3 Exploring the future

5 The current trajectory

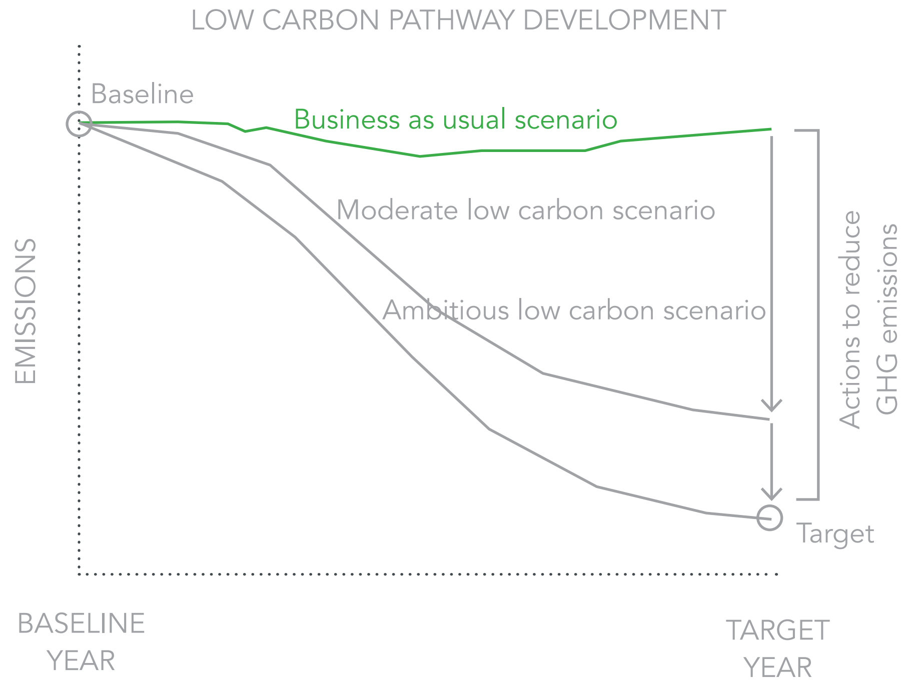


Figure 59. The BAU scenario.

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.

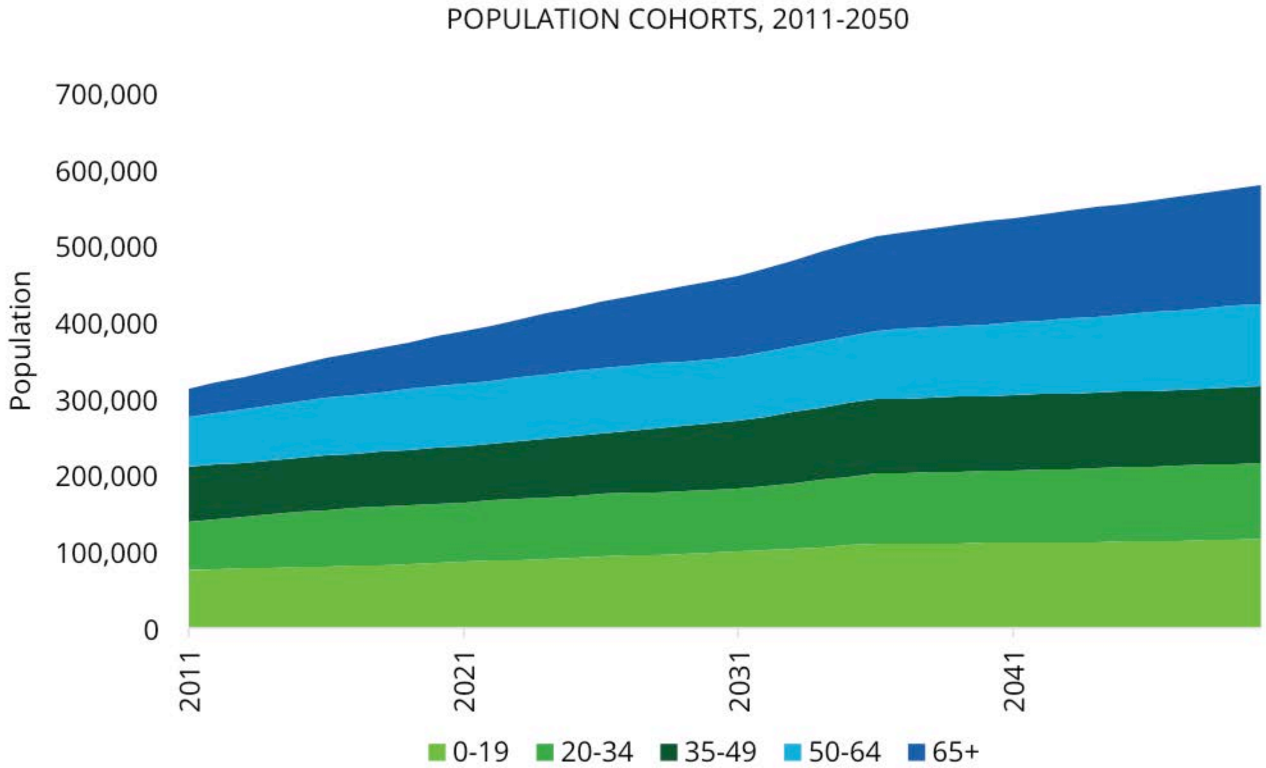


Figure 60. Population projection, 2011-2051.

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.

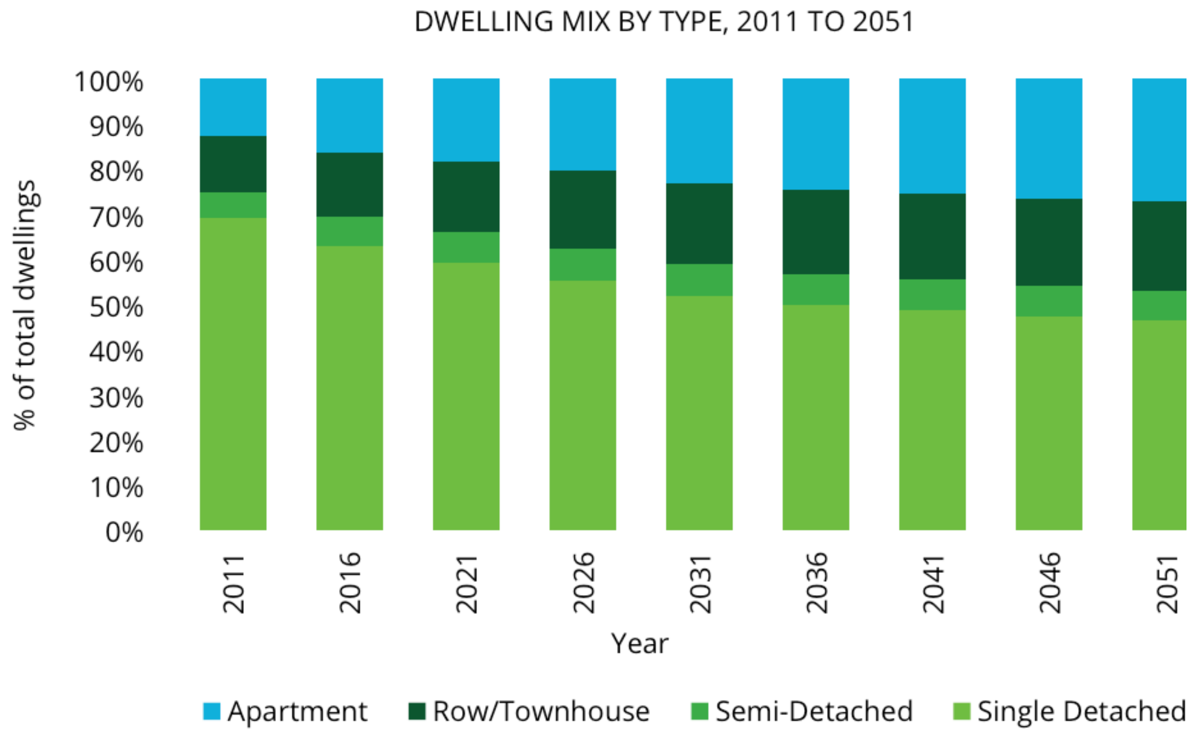


Figure 61. Dwelling mix projections , 2011-2051.

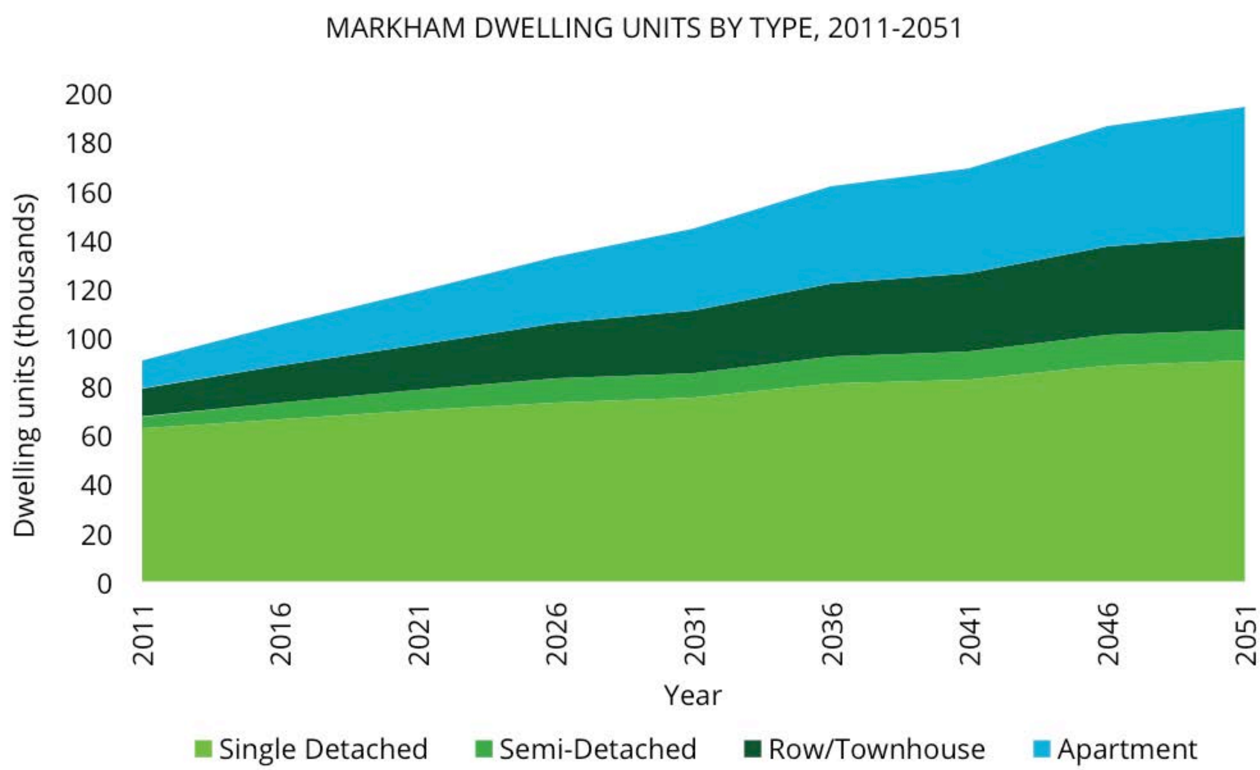


Figure 62. Dwelling projections, 2011-2051.

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.

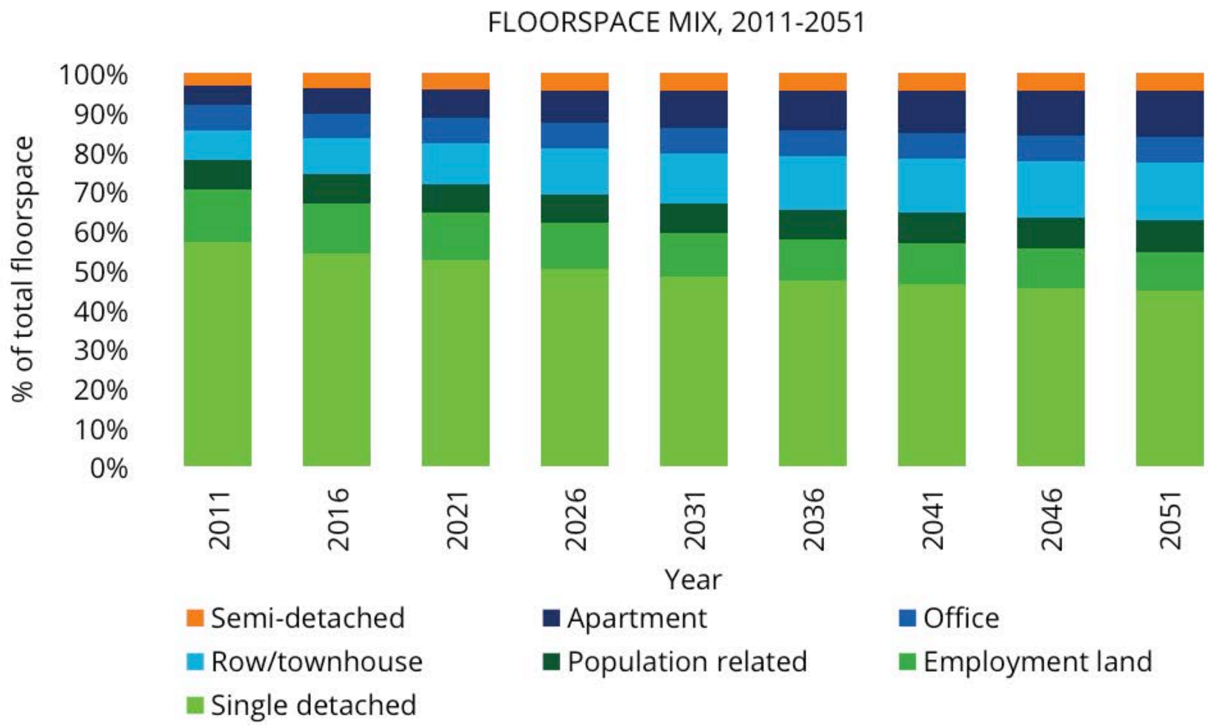


Figure 63. Total floorspace mix, 2011-2051.

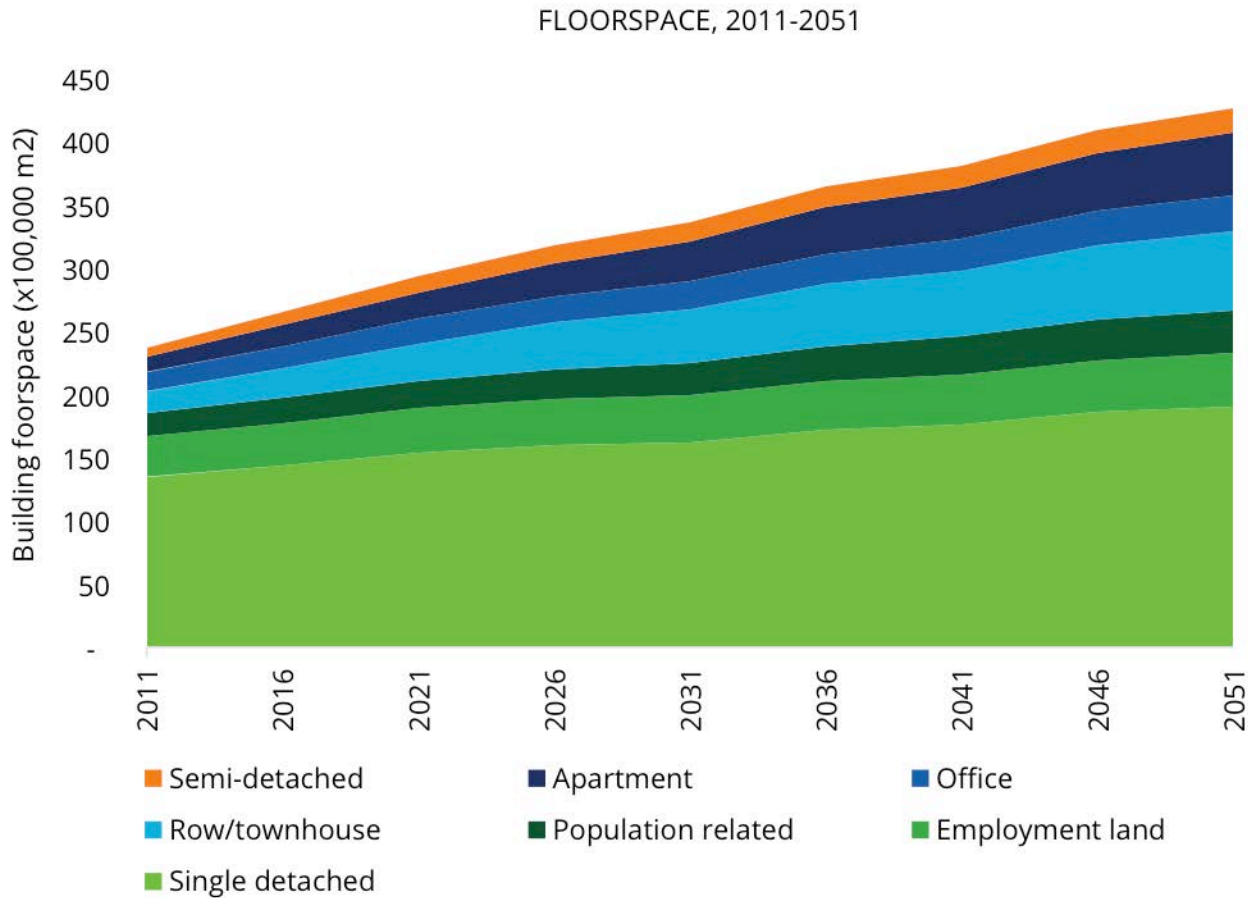


Figure 64. Total floorspace by category, 2011-2051.

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.

RESIDENTIAL BUILDINGS ENERGY BY END-USE, 2011-2051

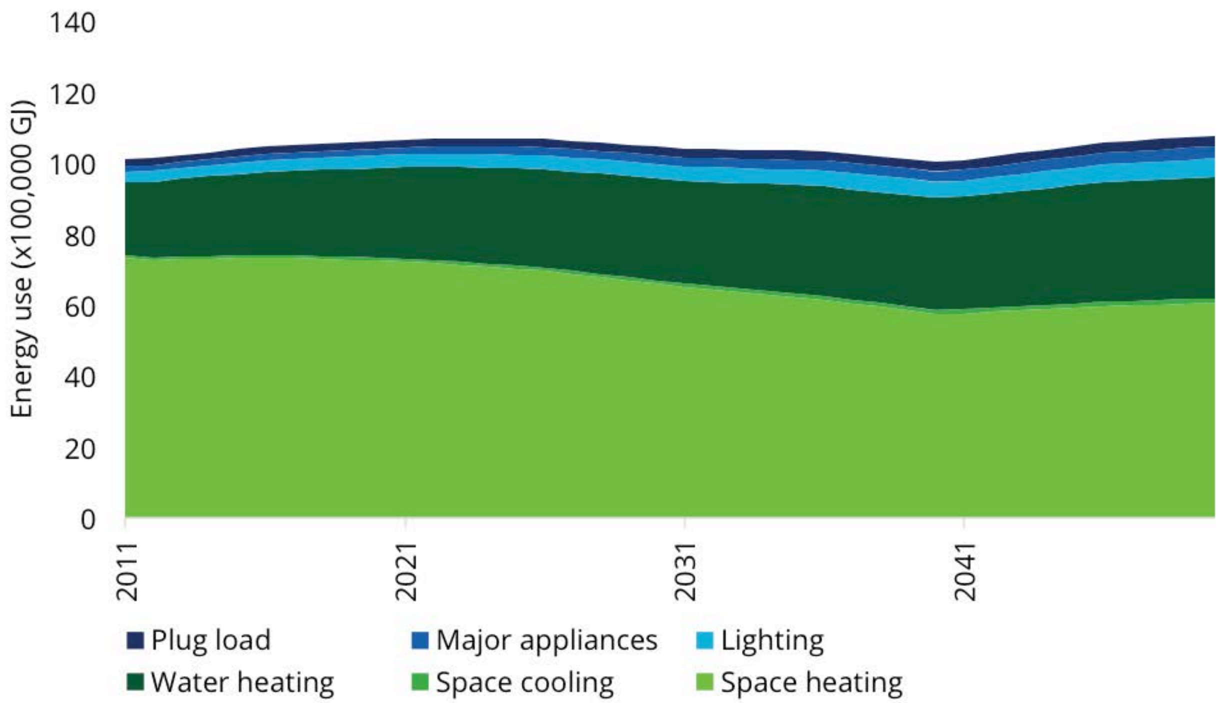


Figure 65. Energy consumption by end-use in residential buildings, 2011-2050.

NON-RESIDENTIAL BUILDINGS- ENERGY BY END-USE, 2011-2050

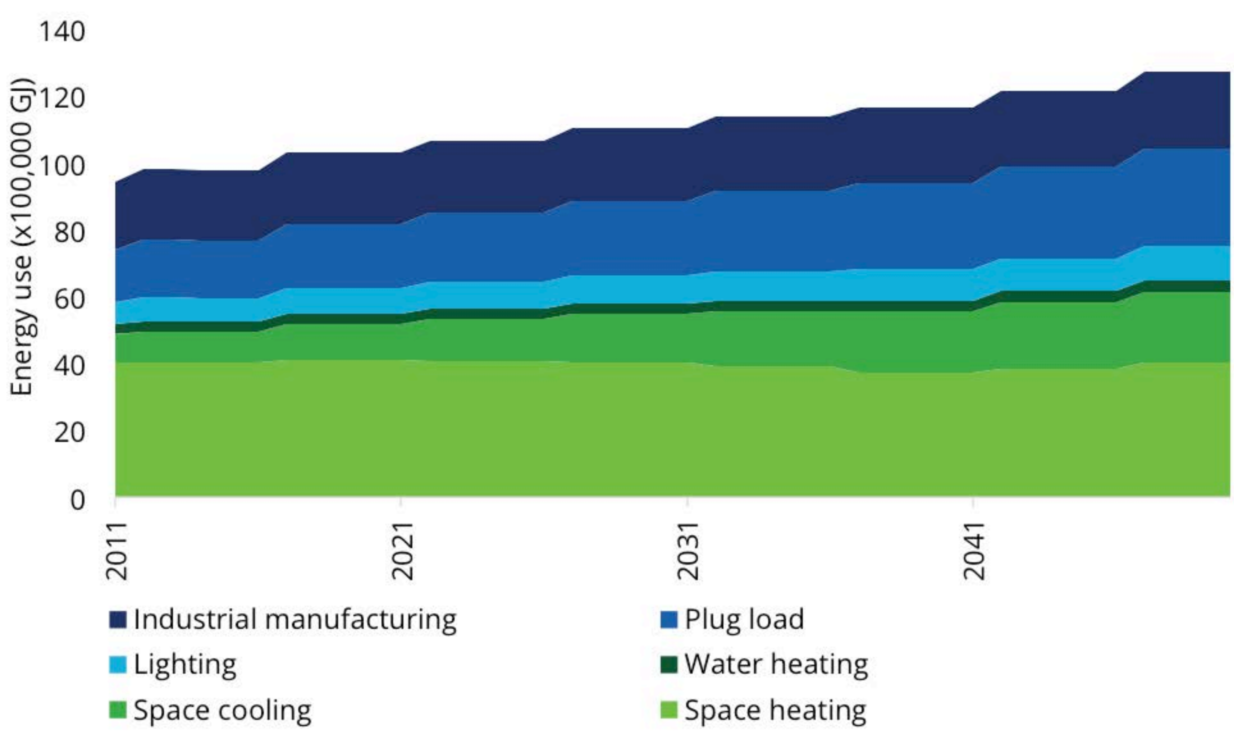


Figure 66. Energy consumption by end-use in non-residential buildings, 2011-2050.

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).

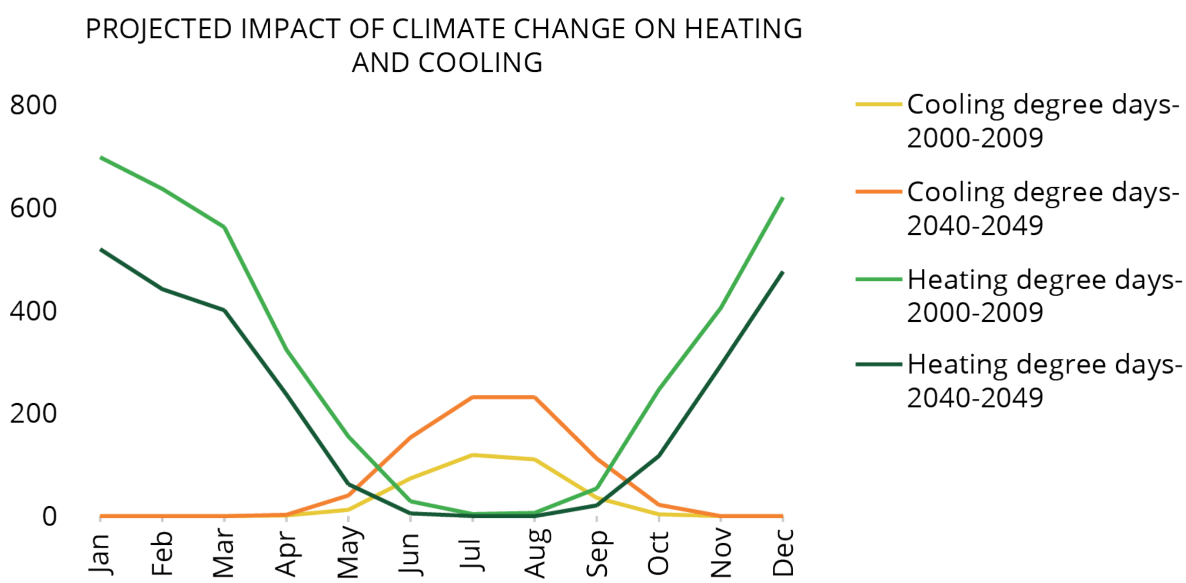


Figure 67. Heating and cooling degree days in 2000–2009 and 2040–2049.

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.

