Modelling Toronto's Low Carbon Future

Technical Paper #1: BAP Results

October 3, 2016

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- Policy, Planning, Finance & Administration
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Toronto Atmospheric Fund
TransformTO Modelling Advisory Group
TransformTO Project Team

Executive Summary

The purpose of this analysis is to understand the drivers of emissions and the basis on which the model, CityInSight, has been built from the ground up to reflect the current and future context of the City of Toronto. This analysis in turn will help inform the development of actions to further reduce emissions.

The report describes the integration of the major urban systems to develop a GHG baseline for 2011 and a projection, Build As Planned (BAP). The BAP projection covers the time period from 2012 to 2050 and is designed to illustrate energy use and greenhouse gas emissions for the City of Toronto, if no additional policies, actions or strategies are implemented; that is, it includes all plans, policies, programs and/or projects that are already approved at the municipal, regional or provincial level.

Main findings:

1. *The BAP projections indicate that emissions will amount to 17.1 MT CO2e in 2020, and 14.9 MT CO2e in 2050.*
2. *The BAP projections indicate that the 2020 target will be met, if the assumptions in the BAP (based on currently approved plans and policies) are implemented (Figure 1).*

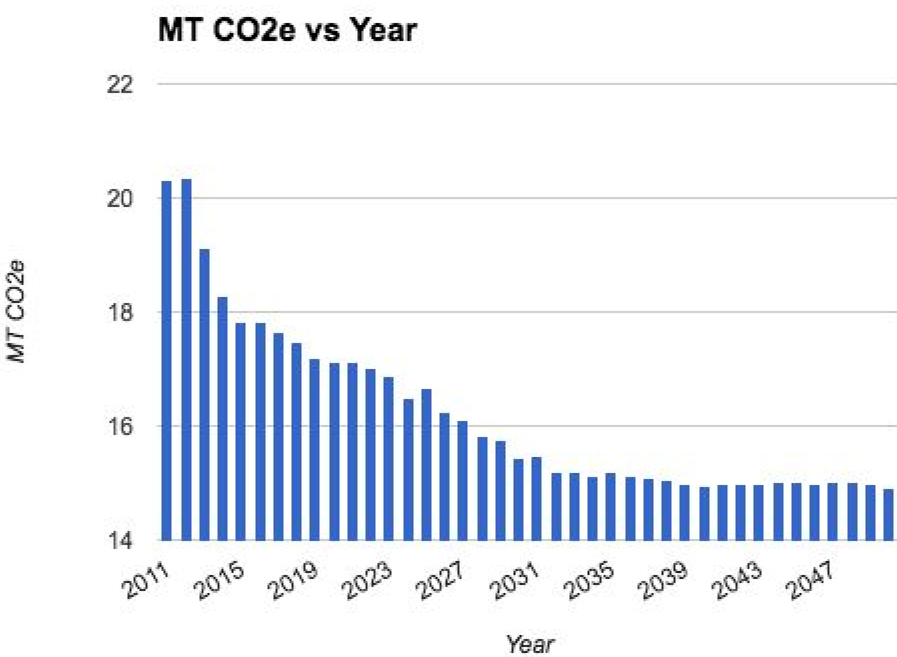


Figure 1. Projected GHG emissions for the City of Toronto, 2011-2050.

3. *While the City's short term target benefits from greening of the Provincial grid and vehicle fuel efficiency standards, the 2050 target represents a major challenge as the remaining major opportunities are more intransigent.*
4. *The emissions factor for the Provincial grid (electricity) continues to decline. This creates an opportunity for fuel switching for vehicles (private and transit) away from gasoline.*

5. *Natural gas is the most significant source of emissions; this creates an opportunity for fuel switching to electricity for space heating.*
6. *Significant efforts to fuel switch to electricity will require new generation with renewables.*
7. *Existing buildings (pre-2011) have a major impact on GHG emissions; the incremental effect of high efficiency new buildings is small, but decreases the upward pressure of an increasing population on the GHG curve. An ambitious retrofit program will be critical.*
8. *Vehicular mode share for external trips is 70% (inbound) and 86% (outbound); there is an opportunity to shift this mode share. Outside of the downtown core, the vehicular mode share remains relatively high, even for internal trips.*
9. *Generally, trip lengths are not projected to decline; in spite of a focus on transportation oriented development.*
10. *Solid waste emissions are driven by the existing landfills, which taper off towards the end of the time period considered.*

While it appears likely that the City will achieve its 2020 target, depending on how the baseline year is addressed, the magnitude of 2050 target is much more challenging. City-scale investments in buildings and transportation systems can easily last 50 years or more: the key message is therefore, not to linger before focusing on the longer game.

1. Introduction

The City of Toronto's Environment and Energy Division (EED) and Toronto Atmospheric Fund (TAF) are undertaking efforts to model energy and greenhouse gas (GHG) emissions as part of a city-wide project called TransformTO, The modelling aspects of TransformTO, known as *Modelling Toronto's Low Carbon Future*, include developing an action plan for reaching the City's 2020 GHG reduction target, and a decision-support framework focused on achieving Toronto's 2050 GHG reduction target.

