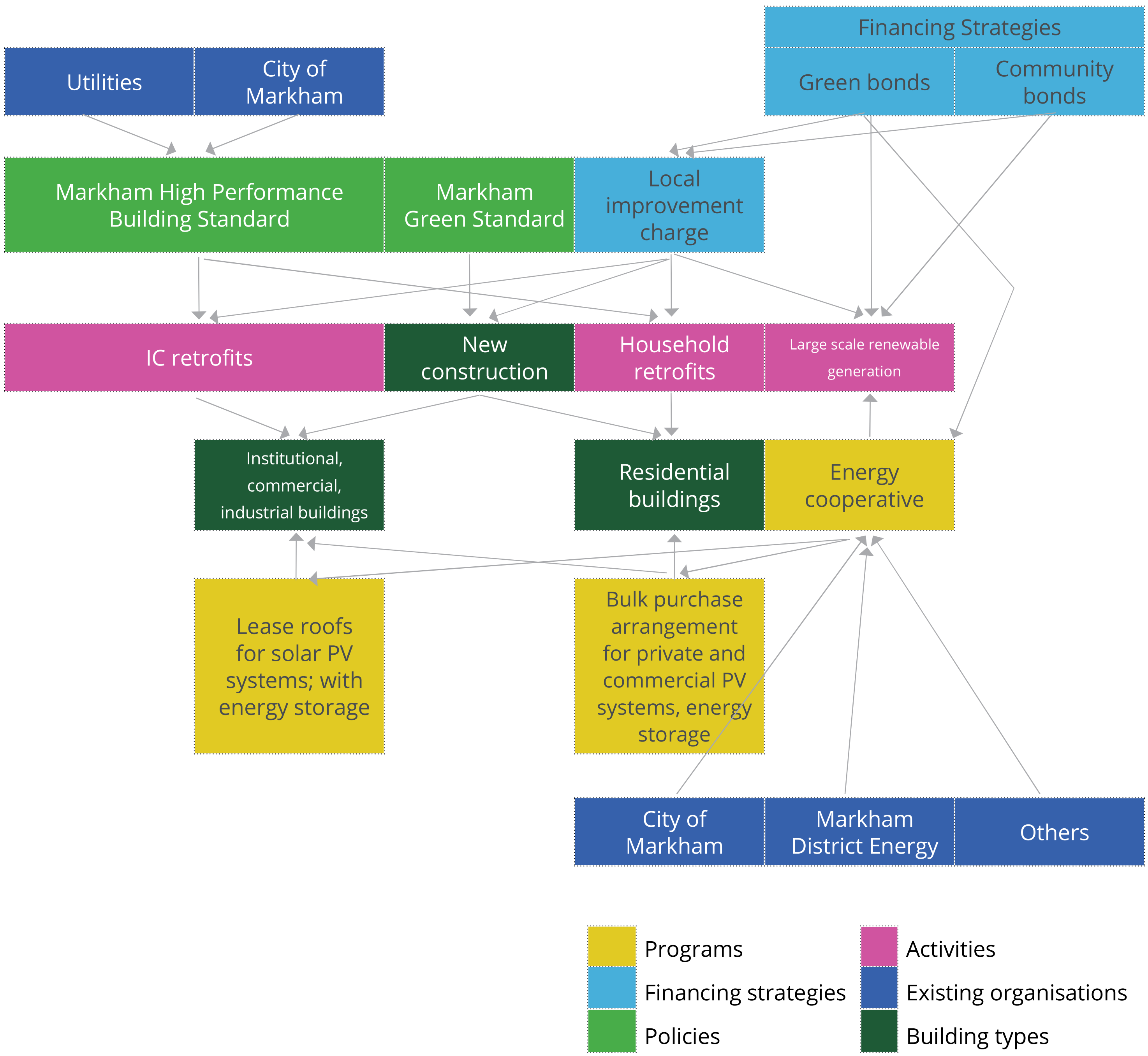


Figure 144. Implementation framework for buildings and renewable energy.

13 Transformation through innovation

The ambitious low carbon scenario represents a pathway to achieve the net zero energy emissions target. The pathway consists of actions in the sectors of buildings, energy and transportation. The implementation of each of the actions requires collaboration by a range of partners and the role of the City of Markham varies for each action. Different policies and mechanisms will be used to support the implementation of the actions. The actions scale up over time so the initial phases include a period of pilot projects and building capacity as the City learns which approaches are more effective. Learning from this process is facilitated through monitoring and evaluation as insights are gained and technologies and methods evolve or transform. The implementation plan includes five key aspects: programs, capacity, finance, communications and engagement, and monitoring and evaluation.

Table 19. Implementation components.

IMPLEMENTATION ASPECTS	DESCRIPTION
PROGRAMS	Programs are the mechanisms that the municipality uses to achieve the GHG emissions reductions. Programs may consist of policies, incentives, regulations and information.
CAPACITY	Capacity includes the resources and expertise to deliver the programs.
FINANCE	The source of funds to enable the programs.
COMMUNICATIONS AND ENGAGEMENT	The process of ensuring citizens are aware of and engage with programs.
MONITORING AND EVALUATION	The process by which the City learns from implementation of programs and makes adjustments.

13.1 MAPPING THE ACTIONS TO STRATEGIES

Each of the actions is supported by programs, capacity and a financing strategy, and in many cases the same strategy can address multiple actions. A number of the strategies build on efforts already underway by the City of Markham or strategies that have been implemented in other jurisdictions in Ontario.

Table 20. Implementation mechanisms .

	PROGRAMS	CAPACITY	FINANCE	ENGAGEMENT	EVALUATION
NEW CONSTRUCTION					
Residential - New residential housing development targets net zero, incl. solar PV	Markham Green Standard (applies to new construction)	City of Markham Planning	Local improvement charge (potential) +other incentives	Net zero engagement strategy	Net Zero Monitoring and Evaluation Strategy
Multi-residential & commercial and institutional- Passivehouse standard applied to multi-unit residential, commercial and institutional buildings					
Renewable energy installation requirements or incentives on multi-res, commercial and institutional buildings					
EXISTING BUILDINGS					
Retrofit homes prior to 1980	Markham High Performance Buildings Initiative (applies to existing buildings)	City of Markham, utilities	Local improvement charge	Net zero engagement strategy	
Retrofit homes after 1980					
Retrofits in ICI sector					
Retrofits of multi-residential					
Re-commissioning of buildings			Utility partnerships		
Renovation threshold requirement to meet codes and standard	Markham Green Standard	City of Markham Planning	Local improvement charge		

	PROGRAMS	CAPACITY	FINANCE	ENGAGEMENT	EVALUATION
RENEWABLE ENERGY GENERATION, BUILDING SCALE					
Installation of heat pumps: air and ground source residential (existing buildings)	Markham High Performance Buildings Initiative	City of Markham, utilities, private sector	Local improvement charge	Net zero engagement strategy	
Installation of heat pumps: air and ground source commercial (existing buildings)					
Solar PV - net metering all existing buildings	Markham Energy Co-operative				
Solar heating/hot water					
LOW OR ZERO CARBON ENERGY GENERATION					
Solar PV - ground mount	Markham Energy Co-operative	Private sector	Green/climate bonds	Net zero engagement strategy	
Switch district energy to renewable natural gas	Markham District Energy Corporation/ Markham Energy Co-operative/ Markham Green Standard	Markham District Energy Corporation			
Energy storage		Markham District Energy Corporation, private sector			
Renewable natural gas	Markham Energy Co-operative	Private sector	To be identified		

<table>
<tr><th></th><th>PROGRAMS</th><th>CAPACITY</th><th>FINANCE</th><th>ENGAGEMENT</th><th>EVALUATION</th></tr>
<tr><td colspan="6">TRANSPORT</td></tr>
<tr><td>Electrify transit system</td><td>Markham Electric Vehicle Strategy</td><td rowspan="3">City of Markham</td><td rowspan="3">Infrastructure funding</td><td rowspan="5">Net zero engagement strategy</td><td rowspan="5"></td></tr>
<tr><td>Increase/improve cycling & walking infrastructure</td><td rowspan="2">City of Markham</td></tr>
<tr><td>Car free zones</td></tr>
<tr><td>Electrify personal vehicles</td><td rowspan="2">Markham Electric Vehicle Strategy/ Markham Green Standard</td><td rowspan="2">City of Markham, businesses</td><td rowspan="2">Non financial</td></tr>
<tr><td>Electrify commercial vehicles</td></tr>
</table>

13.2 PROGRAMS

13.2.1 Markham Green Standard

SECTOR: BUILDINGS

DESCRIPTION

The Markham Green Standard (MGS) is a parallel effort to Toronto's Green Standard (TGS), which requires minimum energy performance when approving zoning bylaw amendments, site plans and draft plans of subdivision.[1] The City of Toronto has developed a specific pathway to net zero emissions buildings. The City of Markham can synchronize with that program for new development. The new version of the TGS uses a performance-based approach for buildings (addressing the difference in types of buildings In Markham and Toronto), which incrementally increases over time, providing certainty to developers and the building industry. Additionally, the incremental costs for the standards were assessed for different building types and the incremental cost was 6% or less. The TGS includes three types of intensity targets – a total energy demand, a thermal energy demand, and GHG intensity, which apply to Part 3 buildings.

It is recommended that Markham also establish targets for net zero energy for single family dwellings, which TGS does not cover. The City is currently developing a Net Zero Energy and Emissions pilot project which will help to inform the direction of the residential component of the the MGS.

LEAD DEPARTMENT	City of Markham Planning	PARTNERS	City of Toronto
OBJECTIVES	The Green Standard seeks to encourage high quality construction while incrementally increasing the energy performance of new buildings and community design. New performance standards are required but higher levels of performance can be achieved in exchange for incentives.		
RISKS	The standard will require education of the building industry in the City of Markham; incentives and financing strategies will be key to ensuring the feasibility of the strategy in order to address up front costs.		
CO-BENEFITS	The quality of buildings will increase, as well as indoor air quality, with improved health outcomes. The resilience of buildings will also increase against extreme weather events. Household and business energy costs will be reduced.		

1 For details on the updated TGS, see The City of Toronto Zero Emissions Building Framework: https://www1.toronto.ca/City%20Of%20Toronto/City%20Planning/Developing%20Toronto/Files/pdf/TGS/Zero%20Emissions%20Buildings%20Framework%20Report.pdf

CAPITAL REQUIREMENTS	Residential buildings: $230 million Multi-unit residential, commercial and institutional buildings: $164 million
RETURN ON INVESTMENT	Residential buildings: 177% Multi-unit residential, commercial and institutional buildings: 223%
OPERATING COSTS	The program will require incentives to encourage builders to achieve higher levels of energy performance, a capacity building strategy, and a communications strategy to support its implementation.
FUNDING OPPORTUNITIES	The standard would be accompanied by a Local Improvement Charge (assuming favourable legal opinion) to offset additional upfront capital costs and distribute the savings over time. In addition there are other incentives that can be incorporated into the requirement, such as: • Savings By Design: An incentive to support high performance building design offered by Enbridge Gas Distribution: High Performance New Construction. • The Independent Electricity System Operator offers packages of incentives according to specific types of energy savings measures. Canadian Mortgage and Housing Corporation (CMHC) Green Home: CMHC offers premium refunds to homeowners who purchase condominium units in high performance buildings.
STAFF REQUIREMENTS	If the City of Toronto's standard is applied, development costs will be minimal. Administration would be managed by City of Markham Planning as a new program.
INITIAL TASKS	Explore program design with the City of Toronto. Plan a program launch for 2018, using green standard work that has already been completed by the City.

Table 21 illustrates the targets for the TGS/MGS for multi-unit residential buildings.

Table 21. Targets for low-rise residential buildings.

TIER	NEW TGS TARGETS			
	ENERGY USE INTENSITY (KWH/m^2)	THERMAL ENERGY DEMAND INTENSITY (KWH/m^2)	GHG INTENSITY ($kgCO_2e/m^2$)	OVERALL % CHANGE IN CONSTRUCTION COSTS
SB-10	235	87	32	N/a
TGS V2 T1	198	97	28	1%
TGS V2 T2	165	65	20	2%
T1	165	65	20	2%
T2	130	40	15	3%
T3	100	25	10	7%
T4	70	15	5	4%

Table 22 illustrates the number of dwelling units targeted for the standard on five-year increments, targeting 1,005 by 2030. A similar approach is applied to non-residential buildings.

Table 22. Number of dwelling units that achieve the MGS/net zero target on a five-year increment.

DWELLING UNIT TYPE	2016	2021	2026	2031	2036	2041	2046	2051
SINGLE DETACHED	0	1295	2140	1752	5677	1962	5677	1962
DOUBLE DETACHED	0	235	415	318	407	249	407	249
ROW HOUSE	0	185	481	504	703	333	703	333
APARTMENT	0	11	23	46	44	29	44	29

13.2.2 Markham High Performance Building Initiative

SECTOR: BUILDINGS			
DESCRIPTION Markham High Performance Building Initiative will support building retrofits in the residential, commercial and industrial sectors as well as building recomissioning. Specific programs will be developed for each sector using the local improvement charge mechanism. See Appendix 7 for more details on local improvement charges.			
LEAD DEPARTMENT	City of Markham or a third party entity	PARTNERS	Utilities
OBJECTIVES	The initiative will coordinate local improvement charge (LIC) programs for each sector, including marketing, education and outreach, participation for property owners and service providers, and integration with other incentive programs. The City can explore neighbourhood scale retrofits using the LIC, where all the dwellings or buildings in a neighbourhood agree to participate in order to achieve economies of scale and increased visibility.		
RISKS	Uptake of the LIC program may be slow. Identification of new opportunities and programs along with successful marketing and engagement will be essential to accelerating the voluntary participation of individual building and portfolio owners.		
CO-BENEFITS	Building retrofits increase indoor air quality, and reduce household and business energy costs.		
CAPITAL REQUIREMENTS	Retrofit pre-1980 homes: $54 million Retrofit post-1980 homes: $213 million Retrofit industrial and commercial buildings: $83 million Retrofit multi-unit residential: $73 million Recommissioning on non-residential and MURBs:$19 million		
RETURN ON INVESTMENT = (total savings-initial investment)/initial investment	Retrofit pre-1980 homes: -7% Retrofit post-1980 homes: 22% Retrofit industrial and commercial buildings: 311% Retrofit multi-unit residential: -87% Recommissioning on non-residential and MURBs: 219%		

OPERATING COSTS	Costs will include staff time, marketing, education and outreach, and administration of the LIC program. These costs can be incorporated into the cost of delivery of the LIC.
FUNDING OPPORTUNITIES	The City can partner with utilities to offer comprehensive building retrofit packages, using the model of Toronto's Better Building Partnership[2]
STAFF REQUIREMENTS	Initially 0.5 full time equivalent (FTE) employees, reaching 2 FTE by 2020.
INITIAL TASKS	Develop the LIC program, seek an envelope of capital funding and launch in 2018.

Table 23. Number of dwelling units targeted for retrofits in five-year increments, targeting 100% of pre-2016 buildings by 2050.

DWELLING UNIT TYPE	2016	2021	2026	2031	2036	2041	2046	2051
SINGLE DETACHED	0	3,268	4,118	5,226	6,676	8,586	11,117	13,737
DOUBLE DETACHED	0	134	180	242	328	447	612	790
ROW HOUSE	0	101	134	178	237	319	432	553
APARTMENT	0	2	2	2	2	3	3	4

Table 24. Total non-residential buildings targeted for retrofits, targeting 100% of pre-2016 buildings by 2050.