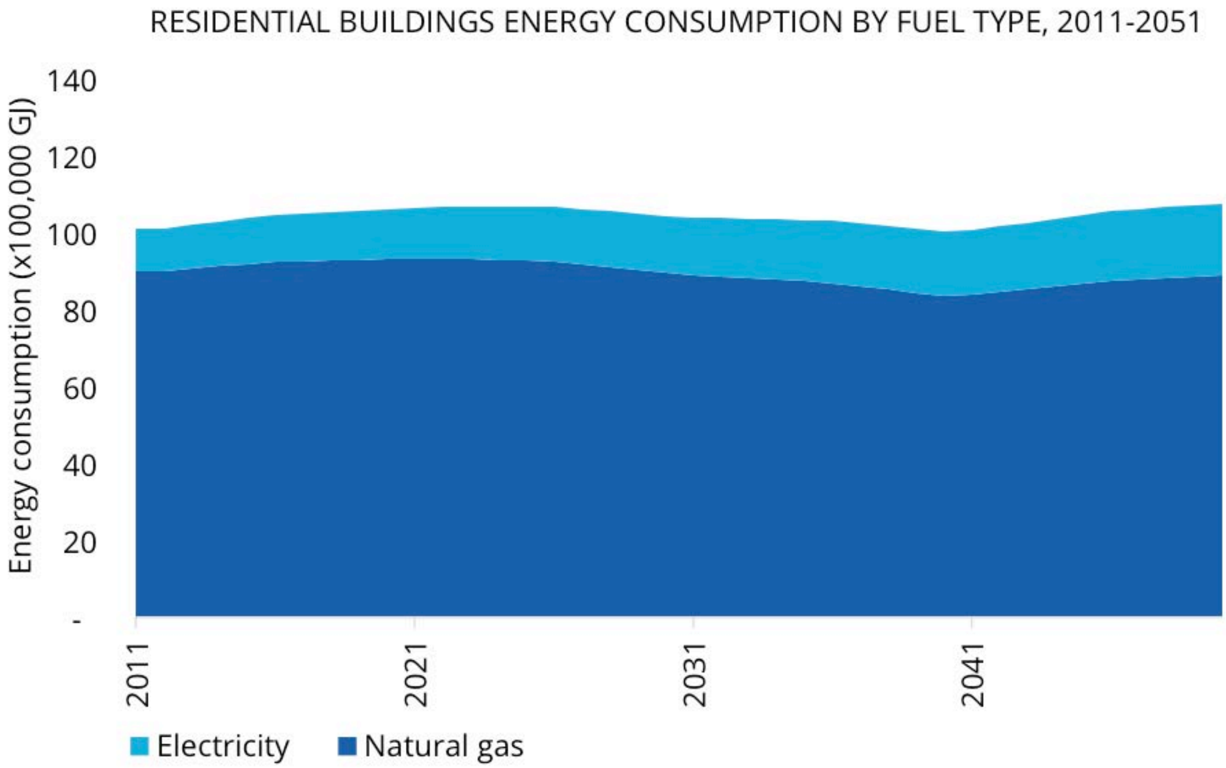


Figure 68. Energy use in residential buildings by fuel type, 2011–2051.

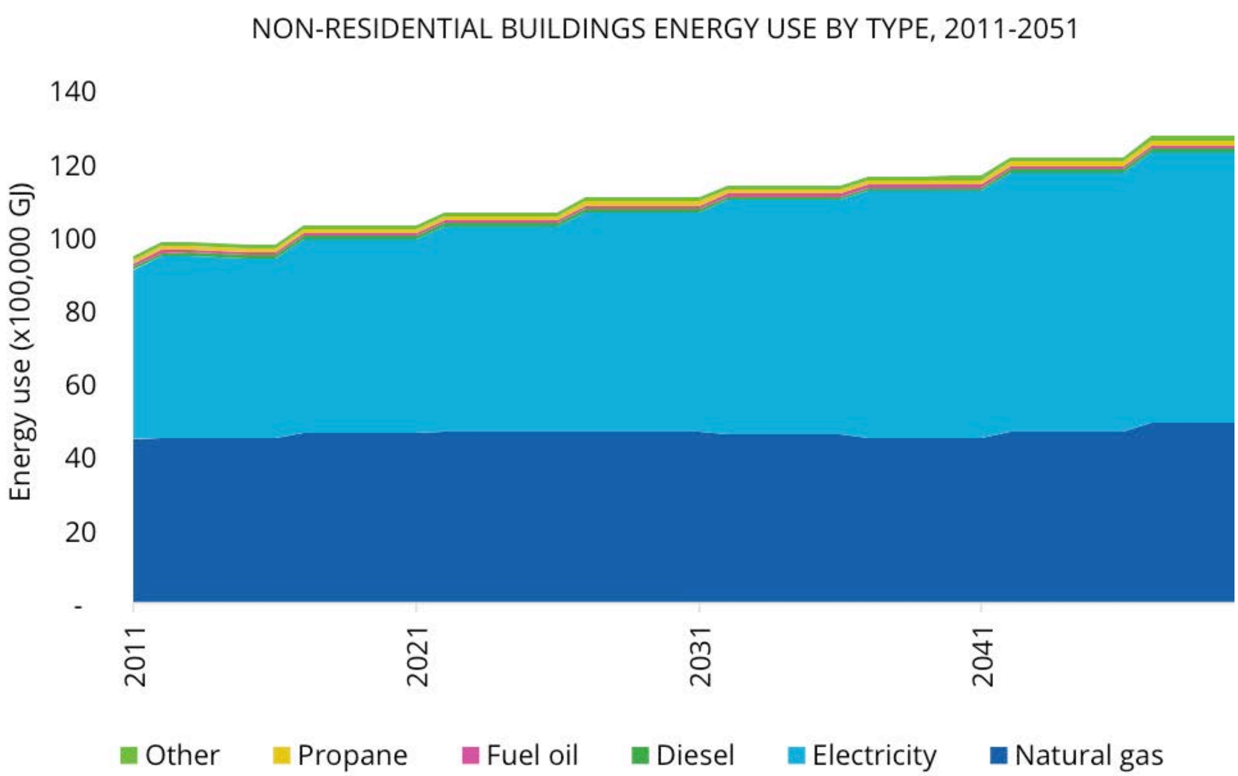


Figure 69. Energy use in non-residential buildings by fuel type, 2011–2051.

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.

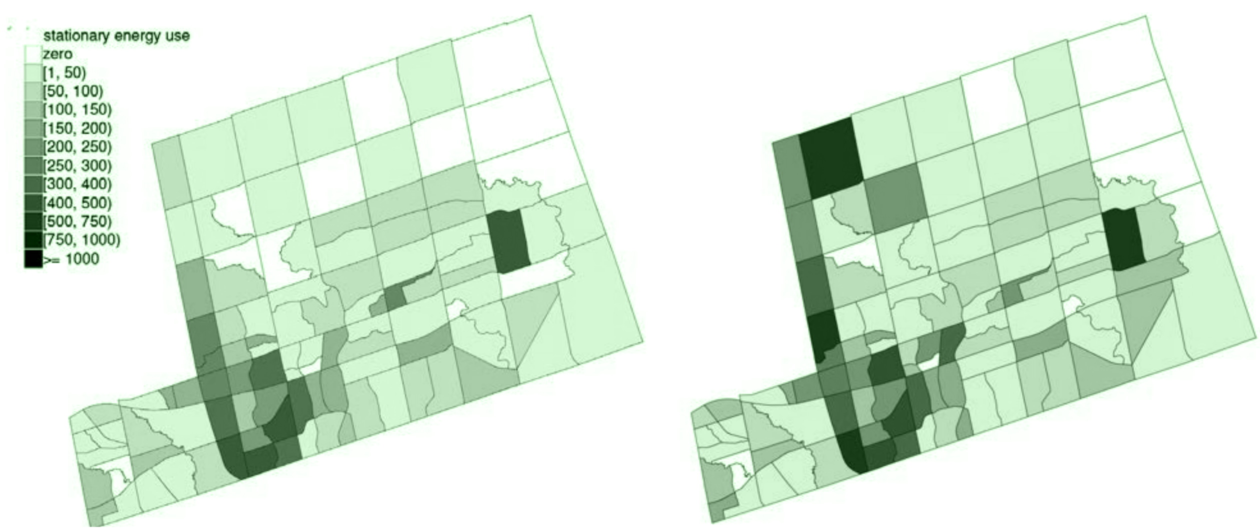


Figure 72. Total energy (TJ) by zone; non-residential buildings, 2011 and 2050.

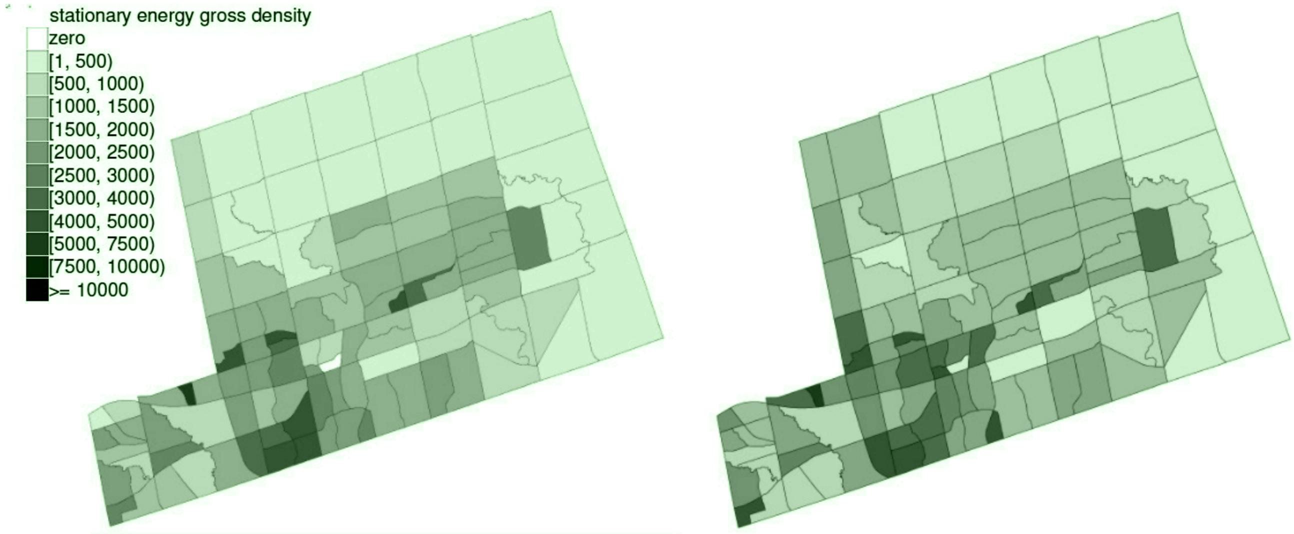


Figure 73. Energy density (GJ/ha) by zone; all buildings, 2011 and 2050.

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.

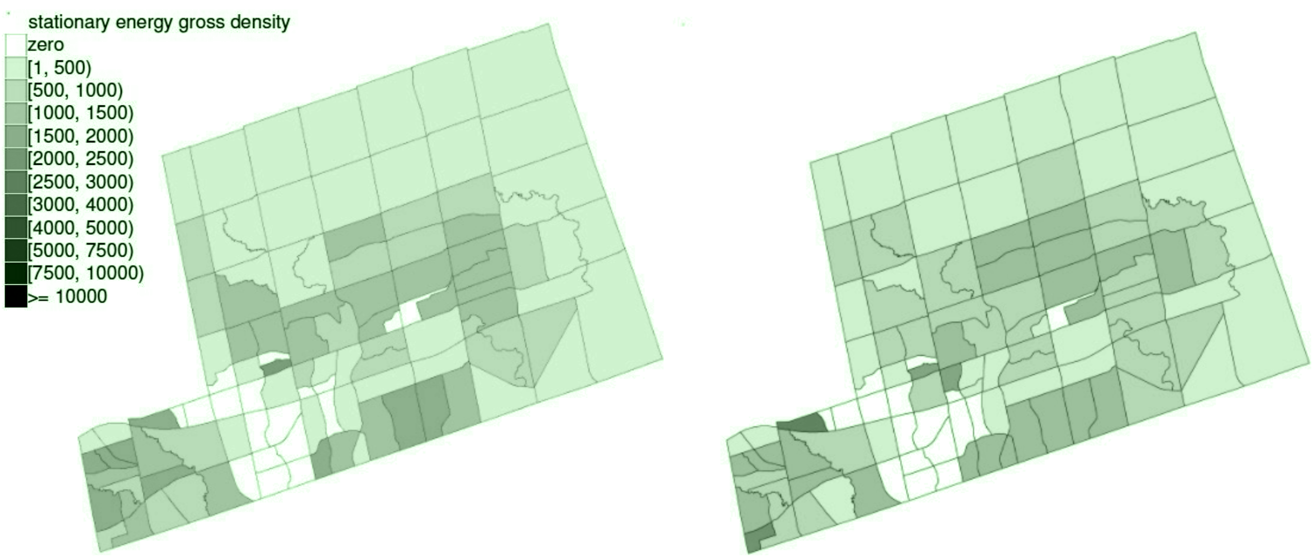


Figure 74. Energy density (GJ/ha) by zone; residential buildings, 2011 and 2050.

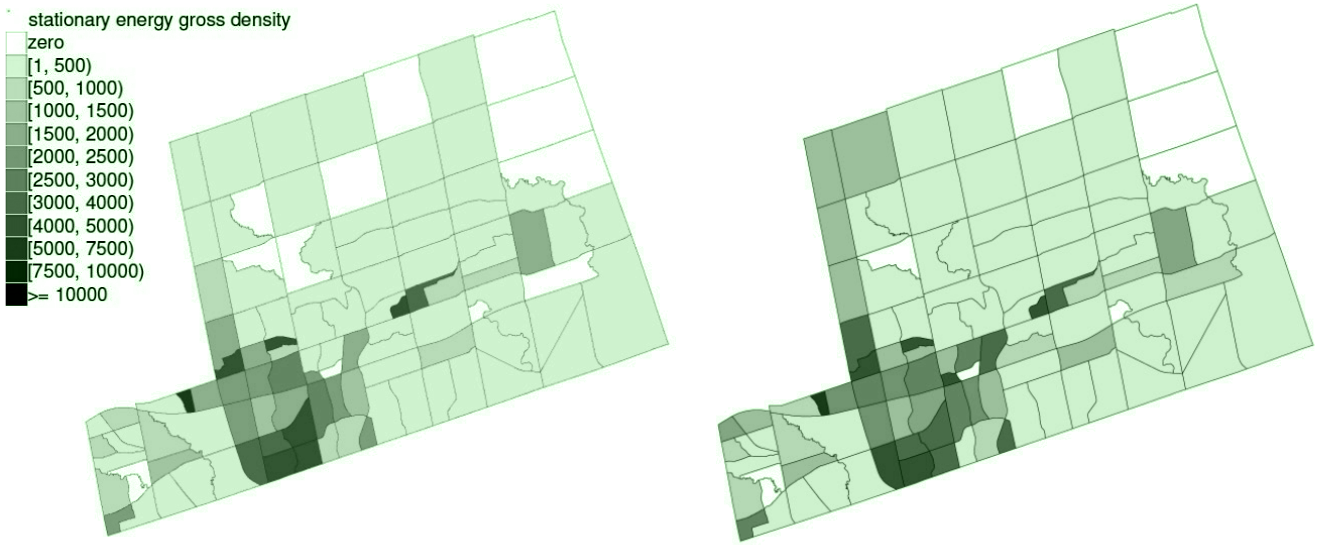


Figure 75. Energy density (GJ/ha) by zone; non-residential buildings, 2011 and 2050.

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.

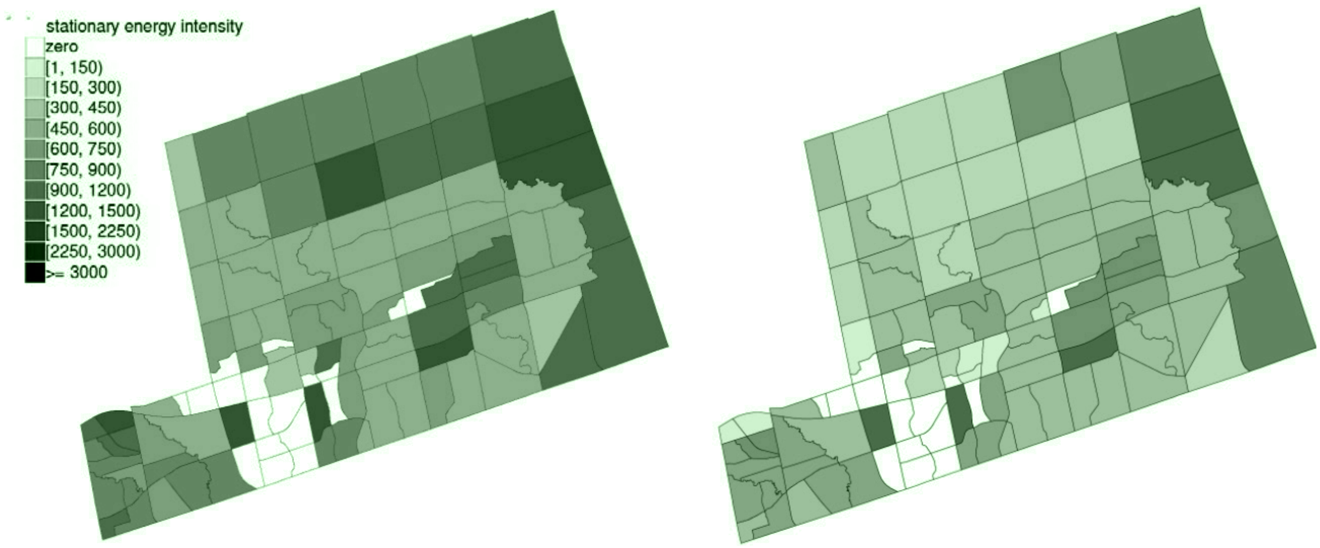


Figure 77. Energy intensity (MJ/m2) by zone; residential buildings, 2011 and 2050.

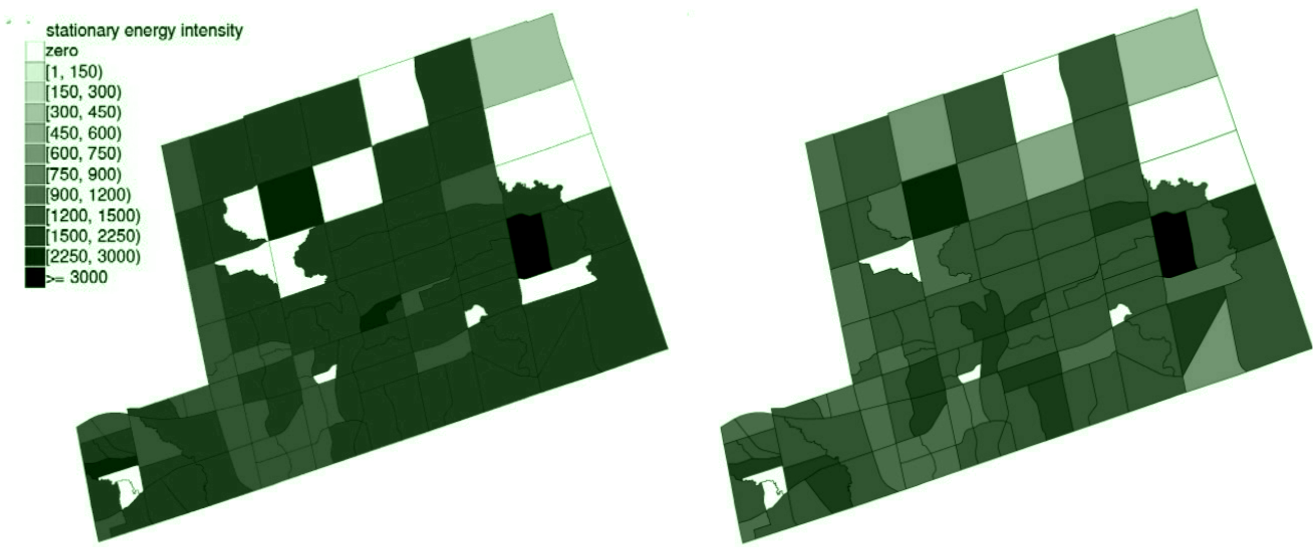


Figure 78. Energy intensity (MJ/m2) by zone; non-residential buildings, 2011 and 2050.

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.

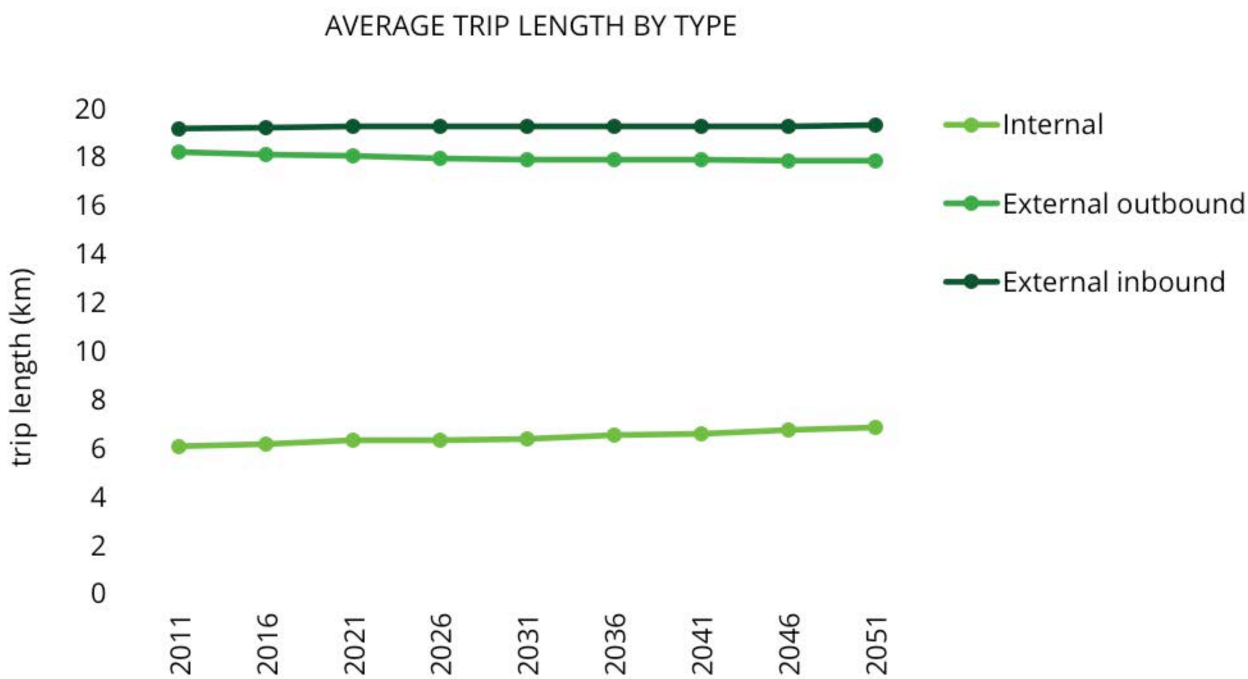


Figure 79. Average trip length, 2011–2050.

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.

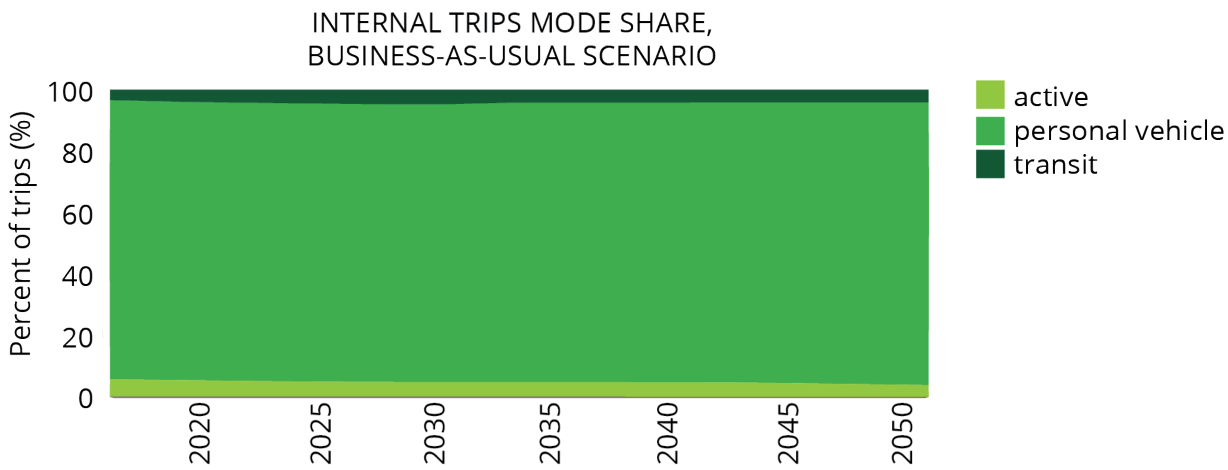


Figure 80. Mode share, internal trips, 2011–2050.

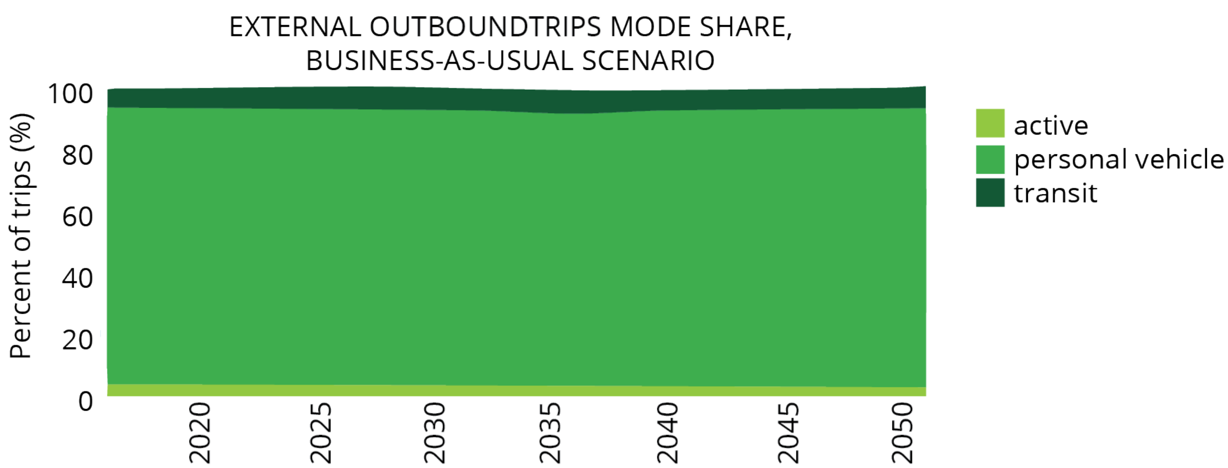


Figure 81. Mode share, external outbound trips, 2011–2050.

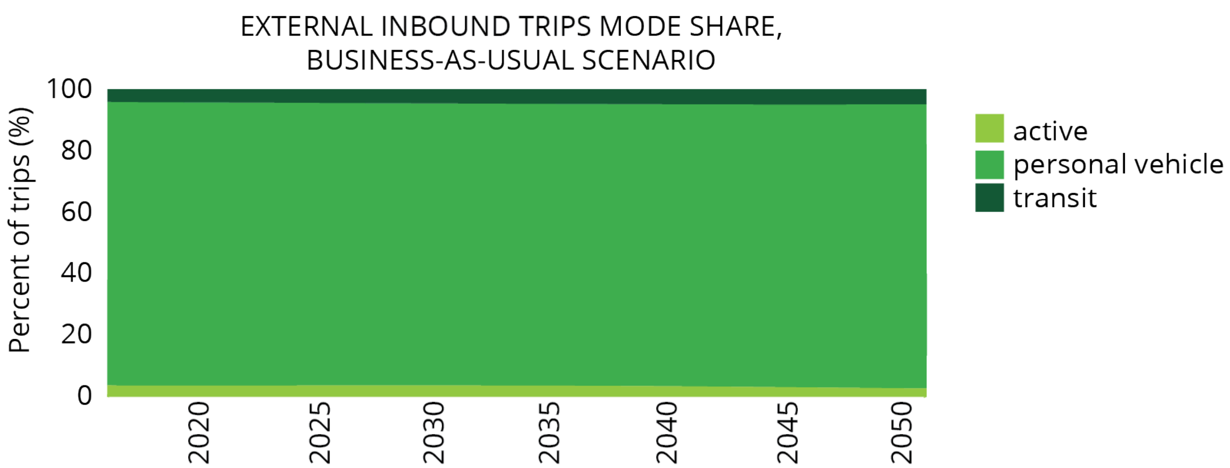


Figure 82. Mode share, external inbound trips, 2011–2050.