The first part of the project involves developing a Build-As-Planned (BAP) scenario to quantify the emissions reductions potentials of Scope 1 and Scope 2 emissions to the year 2050. In order to develop and quantify the BAP scenario, two prior steps are required which include:

- Data collection: A data request is compiled and data is collected from various sources. Assumptions are identified to supplement any gaps in observed data. A data, methods and assumptions manual ensures transparency of data and assumptions used.
- Model calibration and baseline: The model is built from the ground up starting with people, putting people in dwellings, putting jobs in buildings, developing a surface model of the buildings, identifying how people move around and then undertaking other analysis on waste, industry and land-use. At each stage the bottom-up model is calibrated against observed data, and a baseline year is established.

This document, *Technical Paper #1: BAP Results*, includes modelling results for both the baseline year 2011, and a Build-As-Planned (BAP) scenario out to 2050.

2. About Modelling

The modelling for the baseline year 2011, and BAP scenario out to 2050 were completed using CityInSight.

CityInSight is a comprehensive energy, emissions and finance model developed by Sustainability Solutions Group (SSG) and whatIf? Technologies Inc. (whatIf?) . CityInSight uses the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC Protocol), an international standard for greenhouse gas emissions as an accounting framework.

For detailed information on the modelling approach, and a summary of the data and assumptions used as the foundation for the energy and emissions modeling, refer to *Modelling Toronto's Low Carbon Future*: *Data, Methods and Assumptions Manual* (DMA).

3. Baseline Results

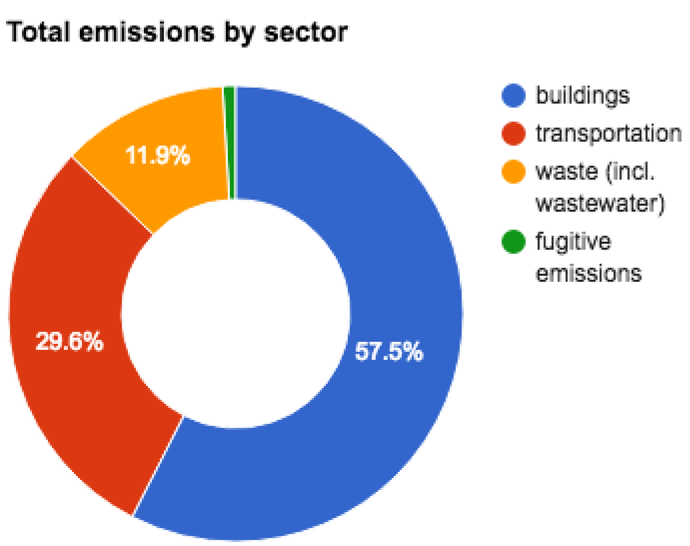
3.1 Total emissions

Total modelled emissions for the City of Toronto for the baseline year 2011 amount to 20,319,400 tonne of carbon dioxide equivalent (CO2e). A breakdown of emissions by sector are shown in Table 1. The buildings sector stands out as a dominant contributor to overall emissions, accounting for 58% of total emissions (Figure 2). This is followed by transportation at 30%, and to a lesser extent, waste and wastewater. In addition to the major sectors, fugitive emissions from natural gas systems amount to 189,600 tonne CO2e. Fugitive emissions account for unintentional emissions associated with the transportation and distribution of natural gas within the city (through equipment leaks, accidental releases etc.) that is used within the buildings sector.

Refer to Appendix 1 for a breakdown of sector emissions by scope and gas according to the GPC Protocol reporting standard.

Table 1: Total emissions for Toronto, 2011.

Sector	**tonne CO2e**
Buildings	11,684,800
Transportation	6,023,900
Waste	2,421,100
Fugitive emissions	189,600
TOTAL	**20,319,400**

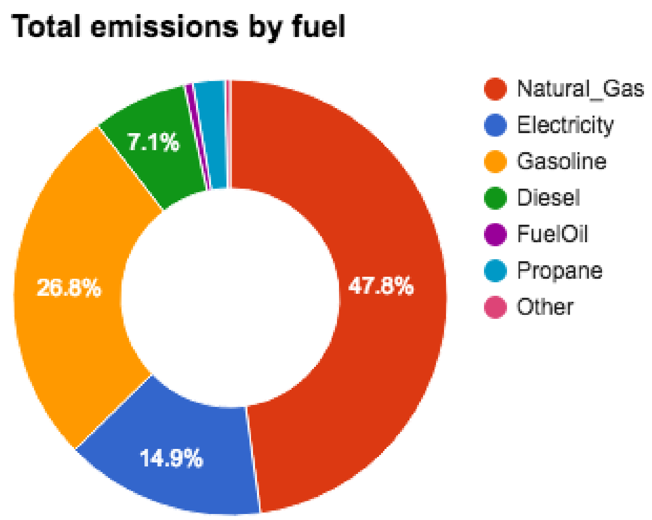


Total emissions ≈ 20,319,400 tonne CO2e

Figure 2. Toronto emissions by sector, 2011.

The buildings and transportation sectors together account for 17,708,700 tonne CO2e; the emissions within these sectors as a direct result of fuel consumption (in comparison with waste, where emissions are as a result of the decomposition of waste).

Of the emissions within buildings and transport, natural gas accounts for 48% (Figure 3). Natural gas is both the largest contributor to total emissions within the buildings sector, and the city overall. Gasoline is the second largest contributor at 27%, and the largest contributor to emissions within the transportation sector.