BUILDING TYPE	2021	2026	2031	2036	2041	2046	2051
RETAIL	19	63	102	136	166	192	211
WAREHOUSE	4	13	22	29	35	41	45
EDUCATION	6	18	30	40	48	56	61
INSTITUTION	8	25	41	54	66	77	84

13.2.3 Markham Energy Co-operative

SECTOR: ENERGY			
DESCRIPTION The City of Markham has specific expertise in solar PV and district energy. Building on this expertise, an arm's length energy cooperative can be launched with the mandate of achieving the renewable energy goals in the MEP. Designed as a multi-stakeholder cooperative, members can include the City, utilities, businesses and individuals. Financial returns will go to the members, as a way to increase the local capture of energy dollars.			
LEAD DEPARTMENT	City of Markham	PARTNERS	Utilities, businesses, individuals
OBJECTIVES	The co-operative will have four primary objectives: firstly to bulk purchase and install solar PV or other renewable energy systems on behalf of local residents and businesses; secondly to develop small scale projects by leasing roof space on dwellings and businesses; thirdly to contract with the private sector on large scale renewable energy projects on behalf of the City, residents or other parties; and fourthly to develop projects itself.		
RISKS	The cooperative may not be able to raise the required funds. The strategy should also include provision for the development of other zero carbon transportation technologies such as hydrogen.		
CO-BENEFITS	The co-operative can be a significant source of local investment and can generate financial returns and employment opportunities for local residents.		
CAPITAL REQUIREMENTS	Solar PV- net metering: $258 million Solar hot water- $109 million Solar PV ground mount- $$63 million Energy storage- $186 million		
RETURN ON INVESTMENT	Solar PV- net metering: -6% Solar hot water- 115% Solar PV ground mount- 94% Energy storage- 92%		
OPERATING COSTS	The start-up costs of the co-operative are estimated at $250,000 for the first year.		
FUNDING OPPORTUNITIES	Additional funding opportunities include the Canada Infrastructure Bank and the Green Bank (Ontario), as well as the Municipal Challenge Fund		

STAFF REQUIREMENTS	Initial volunteer board, with 1 FTE.
INITIAL TASKS	Incorporate the cooperative, identify membership, launch the first project.
TIMELINE	Fall 2018.

13.2.4 Markham Electric Vehicle Strategy

SECTOR: TRANSPORTATION

DESCRIPTION

The Electric Vehicle Strategy will be a multi-departmental coordinated effort by the City to support the increased uptake of electric vehicles. Strategies will include preferential parking rules, an enhanced network of appropriate charging stations, requirements for charging stations in buildings, and other supports.

LEAD DEPARTMENT	Markham Sustainability Services	PARTNERS	Multi-departmental effort
OBJECTIVES	The objectives of the strategy are informed by the City of Vancouver's Electric Vehicle Ecosystem Strategy.[3] The objectives include the following: 1. Maximize access to EV charging; 2. Improve community experience and knowledge in vehicle charging; 3. Displace fossil fuel kilometres travelled with electric kilometres; 4. Create the conditions for EV infrastructure to eventually be a viable private enterprise option; 5. Establish an electric vehicle ecosystem to support the net zero strategy.		
RISKS	The uptake of electric vehicles in the City of Markham is dependent on factors that are not directly within the City's control, although the City can influence factors which support uptake, such as infrastructure.		
CO-BENEFITS	Through the reduced combustion of fossil fuels, the transition to electric vehicles improves air quality and reduces noise from traffic. Air pollution directly influences the health of the population, particularly the elderly and children.		
CAPITAL REQUIREMENTS	The City has access to long-term capital, and can act as an early supporter of the EV charging market that will reduce the future business risk in public charging investments. Electrify personal vehicles: $2.2 billion Electrify commercial vehicles: $71 million		

RETURN ON INVESTMENT	Electrify personal vehicles: -35% Electrify commercial vehicles: 879%
OPERATING COSTS	To be identified
FUNDING OPPORTUNITIES	Federal and provincial infrastructure funding programs.
STAFF REQUIREMENTS	It is anticipated that 1 FTE would be required to support the Electric Vehicle Strategy.
TIMELINE	2018

2 City of Vancouver (2016). EV Ecosystem Strategy. Retrieved from: http://vancouver.ca/files/cov/EV-Ecosystem-Strategy.pdf

13.2.5 Low carbon city planning

SECTOR: INTEGRATED LOW CARBON CITY PLANNING			
DESCRIPTION			
Many of the enabling conditions for low carbon strategies result from city planning. Wherever possible, the City should support land-use patterns focussed on complete, compact community design to enable district energy, walking and cycling, and frequent transit. The City has developed a terms of reference for community energy planning which aims to achieve these objectives at the scale of secondary plans.			
LEAD DEPARTMENT	City Planning	PARTNERS	Markham Sustainability Services
OBJECTIVES	Incorporate analysis and modelling of energy and emissions in all major planning exercises so that land-use planning contributes to the net zero energy emissions objective. This includes three key tasks: 1. Requiring and implementing community energy plans for secondary plans, and energy strategies for major developments; 2. Incorporating the net zero target into transportation planning; 3. Applying the Green Standard through conditions of approval for development applications; and, 4. Integrating net zero targets into Official Plan updates. All plans should be demonstrably aligned with the targets of the Greenprint and the MEP.		
RISKS	There are no major risks		
CO-BENEFITS	Land-use planning that achieves low carbon objectives also results in a healthier, more vibrant community, reduces municipal servicing costs, and increases resiliency.		
CAPITAL REQUIREMENTS	There are no direct capital requirements; this strategy is an enabling approach. There are capital requirements associated with transforming existing, and adding new, infrastructure in order to support added density and new uses in existing residential areas.		
RETURN ON INVESTMENT	Not relevant		
OPERATING COSTS	The City may need to integrate additional expertise into City planning processes but there are no ongoing operating cost requirements.		
FUNDING OPPORTUNITIES	Funding is available from an upcoming provincial program to support low carbon planning and from the Federation of Canadian Municipality's (FCM) Green Municipal Fund to support planning projects. Major financing programs will be required to support the transition of infrastructure over the medium and long term, with supportive governance structures.		
STAFF REQUIREMENTS	Additional staff will be required in the medium term to implement capital programs.		
TIMELINE	Ongoing		

13.3 FINANCING

13.3.1 Local improvement charge

The City of Markham can use Local Improvement Charges (LICs), a financing mechanism authorized by O.Reg. 322/12 under the Municipal Act, 2001 for building retrofits, and assuming that a future legal opinion identifies LICs are also applicable, for the cost increment of new construction of high performance houses and buildings over the building code. For details on the LIC program, see Appendix 7.

Local Improvement Charges (LICs) are a municipal financing mechanism that allows a municipality to enable up-front financing of private environmental retrofits. Key benefits of this mechanism include the following:

- The LIC enables a stewardship approach to the property by the owner who undertakes the retrofits, as the LIC financing is provided up front to the owner with payments made by that owner and any successive owners of the house until the LIC is paid off.
- Since the LIC is provided over longer terms than banks can provide and at a fixed rate, deeper and more affordable deep retrofits can be undertaken over 10, 15 or 20 year periods. The LIC can be designed so that savings exceed payments on an annual basis.
- Because the financing is associated with the property and not the owner, if the owner moves before the LIC is repaid, the next owner continues making the payments and benefiting from the improvements.
- The LIC can be repaid on the property tax bill, which provides security to the municipality since any defaulted payments can be treated like taxes and therefore become subject to a priority lien that is paid out before mortgages on the property. This security is reflected by a lower investment rate.

LICs can be applied to all types of buildings and real property, including conservation authority property and school board property, but cannot be applied to buildings owned by the City or crown properties.

- LICs cannot be used for equipment that is moveable property, i.e. chattels.
- LICs can be used by owners of leased premises and by lessees or sub-lessees under certain conditions.
- LICs are unlikely to be used for brownfield sites because of the risk they pose.
- LICs can finance district energy system connections on private property.
- LICs are not a loan to the owner, but if repayments of LICs are overdue, the overdue payments become a tax lien and the entire amount of the LIC does not become due.
- LICs run with the land.
- Owners can be notified by municipalities of LICs via bills for property taxes, water or garbage.

Table 25. Examples of the assumptions used to model an LIC program for Markham.

CATEGORY	ASSUMPTION
HOME ENERGY RETROFITS	Approximately 25–35% of retrofits planned each year for applicable sectors are presumed to be financed by LICs: this proportion grows in each sector and is fairly moderate.
RENTAL APARTMENT BUILDINGS	A higher proportion of rental apartment buildings are assumed to be financed via LICs. Although there is an absence of data on the relative numbers of rental buildings vis-à-vis condominiums, it is further assumed that obtaining condo owners' permissions to engage in retrofits would be more difficult such that fewer condominiums would be retrofitted. The relative proportion then of the apartment building retrofits and of the high performance new constructions are assumed to be in the same range as the residential sector: approximately 25–35%.
EXISTING COMMERCIAL AND INSTITUTIONAL BUILDINGS	Estimates for the purposes of this study are for across-the-board retrofits for targeted building segments based on the prior assumptions: that is, 25–35% of retrofits for pertinent sectors would be anticipated to be financed using LICs.

Table 26. LIC investments and impacts of those investments.

RESIDENTIAL RETROFITS INVESTMENTS/IMPACTS	TOTALS 2019–2051 (CONSTANT DOLLARS)	RESIDENTIAL RETROFITS INVESTMENTS/IMPACTS IN 2019 (CONSTANT DOLLARS)
CAPITAL COSTS	$380,000,000	$2,000,000
LIC IMPACTS: FUEL COST SAVINGS	$69,191,880	$193,985
LIC IMPACTS: ENERGY COST SAVINGS	$4,208,333	$17,412
NON-RESIDENTIAL RETROFITS INVESTMENTS/IMPACTS	Totals 2019–2051 (constant dollars)	Non-Residential Retrofits Investments/ Impacts in 2019 (constant dollars)
CAPITAL COSTS	$58,500,000	$1,500,000
LIC IMPACTS: FUEL COST SAVINGS	$27,966,555	$729,943
LIC IMPACTS: ENERGY COST SAVINGS	$2,273,791	$50,839
RESIDENTIAL NEW CONSTRUCTION NET ZERO / PASSIVE HOUSE INVESTMENTS/IMPACTS	Totals 2019–2051 (constant dollars)	Residential New Construction Net Zero / Passive House Investments/Impacts in 2019 (constant dollars)
CAPITAL COSTS	$105,000,000	$500,000
LIC IMPACTS: FUEL COST SAVINGS	$18,664,307	$62,455
NON-RESIDENTIAL NEW CONSTRUCTION PASSIVE INVESTMENTS/IMPACTS	Totals 2019–2051 (constant dollars)	Non-Residential NC Passive Investments/ Impacts in 2019 (constant dollars)
CAPITAL COSTS	$28,400,000	$300,000
LIC IMPACTS: FUEL COST SAVINGS	$12,487,070	$86,037

An analysis of the data indicates the following:

LIC program could be delivered on a cost-neutral basis for owners: Using a very rough calculation, it appears that amortizing the first year's (2019's) investments over 15 years with monthly payments at rates of up to 7% show the total fuel and energy savings in the first year would exceed annual payments in every category. Although 7% may be too high to generate market interest, the intent of this particular calculation is to demonstrate that even at that rate the owner would have a net benefit.

LIC program could be delivered on a cost-neutral basis for the City of Markham: There seems to be a very broad interest rate spread that can accommodate program expenses for a cost-neutral program delivery (if that is the sole method of program cost recovery). That is, if rates remain about in the current range, since Infrastructure Ontario financing to municipalities is now less than 3.1% over 15 years, the program would seem to be deliverable on a cost neutral basis. For example, if program costs at the outset are at about 12% of the financing (a high but very conservative estimate), and later falls to about 5% of financing in subsequent tranches; and if ongoing program costs are anticipated to be incurred for each tranche over the duration of the financing, one way to consider cost-neutral feasibility is to look at the difference in interest to be paid by an owner on $500,000 between a rate of 3.1% ($82,138) that the municipality would pay and (for example) 5.5% ($151,157) that the owner would pay. This roughly amounts to $69,000 interest to be paid over the term to cover the program costs of 12% of $500,000 or $60,000 incurred over the term in this early tranche.

Local Improvement Charges are one tool that the City of Markham can use in achieving net zero community energy efficiency targets over the long term. **LICs are a feasible method to achieve net annual savings on owners' energy and fuel utility bills**. An analysis of the Markham Energy Descent Plan data indicates that payments exceed costs on an annual basis resulting in a cost-neutral owner benefit. This approach includes a moderate use of LICs to support the costs of achieving higher performance via retrofits, and via enhancements over code for new construction. Additionally, further analysis of the Markham Energy Descent Plan data indicates that **LIC programs could be delivered on a basis that is cost neutral to the City of Markham.**

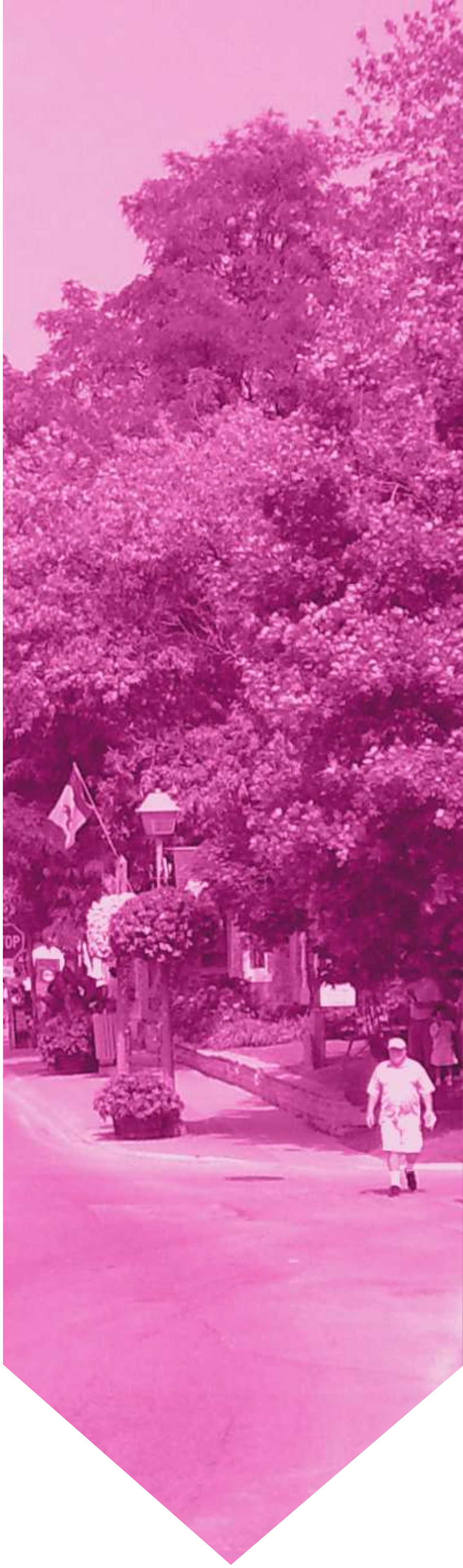
13.3.2 Climate bonds/green bonds

Green or Climate Bonds are any type of bond instruments where the proceeds will be exclusively applied to finance or refinance in part or in full new and/or existing eligible projects. Green Bonds are similar to other bonds in their payment, yield, risk, and liquidity characteristics, but differ from ordinary bonds in that they require reporting to the buyers of the bonds, generally annually, on the use of proceeds. This measurement and reporting requirement, which usually forms part of the legal bond contract, assures the bond buyer of the bond issuer's performance in carrying out the green projects for which the bond was issued.

This assurance is what makes the bond 'green' and qualifies it as a suitable investment for those buyers seeking to support the new green economy. This investor group is growing exponentially as bond investors, including institutional and commercial buyers, divest from fossil fuel support and seek replacement investment opportunities. Consequently, interest in issuing green and climate bonds is growing, in Canada and internationally.

There is a growing movement around issuing municipal bonds at the local level through web-based platforms or other mechanisms that enable local investment in renewable energy projects. Examples include community bonds and platforms such as Neighborly[3], which is currently being used in the US but has not yet been deployed in Canada.

Green or climate bonds can be a key strategy for raising funds for the LIC and for financing renewable energy projects in the City.



3 Neighborly.com. https://neighborly.com/

14 Mobilizing the community

The Municipal Energy Plan (MEP) is an ambitious plan that requires the City to significantly enhance its efforts in new and existing spheres of activity. Community engagement will be a critical element in ensuring support and participation in these activities. The following campaign is designed to engage stakeholders in the implementation of the MEP.

Table 27. Summary of the community engagement campaign.