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)

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

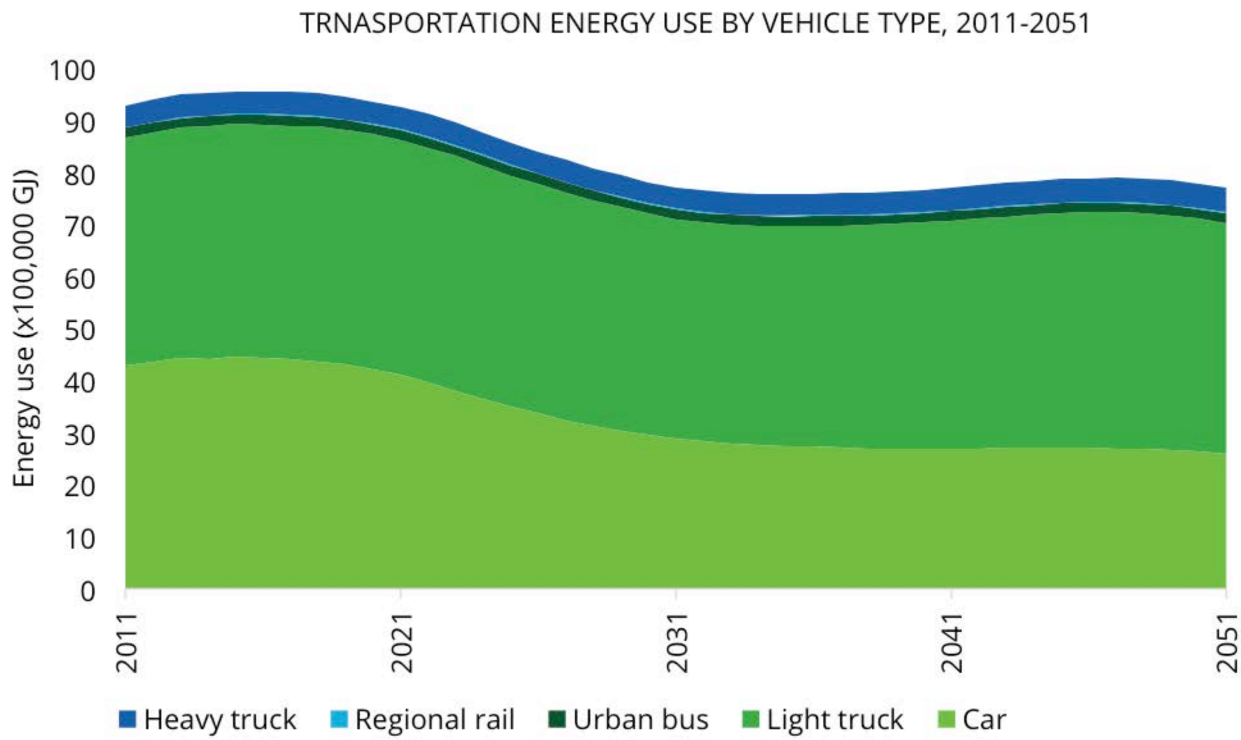


Figure 83. Transportation energy by vehicle type, 2011–2051.

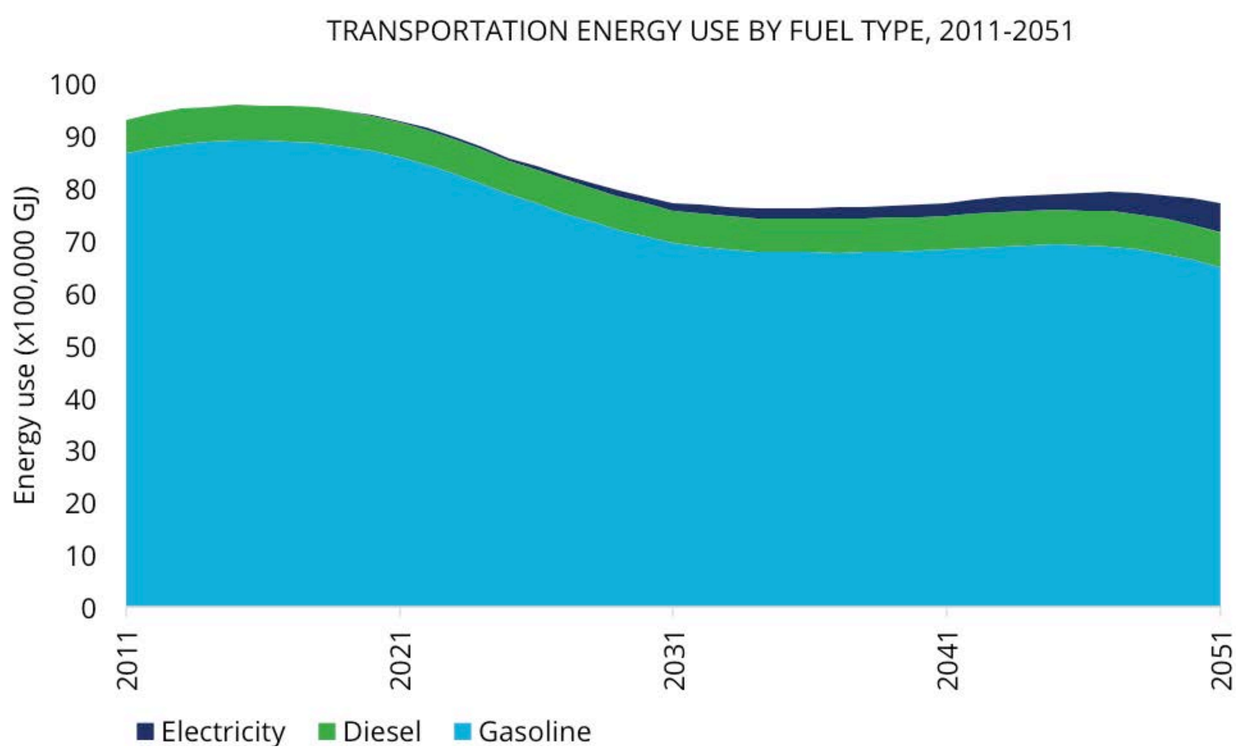


Figure 84. Transportation energy by fuel type, 2011–2051.

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

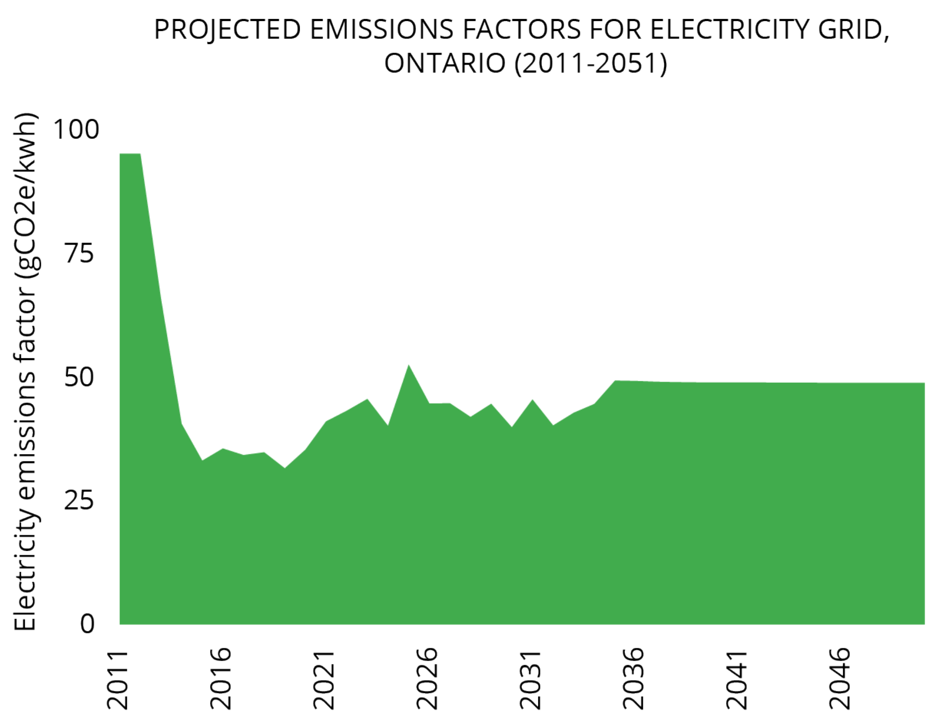


Figure 85. Projected emissions factors for electricity grid, Ontario (2011–2050).

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.

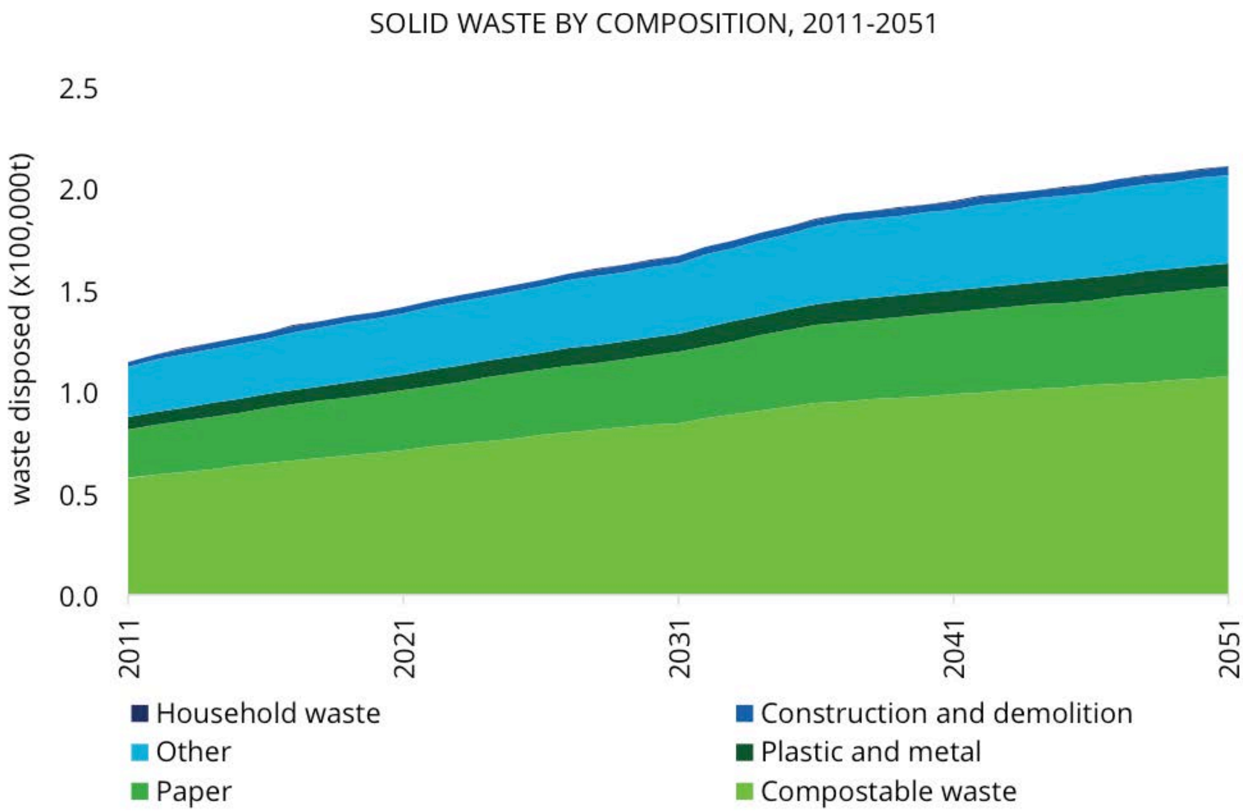


Figure 86. Solid waste by composition (2011–2051).

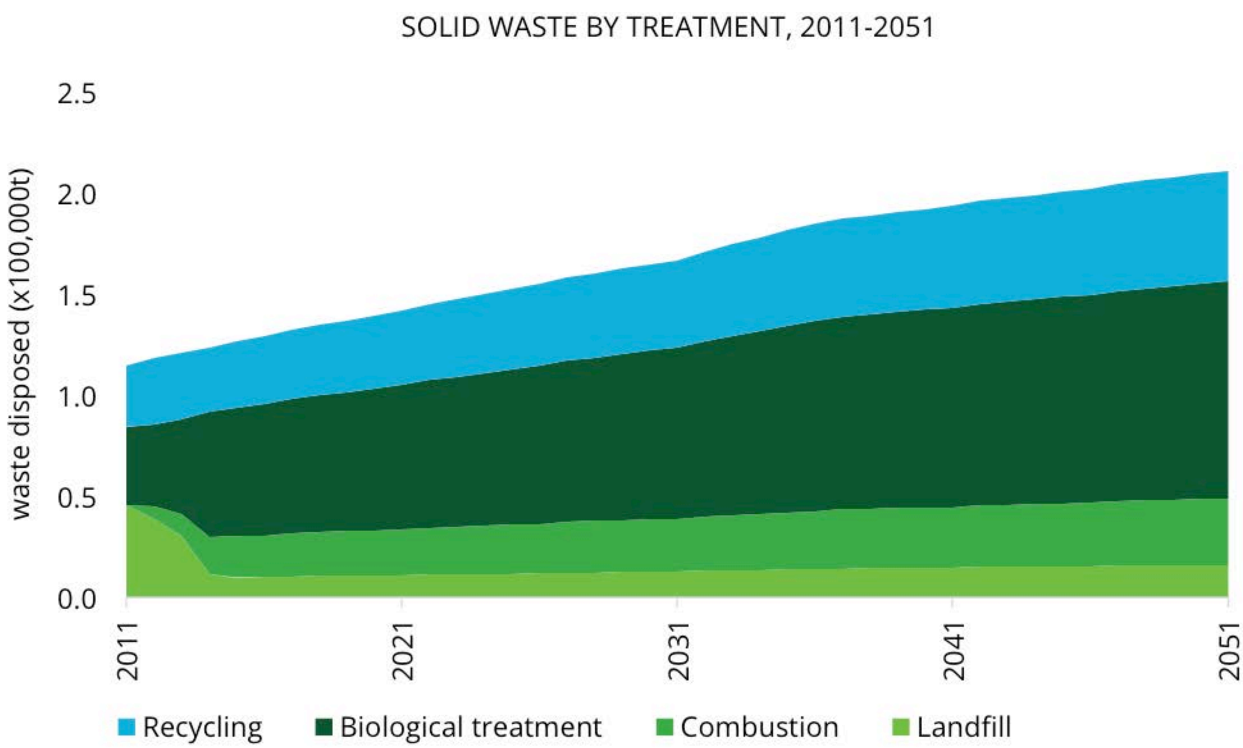


Figure 87. Solid waste by treatment type (2011–2051).

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.

EMISSIONS BY SECTOR, 2011-2051, BUSINESS-AS-USUAL SCENARIO

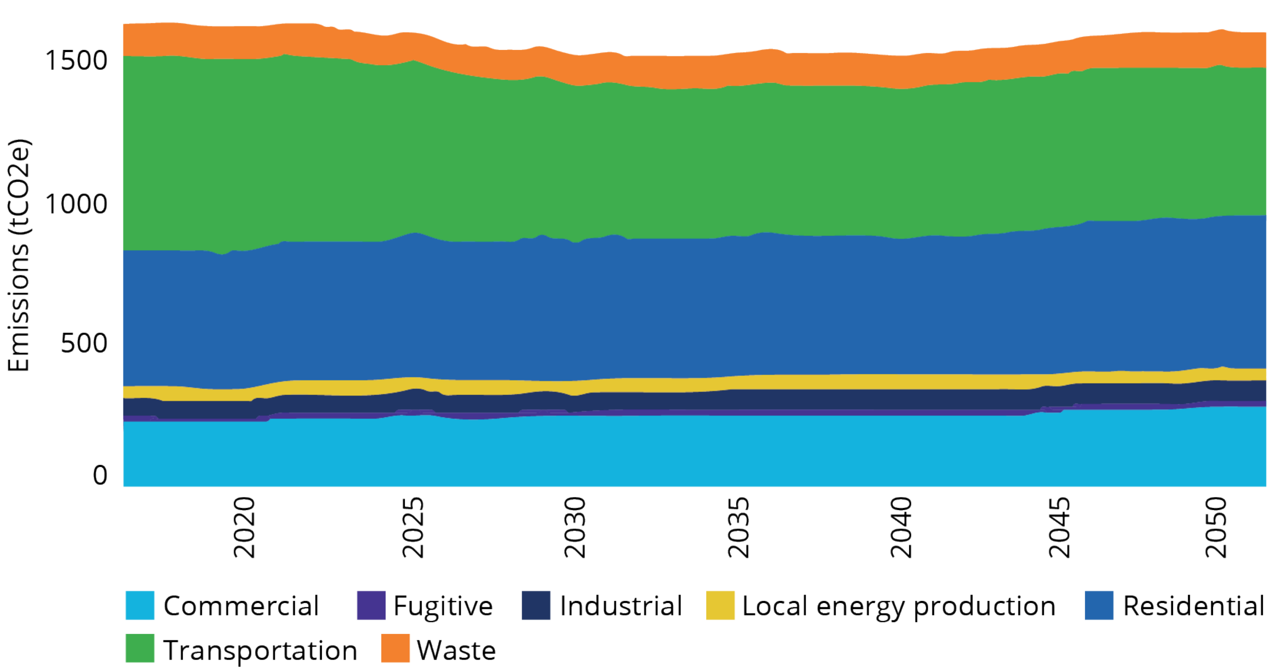


Figure 88. Total GHG emissions by sector (2011–2050).

EMISSIONS BY FUEL TYPE, 2011-2051, BUSINESS-AS-USUAL SCENARIO

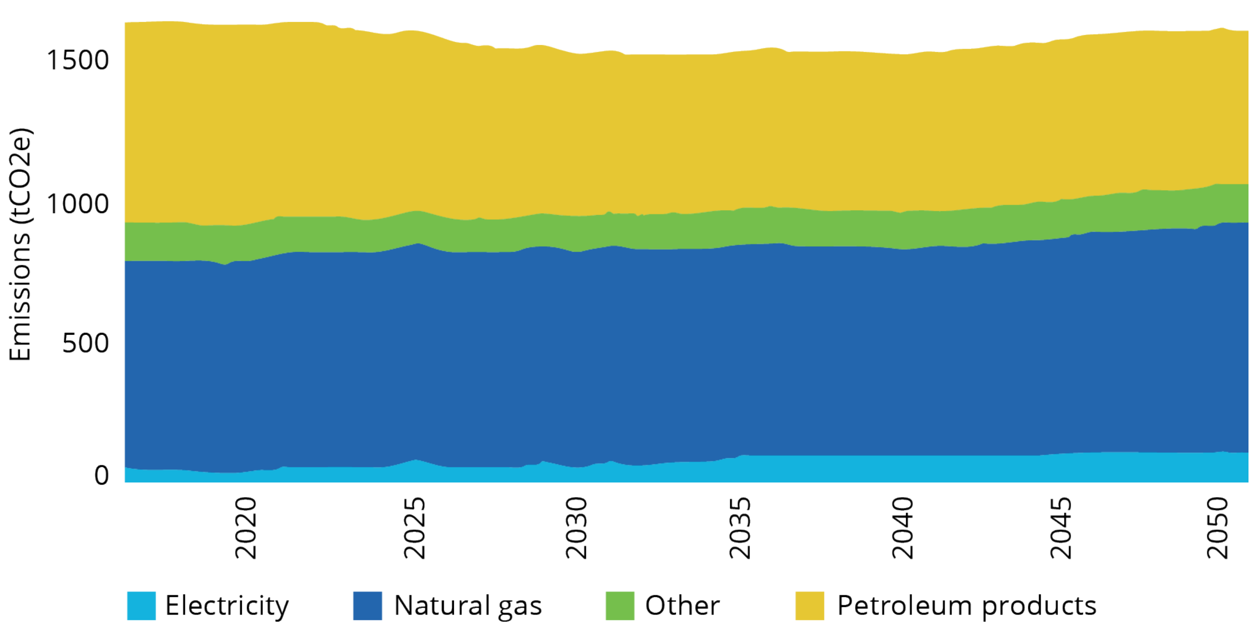


Figure 89. Total GHG emissions by fuel type (2011–2050).

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

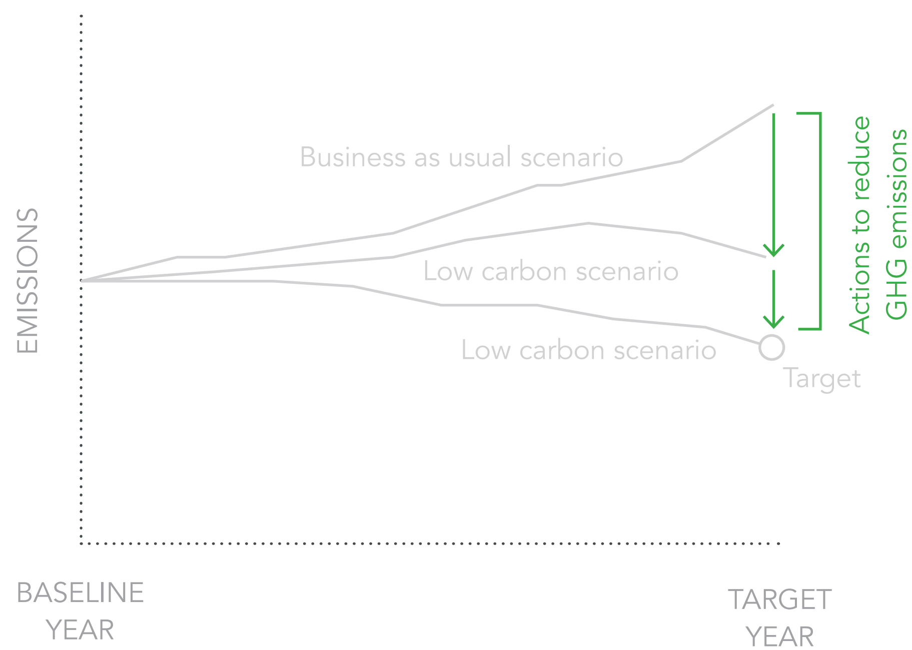
The City has benefitted significantly from the greening of the provincial grid and vehicle fuel efficiency standards, both of which have being implemented at the provincial level, and have not been driven by the City itself.

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

LOW CARBON PATHWAY DEVELOPMENT



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

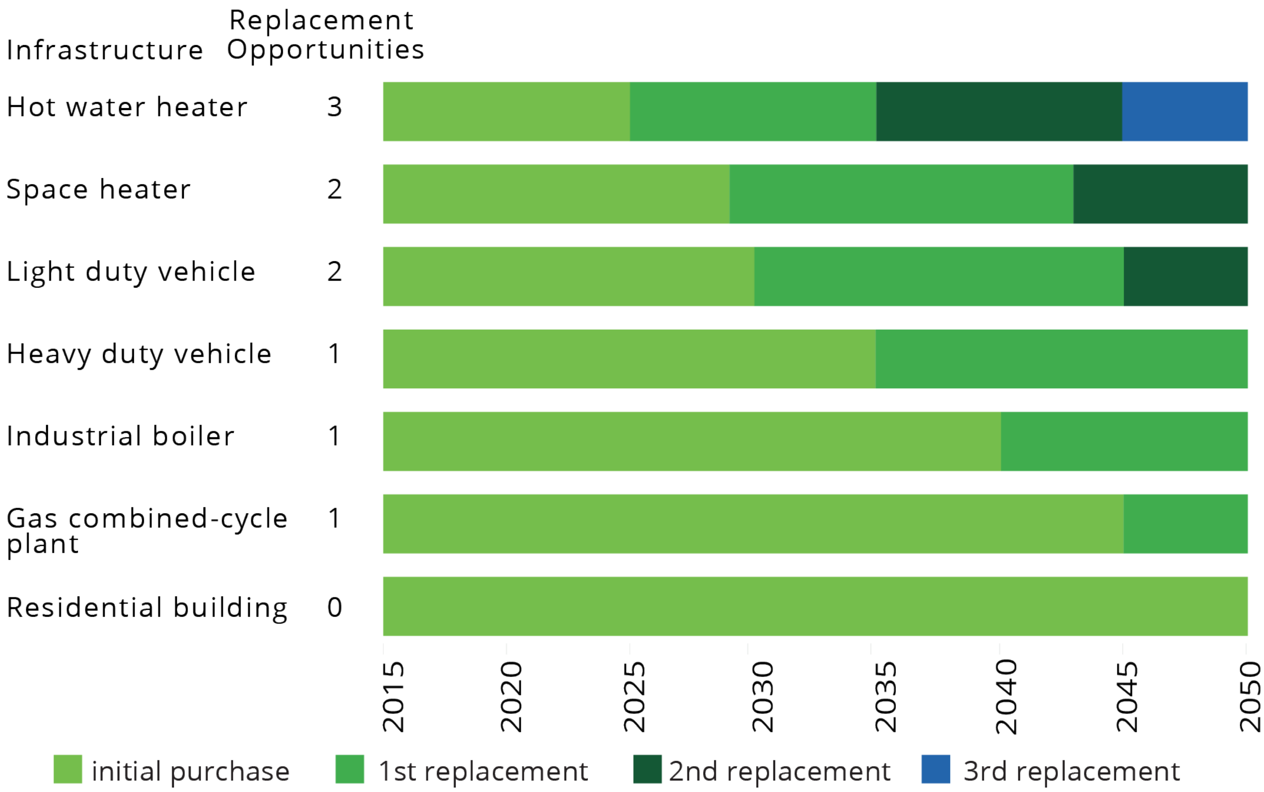


Figure 90. Example of turnover of key stocks.[8]

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.

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.

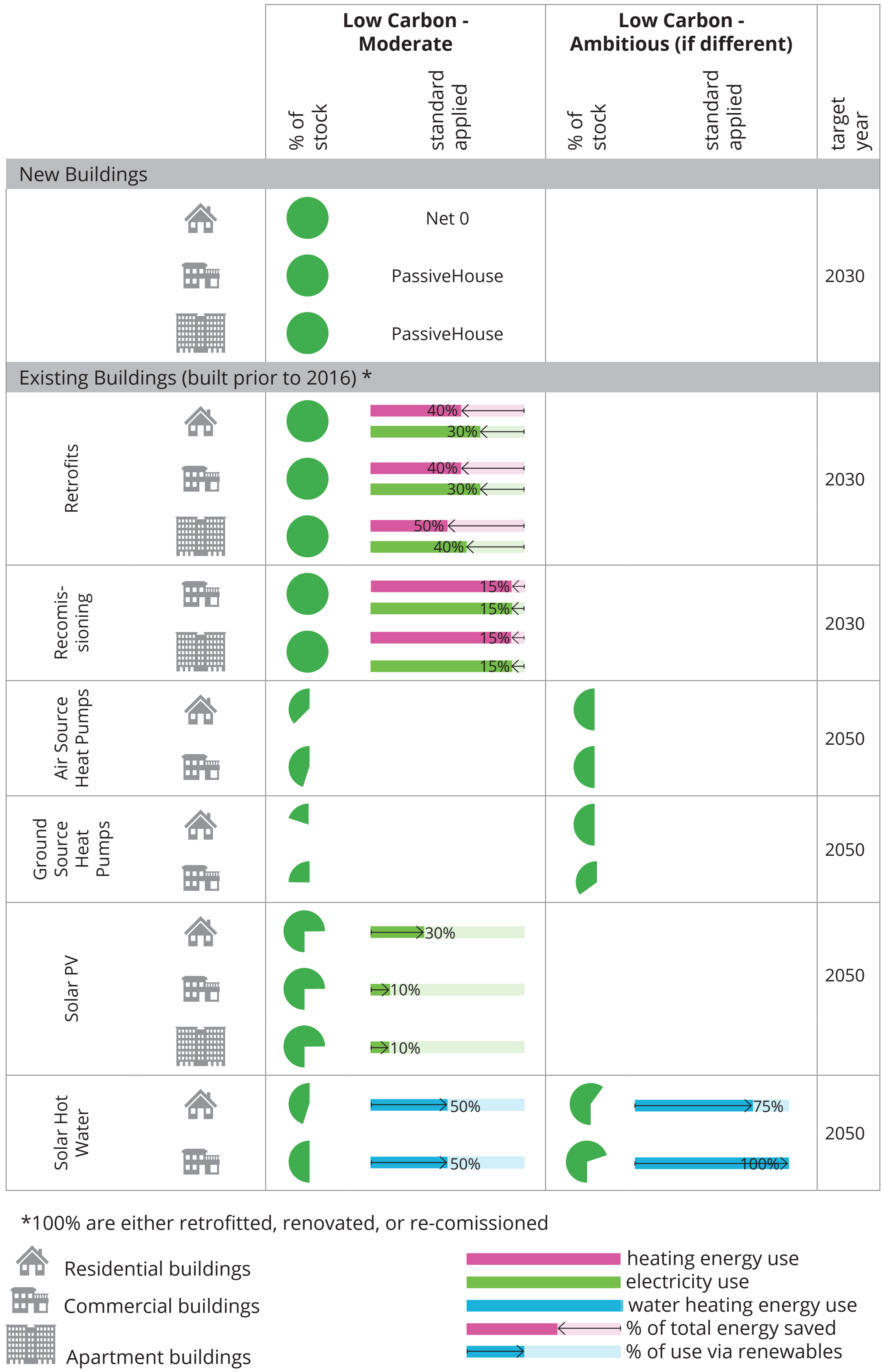


Figure 91. Summary of actions in the low carbon scenarios.