Total buildings & transport emissions ≈ 17,708,700 tonne CO2e

Figure 3. Toronto emissions by fuel, 2011.

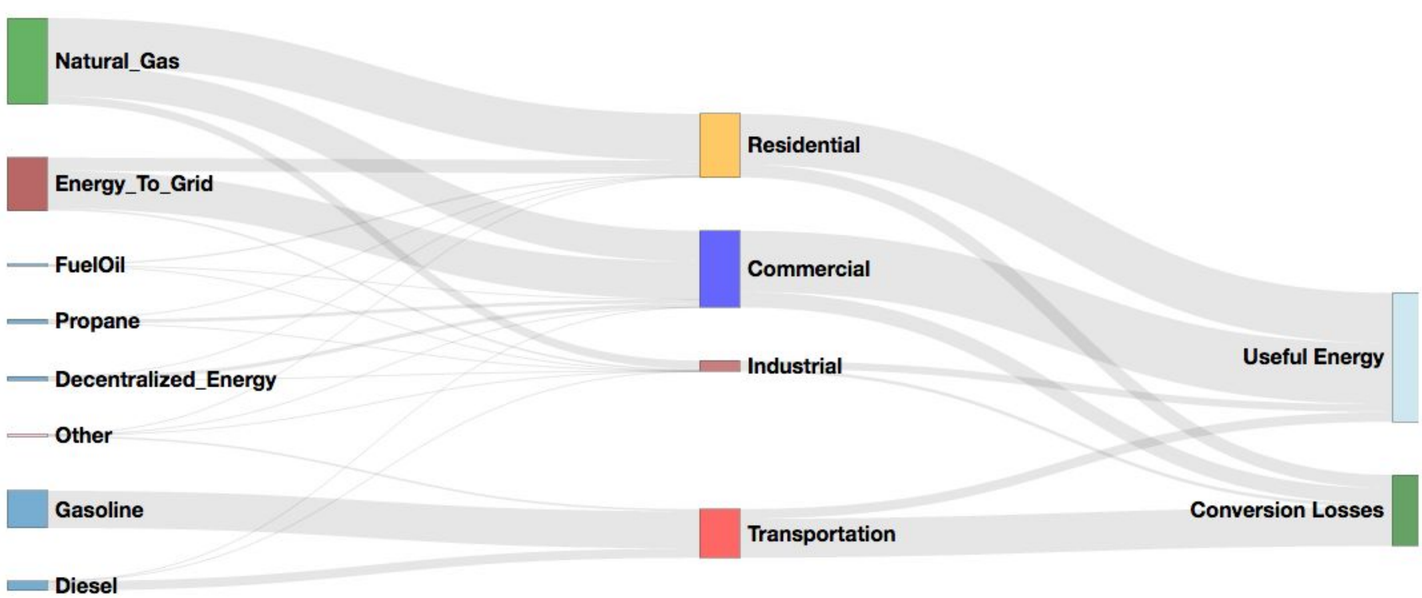


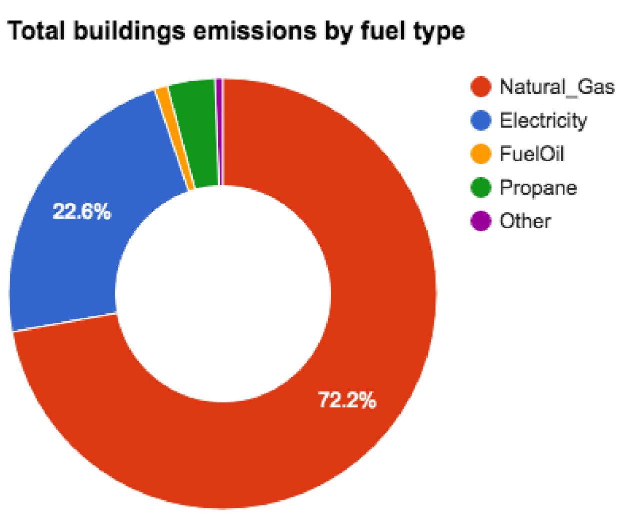
Figure 4. Toronto energy flow, 2011.

3.2 Buildings (stationary energy)

Total buildings emissions

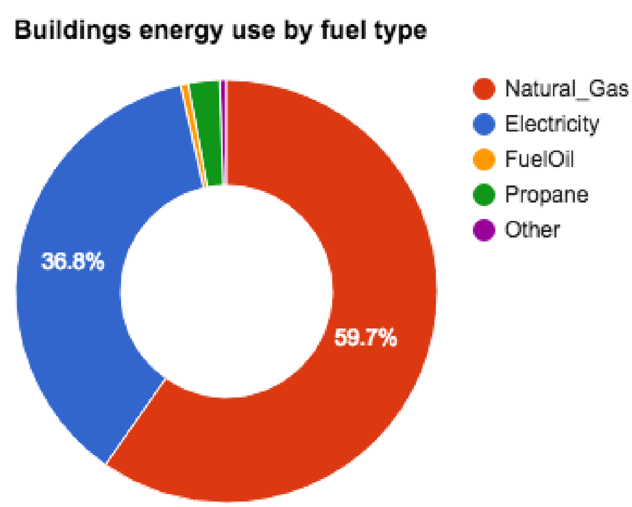
The buildings sector accounts for 11,684,800 tonne CO2e, approximately 58% of total emissions for the city. Note that the "buildings" category includes residential and non-residential buildings, as well as energy industries, that is, the production of energy. Stationary energy is therefore a more encompassing term; it is also how the GPC classifies this sector.