OBJECTIVE	Create an exciting and accessible way for Markham's residents (citizens, businesses, institutions, and community groups) to partner with the City in implementing its new Municipal Energy Plan.
SUMMARY MESSAGE	Markham is committed to reaching net zero greenhouse gas emissions city-wide by 2050. Markham's Municipal Energy Plan is a road map to achieving this goal by improving energy efficiency, creating renewable energy supply, and reducing emissions – a plan that stimulates innovation, generates new business opportunities, improves air quality and health outcomes.
KEY CAMPAIGN MESSAGE	The road to a net zero Markham begins with you.

CAMPAIGN OVERVIEW	The MEP promotional campaign is Net Zero Markham. The campaign is designed to engage stakeholder partners and the community in participating in MEP implementation. The key campaign elements are: • Net Zero Markham branding and design package • Stakeholder/organizational partnerships • Campaign website and microsite • Web newsletter communications • Social media presence • Hosted and attended events • Incentive programs • Advertising

Net Zero Markham has five action themes. Table 28 summarizes the themes and some sample actions that may be included in the MEP. These themes and actions are examples of what will be promoted with Net Zero Markham campaign partners.

Table 28. Key Net Zero Markham communications themes and example actions.

REDUCING ENERGY COSTS	STIMULATING INNOVATION	CREATING NEW BUSINESS OPPORTUNITIES	LEADERSHIP IN REDUCING GHG EMISSIONS AND AIR POLLUTION	IMPROVING QUALITY OF LIFE
Building energy retrofits will reduce energy costs.	Net zero homes will result in innovations in the building industry.	Major retrofit programs will create new employment opportunities.	The City of Markham is a leader in combatting climate change.	The MEP will increase active transportation opportunities, improving health outcomes.

REDUCING ENERGY COSTS	STIMULATING INNOVATION	CREATING NEW BUSINESS OPPORTUNITIES	LEADERSHIP IN REDUCING GHG EMISSIONS AND AIR POLLUTION	IMPROVING QUALITY OF LIFE
Electric vehicles will reduce transpor-tation costs.	Energy storage will result in new technologies being deployed.	Additional deployment of solar PV and solar hot water systems will result in the development of new businesses and expansion of existing businesses.	The City of Markham has the most ambitious climate change plan in Ontario.	Neighbourhoods in Markham will be more walkable and destinations and businesses will be more accessible to all ages.
High per-formance new buildings reduce lifecycle operating costs	The large scale deployment of EVs will stimulate innovation in software, manufacturing and other sectors.	New businesses will be created in the areas of energy storage, energy monitoring, electric vehicles and high performance buildings.	Citizens in Markham are highly engaged in Markham's Municipal Energy Plan.	The MEP will improve the ability of children and adults to get around neighbourhoods and the city.
		New clean technology companies will be initiated to support the MEP.		Indoor and outdoor air pollution will be improved, decreasing hospital visits.

14.1 STAKEHOLDERS AND ENGAGEMENT ACTIVITIES

There are five key stakeholder groups. The groups will participate in the Net Zero Markham campaign in different ways. Table 29 summarizes the goals of stakeholder engagement and stakeholder participation in different engagement mechanisms.

Table 29. Stakeholder engagement actions.

	MUNICIPAL STAFF	BUSINESS COMMUNITY	COMMUNITY GROUPS	INSTITUTIONS	CITIZENS	TARGET ENGAGEMENT (# OF PEOPLE OVER 3 YEARS)
GOALS	Engage the staff in determining how MEP elements integrate into their workplans (implementation)	Engage business community champions in promoting the MEP and partnering in its implementation	Identify community champions to promote the MEP and partner in its implementation	Identify partners in MEP implementation	Engage citizens in responding to MEP challenges with individual and community actions	
STAKEHOLDER GROUP KICK-OFF MEETINGS	✓	✓	✓	✓		125
NET ZERO PARTNERS		✓	✓	✓		75
LAUNCH EVENT	✓	✓	✓	✓	✓	2,000
WEB NEWSLETTER	✓	✓	✓	✓	✓	10,000

	MUNICIPAL STAFF	BUSINESS COMMUNITY	COMMUNITY GROUPS	INSTITUTIONS	CITIZENS	TARGET ENGAGEMENT (# OF PEOPLE OVER 3 YEARS)
PUBLIC WEBSITE/ MICROSITE						5,000
PARTNERS PAGE	✓	✓	✓	✓		
BLOG POSTS	✓	✓	✓	✓	✓	
SOCIAL MEDIA	✓	✓	✓	✓	✓	100,000
COMMUNITY EVENT PARTI-CIPATION: MOBILE ENGAGE-MENT TRAILER	✓	✓	✓	✓	✓	10,000
TARGETED ADVERTIZING		✓	✓	✓	✓	150,000
INCENTIVE PROGRAMS	✓	✓		✓		25,000
ANNUAL NET ZERO EVENTS	✓	✓	✓	✓	✓	2,000

Holding kick-off meetings with each stakeholder group is important to fostering support of the Net Zero campaign. These meetings will identify and cultivate champions and establish their roles and responsibilities in the MEP implementation. Table 30 summarizes the activities of each group's kick-off meeting.

Table 30. Kick-off meetings activities.

MUNICIPAL STAFF	BUSINESS COMMUNITY	COMMUNITY GROUPS	INSTITUTIONS
• Introduction to the MEP presentation • Departmental small group working session on integrating MEP actions into workplans • Identification of next steps of MEP integration (e.g. plan updates, policy revisions) • Establishing departmental and municipal corporate-wide Green Teams and their responsibilities • Establishing reporting mechanisms • Commencing the planning of the launch event (e.g. strike a committee)	• Intro to the Net Zero Campaign presentation • Small group working session brainstorm on business community engagement opportunities (e.g. events, publications) • Video interviews with stakeholders on the business opportunities of achieving Net Zero • Establishment of roles and responsibilities of stakeholders present • Collecting partnership commitments • Collecting commitments for participation in the launch event	• Intro to the Net Zero Campaign presentation • Small group working session brainstorm on community group engagement opportunities (e.g. networks, events, publications) • Video interviews with stakeholders on the community group opportunities of achieving Net Zero • Establishment of roles and responsibilities of stakeholders present • Collecting partnership commitments • Collecting commitments for participation in the launch event	• Intro to the Net Zero Campaign presentation • Small group working session brainstorm on engagement of institution opportunities (e.g. staff/public messaging, events, publications) • Video interviews with stakeholders on the institution opportunities of achieving Net Zero • Establishment of roles and responsibilities of stakeholders present • Collecting partnership commitments • Collecting commitments for participation in the launch event

Outputs

- Municipal, corporate and community action plans for implementation
- A network of business, community, and institutional partners and champions with concrete roles and

responsibilities in carrying out Net Zero campaign promotion and MEP implementation actions

- A collection of brief video interviews for use on the Net Zero campaign website and the websites of the partners
- Identification of the roles of partners at the launch event

14.2 NET ZERO PARTNERS

The Net Zero Partners program will showcase stakeholders who partner with the City in undertaking MEP actions in their organizations or communities. Partnership will have the following benefits:

- Recognition and representation at City events
- Recognition on City websites and publications
- A Net Zero Markham partner badge to display on partners' websites
- Support in delivering energy and emissions actions in partners' organizations and communities
- Support in delivering energy and emissions incentive programs

The Net Zero partnership program is a powerful way to showcase community support for the MEP and its implementation. It also facilitates tracking progress on MEP implementation.

14.2.1 Launch Event

The Launch Event will increase the profile of Net Zero Markham with a festive atmosphere. Features of the event will include:

- Attendance of mayor, council, and staff
- Festival kick-off announcement by prominent community member
- Local musicians

- Local green business kiosks
- Posters and stickers created for partners to place in their homes/businesses/schools to indicate their participation.
- Electric vehicle test drive station
- Kiosks for discounted LED bulb sales and home energy and water efficiency systems by local businesses
- Games featuring home energy efficiency prizes
- Local food trucks/kiosks
- Green trivia stations
- Mobile engagement trailer – MEP information, home energy efficiency information, promotion of campaign partners, home-owner survey stations, etc.

Organizers will sign on partners in advance of the event, working with them to showcase their actions (e.g. schools signed on to launch their own active transportation initiatives to track and measure low-carbon travel to school).

14.2.2 Web newsletter

The Net Zero Markham newsletter will update stakeholders and the community on MEP implementation progress. The content will include:

- Feature energy and emissions actions
- Did you know? section
- Features of local green business
- Features of municipal green incentive
- Features of urban space (e.g. parklet, pedestrian space)
- Local green events
- Volunteer opportunities
- Featured partners
- Special event and holiday updates/actions
- Featured videos
- Policy updates and announcements

- Guest posts by Net Zero partners

The web newsletter will be published ahead of the launch event – distributed to the networks of the municipality and Net Zero partners – as promotion for the event. Follow up issues will be published monthly. Versions of the web newsletters will also be tailored to specific stakeholder groups.

14.2.3 Public Website/Microsite

A website specifically for Net Zero Markham would be an essential central clearinghouse for all information related to the campaign. The website would contain all information related to the campaign, from the full Municipal Energy Plan, to the partner pledge, list of partners, events, links to social media accounts for the campaign, video content, a running list of partners prominently featured on the website, and an animated video on what achieving net zero means and how community members can get involved. A call to action would be placed prominently on the page allowing visitors to join the campaign. A link to the microsite would be placed in an easy-to-navigate to spot on the City of Markham's main website. The navigation menu would include (but not be limited to) the following sections: home page, about the campaign, partners, get involved/partner pledge, connect with us, and download the Municipal Energy Plan.

14.2.4 Community Event Participation: Mobile Engagement Trailer

Markham is host to many events throughout the year. The Net Zero campaign can have a presence at these events with its Mobile Engagement Trailer. The trailer will be a portable all-in-one engagement vehicle, branded with the Net Zero Markham logo and colours. Staffed by the municipality or volunteers, the trailer would provide information, prizes, promotion items, and engagement opportunities (e.g. surveys) to festival and event participants. Having a consistent presence at Markham festivals and events, the Mobile Engagement Trailer would be a fun way to promote the campaign and get people involved.

14.2.5 Targeted Advertising

Promoting MEP actions will benefit from targeted advertising campaigns. Tailored ad campaigns can target each stakeholder group. Table 31 summarizes some examples of advertising approaches. A combination of several advertising approaches can be used for each instance of an event, incentive or promotion. Using the publications and communications channels of Net Zero Markham partners will allow for targeted engagement.

Table 31. Sample advertising strategies.

ADVERTIZING APPROACH	ADVERTIZING PURPOSE
BILLBOARDS	MEP awareness raising
PRINTED ADS IN LOCAL OR INDUSTRY PUBLICATIONS	Net Zero partner promotion
RADIO SPOTS	Green incentive program
PRINTED HANDBILLS	MEP or Net Zero Markham partner event promotion
SOCIAL MEDIA PROMOTIONS	Advertizing location of Mobile Engagement Trailer
TRANSIT/BUS SHELTER ADS	Municipal engagement event promotion
POSTERS	
PUBLIC INSTALLATION (E.G. LIGHT SCULPTURE)	
STRATEGIC PARKING OF MOBILE ENGAGEMENT TRAILER	
AD IN PARTNER PUBLICATION	

14.2.6 Annual Net Zero Markham Events

Celebrating the progress of the MEP and updating stakeholders and residents with accounts of the plan's successes, annual Net Zero Markham events will provide an anchor for the campaign's various promotional efforts. The event can have elements similar to the launch event, recurring themes, and added features each year. Creative, engaging, and dynamic elements can make the annual celebration an anticipated event.

15 Monitoring and evaluation

Many of the policies and interventions in the MEP represent enhancement efforts in existing program areas. Tracking the effectiveness of these actions helps to manage the risk and uncertainty associated with these efforts, as well as external forces such as evolving senior government policy, and new technologies which can disrupt the energy system. Key motivations for monitoring and evaluation include the following:

- Identify unanticipated outcomes
- Adjust programs and policies based on their effectiveness
- Manage and adapt to the uncertainty of climate change
- Manage and adapt to emerging technologies

Specific activities which have been identified to support the implication of the MEP include:

- an annual work plan and review,
- an annual indicator report,
- an update of the GHG inventory every two years, and
- an update of the MEP every five years.

Table 32. Monitoring and evaluation activities.

ACTIVITY	PURPOSE	DESCRIPTION	FREQUENCY
1. ANNUAL WORK PLAN AND REVIEW	Review work to-date and set annual priority actions	Annual report with prioritized actions	Annual
2. ANNUAL INDICATOR REPORT	Track effectiveness of actions	Annual report on set of indicators with an analysis of the results	Annual
3. INVENTORY	Update GHG emissions profile	Re-calculate the GHG emissions inventory	Every 2 years
4. UPDATE THE MEP	Update the MEP to reflect changing conditions	Work through each stage of the community energy and emissions planning process	Every 5 years

15.1 ANNUAL WORK PLAN AND REVIEW

An annual work plan will identify all relevant activities to achieve the actions and policies in the plan, the responsible parties, the budget and the schedule. The results of the previous year's work plan should be reviewed to inform the development of subsequent work plans.

15.2 ANNUAL INDICATOR REPORT

There are two aspects involved in the application of indicators: collecting data on indicators (monitoring), and interpreting the results of those indicators (evaluation). Over time, the City can also evaluate its effectiveness in embedding the knowledge and wisdom gained through this process into the organization.

From the perspective of the MEP, there are multiple purposes for which data is collected: to evaluate the effectiveness of the actions, to evaluate the impact of the actions on the community, and to evaluate the uptake of the lessons from the evaluation.

The City of London launches its implementation report on Earth Day each year and this approach is also recommended for the City of Markham.[4]

Table 33. Types of indicators.

INDICATOR CATEGORY	QUESTION
1. EFFECTIVENESS INDICATORS	Are the actions achieving their objectives?
2. IMPACT INDICATORS	What is the impact of the actions on the community?
3. LEARNING INDICATORS	Is the local government incorporating the knowledge gained?

The indicators identified for tracking the implementation of the community energy and emissions plan have the following characteristics:

- Process-based approach: seeks to illustrate trends rather than specific outcomes. By using process indicators it is possible to consider whether the direction of travel is correct given the current information.
- Ability to tell a story: a good indicator represents a number of different inputs and outcomes so that it provides a quick snapshot of a complex situation.
- Availability of data: local governments are already able to access the data.

Effectiveness Indicators

These indicators will be designed to evaluate whether or not policies or actions are having an effect; they will vary according to the specifics of implementation of the actions. The results of the indicators are then compared against the assumption

4 City of London's reports are available here: https://www.london.ca/residents/Environment/Energy/Pages/Energy-and-Greenhouse-Gas-Emissions.aspx

in the modelling to monitor whether or not the City is on track with projections. Indicators should be developed for each policy or mechanism. Examples might include GHG emissions reduction per investment cost, number of dwellings retrofit as a result of a retrofit program, number of EV charging stations installed as a result of an EV charging station incentive and so on.

Impact Indicators

The following indicators track macro trends and drivers of GHG emissions in the municipality; these are designed to be reported on each year.

Table 34. Recommended community-scale indicators.