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.

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

2 MW

per year of

ground mounted solar PV are added between

2018 and 2050

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

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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

POTENTIAL MARKHAM CAR FREE ZONES

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

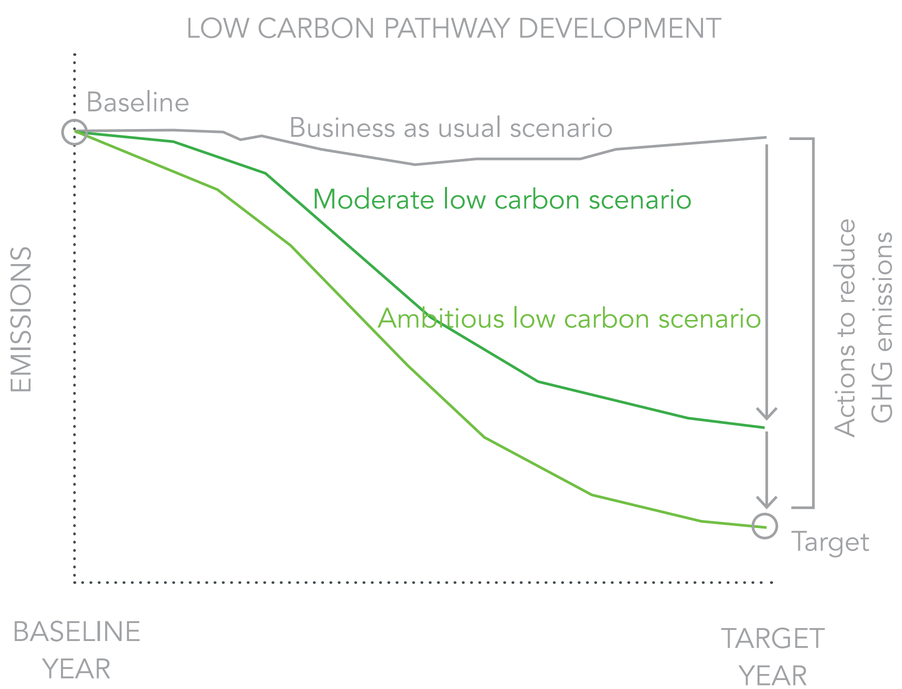
LC-amb increases solar hot water deployment, scaling up to 60% of the residential building stock by 2050 and 70% of commercial stock. Solar hot water supplies 75% of residential and 100% of commercial hot water requirements.

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.

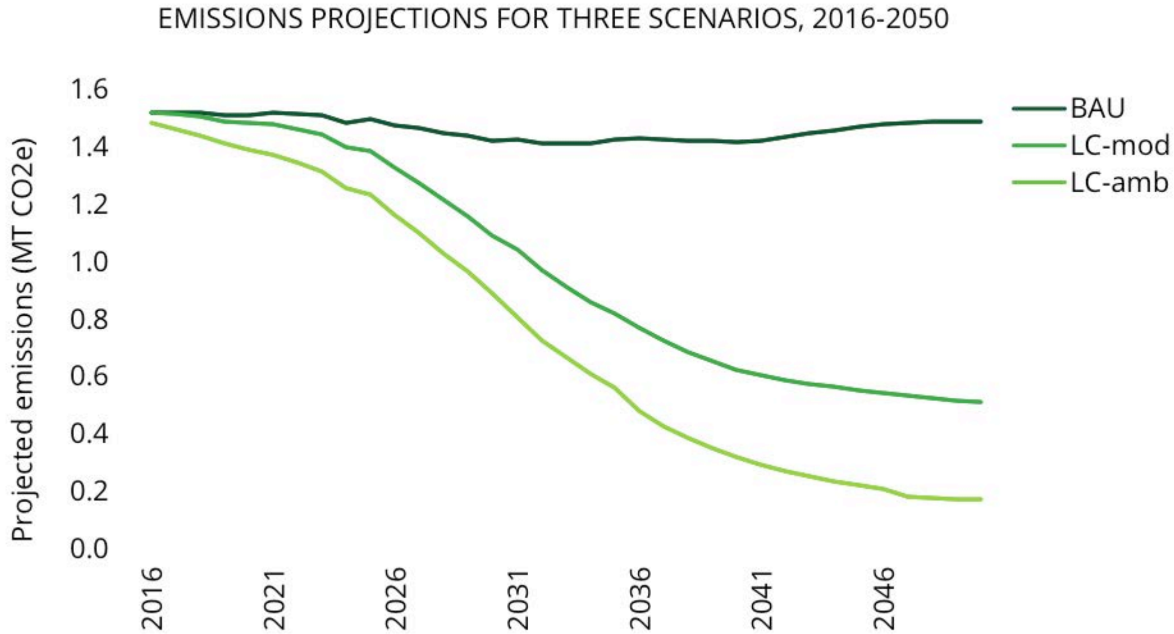


Figure 93. BAU, LC-mod and LC-amb projections, 2016–2050.

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.

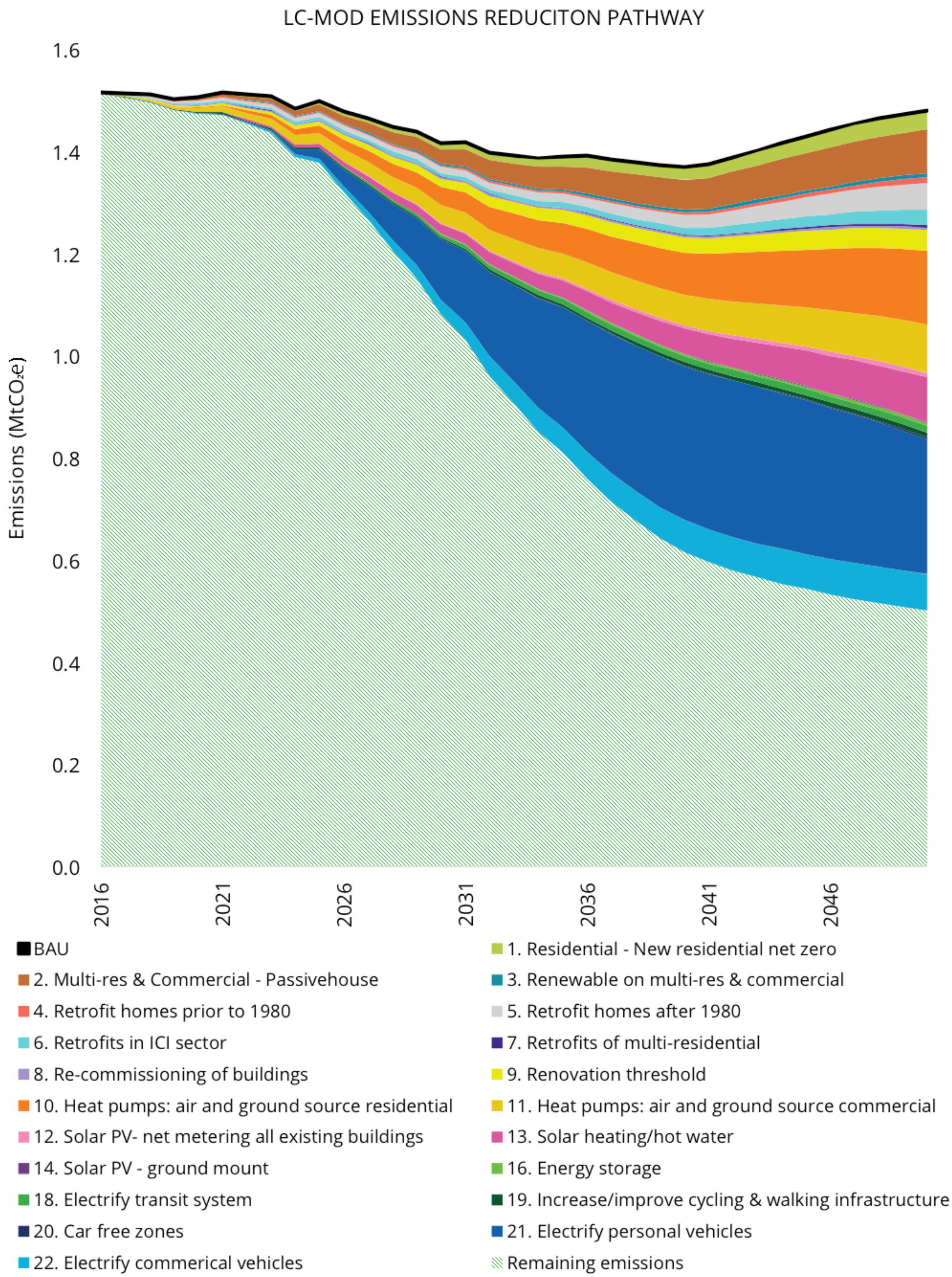


Figure 94. LC-mod emissions reductions, 2016–2050.

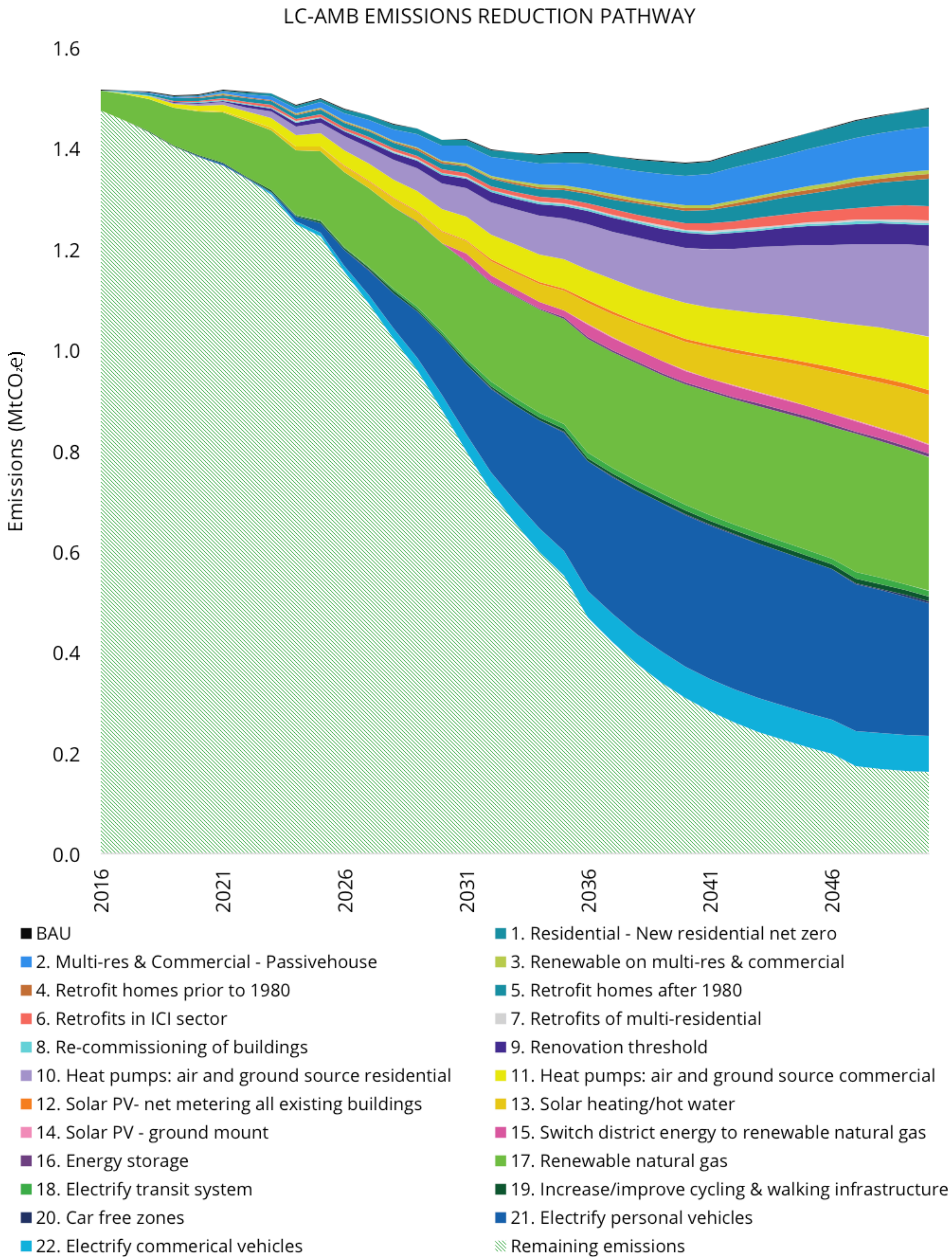


Figure 95. LC-amb emissions reductions, 2016–2050.

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.

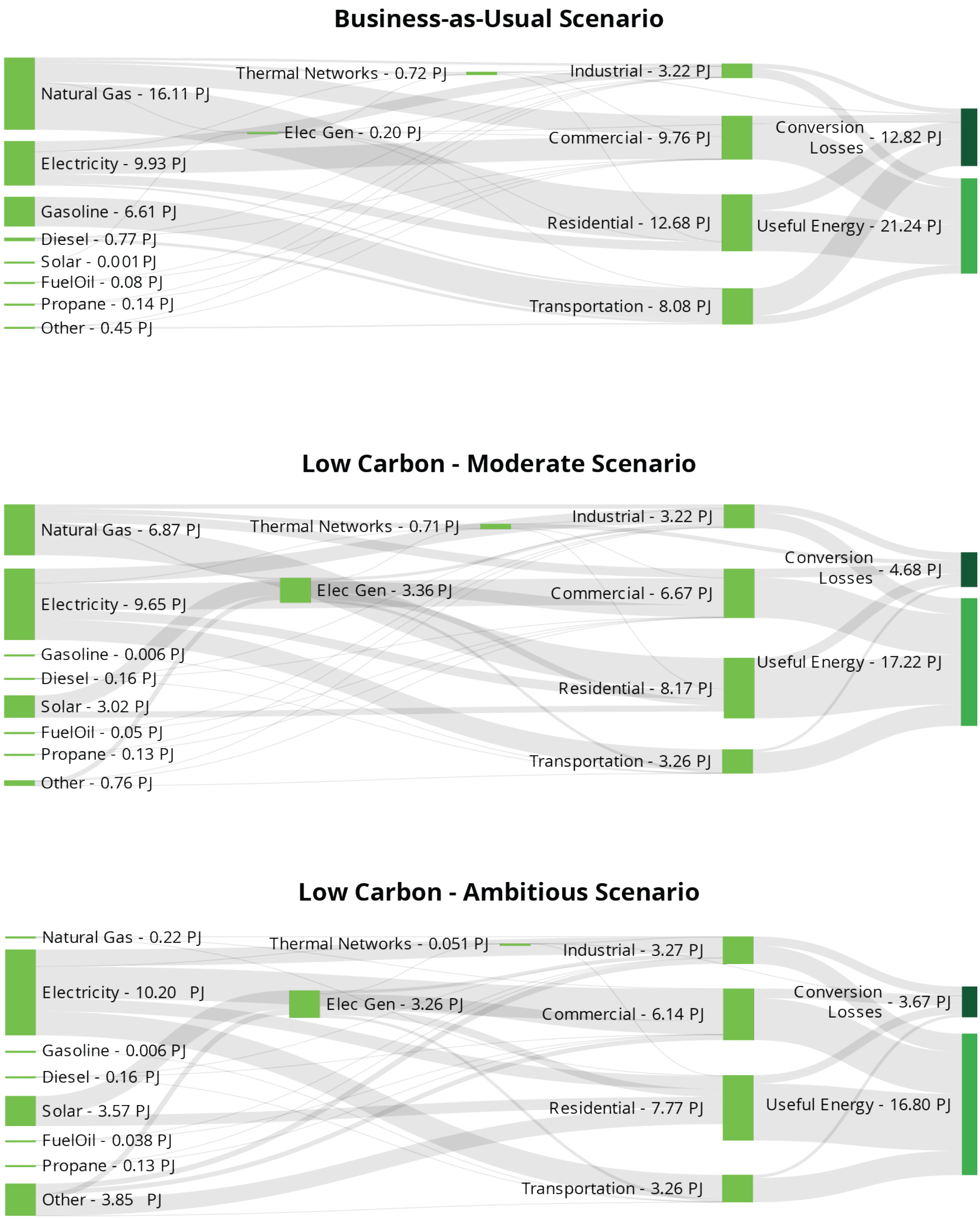


Figure 96. Energy flow sankey diagrams, 2050.

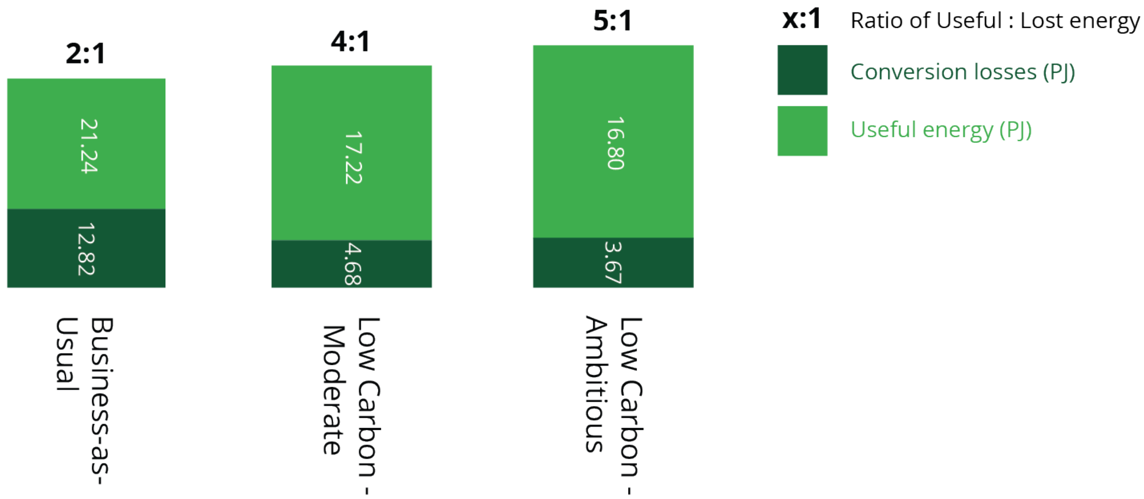


Figure 97. *Ratio of useful to lost energy.*

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).

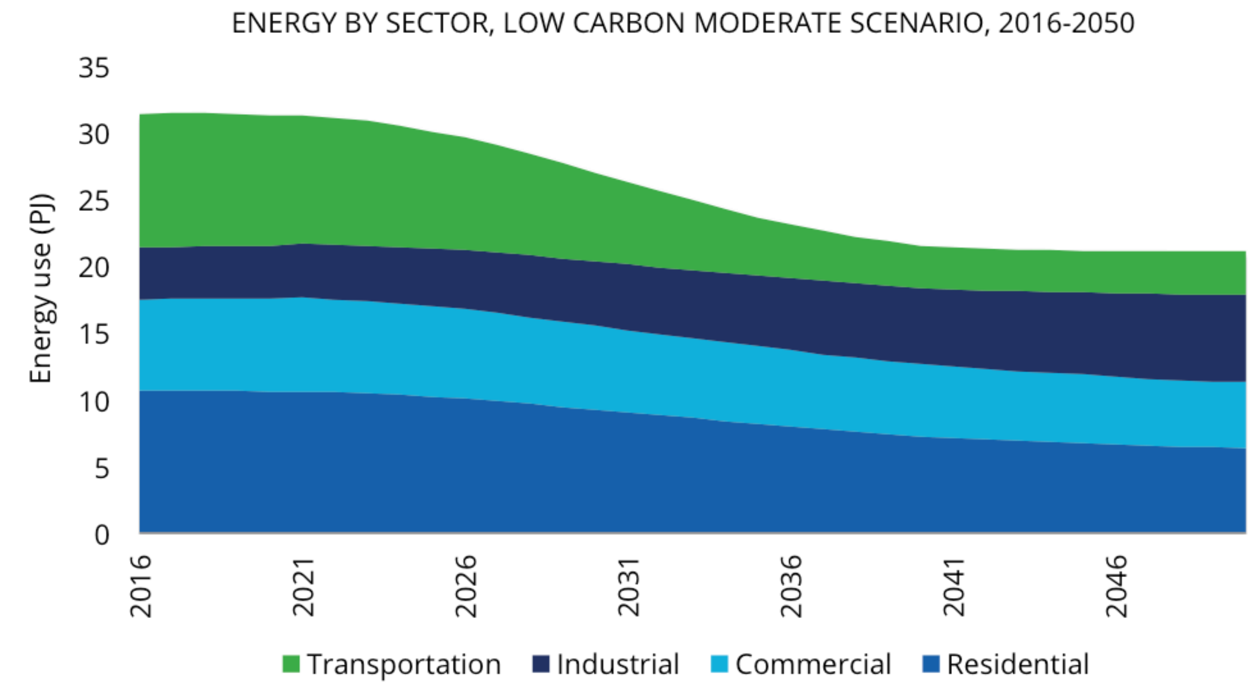


Figure 98. Energy by sector, LC-mod, 2016–2050.

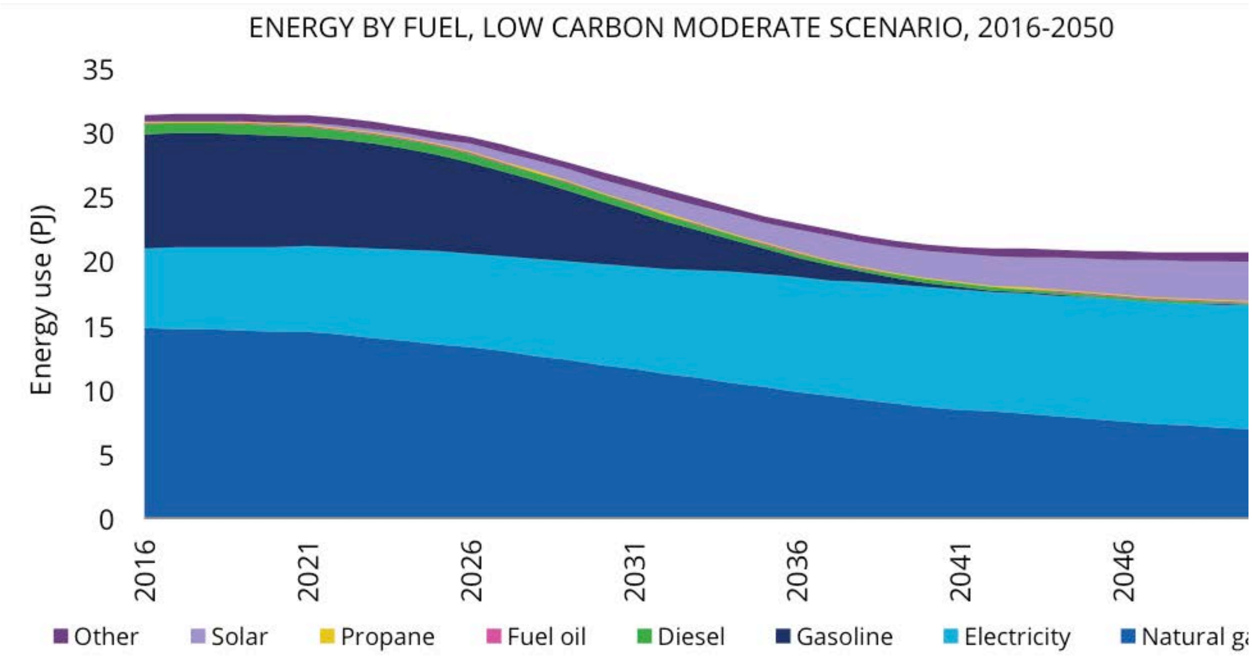


Figure 99. Energy by fuel, LC-mod, 2016–2050.

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

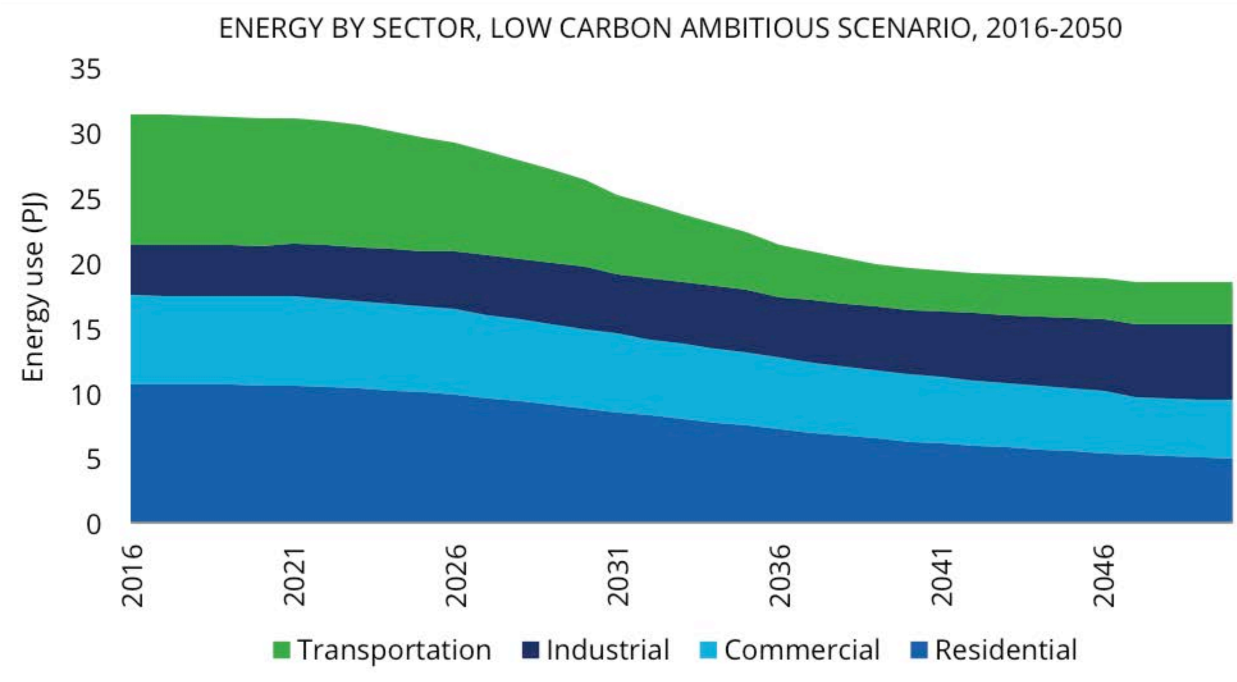


Figure 100. Energy by sector, LC-amb, 2016–2050.