Natural gas accounts for almost three quarters (72%) of emissions within the buildings sector, followed by electricity at just under a quarter (23%) **(**Figure 5). When looking at energy consumption, natural gas and electricity usage have a narrower difference, with natural gas accounting for 60% and electricity accounting for 37% of energy use (Figure 6). The higher emissions for natural gas compared with electricity are as a result of natural gas having a much higher emissions factor than Ontario's relatively "clean" electrical grid.



Total buildings emissions ≈ 11,684,800 tonne CO2e

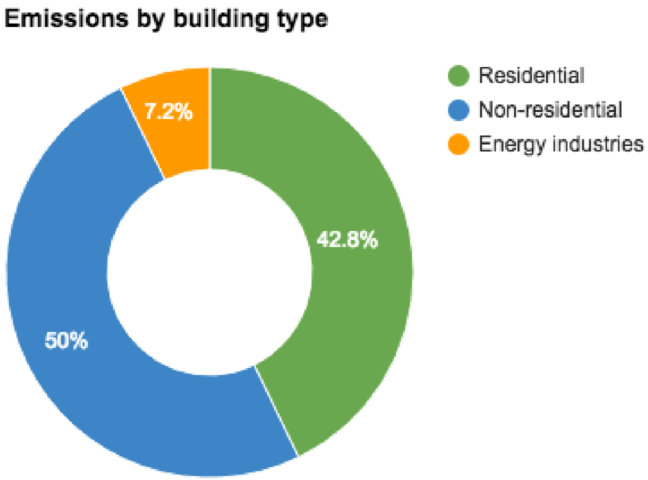
Figure 5. Buildings emissions by fuel, 2011.



Total buildings energy ≈ 286,657,500 GJ

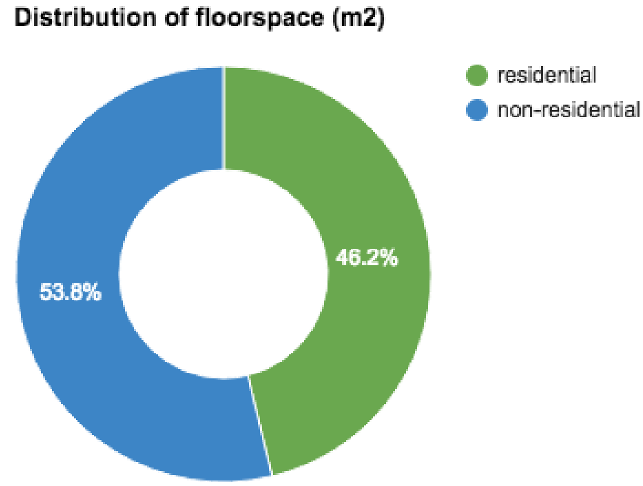
Figure 6. Buildings energy use by fuel, 2011.

The source of buildings emissions are relatively equally distributed between residential and non-residential buildings, with non-residential buildings accounting for half (50%) of total buildings emissions (Figure 7). This aligns relatively well with the distribution of residential and non-residential floorspace within the city (Figure 8). Emissions associated with energy industries (energy production) make up 7%.



Total buildings emissions ≈ 11,684,800 tonne CO2e

Figure 7. Buildings emissions by building type, 2011.



Total floorspace ≈ 256,890,000 m2

Figure 8. Buildings floorspace, 2011.

Figure 9 illustrates the distribution of buildings emissions across the city; darker zones represent higher levels of emissions within that zone. Downtown Toronto exhibits higher levels of emissions; this is congruent with the higher building densities that are common in these areas, which drives energy consumption. The buildings in the downtown area are comprised mostly of commercial and high-rise residential floorspace. In contrast, there are certain zones outside of the downtown area (towards the northwest corner of the city), that have higher levels of emissions, but do not exhibit the same level of building densities. The emissions in these zones are driven by non-residential building uses (eg. manufacturing, energy production).