INDICATOR	TREND	DATA SOURCES
TOTAL NEW DWELLINGS BY TYPE	An indication of the growth of the building stock.	Buildings permits
AVERAGE TOTAL FLOOR AREA OF NEW DWELLINGS	An indication as to whether there is more or less additional floor space to heat or cool.	Building permits
DIVERSITY OF DWELLING TYPES	An indication of the types of dwellings and whether or not they have shared walls.	Building permits
TOTAL NEW NON-RESIDENTIAL FLOORSPACE BY TYPE	An indication of the growth of the building stock.	Building permits
TOTAL DEMOLITIONS	An indication of the change in the building stock.	Demolition permits
PERCENTAGE OF NEW DWELLING UNITS THAT ARE IN CENTRES	An indication as to whether residential development is occurring in areas more appropriate for walking, cycling and transit or not.	Building permits and GIS analysis
PERCENTAGE OF NON-RESIDENTIAL FLOORSPACE THAT IS OCCURRING IN CENTRES	An indication as to whether commercial development is occurring in areas more appropriate for walking, cycling and transit or not.	Building permits and GIS analysis

INDICATOR	TREND	DATA SOURCES
NUMBER OF NEW DWELLINGS THAT ARE WITHIN 400 M OF A TRANSIT STOP	Indication of transit accessibility.	GIS layers of transit and building footprint
ANNUAL OR MONTHLY ENERGY PRICE BY FUEL (ELECTRICITY, NATURAL GAS, GASOLINE, DIESEL) ($/GJ)	Energy costs are an important indicator of opportunities for energy savings and renewable energy, household, municipal and business energy costs.	Electricity and natural gas rates are available from Ontario Energy Board. Fuels are available for major urban centres from Statistics Canada CANSIM Table 326-0009 and for specific locations from sites such as GasBuddy.com
TOTAL ENERGY CONSUMPTION BY SECTOR FOR NATURAL GAS AND ELECTRICITY (GJ)	An indication of trends in energy use in buildings.	Available on request from utilities
TOTAL SOLAR PV INSTALLS (# OF INSTALLATION)	An indication of extent of decentralized renewable energy.	Building permits.
TOTAL GASOLINE SALES ($)	An indication of GHG emissions from vehicles.	Available for purchase from Kent Group Ltd.
TOTAL VEHICLE FLEET BY VEHICLE CLASS (#)	An indication of the number of low or zero emissions vehicles and whether the fleet is becoming more or less efficient.	Available on request from MTO, or for purchase from IHS Polk.
TOTAL TRANSIT TRIPS	An indication of whether non-vehicular trips are increasing or not.	Available from the Region.
LENGTH OF PHYSICALLY SEPARATED CYCLING LANES	An indicator of opportunity for people of all ages to cycle.	Municipality

Learning Indicators

Learning indicators track the organizational response to the MEP and the lessons resulting from the implementation of the plan.

Table 35. Learning indicators.

INDICATOR	TREND	DATA SOURCE
# OF JOB DESCRIPTIONS THAT INCLUDE CLIMATE CHANGE OR GHG EMISSIONS.	Indication of the extent to which climate change planning is embedded in the organization.	Municipal data
% OF MAJOR PLANNING ACTIVITIES THAT INCLUDE CONSIDERATION OF CLIMATE CHANGE AND GHG EMISSIONS.	Indication of the extent to which climate change planning is embedded in the organization.	Assessment of plans completed (neighbourhood, community, transportation, etc).
DESCRIPTION OF MAJOR INFRASTRUCTURES PROJECTS THAT INCLUDE A GHG MITIGATION ASPECT.	Indication of how municipal expenditures are contributing to GHG emissions reductions.	Assessment of infrastructure projects.

External Reporting

The City of Markham should report to the Carbon Disclosure Project[5] (CDP) every year or every other year. CDP collects data both for the Global Covenant of Mayors and CDP's own city reporting process. Reporting to either of these two options on an annual basis provides external validation and feeds into international reporting and analysis of city action on climate change. CDP also has a benchmarking tool municipalities can use to compare their performance against other municipalities.

5 Carbon Disclosure Project. Retrieved October 18, 2017. https://www.cdp.net/en

16 Conclusion- the low carbon future beckons

Cities have a long history of addressing challenges to improve the quality of life of citizens. The transition to a low carbon economy represents an opportunity to stimulate economic development, improve quality of life, improve public health outcomes, reduce air pollution, reduce GHG emissions and generate new employment opportunities. The City is uniquely positioned to unlock opportunities such as large scale building retrofits, building-scale renewable energy generation and low carbon land-use patterns.

The pathway to net zero energy emissions is ambitious. This analysis demonstrates that this pathway is achievable, without substantially more investment in infrastructure and buildings than would occur anyway. The analysis also demonstrates that there are limited opportunities to introduce low carbon technologies, buildings and infrastructures prior to 2050, without needing to undue earlier investments. In other words, time is of essence.

The pathway requires additional investment in capacity and partnerships, as the City cannot achieve these objectives on its own. These investments build on existing and historical successes of the City, most notably in district energy, renewable energy generation and building retrofits. The City of Markham has a history of entrepreneurialism and the MEP requires more of the same.

Appendix 1 - Model assumptions

ACTION		IMPACT	MODELLING ASSUMPTIONS LC-MOD	MODELLING ASSUMPTIONS LC-AMB
BUILDINGS				
New buildings - building codes & standards				
1	Residential - New residential housing development targets net zero	Avoided thermal and electric energy	Scales up to 100% of new homes by 2030 for Part 9 residential under 5 units; Provincial target- strategy is to increase efficiency and remaining power is provided by solar PV. Applies to singles and doubles.	
2	Multi-res & Commercial - Passivehouse standard applied to multi-unit residential and commercial buildings	Avoided thermal and electric energy	Scales up to 100% of new multi res & commercial by 2030: Space Heat Demand < 15 kWh/m2/yr Primary energy demand < 120 kWh/m2/yr	
3	Renewable energy installation requirements or incentives on multi-res and commercial	Fuel-shifting; Local generation	Applies to new construction not covered by action #1; PV equals +/- 25% of total energy use	

	ACTION	IMPACT	MODELLING ASSUMPTIONS LC-MOD	MODELLING ASSUMPTIONS LC-AMB
		Existing buildings - retrofitting		
4	Retrofit homes prior to 1980	Avoided thermal and electric energy	Achieve thermal savings of 40%; electrical savings of 30%: scale up rate of retrofits exponentially beginning in 2020 so that all building stock pre 2016 is retrofit by 2050	
5	Retrofit homes after 1980	Avoided thermal and electric energy	Achieve thermal savings of 40%; electrical savings of 30%: scale up rate of retrofits exponentially beginning in 2020 so that all building stock pre 2016 is retrofit by 2050	
6	Retrofits in the institutional, commercial, and industrial (ICI) sector	Avoided thermal and electric energy	Achieve thermal savings of 40%; electrical savings of 30%: scale up rate of retrofits exponentially beginning in 2020 so that all building stock pre 2016 is retrofit by 2050	
7	Retrofits of multi-residential	Avoided thermal and electric energy	Retrofit all buildings of 5 storeys or more built between 1945 and 1984. Number of retrofits increases exponentially between 2020 and 2050; Achieve 50% savings of thermal energy; 40% of electricity. Fuel switch to geothermal.	
8	Re-commissioning of buildings	Avoided thermal and electric energy	15% savings (split between thermal and electrical)- 5% of commercial buildings and multi-unit residential buildings per year.	

	ACTION	IMPACT	MODELLING ASSUMPTIONS LC-MOD	MODELLING ASSUMPTIONS LC-AMB
9	Renovation threshold requirement to meet codes and standards	Avoided thermal and electric energy	Apply enhanced building code threshold starting in 2020 (beyond 2017 update) followed by 13% improvement on a five-year increment (Energy Conservation Report, 2016/2016, Chp 5, pg 93) 10% of renos to meet threshold/standard by 2021, 25% by 2026, 50% by 2031, 75% by 2036, 100% by 2050: Apply to 2.5% of buildings per year.	
	Renewable energy generation (on-site, building scale)			
10	Installation of heat pumps: air and ground source residential	Fuel-shifting; Local generation	Residential: Air source: scale up to 30% of the residential building stock by 2050; Ground source: scale up to 20% of the residential building stock by 2050.	Residential: Air source: scale up to 50% of the residential building stock by 2050: Ground source: scale up to 50% of the residential building stock by 2050.
11	Installation of heat pumps: air and ground source commercial	Fuel-shifting; Local generation	Commercial: Air source scale up to 40% of the building stock by 2050; Ground source: scale up to 25% of the building stock by 2050	Commercial: Air source: scale up to 50% of the building stock by 2050; Ground source: scale up to 35% of the building stock by 2050
12	Solar PV- net metering all existing buildings	Fuel-shifting; Local generation	30% of consumption for building electrical load for less than 5 storeys; 10% for multi-unit and commercial, adoption rate- scale up to 75% of buildings by 2050.	

ACTION	IMPACT	MODELLING ASSUMPTIONS LC-MOD	MODELLING ASSUMPTIONS LC-AMB
13 Solar heating/hot water	Fuel-shifting; Local generation	Scale up to 40% of residential and 50% of commercial by 2050.	Residential: scale up to 60% of the building stock by 2050: Apply to 75% of the buildings hot water requirements. Commercial: scale up to 70% of the building stock by 2050. Apply to 100% of buildings hot water requirements.
ENERGY GENERATION			
Low or zero carbon energy generation (community scale)			
14 Solar PV - ground mount	Local energy generation	Install 2 MW per year between 2018 and 2050. (~240 ha in total)	
15 Switch district energy to renewable natural gas (RNG)	Fuel-shifting		Existing district energy system switches to RNG; geothermal (small fraction geothermal); small fraction biomass; 80% RNG, 10% geothermal, 10% biomass.
16 Energy storage	Fuel-shifting	Example of how a flywheel can displace a natural gas peaking plant with cost energy parameters: 20% capacity factor for flywheel storage as a backup: 10 MW by 2025; 100 MW by 2050	

ACTION	IMPACT	MODELLING ASSUMPTIONS LC-MOD	MODELLING ASSUMPTIONS LC-AMB
17 Renewable natural gas	Fuel-shifting		Incrementally increase the % of renewable natural gas, so that by 2050 100% of required natural gas is displaced by renewable natural gas.
TRANSPORT			
Transit			
18 Electrify transit system	Fuel-shifting	Electrify GO & local buses; incrementally electrify buses starting in 2020; 100% electric fleet by 2040	
Active			
19 Increase/improve cycling & walking infrastructure	Avoided transportation energy	Mode shift to 50% of the walking and cycling potential away from vehicles and driving. Use 2km for walking and 5km for cycling.	
20 Car free zones	Avoided transportation energy	Vehicular mode share in identified zones declines linearly from 2030 to 2050, reaching zero to and from those zones. Zones selection: by 2050, >150 people and jobs per hectare, roughly even split of people to jobs, close proximity to transit.	

ACTION		IMPACT	MODELLING ASSUMPTIONS LC-MOD	MODELLING ASSUMPTIONS LC-AMB
		Private/personal use		
21	Electrify personal vehicles	Fuel-shifting	Only EVs sold after 2030, incremental increase to 2030. Include AV: ownership rate declines by 50% by 2050, VKT increases by 20% by 2050.	
22	Electrify commercial vehicles	Fuel-shifting	90% electric by 2050; incremental increase from 2020-2050.	

Appendix 2- Document review list

PLAN/POLICY			
City	**Region**	**Province/Federal**	**Utilities**
Markham Official Plan	York Region Growth Strategy	Green Energy Act - Ontario Regulation 397/11	
Greenprint	York Integrated Waste Management Master Plan	PPS	
CEPs for Secondary Plans	York Region Energy Management Action Plan	Cap & Trade	
Net zero ready buildings	York Region Greening Strategy	Ontario Building code	
Markham Climate Action Plan	York Region Corporate Air Quality Strategy	Ontario Climate Change Action Plan	
Corporate Energy Management Plan		Oak Ridges Moraine Conservation Act & Plan	
Markham Strategic Plan 2015-2019			
Markham's Cycling and Pathways Master Plan			
Economic Development Strategy			
Transportation Strategy			
Markham's Roadmap to 80% Diversion - Waste			
Zero Waste			
Sustainable Purchasing Practices Guide			
By-Law 105-95 - Outdoor Water Use			
Stormwater Management Strategy			
Tree Preservation By-law			
Bird Friendly Guidelines			
Markham Food Charter			

PROGRAM/PROJECT

City	Region	Province/Federal	Utilities
Markham Homegrown Community & Allotment Gardens	VIVANext Highway 7 expansion	Rouge National Urban Park	
EV charging station - Civic Centre	Smart Commute	Mission Innovation	
Battle of the Buildings	York Region Water for Tomorrow Program	"The Big Move" Regional Transportation Plan	
Bayview Glen SNAP	Youth On-Board		
Markham Solar Programs	YRT School Service		
Markham Energy Conservation Office (MECO)	YRT diesel-electric and bio-diesel pilot projects		
Markham District Energy	Alternative Energy initiatives		
Active & Safe Routes to School Program			
Markham Homegrown Workshops			
Staff E-learning			
Milk Bag Program			
Recycling Initiatives			
Stormwater Management Strategy			
Trees for Tomorrow			
Emerald Ash Borer			
Pollinators Initiative			
Markham Homegrown Seed Library & Enviropacks			
Paper Reduction			
Green Fleet Program			
LEED Silver for New Construction			
Pathways and trails master plan			

INCENTIVES/FUNDING

City	Region	Province/Federal	Utilities
Markham FIT (Feed-in Tariff)			Community Energy Conservation Program (CEC) - Enbridge
Markham Environmental Sustainability Fund			Save on Energy programs - Powerstream

Appendix 3- List of Actions

Table 36. Actions matrix for LC-mod and LC-amb modelling.

	BUILDINGS	LC-MOD	LC-AMB
NEW BUILDINGS - BUILDINGS CODES & STANDARDS			
1	Residential - New residential housing development targets net zero	X	X
2	Multi-residential & Commercial - Passivehouse standard applied to multi-unit residential and commercial buildings	X	X
3	Renewable energy installation requirements or incentives on multi-res and commercial	X	X
EXISTING BUILDINGS - RETROFITTING			
4	Retrofit homes prior to 1980	X	X
5	Retrofit homes after 1980	X	X
6	Retrofits in ICI sector	X	X
7	Retrofits of multi-residential	X	X
8	Re-commissioning of buildings	X	X
9	Renovation threshold requirement to meet codes and standard	X	X
RENEWABLE ENERGY GENERATION (ON-SITE, BUILDING SCALE)			
10	Installation of heat pumps: air and ground source residential	X	X (LC-amb assumption)
11	Installation of heat pumps: air and ground source commercial	X	X (LC-amb assumption)
12	Solar PV- net metering all existing buildings	X	X

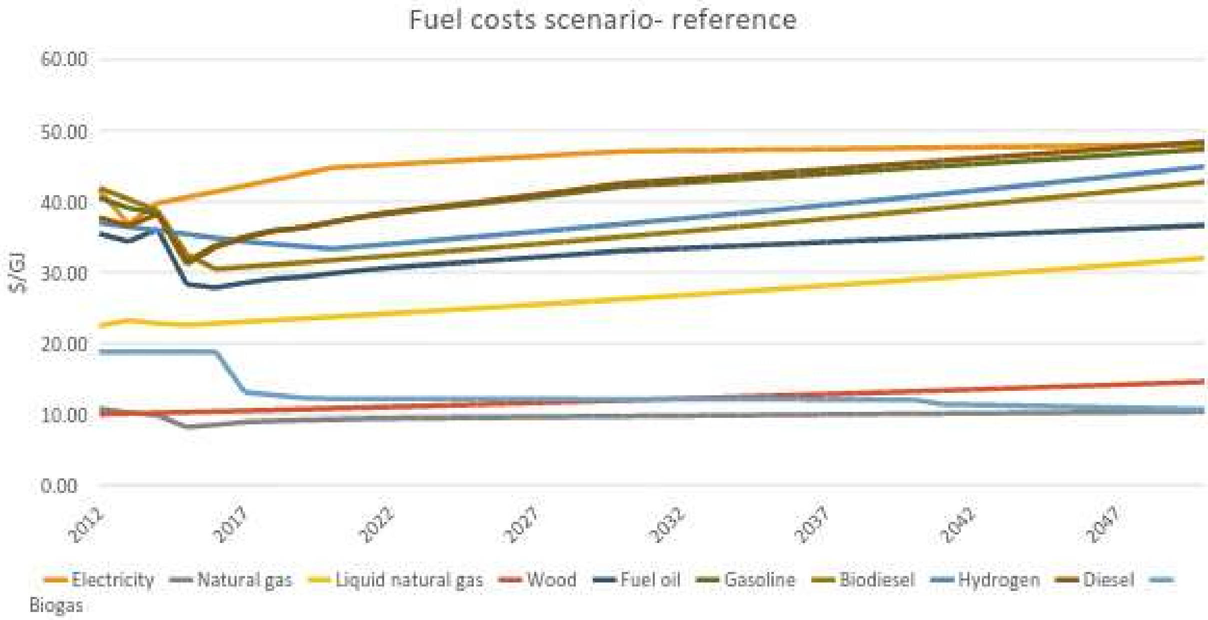
X	LC-mod assumption
X (green)	LC-amb assumption (higher level of ambition than LC-mod)