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

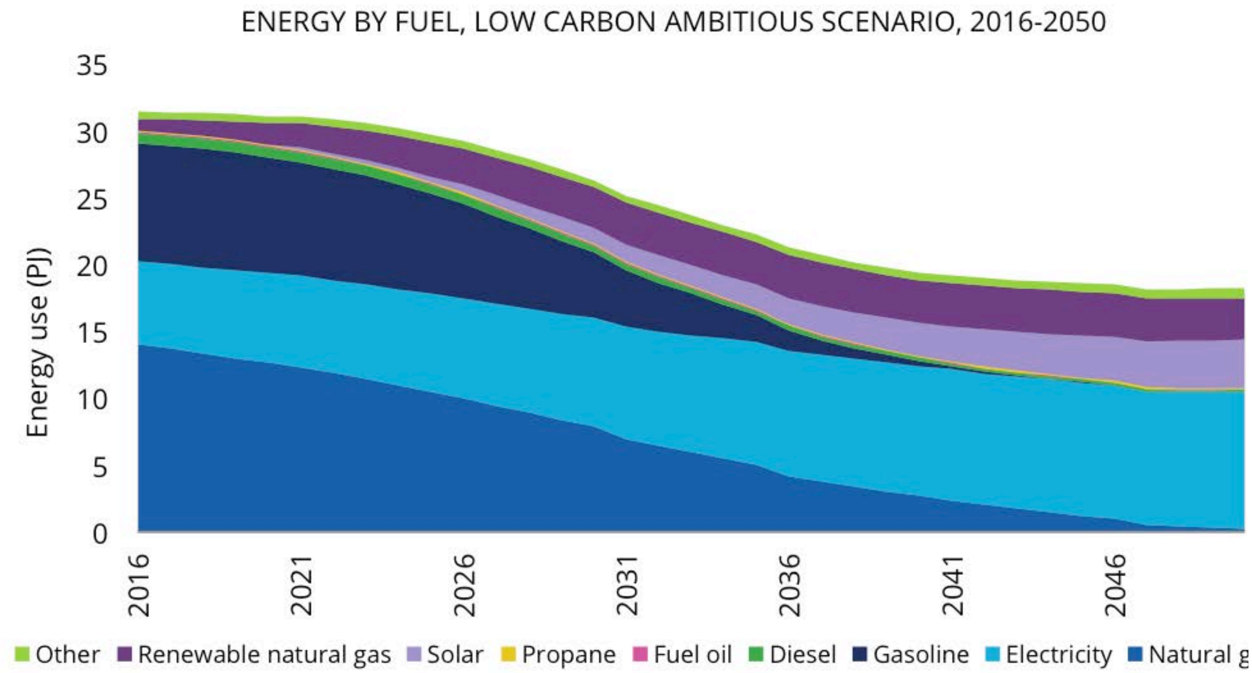


Figure 101. Energy by fuel, LC-amb, 2016–2050.

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.

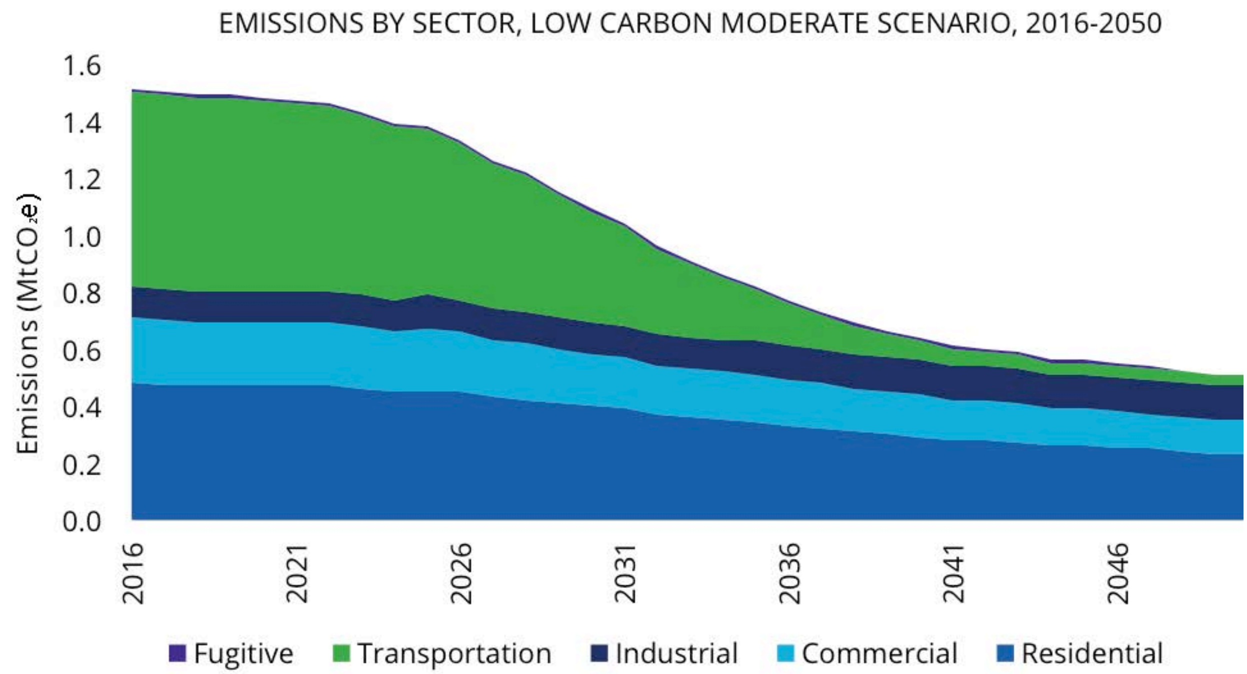


Figure 102. Emissions by sector, LC-mod, 2016–2050.

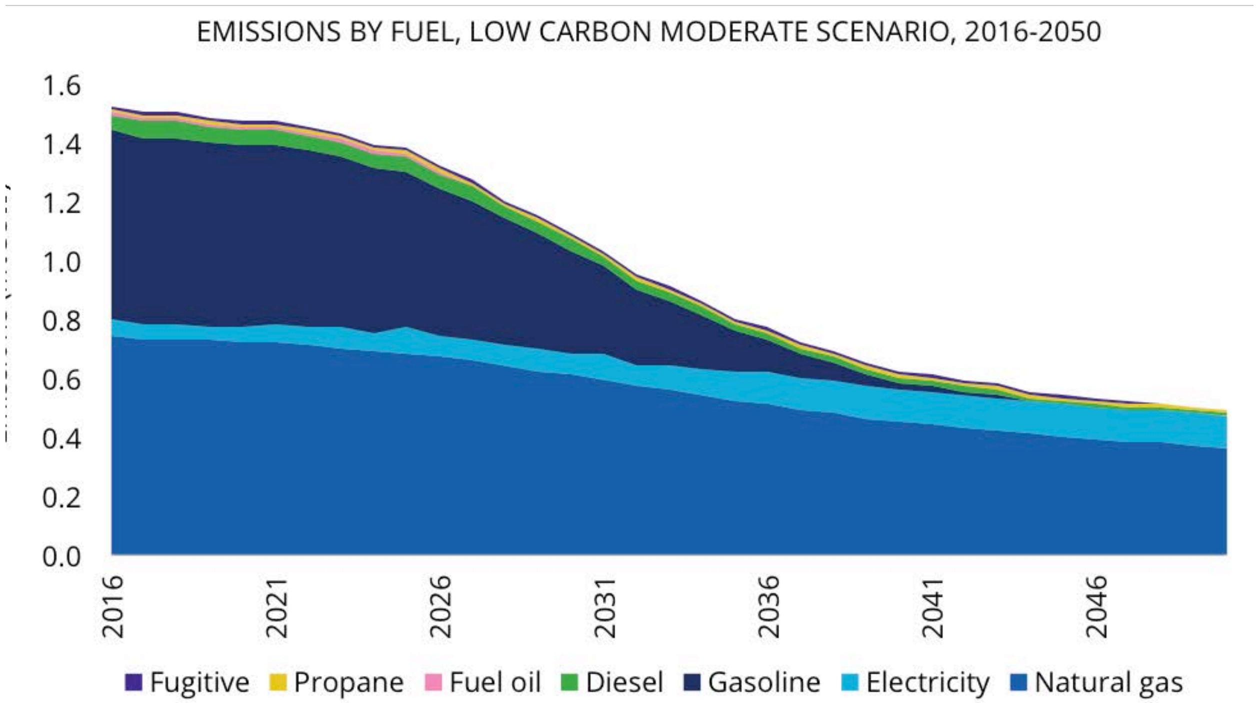


Figure 103. Emissions by fuel, LC-mod, 2016-2050.

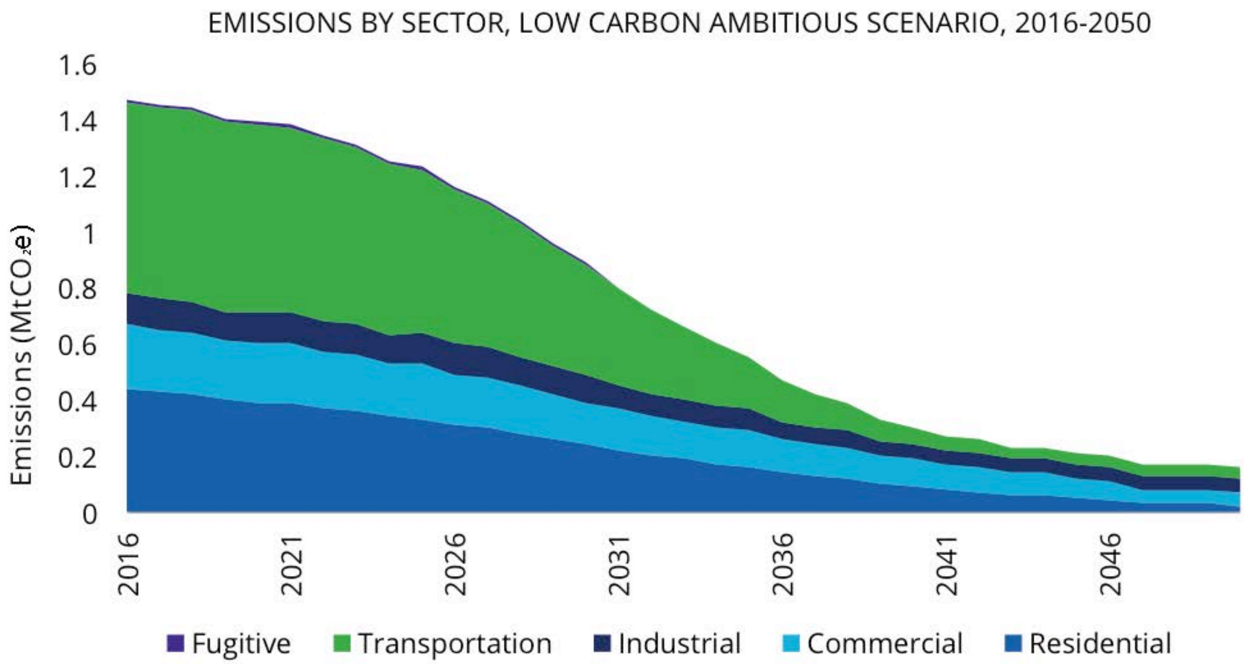


Figure 104. Emissions by sector, LC-amb, 2016–2050.

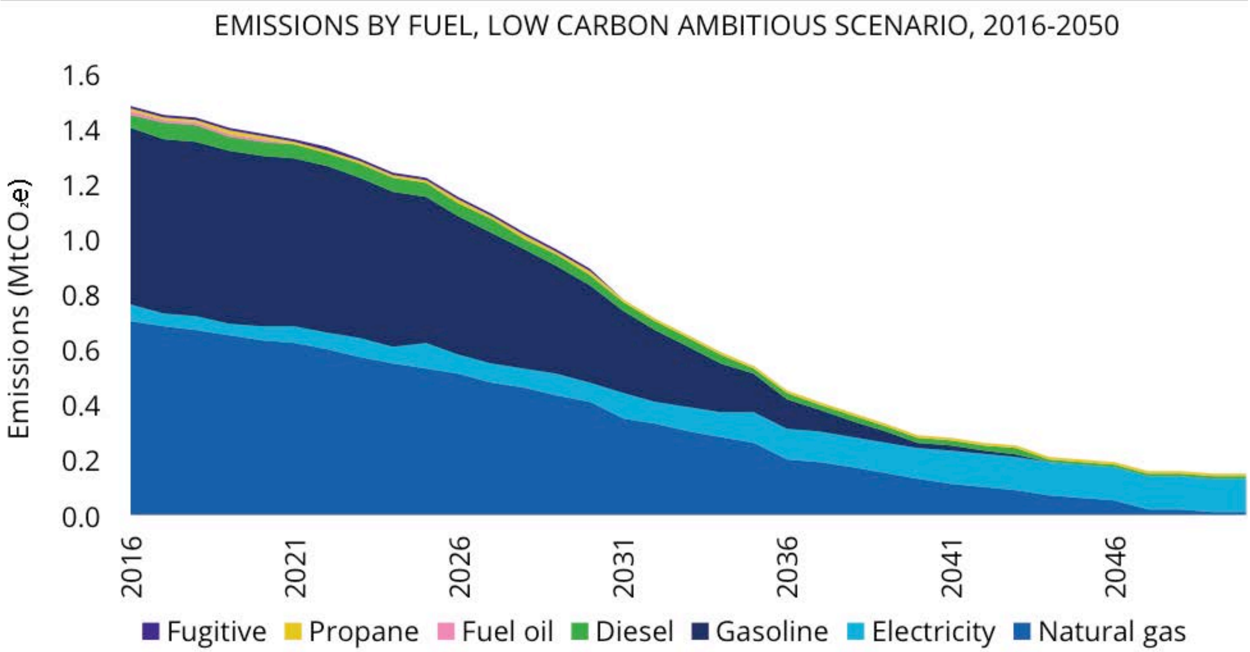


Figure 105. Emissions by fuel, LC-amb, 2016–2050.

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.

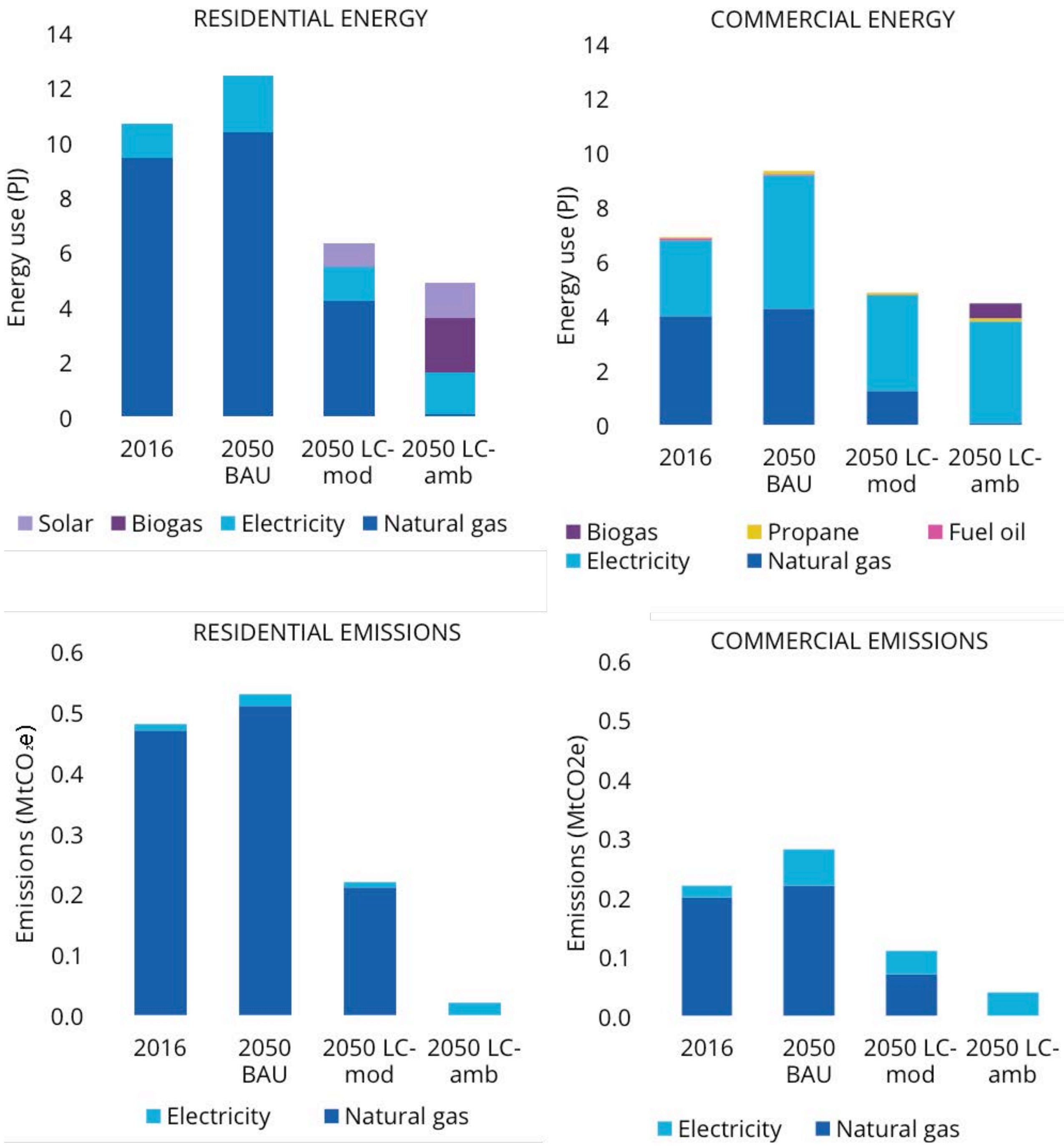


Figure 106. Residential, commercial (includes institutional) buildings energy and emissions by fuel.

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.

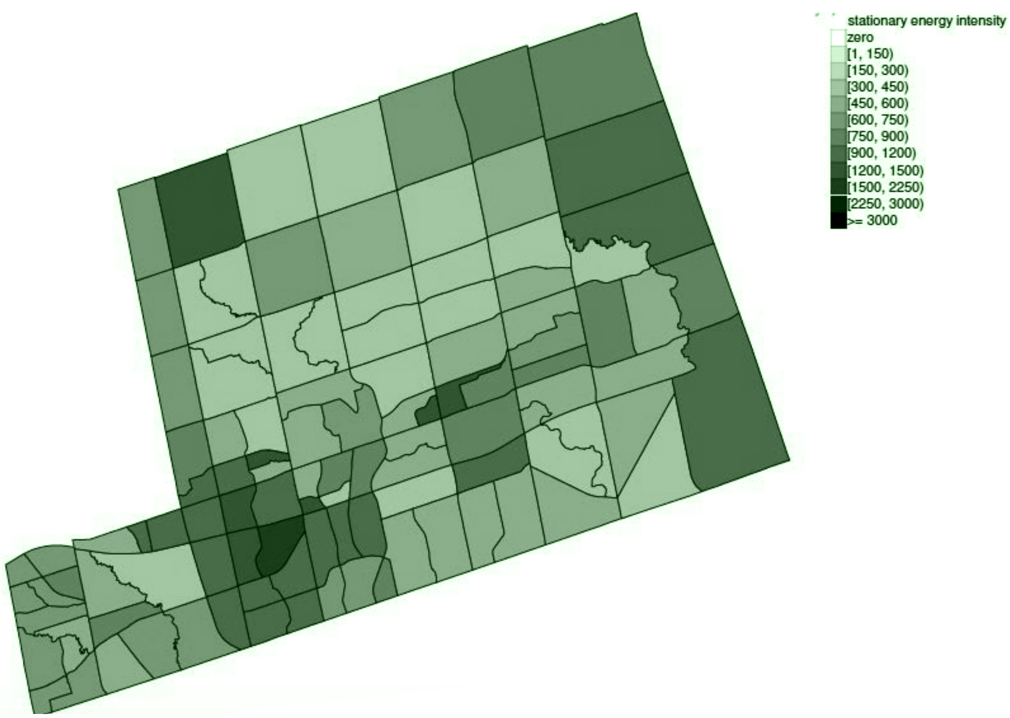


Figure 107. Building energy intensity (MJ/m2 by zone), BAU 2050.

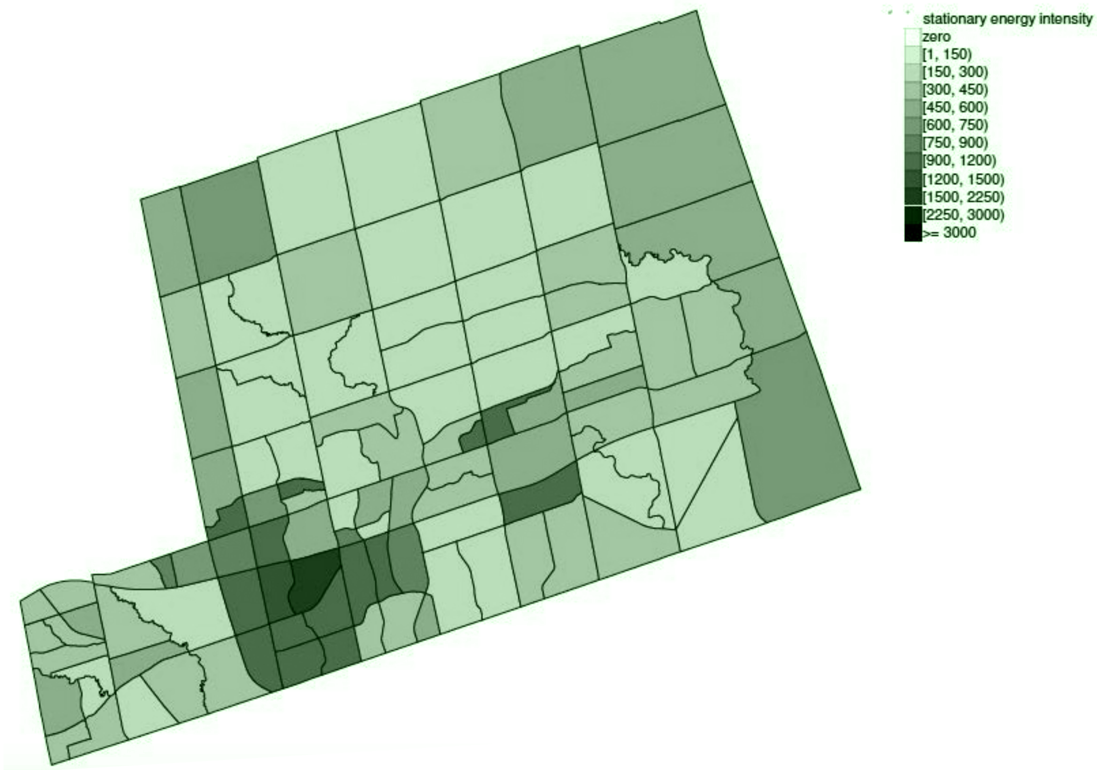


Figure 108. Building energy intensity (MJ/m2 by zone), LC-mod 2050.

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.

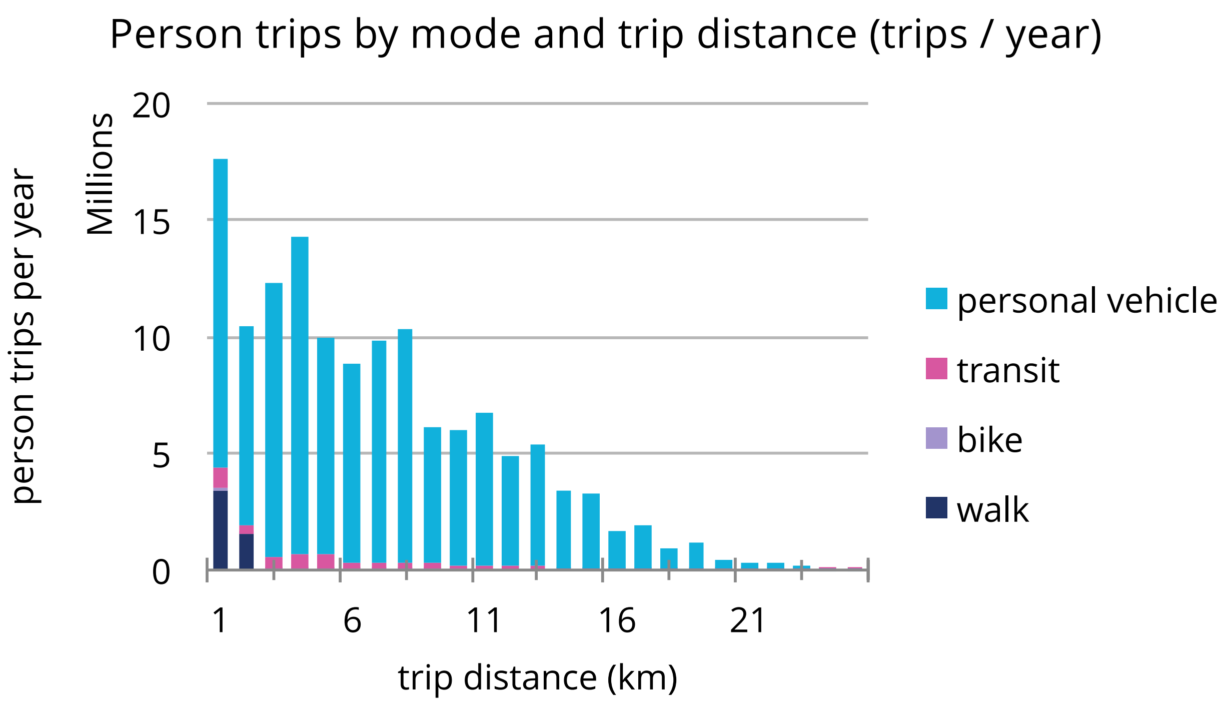


Figure 109. Person trips by mode and distance, BAU 2050.