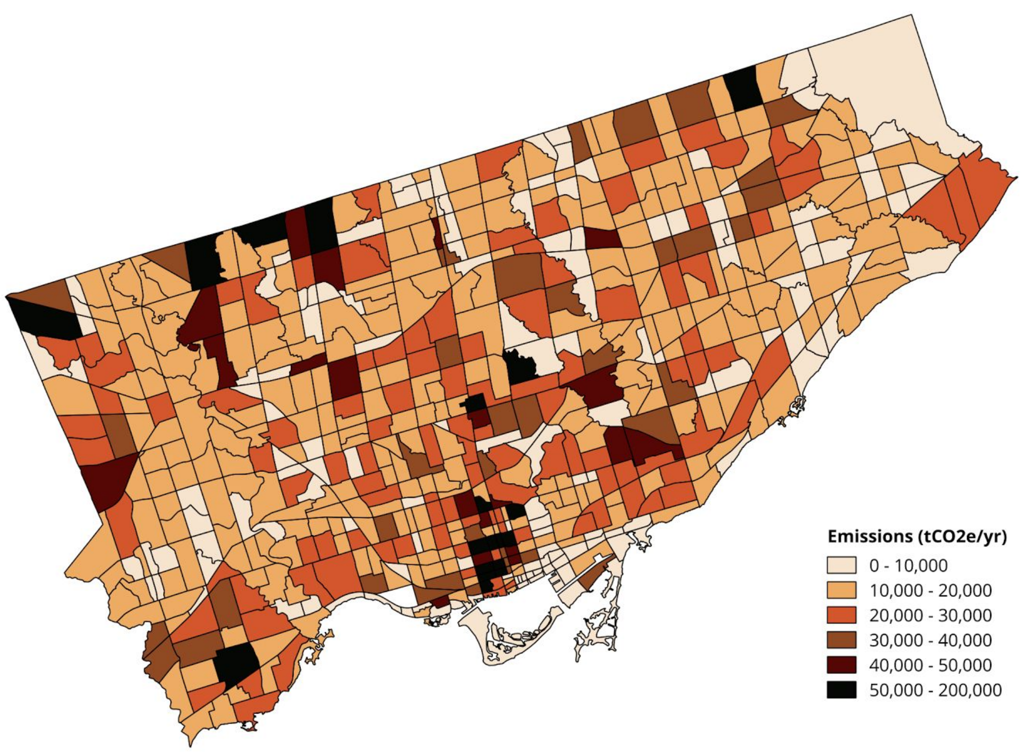
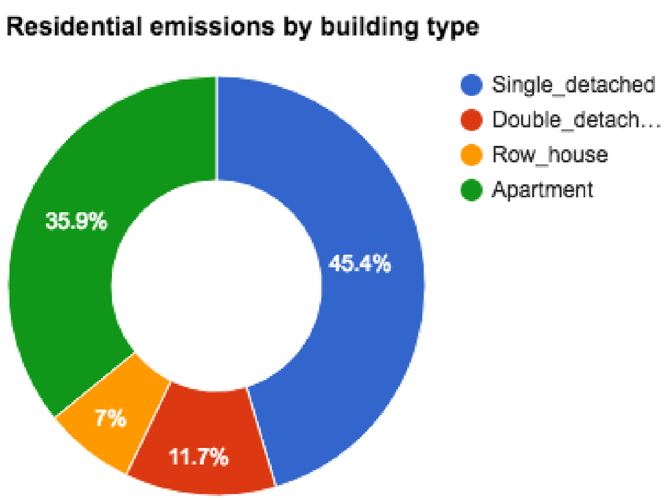


Figure 9. Buildings emissions by zone, 2011.

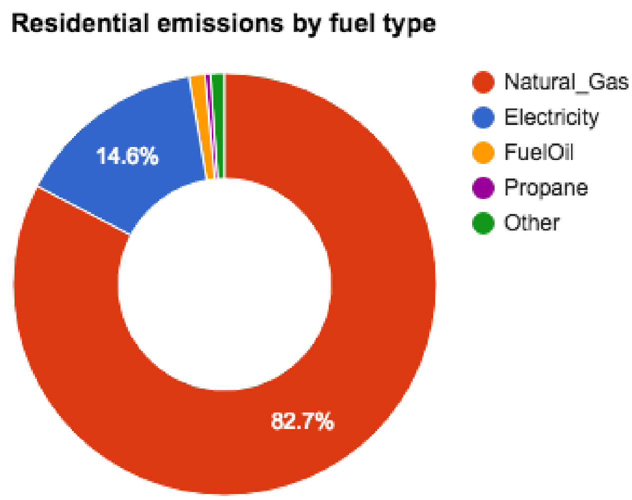
Residential buildings

Residential buildings account for 5,004,000 tonne CO2e. Single family homes account for 45% of emissions, followed closely by apartments with 36% (Figure 10). Residential emissions are significantly dominated by the use of natural gas (Figure 11), accounting for 83% of residential emissions. Together, space heating and water heating account for 80% of energy consumption in residential buildings (Figure 12).



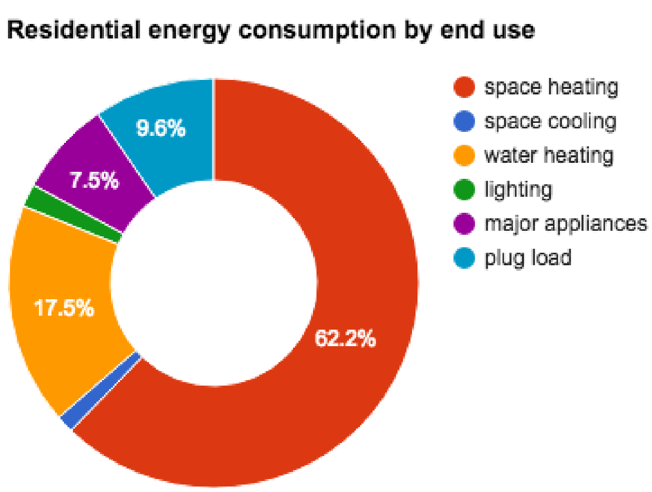
Residential emissions ≈ 5,004,000 tonne CO2e

Figure 10. Residential emissions by building type, 2011.



Residential emissions ≈ 5,004,000 tonne CO2e

Figure 11. Residential emissions by fuel, 2011.