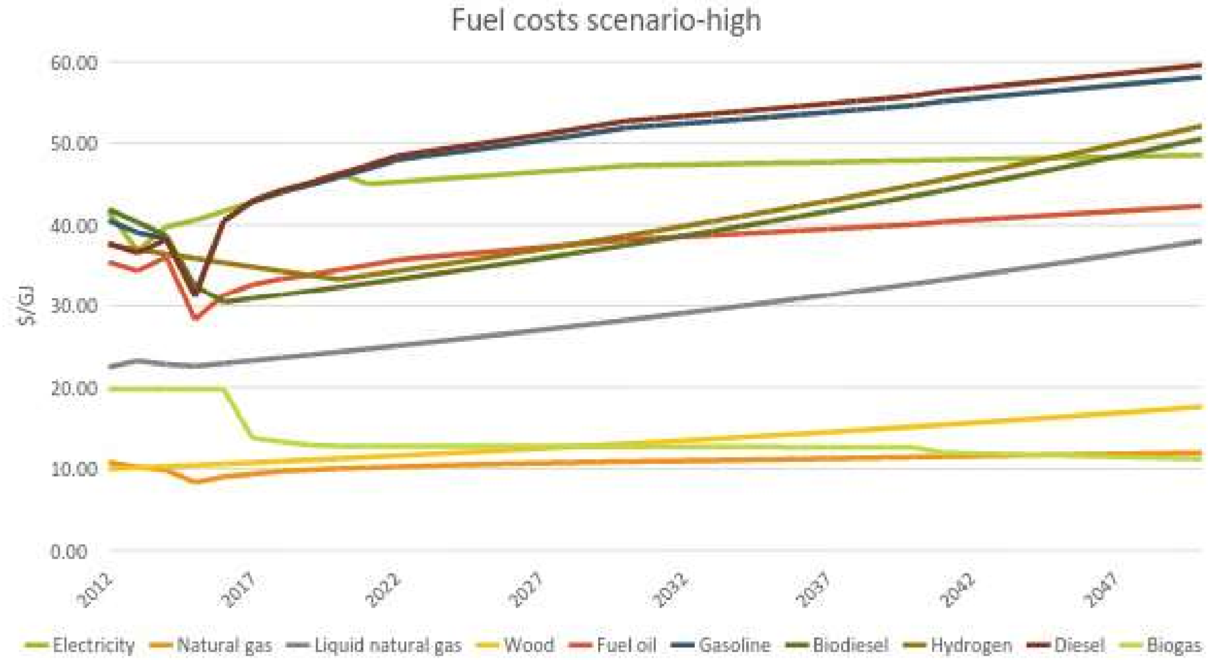
13	Solar heating/hot water	X	X
ENERGY GENERATION			
Low or zero carbon energy generation (community scale)			
14	Solar PV - ground mount	X	X
15	Switch district energy to renewable natural gas		X
16	Energy storage	X	X
17	Renewable natural gas		X
TRANSPORT			
TRANSIT			
18	Electrify transit system	X	X
ACTIVE			
19	Increase/improve cycling & walking infrastructure	X	X
20	Car free zones	X	X
PRIVATE/PERSONAL USE			
21	Electrify personal vehicles	X	X
22	Electrify commercial vehicles	X	X

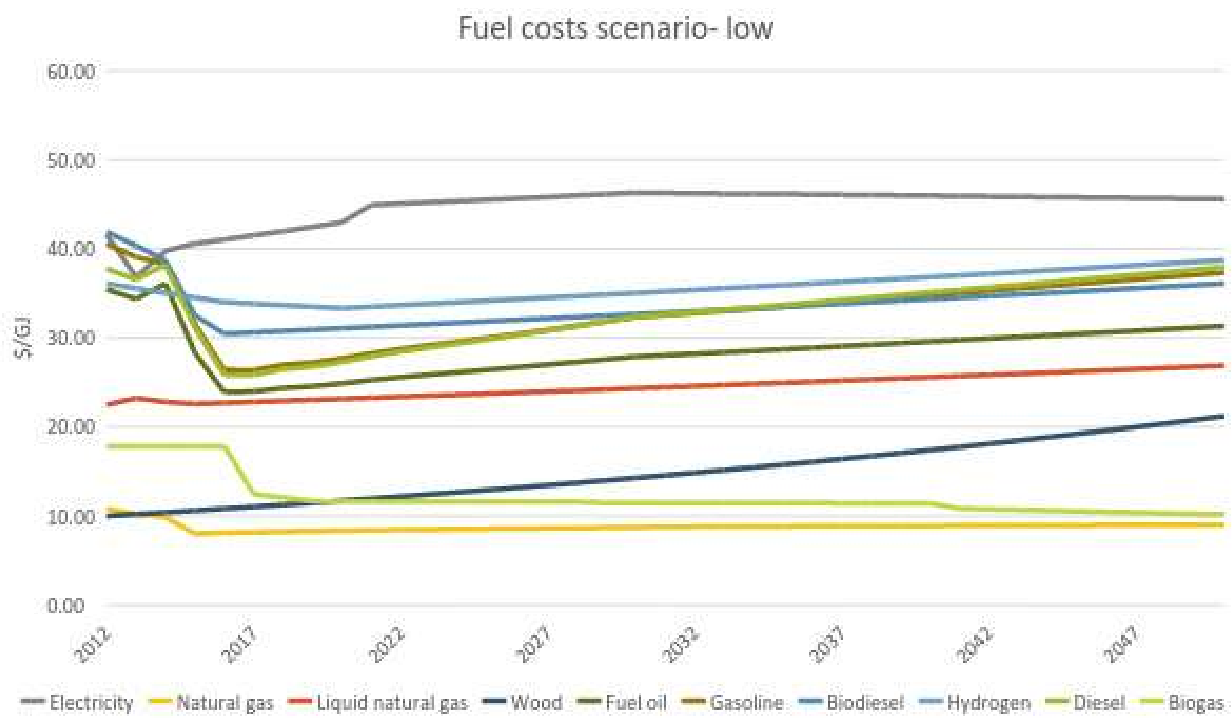
X	LC-mod assumption
X	LC-amb assumption (higher level of ambition than LC-mod)

Appendix 4- Energy cost projections

Energy cost projections were prepared based on projections from the National Energy Board's Energy Futures and the US Department of Energy.




Fuel costs scenario-high
60.00
50.00
40.00
30.00
20.00
10.00
0.00
$/GJ
2012
2017
2022
2027
2032
2037
2042
2047
Electricity
Natural gas
Liquid natural gas
Wood
Fuel oil
Gasoline
Biodiesel
Hydrogen
Diesel
Biogas


Fuel costs scenario- low
60.00
50.00
40.00
30.00
20.00
10.00
0.00
$/GJ
2012
2017
2022
2027
2032
2037
2042
2047
Electricity
Natural gas
Liquid natural gas
Wood
Fuel oil
Gasoline
Biodiesel
Hydrogen
Diesel
Biogas

Assumption/
Fuel type $/GJ ->

High	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Electricity	41.57	36.83	39.77	40.58	41.69	42.83	43.97	45.15	46.33	45.04	45.26	45.52	45.78
Natural gas	10.80	10.23	9.86	8.35	9.04	9.38	9.72	9.87	10.04	10.15	10.27	10.37	10.47
NGL	22.48	23.24	22.81	22.59	22.93	23.27	23.62	23.98	24.34	24.70	25.07	25.45	25.83
Wood	10.00	10.15	10.30	10.46	10.61	10.77	10.93	11.10	11.26	11.43	11.61	11.78	11.96
Kerosene and stove oil	35.45	34.37	36.09	28.31	31.35	32.66	33.37	33.88	34.49	35.07	35.70	36.04	36.34
Motor gasoline	40.54	39.06	38.32	31.56	40.49	42.84	44.05	44.89	45.89	46.86	47.93	48.44	48.89
Biodiesel	41.90	40.34	38.68	32.52	30.47	30.93	31.39	31.86	32.34	32.82	33.32	33.82	34.32
Ethanol	24.75	33.34	51.02	58.09	58.96	59.85	60.74	61.65	62.58	63.52	64.47	65.44	66.42
Methanol	24.75	33.34	51.02	58.09	58.96	59.85	60.74	61.65	62.58	63.52	64.47	65.44	66.42
Hydrogen	37.55	36.99	36.45	35.91	35.38	34.86	34.34	33.83	33.33	33.83	34.34	34.86	35.38
Diesel fuel oil	37.75	36.55	38.24	31.17	40.50	42.98	44.27	45.17	46.25	47.29	48.44	49.00	49.49
District energy	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50

Reference	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Electricity	41.57	36.83	39.77	40.58	41.40	42.21	43.05	43.90	44.78	45.00	45.23	45.48	45.70
Natural gas	10.80	10.23	9.86	8.18	8.52	8.92	9.06	9.17	9.26	9.36	9.42	9.48	9.51
NGL	22.48	23.24	22.81	22.59	22.82	23.04	23.27	23.51	23.74	23.98	24.22	24.46	24.71
Wood	10.00	10.10	10.20	10.30	10.41	10.51	10.62	10.72	10.83	10.94	11.05	11.16	11.27
Kerosene and stove oil	35.45	34.37	36.09	28.31	27.84	28.54	29.10	29.37	29.84	30.29	30.65	30.96	31.25
Motor gasoline	40.54	39.06	38.32	31.56	33.84	35.03	35.94	36.34	37.08	37.80	38.34	38.81	39.23
Biodiesel	41.90	40.34	38.68	32.52	30.47	30.77	31.08	31.39	31.71	32.02	32.34	32.67	32.99
Ethanol	24.75	33.34	51.02	58.09	58.96	59.55	60.15	60.75	61.36	61.97	62.59	63.21	63.85
Methanol	24.75	33.34	51.02	58.09	58.96	59.55	60.15	60.75	61.36	61.97	62.59	63.21	63.85
Hydrogen	37.00	36.45	35.91	35.38	34.86	34.34	34.00	33.67	33.33	33.67	34.00	34.34	34.69
Diesel fuel oil	37.75	36.55	38.24	31.17	33.57	34.84	35.83	36.27	37.08	37.86	38.45	38.97	39.44
District energy	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50

Low	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Electricity	41.57	36.83	39.77	40.58	41.03	41.51	41.98	42.46	42.98	44.93	45.08	45.23	45.37
Natural gas	10.80	10.23	9.86	8.01	8.13	8.18	8.24	8.30	8.35	8.41	8.46	8.49	8.52
NGL	22.48	23.24	22.81	22.59	22.70	22.82	22.93	23.05	23.16	23.28	23.39	23.51	23.63
Wood	10.00	10.20	10.40	10.61	10.82	11.04	11.26	11.49	11.72	11.95	12.19	12.43	12.68
Kerosene and stove oil	35.45	34.37	36.09	28.31	23.92	23.99	24.37	24.56	24.89	25.27	25.59	25.88	26.16
Motor gasoline	40.54	39.06	38.32	31.56	26.40	26.39	26.98	27.22	27.69	28.28	28.75	29.18	29.58
Biodiesel	41.90	40.34	38.68	32.52	30.47	30.62	30.78	30.93	31.08	31.24	31.40	31.55	31.71
Ethanol	24.75	33.34	51.02	58.09	58.38	58.67	58.97	59.26	59.56	59.85	60.15	60.45	60.76
Methanol	24.75	33.34	51.02	58.09	58.38	58.67	58.97	59.26	59.56	59.85	60.15	60.45	60.76
Hydrogen	36.09	35.56	35.03	34.52	34.01	33.84	33.67	33.50	33.33	33.50	33.67	33.84	34.01
Diesel fuel oil	37.75	36.55	38.24	31.17	25.82	25.85	26.50	26.77	27.29	27.94	28.46	28.94	29.39
District energy	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50

Assumption/
Fuel type $/GJ ->

High	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Electricity	46.00	46.26	46.51	46.74	46.99	47.25	47.32	47.36	47.43	47.51	47.58	47.62	47.69
Natural gas	10.56	10.64	10.71	10.78	10.85	10.90	10.95	10.99	11.04	11.10	11.15	11.21	11.27
NGL	26.22	26.61	27.01	27.41	27.83	28.24	28.67	29.10	29.53	29.98	30.43	30.88	31.35
Wood	12.14	12.32	12.50	12.69	12.88	13.07	13.27	13.47	13.67	13.88	14.08	14.30	14.51
Kerosene and stove oil	36.64	36.94	37.25	37.56	37.88	38.21	38.38	38.56	38.74	38.93	39.12	39.31	39.50
Motor gasoline	49.35	49.83	50.33	50.83	51.37	51.90	52.15	52.42	52.68	52.95	53.22	53.51	53.79
Biodiesel	34.84	35.36	35.89	36.43	36.98	37.53	38.09	38.67	39.25	39.83	40.43	41.04	41.65
Ethanol	67.42	68.43	69.45	70.50	71.55	72.63	73.72	74.82	75.94	77.08	78.24	79.41	80.60
Methanol	67.42	68.43	69.45	70.50	71.55	72.63	73.72	74.82	75.94	77.08	78.24	79.41	80.60
Hydrogen	35.91	36.45	36.99	37.55	38.11	38.68	39.26	39.85	40.45	41.06	41.67	42.30	42.93
Diesel fuel oil	50.00	50.53	51.06	51.61	52.18	52.75	53.03	53.33	53.62	53.92	54.23	54.54	54.86
District energy	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	11.55	11.55

Reference	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Electricity	45.93	46.15	46.37	46.62	46.85	47.07	47.14	47.18	47.21	47.29	47.32	47.36	47.40
Natural gas	9.55	9.58	9.62	9.65	9.69	9.72	9.75	9.79	9.82	9.86	9.89	9.92	9.96
NGL	24.95	25.20	25.45	25.71	25.97	26.23	26.49	26.75	27.02	27.29	27.56	27.84	28.12
Wood	11.38	11.49	11.61	11.73	11.84	11.96	12.08	12.20	12.32	12.45	12.57	12.70	12.82
Kerosene and stove oil	31.54	31.83	32.13	32.43	32.74	33.05	33.22	33.39	33.57	33.74	33.92	34.10	34.28
Motor gasoline	39.68	40.14	40.62	41.10	41.61	42.12	42.36	42.61	42.86	43.11	43.37	43.63	43.90
Biodiesel	33.32	33.66	33.99	34.33	34.68	35.02	35.37	35.73	36.09	36.45	36.81	37.18	37.55
Ethanol	64.49	65.13	65.78	66.44	67.10	67.77	68.45	69.14	69.83	70.53	71.23	71.94	72.66
Methanol	64.49	65.13	65.78	66.44	67.10	67.77	68.45	69.14	69.83	70.53	71.23	71.94	72.66
Hydrogen	35.03	35.38	35.74	36.10	36.46	36.82	37.19	37.56	37.94	38.32	38.70	39.09	39.48
Diesel fuel oil	39.93	40.43	40.95	41.47	42.02	42.57	42.84	43.11	43.39	43.67	43.96	44.26	44.55
District energy	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	11.55	11.55

Low	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Electricity	45.52	45.67	45.81	46.00	46.15	46.29	46.26	46.22	46.18	46.15	46.15	46.11	46.07
Natural gas	8.56	8.59	8.63	8.66	8.69	8.73	8.76	8.80	8.82	8.84	8.85	8.87	8.88
NGL	23.75	23.86	23.98	24.10	24.22	24.34	24.47	24.59	24.71	24.84	24.96	25.08	25.21
Wood	12.94	13.19	13.46	13.73	14.00	14.28	14.57	14.86	15.16	15.46	15.77	16.08	16.41
Kerosene and stove oil	26.44	26.72	27.01	27.30	27.60	27.90	28.06	28.22	28.39	28.55	28.72	28.89	29.07
Motor gasoline	30.01	30.45	30.90	31.37	31.85	32.34	32.57	32.80	33.03	33.27	33.51	33.76	34.01
Biodiesel	31.87	32.03	32.19	32.35	32.51	32.67	32.84	33.00	33.17	33.33	33.50	33.67	33.83
Ethanol	61.06	61.37	61.67	61.98	62.29	62.60	62.92	63.23	63.55	63.86	64.18	64.50	64.83
Methanol	61.06	61.37	61.67	61.98	62.29	62.60	62.92	63.23	63.55	63.86	64.18	64.50	64.83
Hydrogen	34.18	34.35	34.52	34.69	34.86	35.04	35.21	35.39	35.57	35.74	35.92	36.10	36.28
Diesel fuel oil	29.85	30.33	30.83	31.33	31.86	32.39	32.64	32.90	33.16	33.42	33.69	33.97	34.25
District energy	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	11.55	11.55