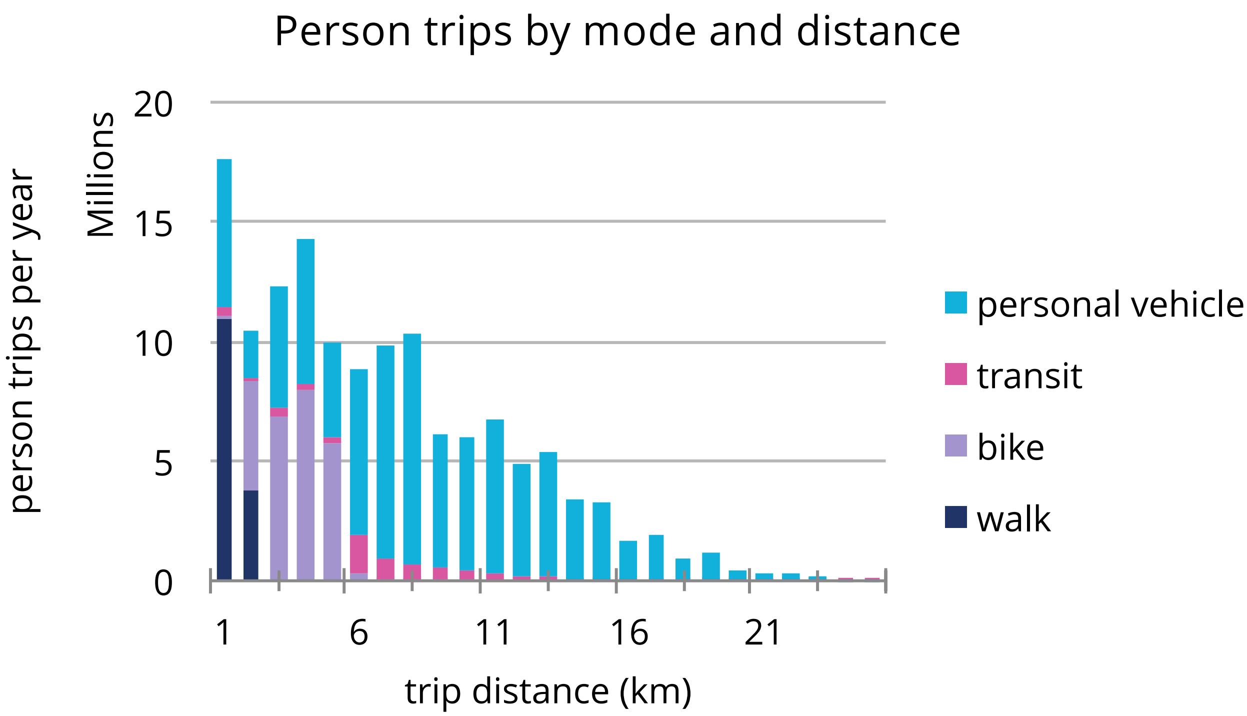


Figure 110. Person trips by mode and distance, LC-mod 2050.

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.

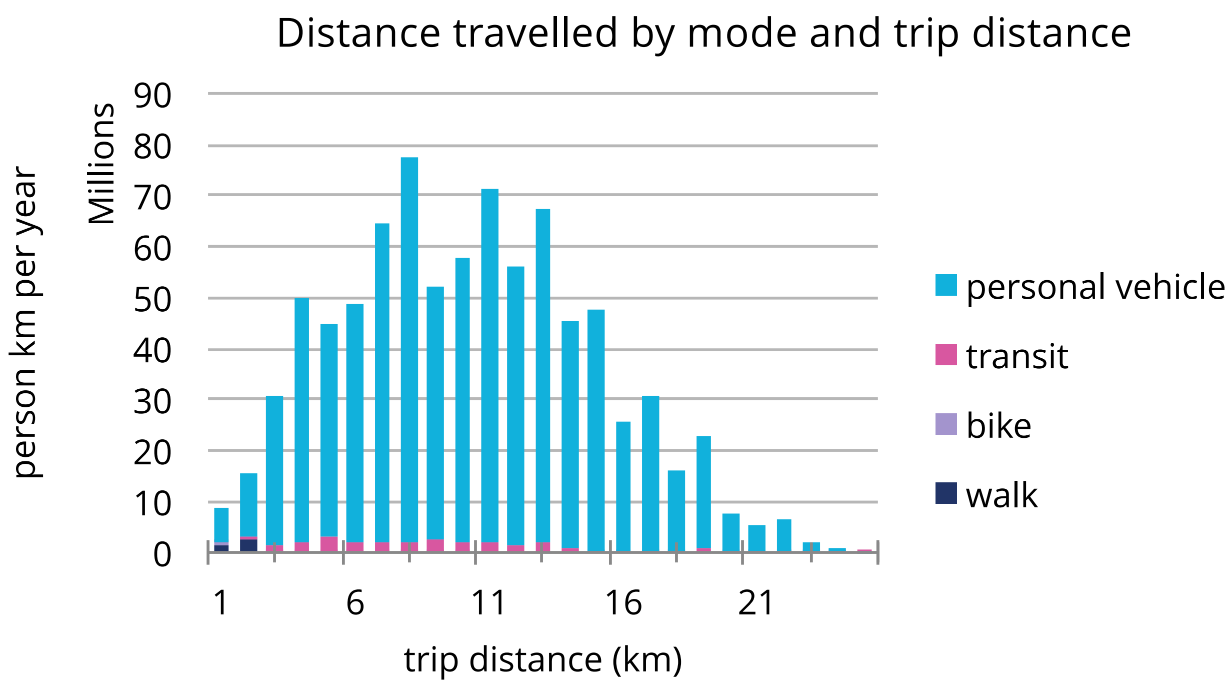


Figure 111. Distance travelled by mode and trip distance, BAU 2050.

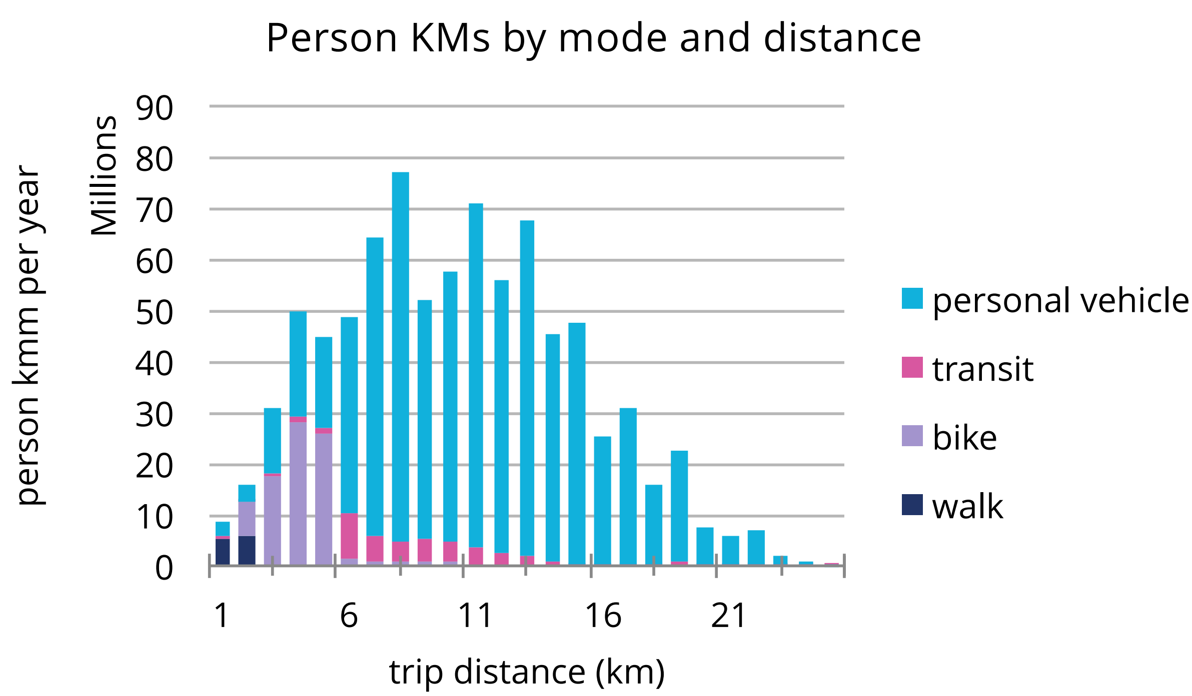


Figure 112. Distance travelled by mode and trip distance, LC-mod 2050.

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.

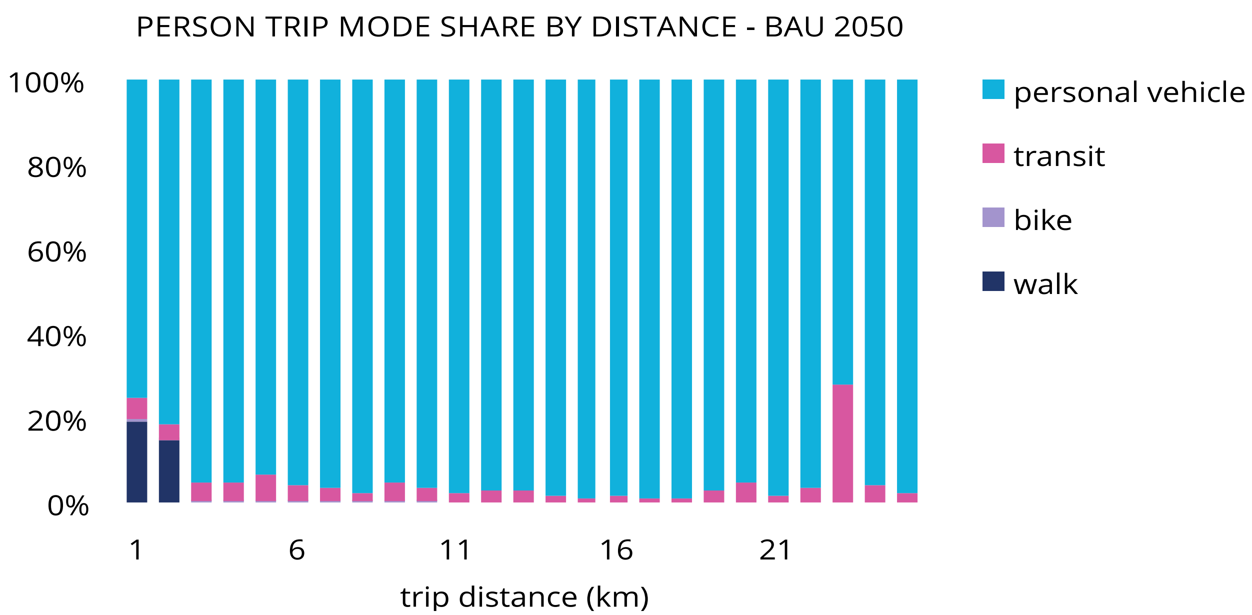


Figure 113. Person trip mode share by distance, BAU 2050.

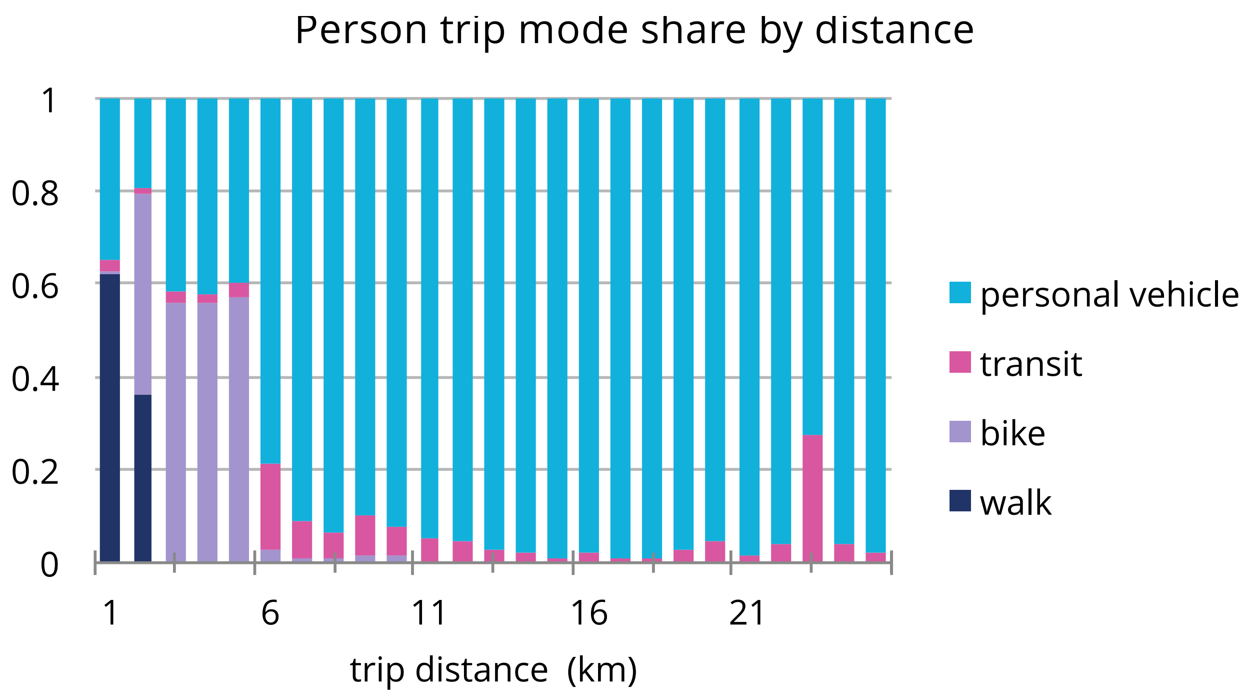


Figure 114. Person trip mode share by distance, LC-mod 2050.

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.

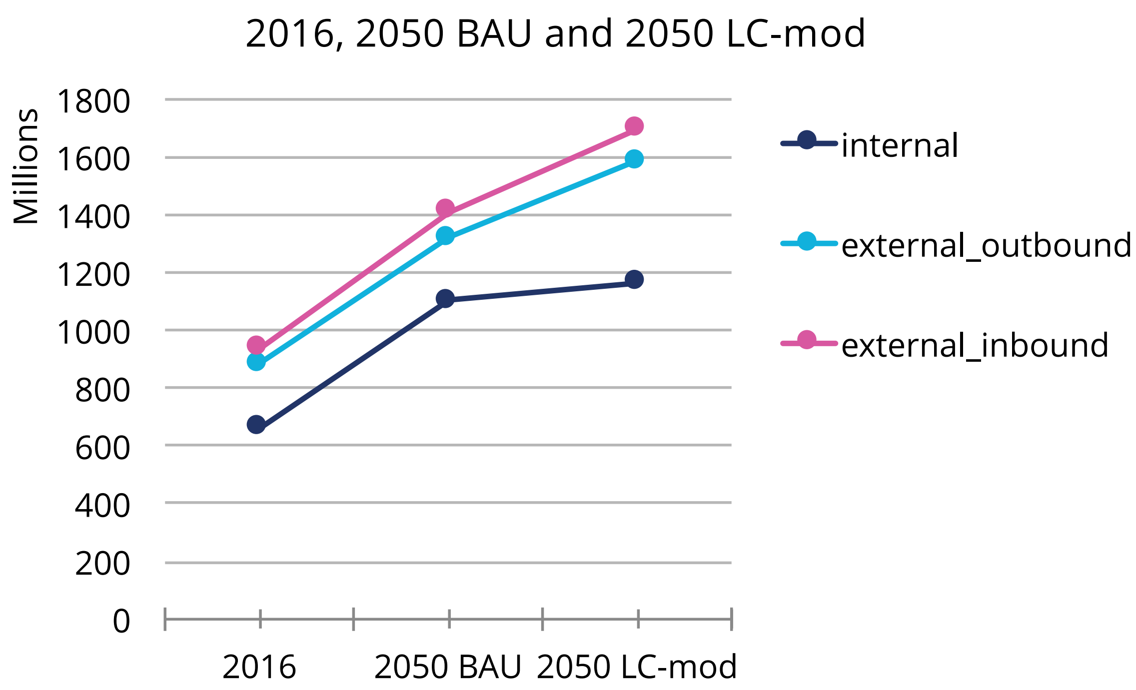


Figure 115. Personal use VKT.

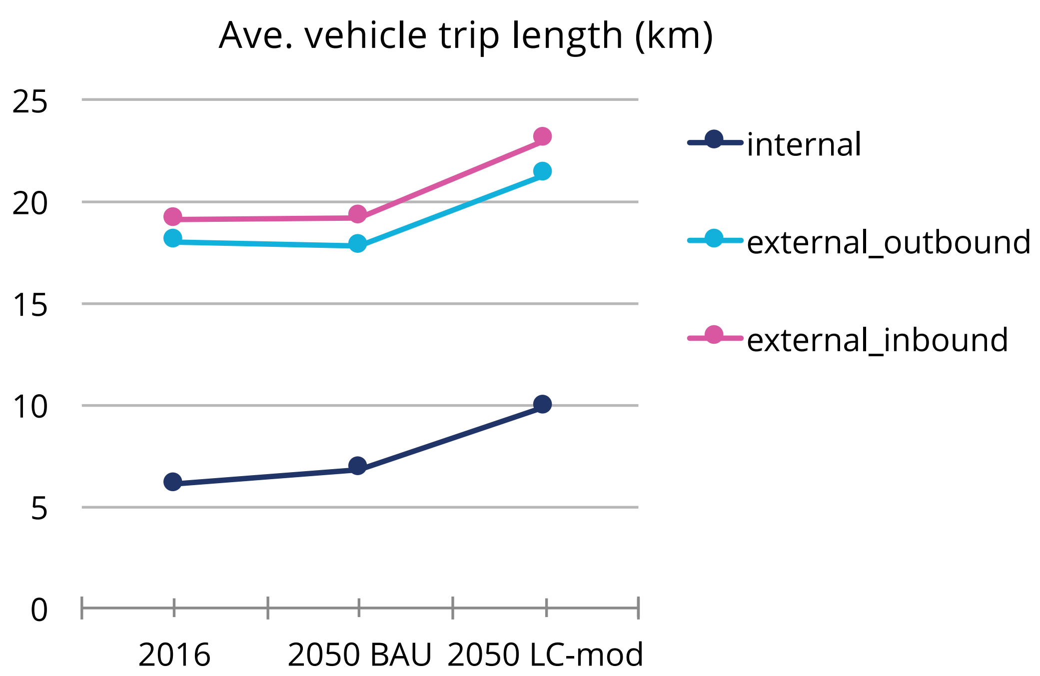


Figure 116. Average vehicle trip length.

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.

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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.

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

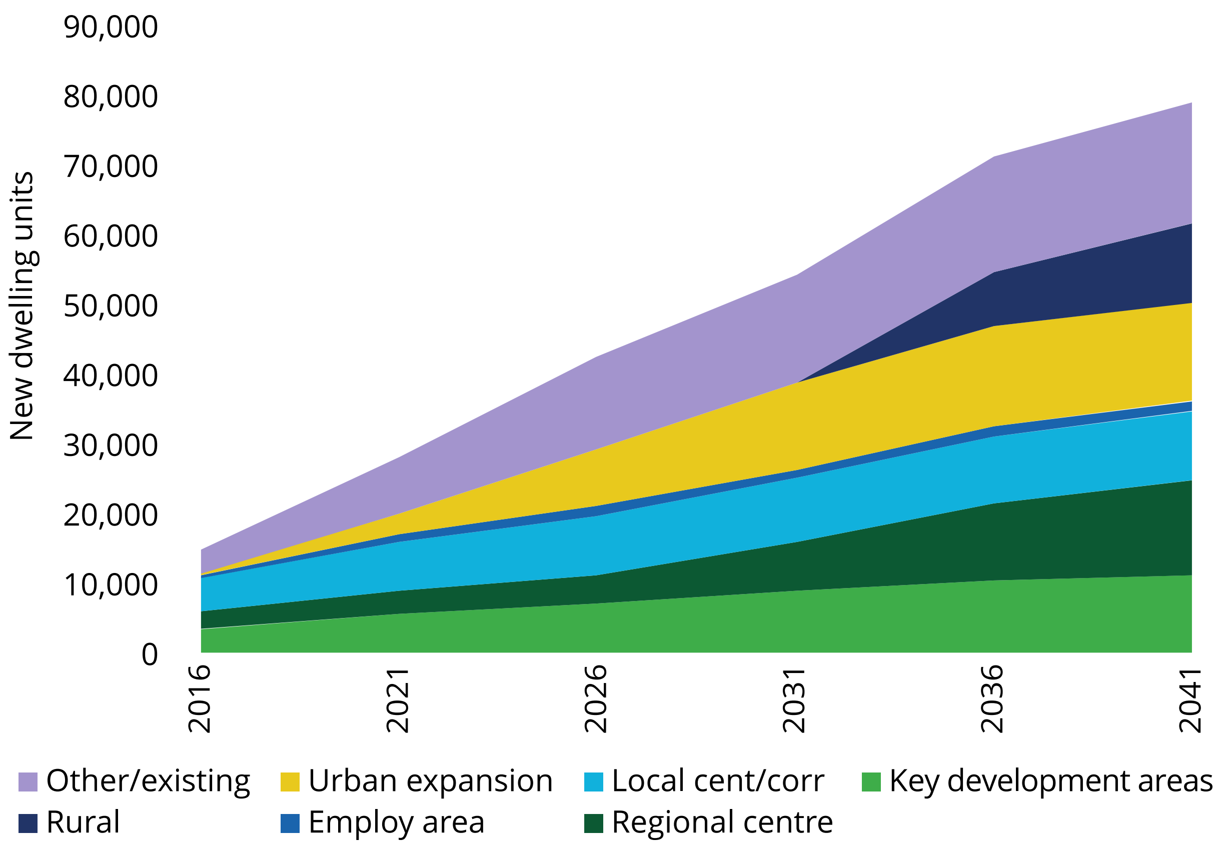

Figure 117. Projected new dwelling units for Markham, 2016-2041, from Region of York 2041 Preferred Growth Strategy.

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.

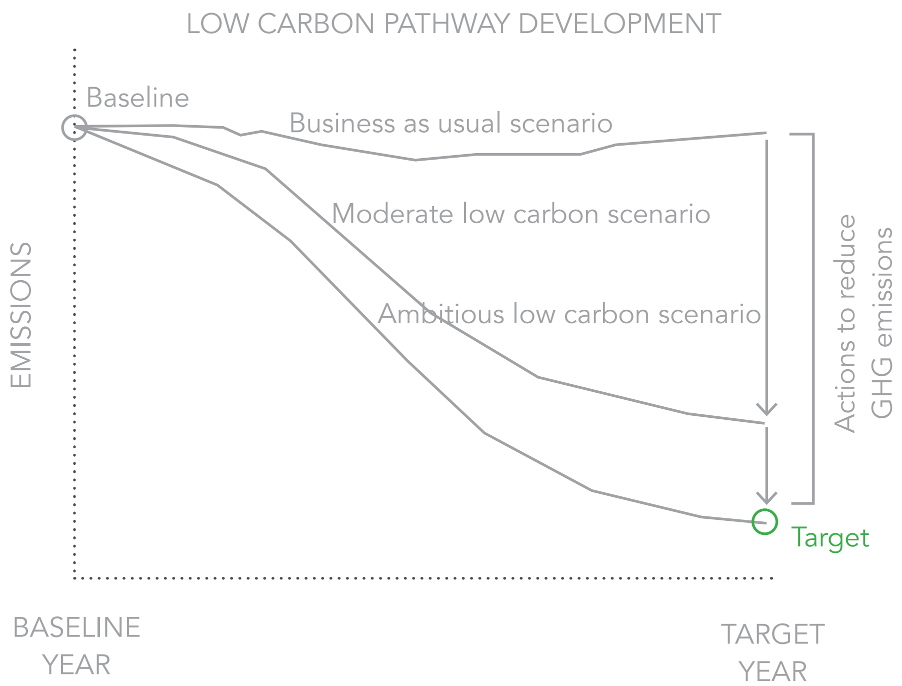
The aging population may have additional impacts on energy use, as the cohorts of 65+ population are likely to drive less than during their working years, whereas the modelling assumed that VKT rates are not influenced by demographic characteristics. As a result, energy use and GHG emissions may decrease 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.

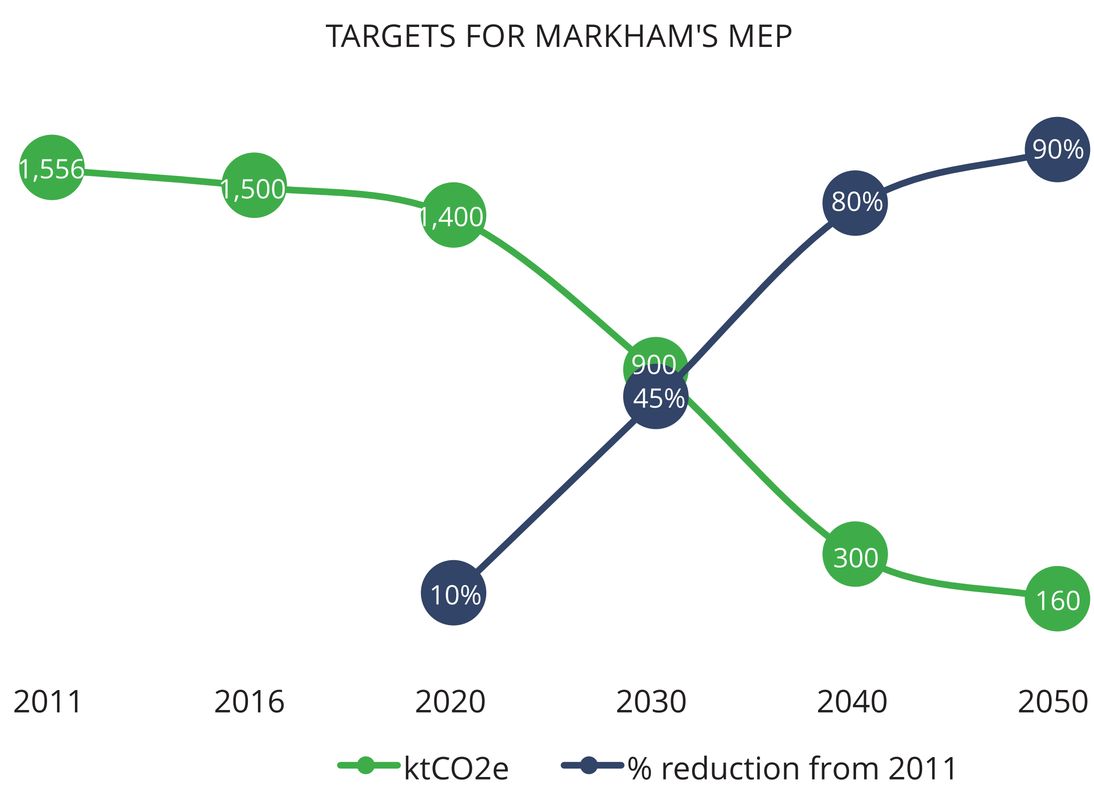
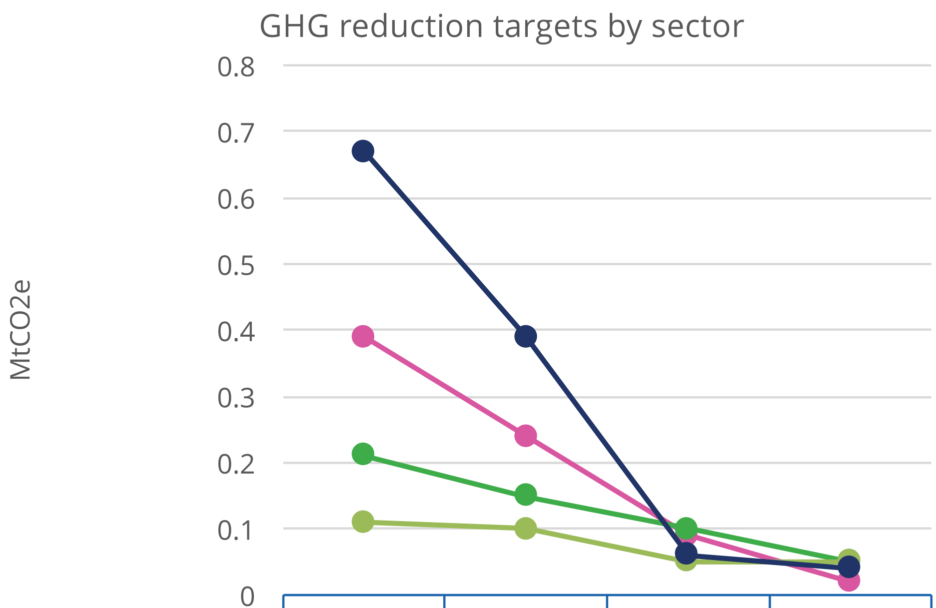


Figure 118. GHG reductions targets for the MEP.