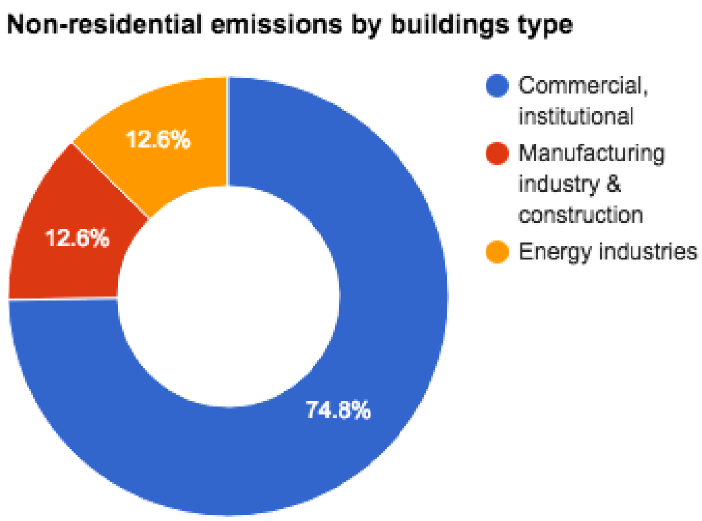


Residential energy consumption ≈ 114,608,000 GJ

Figure 12. Residential emissions energy consumption by end use, 2011.

Non-residential buildings and energy industries

Non-residential buildings and energy industries account for 6,680,700 tonne CO2e. Commercial and institutional buildings account for majority of emissions (75%) (Figure 13), with manufacturing industries and construction at 12.6%, and energy industries at 12.6%.

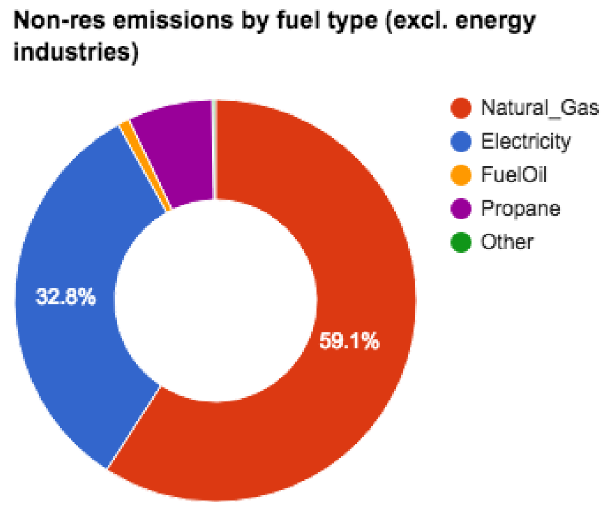


Non-residential emissions ≈ 6,680,700 tonne CO2eq

Figure 13. Non-res emissions by building type, 2011.

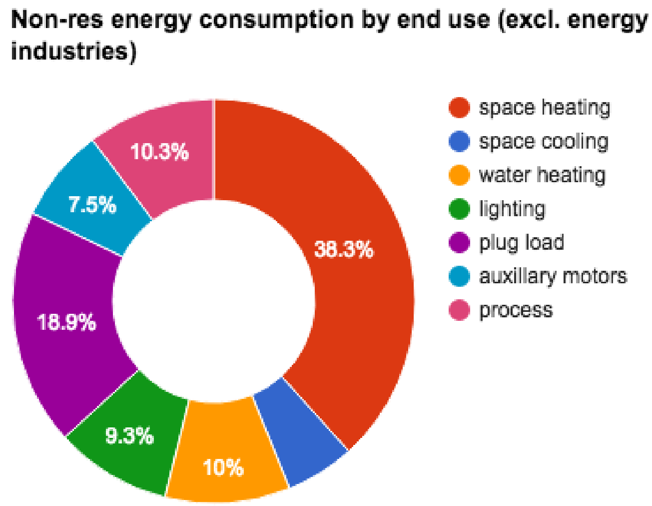
Energy industries account for 843,200 tonne CO2e, and include the emissions from the production of energy within the city boundary, which includes district energy and the Portlands Energy Centre. These emissions are exclusively from the use of natural gas.

When looking at non-residential buildings, that is, commercial, institutional, manufacturing and construction industries, they account for 5,837,500 tonne CO2e. Similar to residential, non-residential emissions are significantly dominated by the use of natural gas (Figure 14), accounting for 59% of non-residential emissions. In stark contrast to residential buildings, energy end use in non-residential buildings is more widely distributed (Figure 15). Space heating remains dominant (38%), but higher proportions are seen in plug loads (19%), lighting (9%), and process (10%).



Non-residential emissions ≈ 5,837,500 tonne CO2eq

Figure 14. Non-res emissions by fuel, 2011. 2011.