Assumption/
Fuel type $/GJ ->

High	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Electricity	47.77	47.84	47.88	47.96	48.03	48.09	48.16	48.22	48.29	48.35	48.42	48.48	48.55
Natural gas	11.32	11.38	11.44	11.49	11.55	11.61	11.66	11.72	11.77	11.83	11.89	11.94	12.00
NGL	31.82	32.29	32.78	33.27	33.77	34.27	34.79	35.31	35.84	36.38	36.92	37.48	38.04
Wood	14.73	14.95	15.17	15.40	15.63	15.87	16.10	16.34	16.59	16.84	17.09	17.35	17.61
Kerosene and stove oil	39.69	39.88	40.07	40.38	40.60	40.81	41.02	41.24	41.45	41.67	41.88	42.09	42.31
Motor gasoline	54.09	54.37	54.67	55.16	55.48	55.81	56.14	56.47	56.79	57.12	57.45	57.77	58.10
Biodiesel	42.28	42.91	43.56	44.21	44.87	45.55	46.23	46.92	47.63	48.34	49.07	49.80	50.55
Ethanol	81.81	83.04	84.29	85.55	86.83	88.14	89.46	90.80	92.16	93.54	94.95	96.37	97.82
Methanol	81.81	83.04	84.29	85.55	86.83	88.14	89.46	90.80	92.16	93.54	94.95	96.37	97.82
Hydrogen	43.58	44.23	44.90	45.57	46.25	46.95	47.65	48.36	49.09	49.83	50.57	51.33	52.10
Diesel fuel oil	55.18	55.49	55.82	56.35	56.71	57.07	57.43	57.79	58.14	58.50	58.86	59.22	59.58
District energy	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55

Reference	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Electricity	47.47	47.51	47.55	47.60	47.65	47.70	47.75	47.79	47.84	47.89	47.94	47.98	48.03
Natural gas	9.99	10.03	10.06	10.10	10.13	10.17	10.20	10.23	10.27	10.30	10.34	10.37	10.41
NGL	28.40	28.68	28.97	29.26	29.55	29.85	30.15	30.45	30.75	31.06	31.37	31.68	32.00
Wood	12.95	13.08	13.21	13.35	13.48	13.61	13.75	13.89	14.03	14.17	14.31	14.45	14.60
Kerosene and stove oil	34.47	34.65	34.83	35.01	35.19	35.37	35.55	35.73	35.91	36.10	36.28	36.46	36.64
Motor gasoline	44.18	44.45	44.73	44.98	45.25	45.52	45.79	46.05	46.32	46.59	46.86	47.13	47.39
Biodiesel	37.93	38.31	38.69	39.08	39.47	39.86	40.26	40.66	41.07	41.48	41.89	42.31	42.74
Ethanol	73.39	74.12	74.87	75.61	76.37	77.13	77.91	78.68	79.47	80.27	81.07	81.88	82.70
Methanol	73.39	74.12	74.87	75.61	76.37	77.13	77.91	78.68	79.47	80.27	81.07	81.88	82.70
Hydrogen	39.87	40.27	40.67	41.08	41.49	41.91	42.32	42.75	43.18	43.61	44.04	44.48	44.93
Diesel fuel oil	44.85	45.15	45.46	45.74	46.04	46.33	46.63	46.93	47.22	47.52	47.81	48.11	48.41
District energy	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55

Low	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Electricity	46.04	46.00	45.96	45.93	45.89	45.85	45.81	45.78	45.74	45.70	45.67	45.63	45.59
Natural gas	8.89	8.90	8.91	8.92	8.93	8.95	8.96	8.97	8.98	8.99	9.00	9.01	9.03
NGL	25.34	25.46	25.59	25.72	25.85	25.98	26.11	26.24	26.37	26.50	26.63	26.76	26.90
Wood	16.73	17.07	17.41	17.76	18.11	18.48	18.85	19.22	19.61	20.00	20.40	20.81	21.22
Kerosene and stove oil	29.24	29.41	29.59	29.76	29.94	30.11	30.28	30.46	30.63	30.80	30.98	31.15	31.32
Motor gasoline	34.27	34.52	34.79	35.04	35.29	35.55	35.80	36.06	36.31	36.57	36.83	37.08	37.34
Biodiesel	34.00	34.17	34.34	34.52	34.69	34.86	35.04	35.21	35.39	35.56	35.74	35.92	36.10
Ethanol	65.15	65.48	65.80	66.13	66.46	66.80	67.13	67.47	67.80	68.14	68.48	68.83	69.17
Methanol	65.15	65.48	65.80	66.13	66.46	66.80	67.13	67.47	67.80	68.14	68.48	68.83	69.17
Hydrogen	36.46	36.65	36.83	37.01	37.20	37.39	37.57	37.76	37.95	38.14	38.33	38.52	38.71
Diesel fuel oil	34.53	34.81	35.11	35.38	35.67	35.95	36.23	36.51	36.80	37.08	37.36	37.65	37.93
District energy	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55

Assumption/
Fuel type $/GJ ->

High	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061
Electricity	48.62	48.68	48.75	48.81	48.88	48.94	49.01	49.08	49.14	49.21	49.27
Natural gas	12.06	12.11	12.17	12.23	12.28	12.34	12.39	12.45	12.51	12.56	12.62
NGL	38.61	39.19	39.78	40.37	40.98	41.59	42.22	42.85	43.49	44.15	44.81
Wood	17.87	18.14	18.41	18.69	18.97	19.25	19.54	19.84	20.13	20.43	20.74
Kerosene and stove oil	42.52	42.74	42.95	43.17	43.38	43.59	43.81	44.02	44.24	44.45	44.67
Motor gasoline	58.43	58.76	59.08	59.41	59.74	60.06	60.39	60.72	61.05	61.37	61.70
Biodiesel	51.31	52.08	52.86	53.65	54.46	55.27	56.10	56.94	57.80	58.66	59.54
Ethanol	99.28	100.77	102.28	103.82	105.38	106.96	108.56	110.19	111.84	113.52	115.22
Methanol	99.28	100.77	102.28	103.82	105.38	106.96	108.56	110.19	111.84	113.52	115.22
Hydrogen	52.88	53.68	54.48	55.30	56.13	56.97	57.83	58.69	59.57	60.47	61.37
Diesel fuel oil	59.94	60.30	60.66	61.02	61.38	61.74	62.09	62.45	62.81	63.17	63.53
District energy	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55

Reference	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061
Electricity	48.08	48.13	48.17	48.22	48.27	48.32	48.37	48.41	48.46	48.51	48.56
Natural gas	10.44	10.48	10.51	10.55	10.58	10.61	10.65	10.68	10.72	10.75	10.79
NGL	32.32	32.64	32.97	33.30	33.63	33.97	34.31	34.65	35.00	35.35	35.70
Wood	14.74	14.89	15.04	15.19	15.34	15.49	15.65	15.80	15.96	16.12	16.28
Kerosene and stove oil	36.82	37.00	37.18	37.36	37.54	37.72	37.90	38.09	38.27	38.45	38.63
Motor gasoline	47.66	47.93	48.20	48.46	48.73	49.00	49.27	49.54	49.80	50.07	50.34
Biodiesel	43.16	43.60	44.03	44.47	44.92	45.37	45.82	46.28	46.74	47.21	47.68
Ethanol	83.52	84.36	85.20	86.06	86.92	87.79	88.66	89.55	90.45	91.35	92.26
Methanol	83.52	84.36	85.20	86.06	86.92	87.79	88.66	89.55	90.45	91.35	92.26
Hydrogen	45.38	45.83	46.29	46.75	47.22	47.69	48.17	48.65	49.14	49.63	50.13
Diesel fuel oil	48.70	49.00	49.29	49.59	49.88	50.18	50.48	50.77	51.07	51.36	51.66
District energy	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55

Low	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061
Electricity	45.56	45.52	45.48	45.44	45.41	45.37	45.33	45.30	45.26	45.22	45.19
Natural gas	9.04	9.05	9.06	9.07	9.08	9.09	9.11	9.12	9.13	9.14	9.15
NGL	27.03	27.17	27.30	27.44	27.58	27.72	27.85	27.99	28.13	28.27	28.42
Wood	21.65	22.08	22.52	22.97	23.43	23.90	24.38	24.87	25.36	25.87	26.39
Kerosene and stove oil	31.50	31.67	31.85	32.02	32.19	32.37	32.54	32.71	32.89	33.06	33.24
Motor gasoline	37.59	37.85	38.10	38.36	38.61	38.87	39.12	39.38	39.64	39.89	40.15
Biodiesel	36.28	36.46	36.65	36.83	37.01	37.20	37.38	37.57	37.76	37.95	38.14
Ethanol	69.52	69.86	70.21	70.56	70.92	71.27	71.63	71.99	72.34	72.71	73.07
Methanol	69.52	69.86	70.21	70.56	70.92	71.27	71.63	71.99	72.34	72.71	73.07
Hydrogen	38.91	39.10	39.30	39.49	39.69	39.89	40.09	40.29	40.49	40.69	40.90
Diesel fuel oil	38.21	38.49	38.78	39.06	39.34	39.63	39.91	40.19	40.47	40.76	41.04
District energy	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55	11.55

Fuel	Source
Electricity	1
Natural gas	1
NGL	3
Wood	
Kerosene and stove oil	1
Motor gasoline	1
Biodiesel	2
Ethanol	2
Methanol	3
Hydrogen	4
Diesel fuel oil	1
District energy	

Key

1 National Energy Board Energy Futures

2 Clean Cities Alternative Fuel report

3 General assumption

4 https://energy.gov/sites/prod/files/2015/06/f23/fcto_myrdd_production.pdf

Appendix 5- Acronyms and Glossary

ACRONYMS

BAU	Business-As-Usual
CAFE	Corporate Average Fuel Economy
CANSIM	Canadian Socio-Economic Information Management System
CHP	Combined heat and power
CO_2e	Carbon dioxide equivalents
GJ	Gigajoule; one billion joules; one gigajoule is equivalent to about 30 litres of gasoline
GPC	Global Protocol for Cities
HVAC	Heating, ventilation and cooling
ICE	Internal combustion engine
IESO	Independent Electricity System Operator
LIC	Local improvement charge
LPG	Liquefied Petroleum Gas
MJ	Mega Joule
NEB	National Energy Board
NIR	National Inventory Report
NPV	Net present value
PIHB	Plug in hybrid
PJ	Petajoule
PV	photovoltaic
RESD	Report on Energy Supply and Demand
RNG	Renewable Natural Gas
TJ	Tera Joule
VKT	Vehicle Kilometers Travelled

Glossary

TERM	DEFINITION
Business as usual (BAU)	A scenario that illustrates energy use and GHG emissions if no additional policies, actions or strategies are implemented.
Capital investment	Funds invested in fixed assets. Also known as CAPEX.
Carbon price	A representation of the cost of carbon as a result of the introduction of cap and trade in Ontario or carbon pricing by the Federal Government.
Cohort-survival population model	
Constant dollars	Adjusted value of currency so that future expenditures are represented in 2017 dollars using a discounting rate of 3%.
Cumulative investment	The sum of annual investments added up over a defined period of years. For example, the cumulative investment from 2017 to 2020 is the sum of the investments in each of those years. Can be represented in either constant or current dollars.
Current dollars	Un-adjusted value of currency; future dollars are not adjusted. Also known as the nominal dollar value.
Discount rate	A rate that converts current dollars to constant dollars, indicating that future dollars are worth less than current dollars. For this analysis a discount rate of 3% was used.
Energy demand	
Energy expenditures	Expenditures on fuel.
Energy supply	
Flywheel	
Low carbon moderate (LC-mod)	A scenario that includes 22 actions to achieve significant GHG emissions reductions for the City of Markham. Total remaining emissions in 2015 are 0.5 $MtCO_2e$ (68% reduction over 2011).
Low carbon ambitious (LC-amb)	A scenario that builds upon the moderate scenario with a set of more ambitious assumptions, which focus on increasing the deployment of solar heating/hot water and air and ground source heat pumps in the residential and commercial sectors to reduce consumption of natural gas for heating. Total remaining emissions in 2015 are 0.16 $MtCO_2e$ (90% reduction over 2011).
Net present value (NPV)	The value in the present of a sum of money, in contrast to some future value it will have when it has been invested at compound interest. A discounting rate of 3% was applied.

TERM	DEFINITION
Net zero emissions	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.
Operating expenditures	Operating expenses include maintenance expenditures, energy expenditures and carbon price expenditures. Also known as OPEX.
Person-years of employment	A person-year is defined as the amount of work done by an individual during a working year, on a specific job.
Total expenditures	Total expenditures include capital investments and operating expenses.

Appendix 6 - SWG Recommendations

Markham Municipal Energy Plan Stakeholder Working Group Meeting #9
Brainstorming Session for MEP Recommendations
July 12, 2017

Residential – Existing

Consumer centered digital platform

- An interactive, user-friendly, accessible consumer focused digital platform
- Provides free home energy assessment services, engaging educational tools, targeted messaging and content on how to embed energy efficiency products and services in home renovations
- Examples: Mass Save – Online home Energy Assessment and Rise

Communication Platform

- Sharing positive energy saving project experiences with other homeowners
- Current influx in home renovations could foster energy improvements
- City of Markham can potentially publish a list of qualified home improvement contractors who meet the standard ability to deliver home improvements that also reduce energy use
- Example: York Region has a program for publicizing qualified irrigation contractors who have received training in water savings
- Buyer's Group Platform: connecting local buyers' groups with suppliers of energy efficient products and services to empower homeowners through collective buying or sharing of information and experiences

Additional Ideas

- Increase homeowner awareness, motivation and involvement in order to make substantial impact in reducing energy consumption in existing buildings
- Ensure that the appropriate action list from SSG are addressed in developing plans regarding the above two items
- Information on existing rebate programs need to be made available and publicized to existing homeowners (i.e. IESO platform that is in the works)

Residential – New

- Continuous information, education and engagement of the public in general, and new construction stakeholders and prospective customers specifically, on new technologies, or arrival of these technologies in the market
- Encourage and support utilities to promote voluntary stretch codes via incentive programs to encourage early adoption of energy efficiency before it becomes "codified". Early adopters and leaders should be continually encouraged and recognized. Incentives such as reduced development charges could be considered, with rationale explained clearly to developers
- Reach out and provide opportunities to builder-developers to participate in new technology pilot programs
- Continue exploring new technologies through demonstration projects to increase broad adoption
- Commercialization, adoption and wider proliferation of new energy efficient and low carbon technologies leads to eventual cost reductions to bring such technologies to the market. This will reduce the incremental cost barriers to building energy efficiency homes
- Increase incentives for builders and developers to build energy efficient homes above the building code

Transportation

Commercial Vehicles

- Scope alternative fuel sources, not sure if electrifying these vehicles as listed in SSG's actions is feasible especially for heavy trucks
- Recommend evaluating truck operations on alternative fuels such as propane, renewable natural gas or compressed natural gas. Also get NOx, PM2.5 and PM10 benefits.
- Discuss this with local transportation companies
- Scope a fueling station in Markham based on EnerCan road map
- Apply for the FCM Green Transportation application to examine the business proposition of converting municipal medium to heavy commercial fleet to alternative fuels

Personal Vehicles

- Electrify personal vehicles as recommended by SSG
- Engage with Plug n' Drive to educate consumers
- Engage QUEST Ontario group

Public Transit

- Electrify rapid transit per Metrolinx plan as recommended by SSG (seek funding to implement this)
- Look at getting conventional public transit early in new neighbourhoods and increase service within established neighbourhoods, especially the "last mile" problem
- Seek FCM green transportation funding to develop pilot proposals and partially fund capital projects
- Pursue transportation pilots such as:
    - increasing shuttle bus service to GO train stations to complement the increased service recently initiated and alleviate parking issues
    - Try free transit or no-fare zones as a pilot
    - Continue to track York Region Transit interest in hydrogen vehicles

Active Transportation

- Increase and improve active transportation infrastructure as recommended by SSG
- Seek funding opportunities to increase active transportation initiatives (i.e. CycleON)
- Update Markham Masterplan for active transportation infrastructure

Car-Free Zones

- As recommended by SSG, this creates a culture of transit and active transportation which aligns with the priorities in the Greenprint
- Continue to use land use planning principles to create communities that are more transit and active transportation friendly

ICI Sector (Industrial, Commercial and Institutional)

Accelerating Energy Emissions Descent in the City of Markham

- Technologies exist already today that can drastically energy consumption in both new construction and existing buildings
- Partner with early adopters to lead and share their best practices and lessons learned in reducing energy consumption (i.e. emissions reduction, cost, effectiveness of technologies)
- Identify Markham's largest energy users and organizations who use a significant amount of energy on a monthly basis to pilot demonstration projects
- Create an engagement strategy to engage small businesses in Markham where individual energy use is small, but together create significant energy usage within the city

New Construction

- Need to drive the building specification (architect/engineers)
- Educate end users and design professionals (architects/engineers) on initiatives that will deliver the most amount of emissions reductions
- Ensure that the construction process does not substitute "value engineer" out the improved performance
- Need to highlight the post installation feedback loop that emission reduction techniques actually delivered intended reductions
- Lobby the Ontario building energy code to aggressively reduce the energy footprint of new construction
- City of Markham could provide approval prioritization incentives for projects with largest energy emission reductions

Existing Buildings

- Encourage property owners and managers to develop corporate sustainability goals to reduce energy consumption with short-long term goals
- For large leased commercial space, encourage property owners and tenants to break the barriers on implementing energy emission retrofits that have a longer payback period than lease terms

Appendix 7

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Using Local Improvement Charges in Implementation of the City of Markham Energy Descent Plan

by: Sonja Persram, Sustainable Alternatives Consulting Inc.
for: Sustainability Solutions Group in a Collaboration for the City of Markham

August 29, 2017

Executive Summary

The City of Markham has a long-term 'Greenprint'[1] commitment toward carbon neutrality as part of a suite of objectives aimed to achieve a sustainable, socially equitable and prosperous community over a 50- to 100-year timeframe.