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.

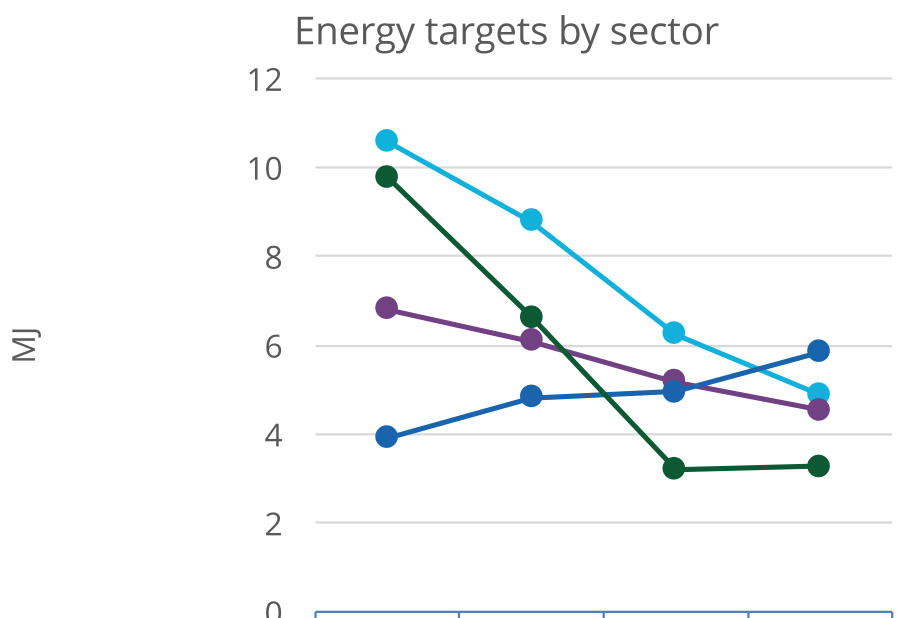
The most significant GHG emissions reductions are in the transportation sector.



	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 $MtCO_2e$.

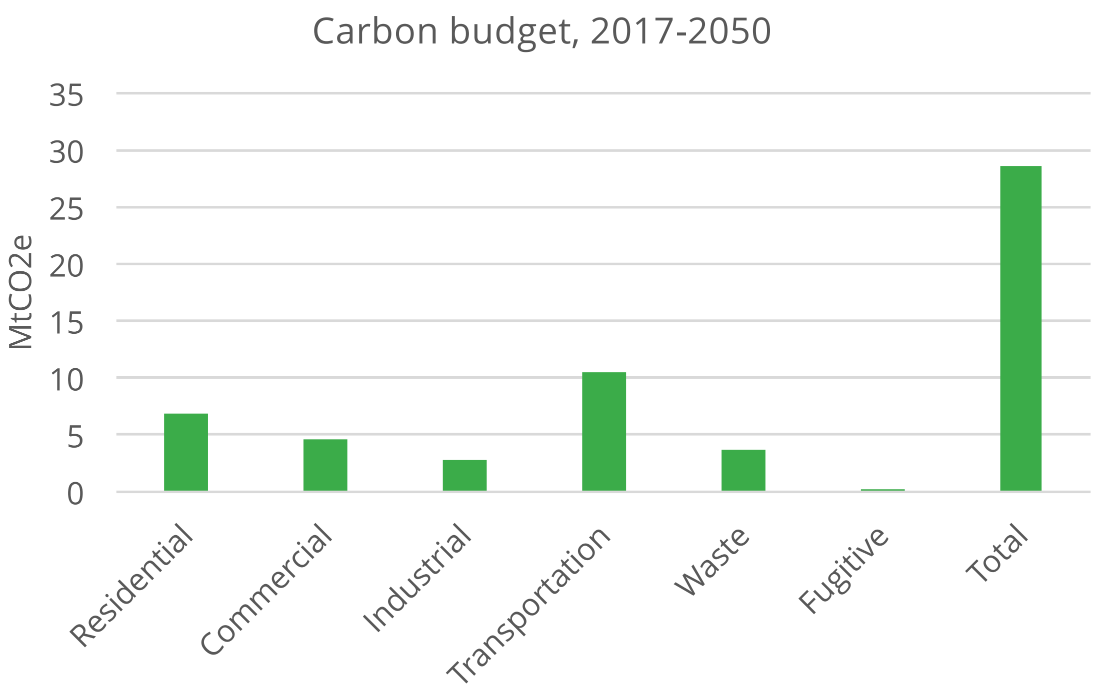


Figure 121. Carbon budget for each sector, 2017–2050.

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%

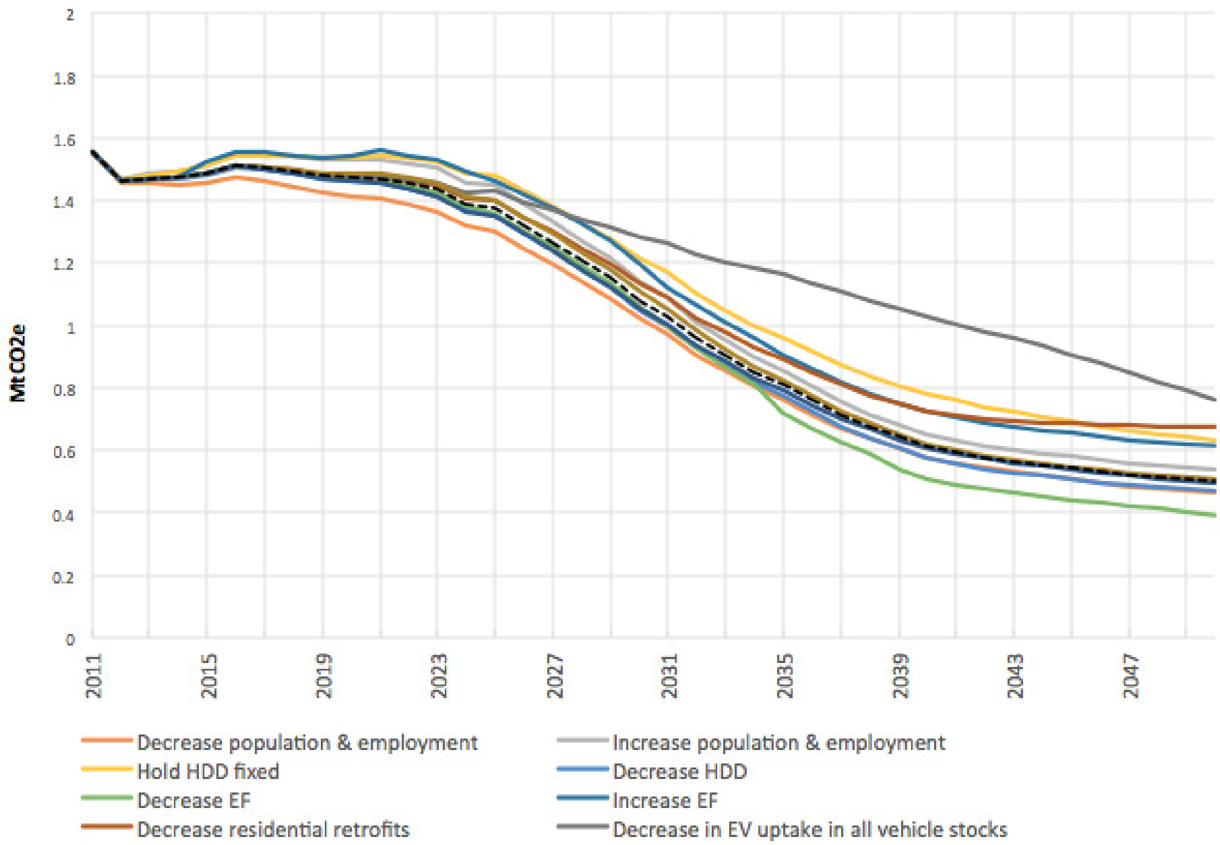


Figure 122. Change in LC-mod projection for modelled variables.

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]

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.

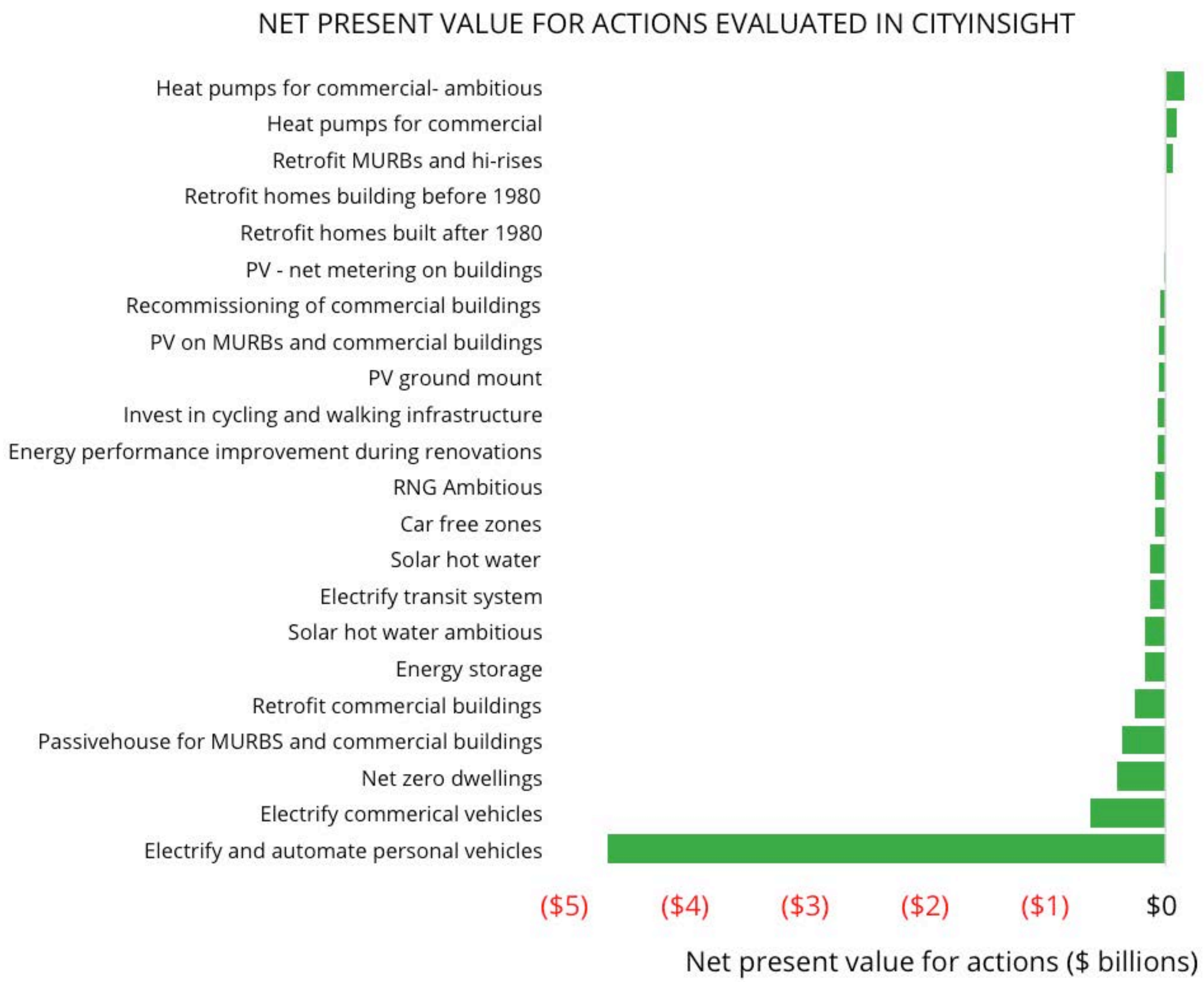


Figure 123. Net present value for each of the actions.

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

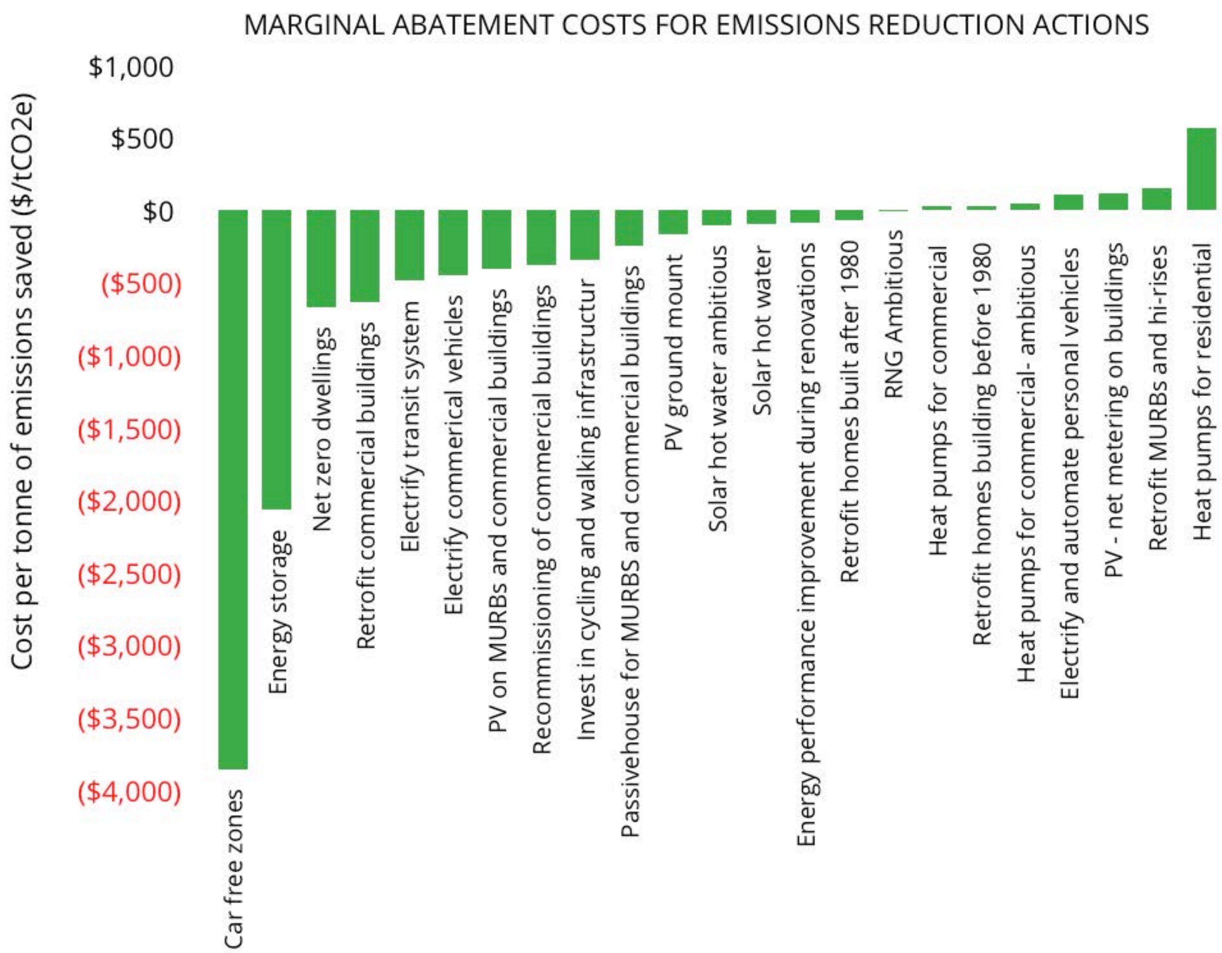


Figure 124. Marginal abatement costs.[34]

34 While the electric and autonomous vehicles action saves money, it results in increased GHG emissions as a result of increased VKT. This double negative (financial savings and increased GHG emissions) results in a distorted result on the marginal abatement cost curve.

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.

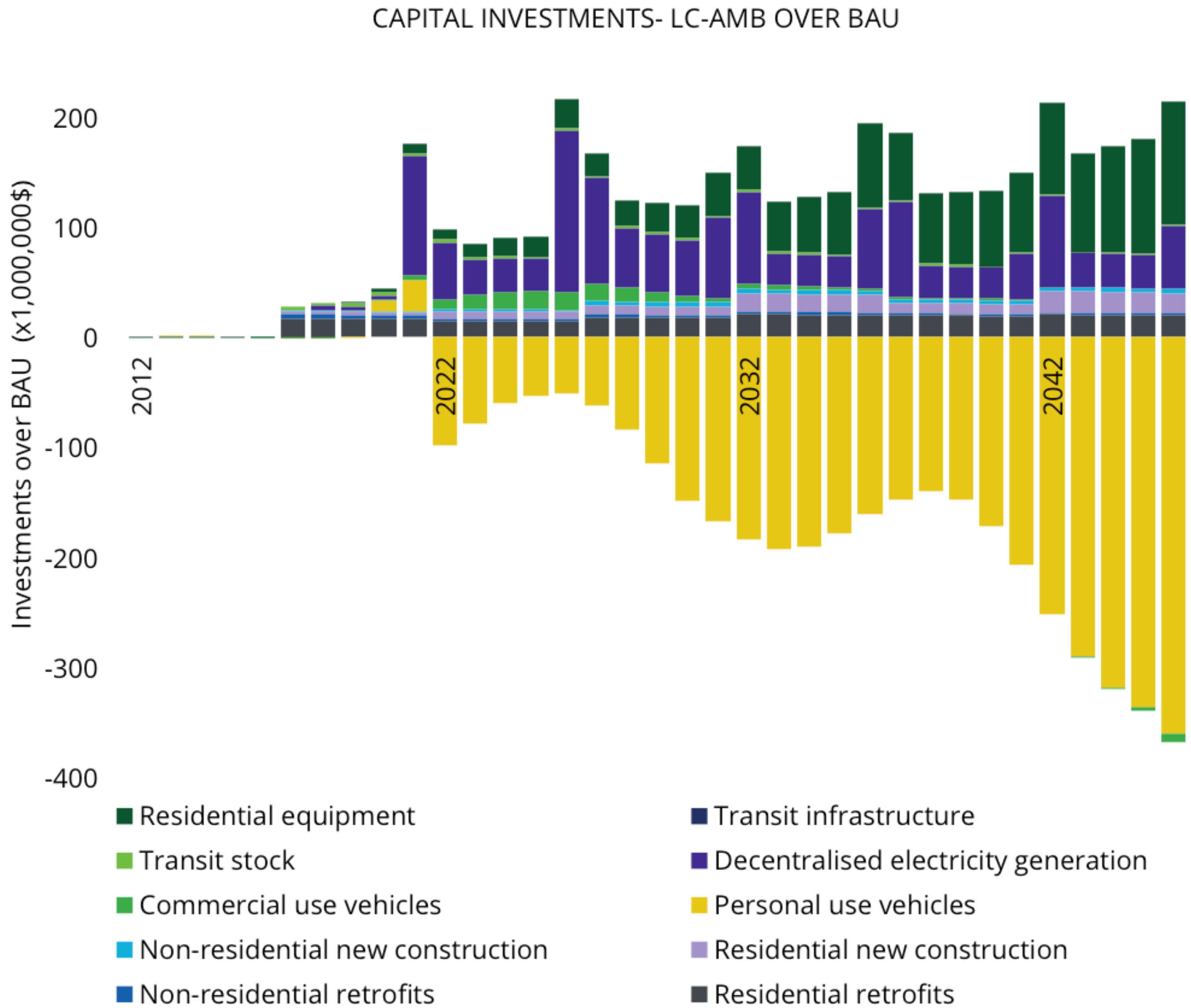


Figure 125. Incremental investment in LC-amb over BAU.

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.

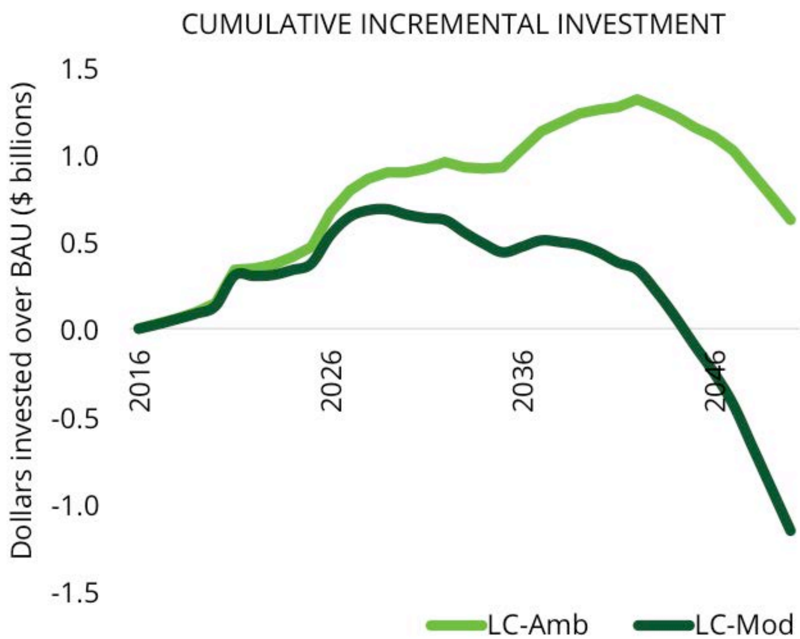


Figure 126. Total cumulative investment for Low Carbon Scenarios over BAU, 2017 dollars.

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.

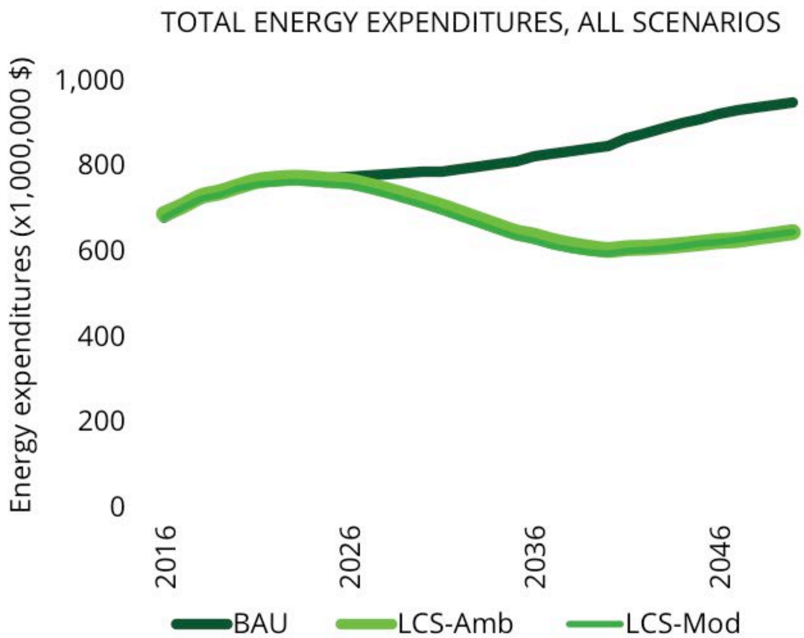


Figure 127. Total energy expenditures, all scenarios.

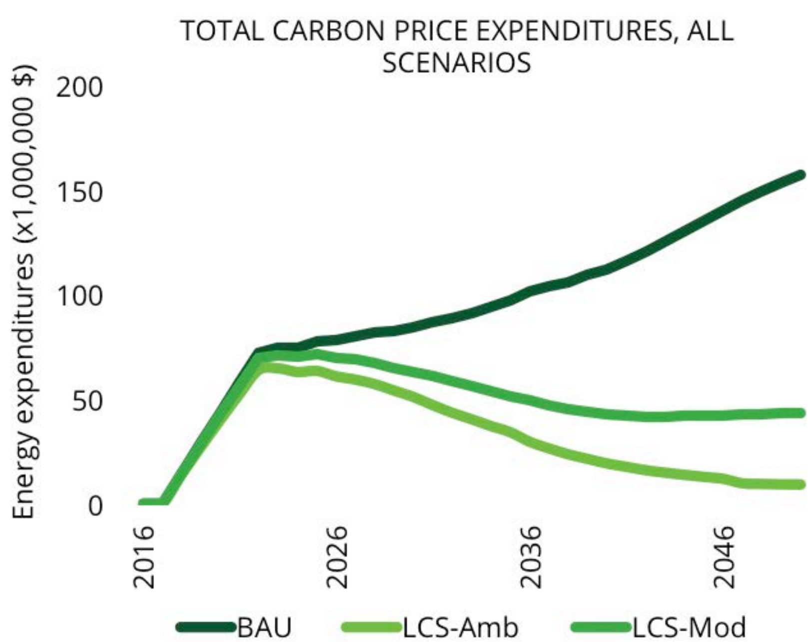


Figure 128. Total carbon price expenditures, all scenarios.

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.

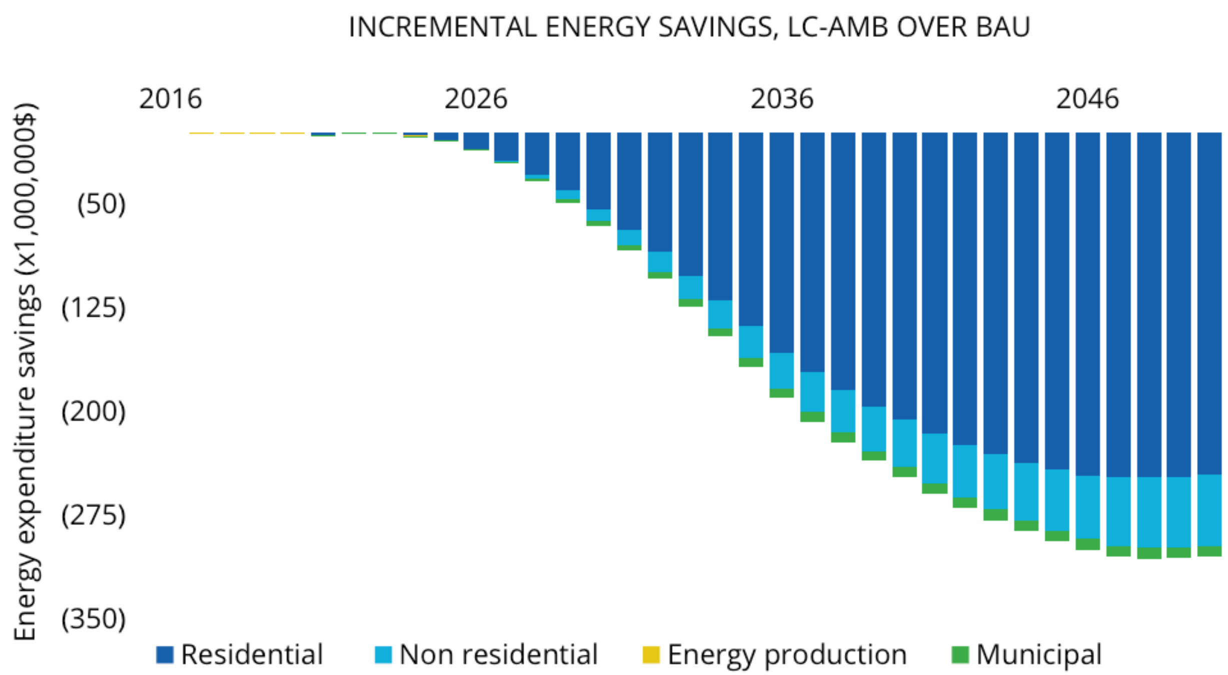


Figure 129. Avoided energy spending, constant $, LC-amb over BAU.