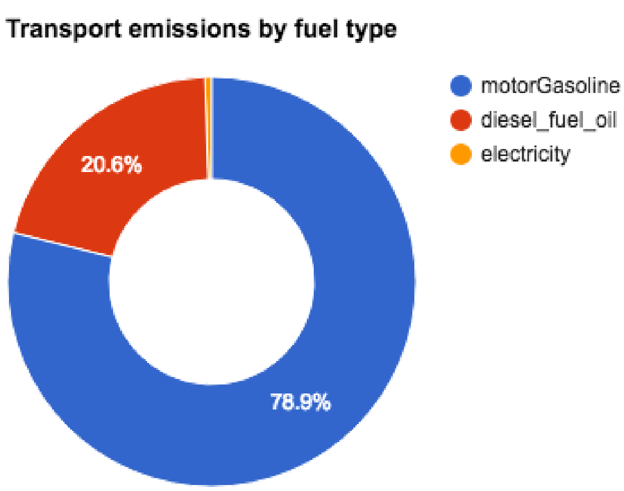


Non-residential energy consumption ≈ 154,959,100 GJ

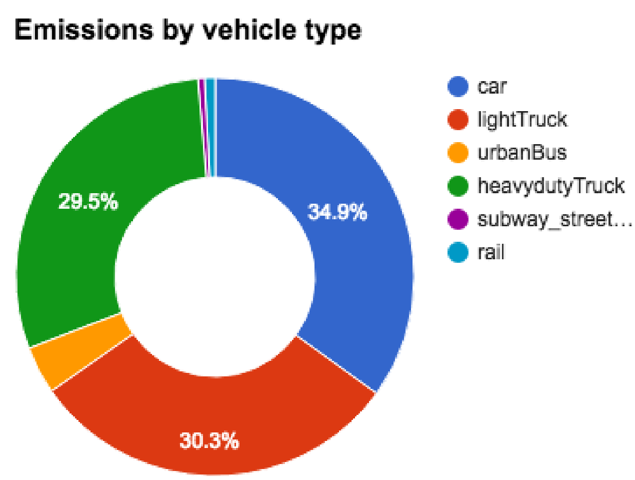
Figure 15. Non-res energy consumption by end use,

3.3 Transportation

The transportation sector accounts for 6,023,900 tonne CO2e, approximately 30% of total emissions for the city. Emissions within the transport sector are dominated by gasoline (79%) (Figure 16). A very small portion (0.5%) of emissions were associated with electric vehicle stock; this was attributed entirely to electric transit (streetcars and subways), as personal EV uptake was negligible in 2011. Majority of emissions come from personal vehicles (61%) (Figure 18); however, when looking at vehicle stocks, cars (35%), light trucks (30%) and heavy duty vehicles (30%) contribute to total emissions more equally (Figure 17). This is as a result of a large proportion of light trucks being owned as personal vehicles.

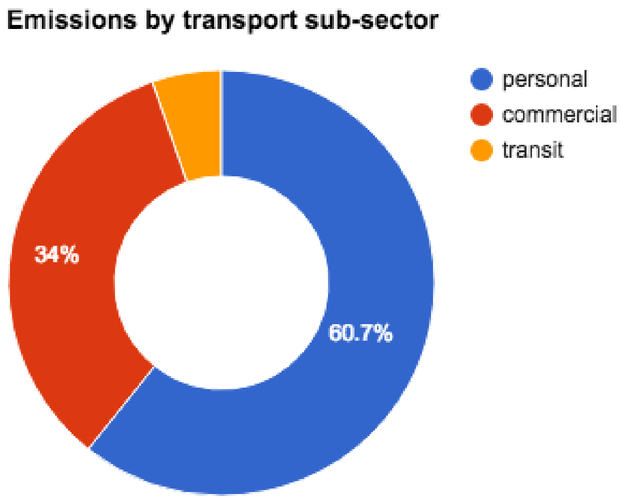


Transportation emissions ≈ 6,023,900 CO2e



Transportation emissions ≈ 6,023,900 CO2e

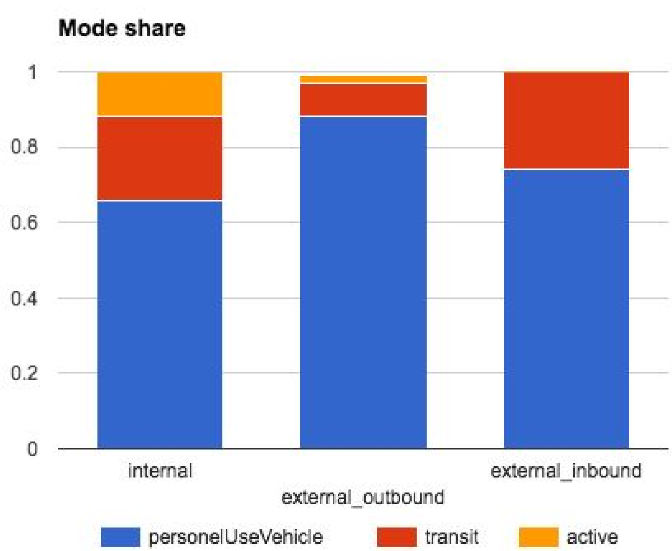
Figure 16. Transport emissions by fuel, 2011. *Figure 17.Transport emissions by vehicle type, 2011.*



Transportation emissions ≈ 6,023,900 CO2e

Figure 18. Transport emissions by sub-sector, 2011.

Mode share is significantly dominated by personal vehicle use (Figure 19); however, higher shares of active transport and transit are more common for internal trips. As trip distances increases when travelling outside of the city boundary (Figure 20), vehicle trips (ie. vehicle mode share) increases.