Existing building retrofits have been identified in the Greenprint as providing the greatest opportunity for energy efficiency and conservation: key ingredients in achieving a carbon neutral community since residential and commercial sector carbon emissions total 61%.

Markham's Greenprint also includes the use of new financing approaches to help achieve this goal. The Sustainability Solutions Group's Energy Descent Plan for the city incorporates use of Local Improvement Charges (LICs), a financing mechanism authorized by O.Reg. 322/12 under the Municipal Act, 2001 for building energy and water efficiency retrofits. This report explores key aspects of LICs and legal opinion elements that have already been obtained on this regulation's applicability for sectors and uses to be considered in an LIC program, and it analyzes the data for Markham's Energy Descent Plan in a strategy to use LICs for a proportion of the retrofits from 2019 through to 2051.

Additionally, assuming that a future legal opinion identifies LICs are also applicable for the cost increment of new construction of high performance houses and buildings over code, a proportion of these costs are also included in an LIC funding strategy of the Energy Descent Plan.

An analysis of the Markham Energy Descent Plan data indicates that an LIC financing program can be delivered at no net cost to the municipality; and that savings from the higher performance retrofits/construction can exceed payments on an annual basis for a cost-neutral benefit to owners from the first year.

[1] Markham's Greenprint Sustainability Plan, 2011

1. Introduction

The City of Markham's 'Greenprint' commitment toward long-term carbon neutrality is one of a suite of objectives aimed to achieve a sustainable, socially equitable and prosperous community over a 50- to 100-year timeframe.

Existing building retrofits have been identified in the Greenprint as providing the greatest opportunity for energy efficiency and conservation: key ingredients in achieving a carbon neutral community since residential and commercial sector carbon emissions total 61%.

Markham's Greenprint also includes the use of new financing approaches to help achieve this goal. The Sustainability Solutions Group's Energy Descent Plan for the city incorporates use of Local Improvement Charges (LICs), a financing mechanism authorized by O.Reg. 322/12 under the Municipal Act, 2001 for building energy and water efficiency retrofits. This report explores key aspects of LICs and legal opinion elements that have already been obtained on this regulation's applicability for sectors and uses to be considered in an LIC program, and it analyzes the data for Markham's Energy Descent Plan in a strategy to use LICs for a proportion of the retrofits from 2019 through to 2051.

Additionally, assuming that a future legal opinion identifies LICs are also applicable for the cost increment of high performance houses and buildings over code, a proportion of these costs are also included in an LIC funding strategy of the Energy Descent Plan.

2. What are Local Improvement Charges

Local Improvement Charges (LICs) are a municipal financing mechanism that allows a municipality to enable up-front financing of private environmental retrofits. Key benefits of this mechanism include the following:

- The LIC enables a stewardship approach to the property by the owner who undertakes the retrofits, as the LIC financing is provided up front to the owner with payments made by that owner and any successive owners until the LIC is paid off.
- Since the LIC is provided over longer terms than banks can provide and is at a fixed rate, this enables affordable deep retrofits over 10, 15 or 20 years, where savings can be intended to exceed payments on an annual basis.
- Because the financing is associated with the property and not the owner, if the owner moves before the LIC is repaid, the next owner continues making the payments and benefiting from the improvements.
- The LIC can be repaid on the property tax bill and provides security to the municipality since any defaulted payments can be treated like taxes and subject to a priority lien that is paid out before mortgages on the property. This security is reflected by a lower investment rate.
- Additional features and benefits are discussed in Section 2.3 on the legal opinion.

3. LIC uses

a. Original LICs

Prior uses of LICs were for financing infrastructure on *public* property, such as buried utilities, sidewalks and parks. The municipality would front the costs and benefiting owners would repay them or a predetermined proportion. The method of assigning costs to a property is different for this type of LIC than for the new regulation.

b. New LIC Regulation

With the approval of Ontario Regulation 322/12, energy and water efficiency are specified measures on private property that can be financed via LICs from the municipality. The regulation also authorizes program costs for marketing, interest and administration to be included in the LIC, which is a critical factor enabling the LIC program's net zero cost to the municipality.

c. Legal Opinion

i. Sectors: The request for the LIC regulation[2] was based on the author's underlying rationale and evidence-based analysis of best practices for the single family residence sector[3] based on discussions with key informants primarily in the US, and key Property Assessed Clean Energy (PACE) proponents of leading US projects.

Subsequent research on using LICs for the commercial building sector is summarized in the author's *Final Report: Local Improvement Charges for Commercial and Industrial Buildings Project*[4] from which the following excerpt is obtained:

> *Rationales for this regulatory change had been provided by this report author's work for the David Suzuki Foundation … The rationales had outlined the case primarily for single family dwellings, and there had been no similar foundation provided for commercial and industrial buildings: the regulation does not specify eligible building types, and considerations for each type had to be addressed.*
>
> *For example, the eligibility of buildings for LIC financing was unclear under the following circumstances: leased as well as owner-occupied buildings; industrial buildings on brownfields; for building energy as well as process energy; and whether buildings not subject to property taxes are eligible – since LICs are repayable on the property tax bill.*
>
> *Additionally, there was no prior discussion about using LICs to address district energy systems, nor whether LICs were also applicable to financing climate change adaptation via installing stormwater management low impact development measures.*

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[2] Bill Johnston, Peter Love, David McRobert & Sonja Persram, *Request for a Review of Local Improvement Charges and Related Regulations and Legislation* for the Environmental Commissioner of Ontario, January 11, 2012.
[3] Sonja Persram, "*Property Assessed Payments for Energy Retrofits: Recommendations for Regulatory Change and Optimal Program Features"; "Property Assessed Payments for Energy Retrofits and Other Financing Options";* and *"Strategic Recommendations for an Optimal PAPER Program,"* David Suzuki Foundation and Sustainable Alternatives Consulting Inc., 2011.
[4] Sonja Persram, *Final Report: Local Improvement Charges for Commercial and Industrial Buildings Project,* Sustainable Buildings Canada and Sustainable Alternatives Consulting Inc., 2016.

Also, some additional questions remained as prior legal opinion had: declared LICs to be loans whereas the Ontario Ministry of Municipal Affairs and Housing noted LICs are not loans; and had raised concerns about bonusing (preferential treatment for commercial properties) and whether legislation was needed to require subsequent owners to continue making payments.

The project's legal opinion addressed these issues noted above, and the following excerpt from the final report summarized the legal opinion findings.[5]

Figure 1. Summary of Legal Opinions on the Applicability of LICs for Ontario CI Properties

1) LICs used for a municipal purpose (such as environmental benefit) can be applied to all types of buildings and real property, including conservation authority property and school board property -- except buildings owned by municipalities and their local boards. Note that Crown properties cannot be subject to a priority lien.
2) LICs cannot be used for equipment that is moveable property, i.e. chattels.
3) LICs can be used by owners of leased premises and by lessees or sub-lessees under certain conditions.
4) LICs are unlikely to be used for brownfield sites because of the risk they pose.
5) All permanent aspects of stormwater management systems including low impact development, green roofs, rainwater harvesting and backflow preventers, and other measures such as greywater reuse systems may be financed using LICs. [This segment of the opinion deals with municipalities' capacity to address climate change adaptation.]
6) LICs can finance district energy system connections on private property.
7) LICs are not a loan to the owner, but if repayments of LICs are overdue, the overdue payments become a tax lien; the entire amount of the LIC does not become due.
8) LICs run with the land.
9) Owners can be notified by municipalities of LICs via bills for property taxes, water or garbage.

ii. Financing Sources

Given that LIC amounts for CI buildings would be expected to be larger than those for residential single family dwellings, it was important to ascertain whether LIC financing could be provided by sources other than the municipality. Here is the relevant legal opinion on this topic:

10) LICs are financed by municipalities through their own borrowing, borrowing through provincial lending institutions such as Infrastructure Ontario (IO), or through private lending institutions.

[5] Stanley M. Makuch, B.A., M.A., Juris Doctor, LL.M., *Legal Opinion on Local Improvement Charges for Institutional / Commercial / Industrial Sectors and District Energy Projects,* September 2015, published by Sustainable Buildings Canada and Sustainable Alternatives Consulting Inc.

Additionally, to avert concerns about use of municipally-financed LICs impacting available debt earmarked for specific, other municipal programs, the legal opinion found:

11) If municipalities or IO issue financing for municipal LICs, this general obligation bond financing can be adjusted from calculations of municipal debt totals, i.e. does not impact calculations of municipal borrowing capacity.

In considering financing for LICs as a revolving fund, it would be important to replenish the fund as needed. The LICs for CI Buildings project's legal opinion on this topic follows:

12) LIC financing can be securitized.

4. Additional LIC applications for the City of Markham and its LDC, Alectra[6]:

a. Necessary to understand interaction between the City of Markham and the Region of York

Understanding York Region's participation in its lower-tier municipalities' LIC financing discussions (and in the case of municipally-financed LICs, participation in debenture issues), would require analysis among Regional departments from a legal, finance, building services, and energy and environmental perspectives. If LIC financing comes from a third party, the Region may not need to go to Council if Regional Departments preliminarily analyze and establish the process.

b. Measures and pilot expansion

i. Alectra (previously PowerStream)

1. PowerHouse

The former PowerStream has been aiming to utilize on-site PV as a cost-mitigation approach to expanding distribution. Currently the LDC is piloting a Power.House initiative, which they are aiming to expand. However, when the Power.House pilot is expanded, it will require reducing the owner incentive, and this reduction would be assisted by using LICs to finance the additional amount owners would pay.

There are some issues to be resolved between the current pilot and its expansion. These are as follows. In the current pilot, PowerStream is the owner of the solar PV installations which are on private owners' properties; and the City of Markham has ownership in PowerStream with associated financial arrangements. However, LICs for energy measures are related to private property, therefore LIC viability vis-à-vis PV ownership, and the financing arrangements would need to be resolved.

2. New Houses

[6] Information in this section is based on Sonja Persram, President Sustainable Alternatives Consulting's meetings/ discussions with the City of Vaughan, PowerStream, York Region, and other York Region municipalities from July through December 2016; in addition to materials developed by the partnership between Sustainable Alternatives Consulting Inc. with Sustainable Buildings Canada and EnerQuality, and related material.

There needs to be a written legal opinion on the viability of using LICs for enhancing the performance of new houses; a verbal acknowledgement has been obtained from a legal consultant who has provided opinions since 2010 on this topic.[7] This new opinion would also include applicability for new CI buildings.

3. Energy storage

See Section 3.1.2 above.

4. Electric Vehicle Charging stations

See Section 3.1.2 above for EV charging stations on private property. Charging stations on *public* property may also be subject to LICs – but this would be the first type of LIC and not the more recent regulation. The City of Markham may also wish to seek an opinion on this applicability for existing buildings, as the new building code will include a requirement for charging station rough-ins.

5. LIC program design

Pilots and programs would need to be designed to optimize uptake and for delivery at no net cost to the City of Markham.

c. Property types

As noted above, LICs are applicable for retrofits of single family dwellings, and Ontario CI buildings. LICs have been used for MURBs by the City of Toronto, specifically apartment buildings. It has been noted that new condominiums are ineligible for LICs since developers are not permitted by law to transfer ownership with a 'debt' outstanding.[8] This may be a matter for legal opinion: note that LICs are not loans according to the legal opinion item 7.

d. TBD: existing condo buildings

Given the above analysis it may be viable for LICs to be used for environmental retrofits of existing condominiums. This would also require legal opinion, and in its absence the condominium sector is not included in viable LIC applications in this report. Since condominiums are not segmented from rental apartment buildings, and in the absence of data that identify the relative proportion, a ratio of 20% rental buildings to condominiums is assumed, of which a proportion are analyzed with regards to using LICs for financing high performance upgrades and above-code new construction costs.

5. Why are municipalities engaging in using LICs:[9]

a. Control of program

LICs are a way for municipalities to control a program enabling reductions in energy use and GHG emissions at a zero-net-cost to the municipality. Incremental program costs (for administration, marketing, and interest) are added as an additional LIC charge to the property owner on top of the costs for the installed measures which is then offset by the resulting

[7] Stanley M. Makuch, LL.M., J.D.
[8] Subhi Al Sayed, then Director of Projects, TowerLabs, presentation to CaGBC Greater Toronto Chapter Municipal Leaders Forum, November 8, 2016.
[9] See Note 2.

energy and water savings on an annual basis. The program costs are applied directly as part of participation or other fees, or included into the interest rate spread.

i. A government-led program enables financing of measures that meet government goals. Banks or other non-governmental financing entities do not make meeting government goals a condition of the financing – only the ability to repay.

b. **LIC programs can be designed to offer a net low- or no-cost energy retrofit solution to the property owner**: if the program aim is to have resulting energy savings exceed payments.

i. A municipal-led program allows social equity considerations to be included, such as:
   a. Enabling financing for fiscally-responsible homeowners at all income levels, which in turn enables energy retrofits and utility bill savings.
   b. Providing financing at the same rate for all homeowner financial status levels (banks may offer preferential rates for customers with higher assets/income).

c. LICs remove financing barriers to energy efficiency that primarily benefit social equity:

i. Financing is up-front. A City of Toronto quantitative study[10] looked at reasons why owners did not conduct retrofits after having energy assessments; two-thirds of homeowners who did not carry out all post-audit recommended energy upgrades to their homes said the retrofits were too expensive.

ii. Up-front financing becomes another social equity benefit for owners who are fiscally responsible with other uses for their available cash flow or available credit. Over one-half of those not carrying out all post-audit retrofits said they had other uses for their available cash.

iii. There is a longer term for financing than is available through banks, for example 10, 15 and 20-year terms. By contrast, banks' fixed residential financing are typically over 5 years, and for CI buildings financing may be up to 7-10 years.

iv. A fixed rate over these long terms reduces the risk of rising rates for the owner, allows a greater comfort level with the financing affordability, and enables the same, lower rate to be available to all owners, regardless of income level. This is a significant social equity feature since typically owners' access to lower rates at good terms varies directly with their income and assets and with their prior engagement with their financing firm, so the owners who need the best rates and terms are the ones least eligible for them.

v. Programs that aim to have savings from the installed measures exceed payments for the installations on an annual basis due to the longer financing terms available, make energy and water efficiency savings – and GHG emission reductions – affordable. They also address concerns from banking communities since having a net zero or positive cash flow from the retrofits increases the ability to pay.

vi. The new owner continues making any payments still owing on the financing on sale, while continuing to also benefit from the savings. This LIC feature allows owners to invest on behalf of current and future property owners in an investment, stewardship[11] approach.