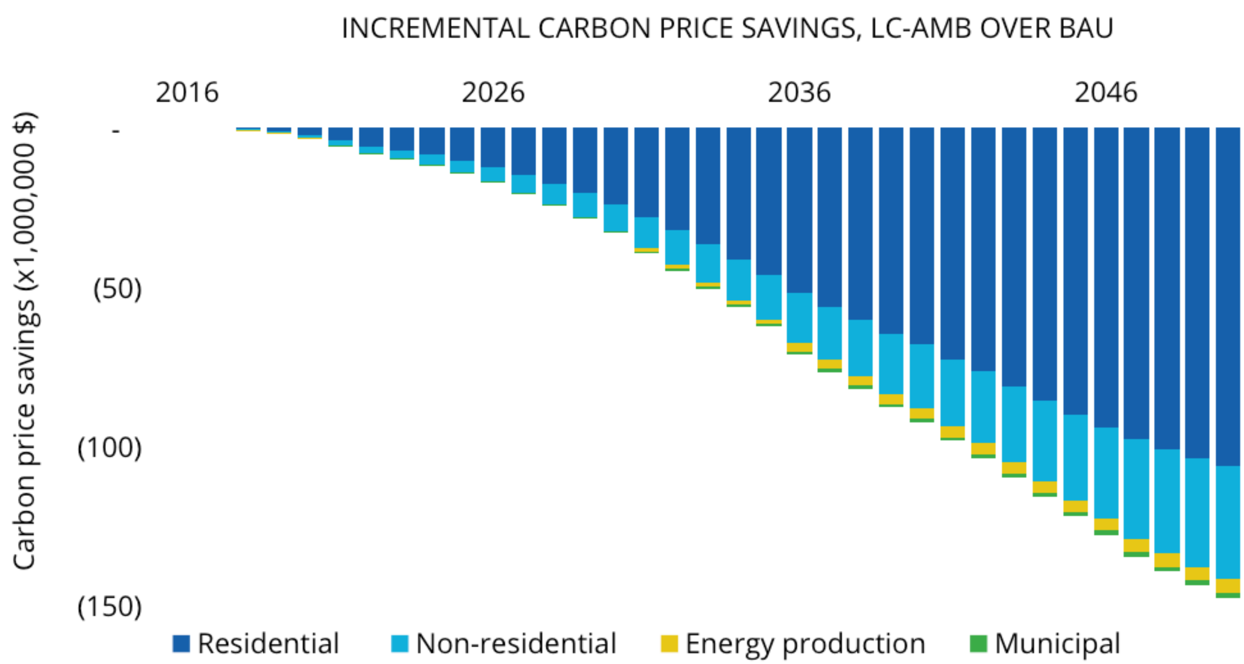


Figure 130. Avoided carbon price spending, constant $, LC-amb over BAU.

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).

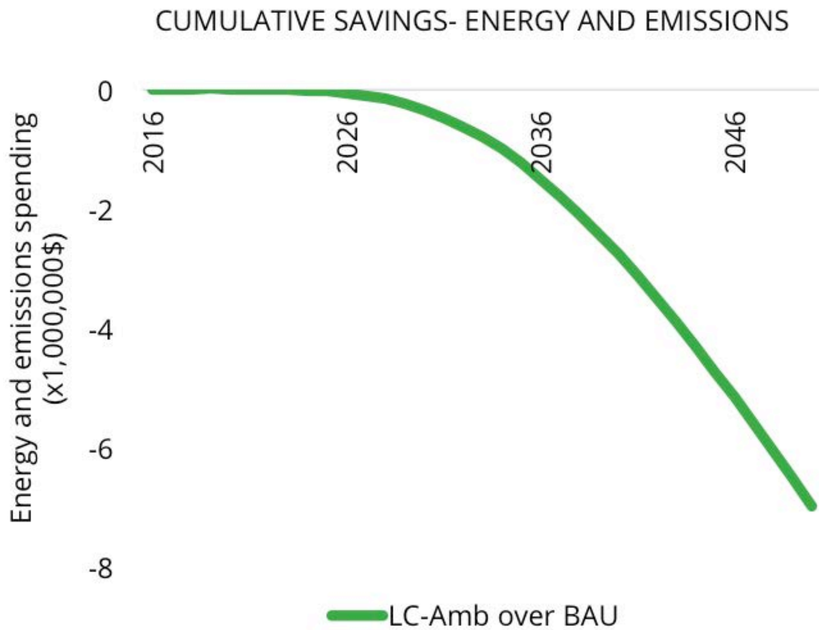


Figure 131. Cumulative savings from reduced spending on energy and carbon price in constant dollars, LC-amb over BAU.

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.

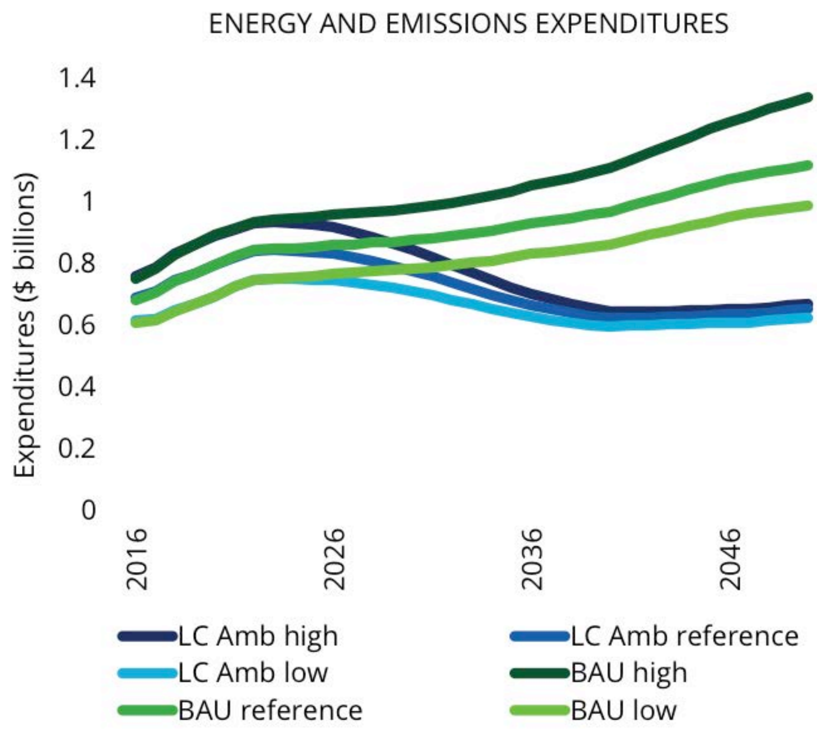


Figure 132. Total projected fuel costs and carbon costs for LC-amb and BAU using three cost scenarios.

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.

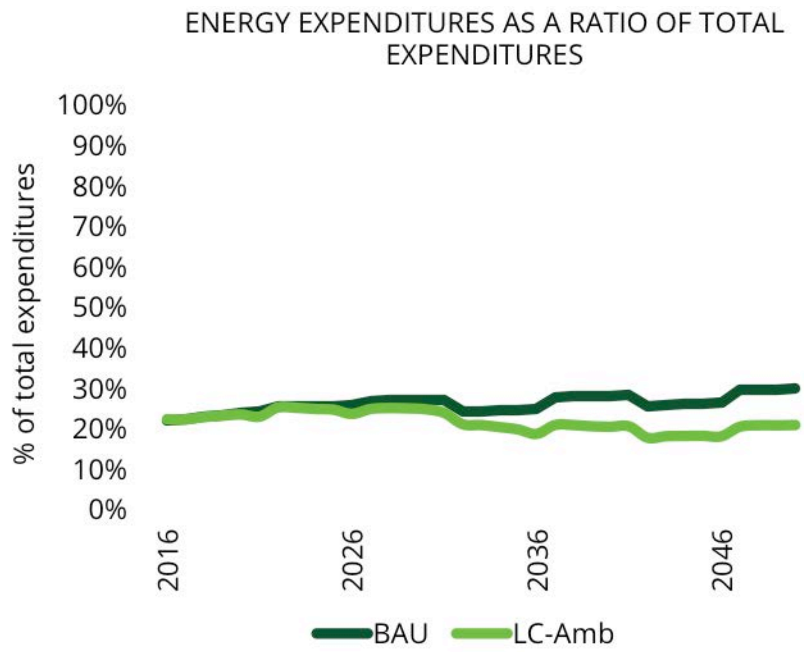


Figure 133. Total cumulative savings from fuel costs and carbon tax for LC-amb.

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.

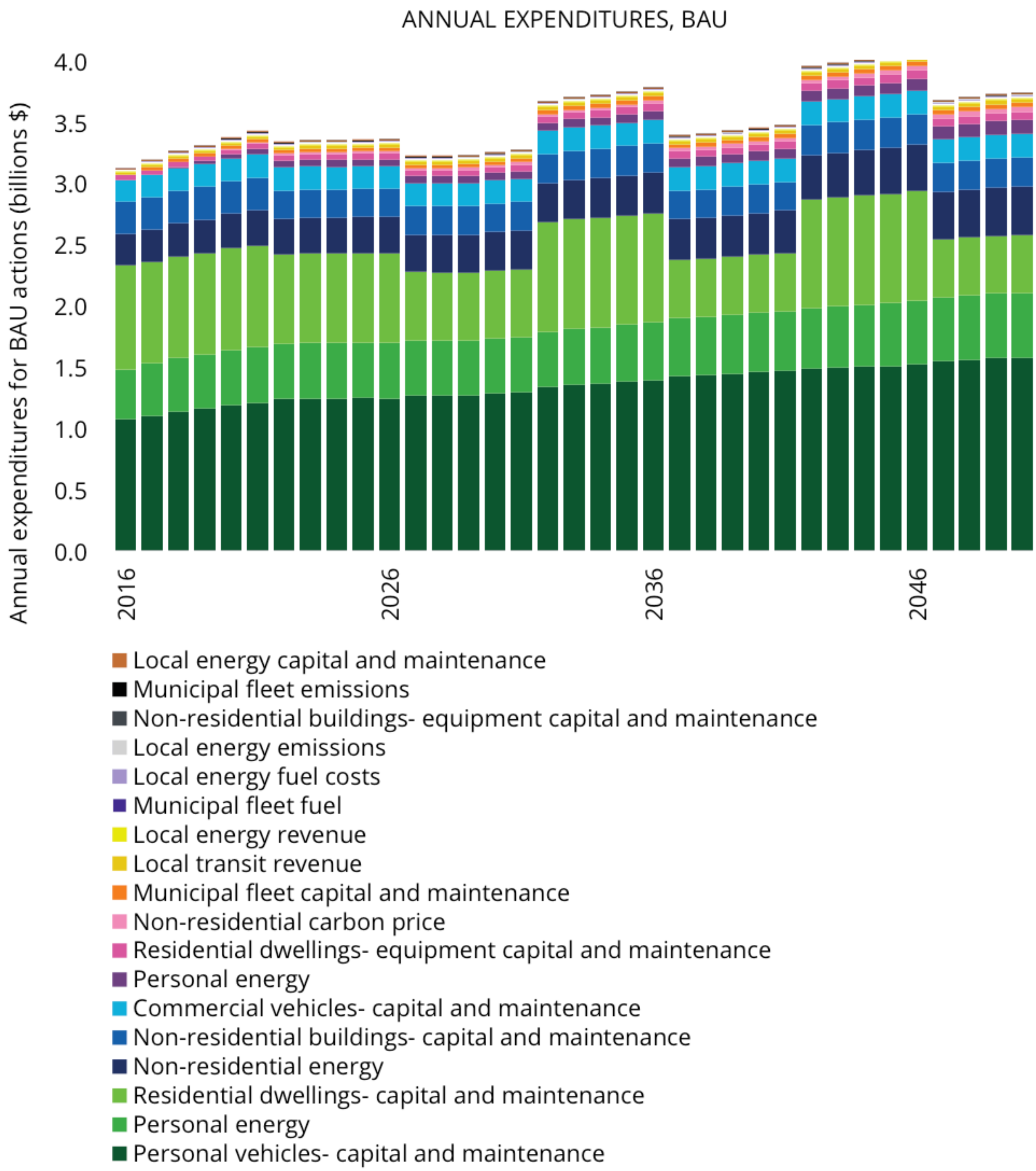


Figure 134. Annual expenditures by sector for BAU, constant $.

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.

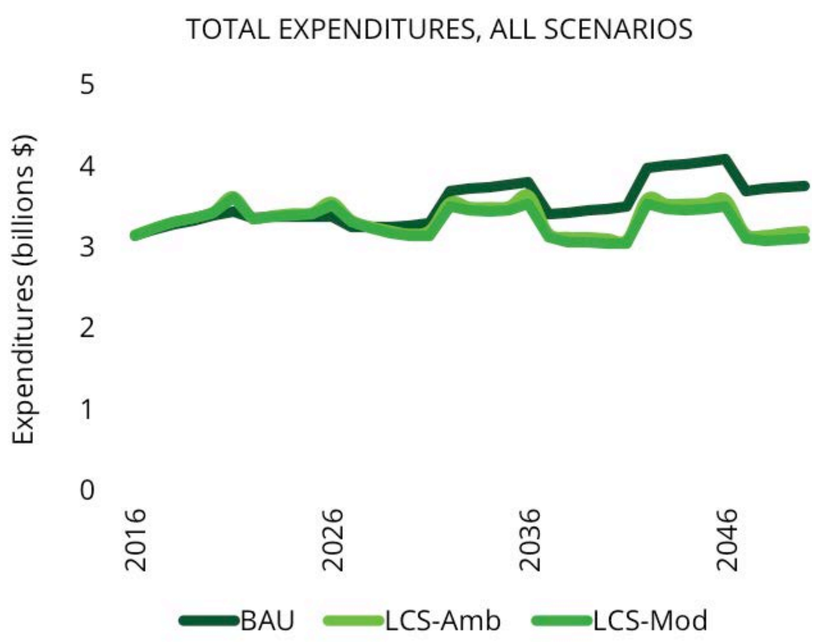


Figure 135. Annual total expenditures for the three scenarios, constant $.

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.

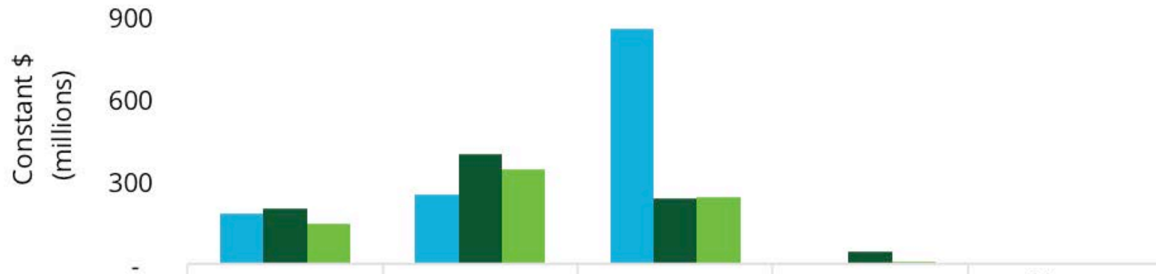
12.4.1 Annual expenditures decline in the low carbon scenarios in many categories of expenditures

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.

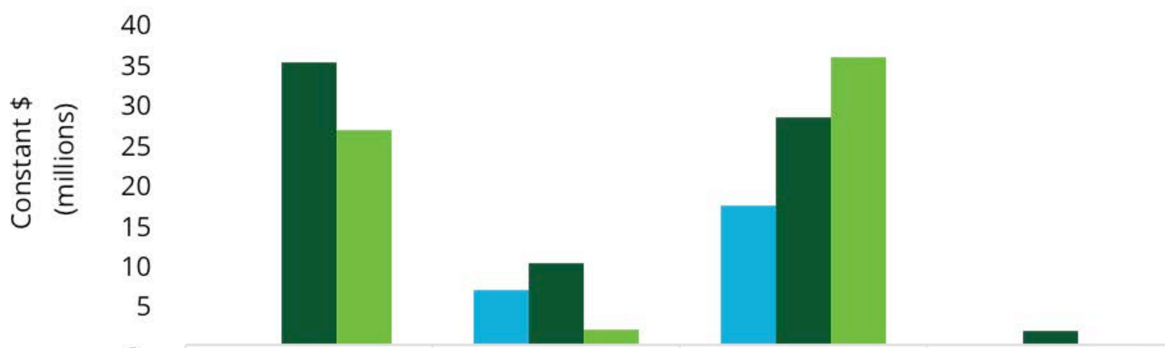
NON-RESIDENTIAL, 2016 AND 2050



	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

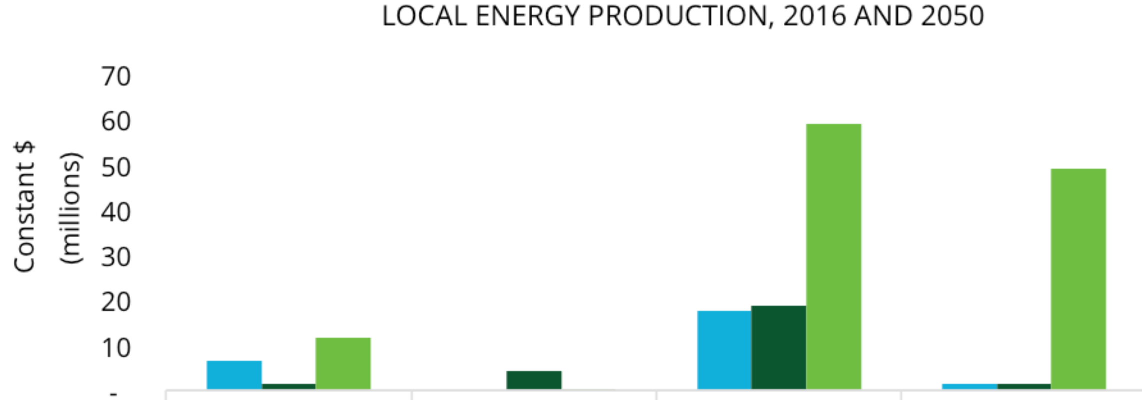
Figure 137. Non-residential ependitures by spending category.

MUNICIPAL FLEET AND TRANSIT SYSTEM, 2016 AND 2050



	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.

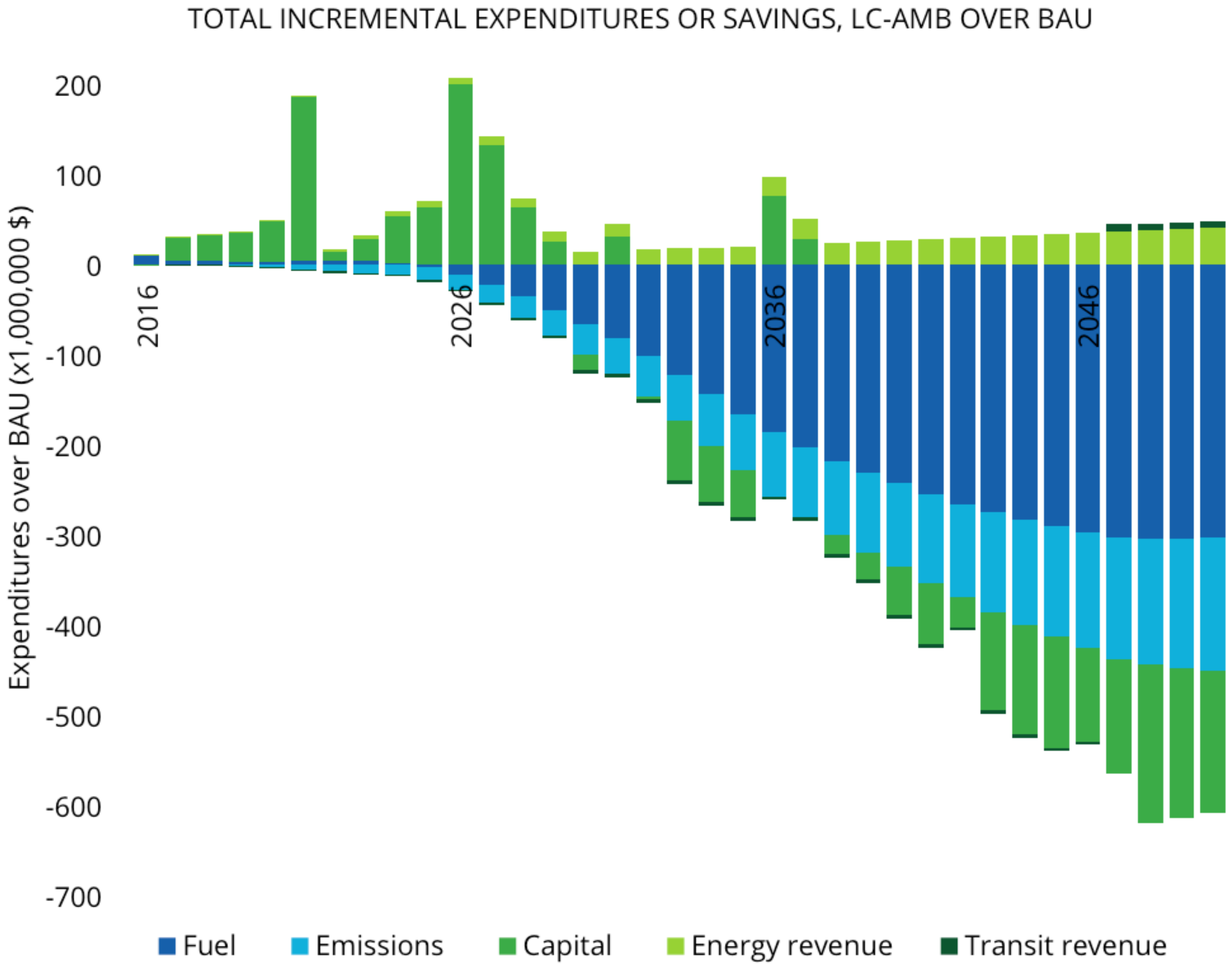


Figure 140. Total incremental investment in LC-amb over BAU, constant $.

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.

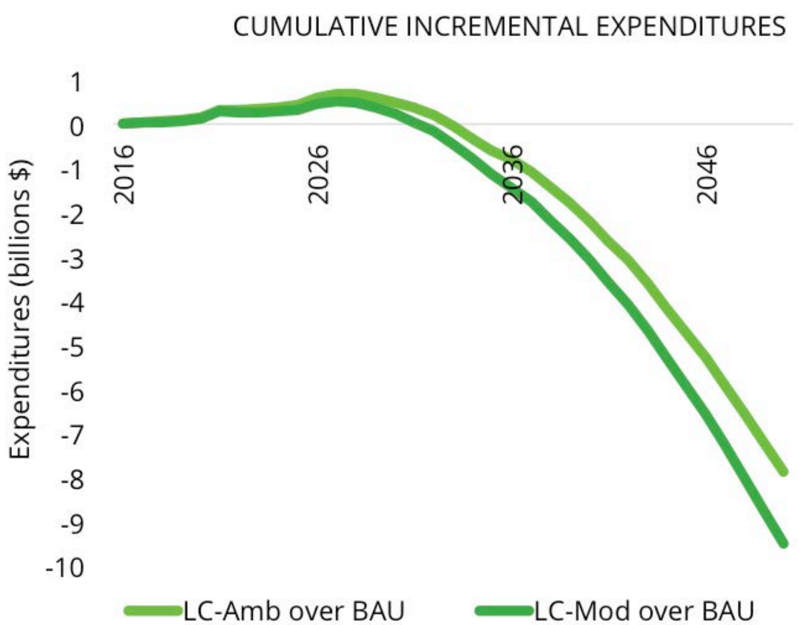


Figure 141. Trajectory of savings versus investments for the low carbon scenarios, constant $.

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.

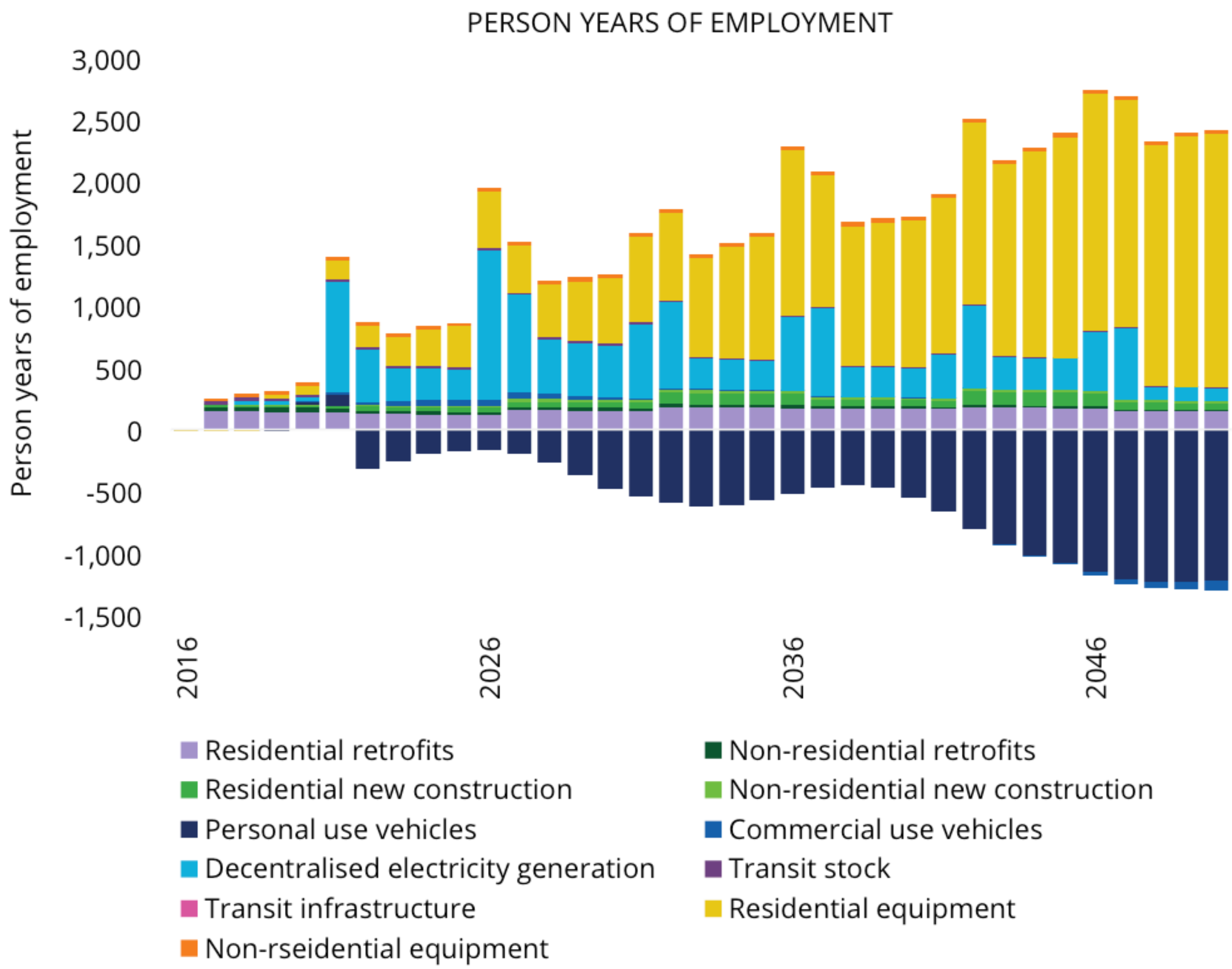


Figure 143. Employment by sector.

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.

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

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