[10] Ipsos Reid, *City of Toronto Home Energy Retrofit Financing Study,* 2010
[11] The term 'stewardship' applied to LICs is from Bob Baser, P.Eng., in a 2011 Ecology Ottawa briefing paper on LICs.

vii. This financing method leverages utility incentives to achieve enhanced impacts due to the deeper retrofits available.

viii. LICs allow a stewardship approach to their property that enables long-term investments in their energy security to be made for the property by all fiscally responsible owners, regardless of income level.

d. LICs assist the municipality in achieving corporate and community water efficiency goals:

i. The City of Markham can align LIC goals with optimizing for reductions in energy use and GHG emissions via energy efficiency and renewable energy installations, as well as reductions in water use.

ii. Onsite residential/commercial and municipal corporate energy efficiency can be achieved via onsite water efficiency which aggregates at a community level to reduce energy use and water pumping energy costs. Utilizing water efficiency and conservation reduces household water heating costs and utility bills.[12] It also impacts municipal energy costs for water and wastewater treatment and pumping, [13] [14] [15] which account for 38% of Ontario municipal energy use.[16]

e. Reduction of carbon risk

i. Institutions with portfolios of properties – or property financing portfolios that are energy efficient have a lower carbon risk than institutions without energy efficiency in their portfolio and product mix.

f. LICs produce jobs and local economic benefits

i. As of May, 2017, Commercial PACE in the US has funded projects totalling US $400 million,[17] from which an estimated 6,000 jobs were created based on 15 jobs per $1 million spent, including direct, indirect and induced jobs.[18] US Residential PACE funded 154,000 home upgrade projects totalling $US 3,835 million and created 44,500 jobs.

ii. This level of Commercial PACE investments – according to the same study, would have produced 2.5 times that amount, or US $1 billion in gross economic output and 25% of that amount in combined Federal, State and local tax revenues, or about US $100 million. Similarly, for the Residential PACE investments, produced US $9.588

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[12] 15 per cent of home energy costs comes from heating water in the hot water tank: York Region, *Water Efficiency: An At-Home Guide,* Water for Tomorrow, http://watercanada.net/2011/savings-at-the-pump/

[13] See also: https://www1.toronto.ca/wps/portal/contentonly?vgnextoid=ce4907ceb6f8e310VgnVCM10000071d60f89RCRD&vgnextchannel=ff3cd4818444f310VgnVCM10000071d60f89RCRD

[14] Maas, Carol, *Greenhouse Gas and Energy Co-Benefits of Water Conservation,* POLIS Research Report 09-01, Water Sustainability Report, POLIS Project on Ecological Governance, 2009. http://polisproject.org/files/pub_database/maas_ghg_.pdf

[15] See also: City of Guelph, *2016 Water Efficiency Strategy Update* http://guelph.ca/wp-content/uploads/WESU_Draft_Final_Report.pdf

[16] Environmental Commissioner of Ontario, *Every Drop Counts: Reducing the Energy and Climate Footprint of Ontario's Water Use: Annual Energy Conservation Report, 2016/2017 (Volume One),* 2017 http://docs.assets.eco.on.ca/reports/energy/2016-2017/Every-Drop-Counts.pdf

[17] See: http://pacenation.us/pace-market-data/

[18] ECONorthwest, *Economic Impact Analysis of Property Assessed Clean Energy (PACE) Programs,* PACENow, 2011; direct jobs are a direct result of the work required; indirect jobs result from other purchases by the companies hired; and induced jobs result from the consumption by those hired in direct and indirect jobs. http://www.pacenation.us/wp-content/uploads/2014/11/Economic-Impact-Analysis-of-Property-Assessed-Clean-Energy-Programs-PACE.pdf

billion in gross economic output and about $US 958 million in combined tax revenues.

g. Municipal leadership

An LIC program positions the municipality as a leader in achieving municipal, provincial and federal carbon targets as well as goals of reducing energy/water use.

6. LICs and potential contributions to the City of Markham Energy Descent Plan

LIC contributions are dependent on: the City of Markham's ramping up of energy efficiency requirements for new and existing buildings, and the plan for EV vehicle uptake, the latter requiring charging stations with energy storage on CI as well as residential properties.

a. Assumptions in this analysis include:

   i. All legal opinions are obtained and pilots and analyses are conducted to ascertain optimal program design as noted in Section 3, and develop stakeholder relationships. Assume this duration is 1-1.5 years, i.e. in year 3 – 2019, LIC scaled-up financing would begin.
   ii. Both energy and water efficiency measures may be applied, particularly in new construction – the latter resulting in lengthening of the life of water infrastructure and reduction of electricity costs for pumping. However, only energy retrofits and cost increments of new construction of net zero and passivhaus standard houses/buildings are analyzed with respect to costs and fuel/energy savings.
   iii. New building code efficiencies and energy escalation factors are included.
   iv. Early adopters for LICs would also be early adopters for higher performance buildings.
   v. Co-Marketing of the programs will be sufficient to stimulate uptake (where the municipality's portion of costs are covered by program expenses passed on to the owners).
   vi. Issues are addressed related to uptake of the Toronto pilot initiative (vis-à-vis comparatively higher uptake by the Halifax and other Nova Scotia pilots). E.g. in the Toronto initiative LICs are considered as loans, whereas the Halifax initiative treated LICs as fees or charges instead.

7. Plan for LICs to Finance High Performance Cost Increments for Above-Code New Houses:

a. New Housing/New Construction

Analyses were conducted assuming that about 25-35% of the capital cost increment of passivhaus/net zero new properties would be financed via LICs. Exceptions were: appliances (since they are moveable), retirement/nursing home (presumed to be under provincial jurisdiction and budget), and buildings presumed to be under municipal jurisdiction (municipal building, fire station, police station, transit terminal, recreation building) or utility ownership.

8. Plan for Retrofits of Existing Homes:

a. Retrofits of existing homes

In the absence of greater granularity, the following assumptions were made in the calculations:

i. The City utilizes a third-party LIC financing approach at the outset so there is no concern about the level of capital costs vis-à-vis the City budget.
ii. For the reasons discussed previously, 25%-35% of apartment properties are included – assuming them to be rental apartment buildings.
iii. Moderate retrofits are carried out per Scenario 1C as noted by Sustainability Solutions Group.

9. Methodology

The LIC analysis was conducted based on the energy descent plan data

The analysis was based on the following assumptions:

a) All properties' retrofits would not exceed 10% of value. This would be logical given home values in the City of Markham.
b) Energy/fuel savings spreadsheet data represent savings from newly retrofitted (or built) properties that particular year. So total energy/fuel savings for any particular year is the sum of savings for that year plus savings for all previous years.
c) For the purposes of the LIC program, retrofits are anticipated to begin in 2019.
d) LICs are estimated based on a rounded amount, although actual numbers would not be rounded.
e) Capital costs for the LICs are equally spread over the stated property types (highlighted rows in the excel files represent properties that would not be using LICs: for non-residential properties – hospitals, fire stations, police stations, transit terminals, airport, municipal building, recreation/community centres, golf course, and utility property. Some comments:
    - Although hospitals would be eligible for LICs, ESCOs would conduct the retrofits using long-term financing.
    - The airport would be subject to a complex budget combination among all governments.
    - Utility property would be retrofitted or constructed via self-financing.
f) The amount spent on each measure type in each property type in the LIC programs is directly related to ratio of the total LICs for that year divided by the total retrofit costs for eligible properties for that year.
g) Energy/fuel savings for each use (e.g. space heating) in each relevant property type are directly related to the ratio of the total LIC to the total capital cost of all retrofits for the relevant segments.
h) No appliances would be invested in with residential LIC financing. This is due to assumptions that the appliances are moveable and that the appliances would be replaced before the end of the financing term. All measures would be required to

have a life span equal to or greater than the financing term to be eligible for the LIC investment.

The data analysis would be different from the actual implementation. One particular example might be consideration of policies around house value via-a-vis the cap on LIC financing. For example, will the City of Markham plan for an LIC investment cap, or a cap based on property value (typically 10% for LICs is a best practice). If the latter, this could potentially provide more financing to higher-income owners. Also, will Markham plan to extend the program to all postal codes, equally, or to some postal codes first (e.g. greener codes to enhance uptake at program outset, and lower-income postal codes as a social equity factor)?

10. Strategies for house/building sectors

Home Energy Retrofits

Approximately 25-35% of retrofits planned each year for applicable sectors are presumed to be financed by LICs: this proportion grows in each sector and is fairly moderate.

Rental Apartment Buildings

A higher proportion of rental apartment buildings are assumed to be financed via LICs. Although there is an absence of data on the relative numbers of rental buildings vis-à-vis condominiums, it is further assumed that obtaining condo owners permissions to engage in retrofits would be more difficult and so that fewer condominiums would be retrofitted. The relative proportion then of the apartment building retrofits and of the high performance new construction are assumed to be in the same range as of the residential sector: approximately 25-35%.

Existing CI Buildings

Estimates for the purposes of this study are for across-the-board retrofits for targeted building segments based on the prior assumptions: that is, 25-35% of retrofits for pertinent sectors would be anticipated to be financed using LICs.

Granular information on retrofits by floor area will allow a refined implementation plan for CI buildings which would incorporate energy services companies' (ESCOs') involvement in the retrofits as follows:

> Information on anticipated uptake of LICs for this sector is based on the information LICs for CI Buildings project segment in which a qualitative market analysis was conducted of stakeholders' anticipated uptake of CI LIC projects with similar features to US program best practices. These findings are also outlined in the LICs for CI Buildings Final Report by this author[19] for the Sustainable Buildings Canada/Sustainable Alternatives Consulting project excerpted below.

[19] Op. cit.: see note 3.

Table 1. Buildings that can benefit from LICs

Stakeholders in the LICs for CI buildings study noted that LICs could benefit the following buildings:

- All building types except for universities with endowments (*as recommended by*: ESCO 3)
- Industrial buildings (ESCO 1, Canadian Manufacturers & Exporters)
- Commercial buildings owned independently (ESCO 3)
- Commercial buildings between 30,000 and 200,000 sf (ESCO 3)
- Commercial buildings 100,000 sf needing $500,000 in retrofits minimum (ESCO 2)
- Commercial buildings 50,000 sf needing $1 million in retrofits minimum (ESCO 4)
- Owners with fewer options for financing energy retrofits (*as recommended by:* Utilities and industry associations)

Note that it is anticipated that there would be a longer sales cycle for CI buildings, based on the LICs for CI Buildings study findings; and that some market sector leaders would nevertheless be early adopters.

a. Future granular analysis could include the following from additional study findings:
   i. Segment all building types except eliminate all universities with endowments.
   ii. Identify where possible:
      1. Commercial buildings owned independently.
      2. Commercial buildings between 30,000 and 200,000 sf needing $500,000 in retrofits
      3. Segment out those buildings owned by large entities like pension funds: they would be less likely to need LICs as these owners have more options to self-finance energy retrofits.
   iii. Identify building energy cost upgrades for industrial buildings (not process energy since a portion of process energy costs may be applicable i.e. where they are not moveable).
   iv. Create estimates of LIC uptake based on 20%, 50%, 75% uptake.
   v. Note # buildings also.
   vi. Start estimates of LIC uptake after 1-2 years (longer sales cycle for these building types).

New CI Buildings:

Identify goals for buildings performing above-code that meet the above sectoral, ownership and size criteria: schools, post-secondary educational institutions, hotels/motels, retail, buildings associated with vehicle and heavy equipment service, restaurants, museums and art galleries (assumed to be private), retail residential (assuming this is different from commercial residential i.e. not rental apartment buildings), commercial retail, commercial, religious institutions and warehouses (assuming that none of the sectors include brownfield).

Identify cost increments for building above code for the eligible buildings.

11. Findings

Table 10.1 summarizes LIC investments and impacts of those investments as follows:

- **capital costs, fuel cost savings** and **energy cost savings associated with LIC capital cost investments**
- for both **retrofits** and **new construction incremental costs over code of: net zero and passivhaus high performance homes / passive standard high performance buildings**
- for applicable building segments in both **residential** and **non-residential sectors**
- showing both Totals and investments/impacts in 2019 – the first year.

Table 10.1 LIC investments and impacts of those investments

Residential Retrofits Investments/Impacts	**Totals 2019-2051 (constant dollars)**	**Residential Retrofits Investments/Impacts in 2019 (constant dollars)**
Capital Costs	$380,000,000	2,000,000
LIC Impacts: Fuel Cost Savings	$69,191,880	$193,985
LIC Impacts: Energy Cost Savings	$4,208,333	$17,412
Non-Residential Retrofits Investments/Impacts	**Totals 2019-2051 (constant dollars)**	**Non-Residential Retrofits Investments/Impacts in 2019 (constant dollars)**
Capital Costs	$58,500,000	$1,500,000
LIC Impacts: Fuel Cost Savings	$27,966,555	$729,943
LIC Impacts: Energy Cost Savings	$2,273,791	$50,839
Residential New Construction Net Zero / Passive House Investments/Impacts	**Totals 2019-2051 (constant dollars)**	**Residential New Construction Net Zero / Passive House Investments/Impacts in 2019 (constant dollars)**
Capital Costs	105,000,000	500,000
LIC Impacts: Fuel Cost Savings	18,664,307	62,455
LIC Impacts: Energy Cost Savings	1,222,665	4,776
Non-Residential New Construction Passive Investments/Impacts	**Totals 2019-2051 (constant dollars)**	**Non-Residential NC Passive Investments/Impacts in 2019 (constant dollars)**
Capital Costs	$28,400,000	$300,000
LIC Impacts: Fuel Cost Savings	$12,487,070	$86,037
LIC Impacts: Energy Cost Savings	$461,959	$7,959

An analysis of the data indicates the following:

- **LIC program could be delivered on a cost-neutral basis for owners:** Using a very rough calculation, it appears that amortizing the first year's (2019's) investments over 15 years with monthly payments at rates of up to 7% show the total fuel and energy savings in the first year would exceed annual payments in every category. Although 7% may be too high to generate market interest the intent of this particular calculation is to demonstrate that even at that rate the owner would have a net benefit.

- **LIC program could be delivered on a cost-neutral basis for the City of Markham:** There seems to be a very broad interest rate spread that can accommodate program expenses for a cost-neutral program delivery (if that is the sole method of program cost recovery). That is, if rates remain about in the current range, since Infrastructure Ontario financing to municipalities is now less than 3.1% over 15 years,[20] the program would seem to be deliverable on a cost neutral basis.
  For example, if program costs at the outset are at about 12% of the financing (a high but very conservative estimate), and later fall to about 5% of financing in subsequent tranches; and if ongoing program costs are anticipated to be incurred for each tranche over the duration of the financing, one way to consider cost-neutral feasibility is to look at the difference in interest to be paid by an owner on $500,000 between a rate of 3.1% ($82,138) that the municipality would pay and (for example) 5.5% ($151,157) that the owner would pay. This roughly amounts to $69,000 interest to be paid over the term to cover the program costs of 12% of $500K or $60,000 incurred over the term in this early tranche.

- There are other methods to contribute to early recovery of some program expenses outlined in the consultant's previously cited reports for the David Suzuki Foundation.

11. Conclusion

Local Improvement Charges are one tool that the City of Markham can use in achieving net zero community energy efficiency targets over the long term.

LICs are a feasible method to achieve net annual savings on owners' energy and fuel utility bills. An analysis of the Markham Energy Descent Plan data indicates that payments exceed costs on an annual basis resulting in a cost-neutral owner benefit. This approach includes a moderate use of LICs to support the costs of achieving higher performance via retrofits, and via enhancements over code for new construction.

Additionally, further analysis of the Markham Energy Descent Plan data indicates that **LIC programs could be delivered on a basis that is cost neutral to the City of Markham.**

[20] Rates as at 29 Aug, 2017: http://www.infrastructureontario.ca/Lending-Rates/?ekfrm=2147483942&sector=mun

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