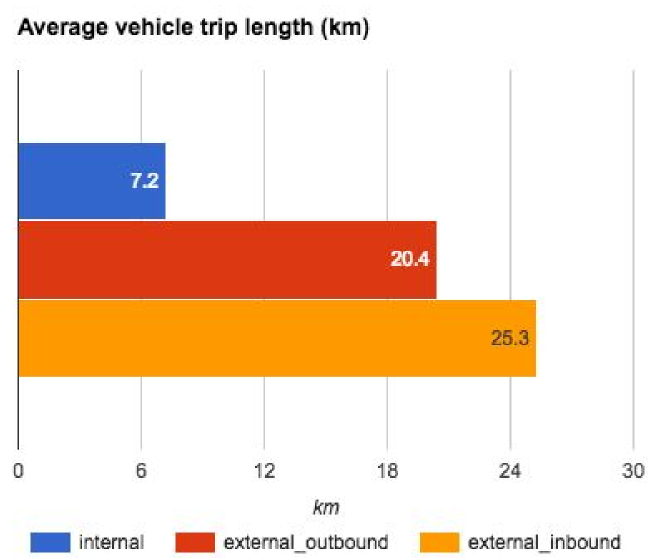
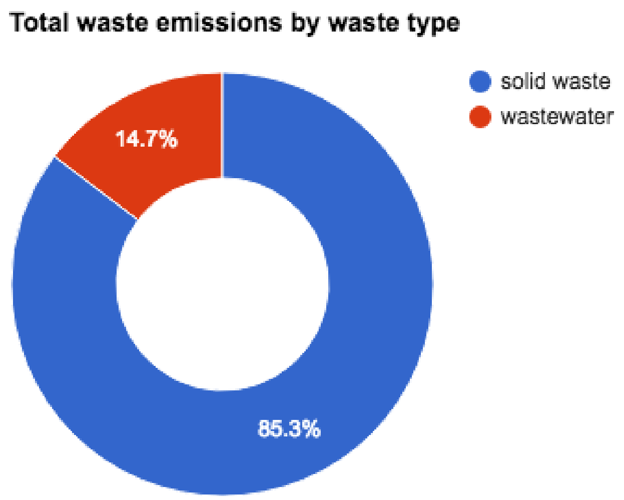


Figure 19. Mode share , 2011. *Figure 20. Average vehicle trip length, 2011.*

3.4 Waste

The waste sector accounts for 2,421,100 tonne CO2e, approximately 12% of total emissions for the city. Within the sector, emissions from solid waste account for 85%, with the remaining 15% coming from wastewater (Figure 21).



Waste emissions ≈ 2,421,100 CO2e

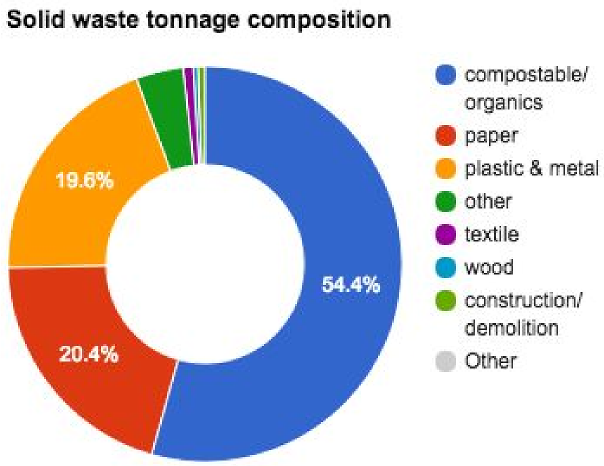
Figure 21. Waste emissions by sub-sector, 2011.

Solid waste

In 2011, Toronto produced over 1 million tonnes of solid waste. More than half consisted of compostable materials (54%), followed by paper (20%) and plastic and metal (20%) (Figure 22). Of this waste, more than half (52%) was sent to landfills, with the remainder being biologically treated (25%), and recycled (23%), and (Figure 23). Biological treatment refers to waste that is treated in a sorting facility through composting and/or anaerobic digestion. Biological treatment emissions are from the Disco Road Organics Processing Facility.

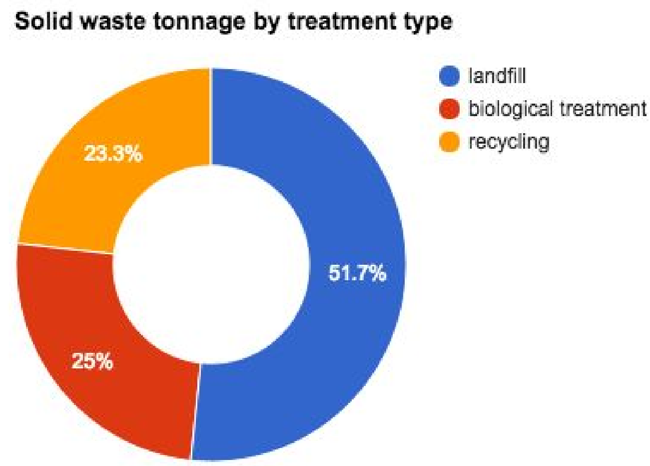
The emissions from this solid waste amount to 2,065,800 tonne CO2e. These emissions come predominantly from landfills (98%), with the remainder from biological treatment (Figure 24). The recycling of solid waste results in zero waste emissions; the emissions associated with the energy used at recycling facilities is accounted for under the buildings sector. Similarly, emissions associated with the transportation of waste are accounted for under the transportation sector.

Landfill emissions include those from both open and closed landfills, including Green Lane, Keele Valley, Brock, Beare and Thackeray.



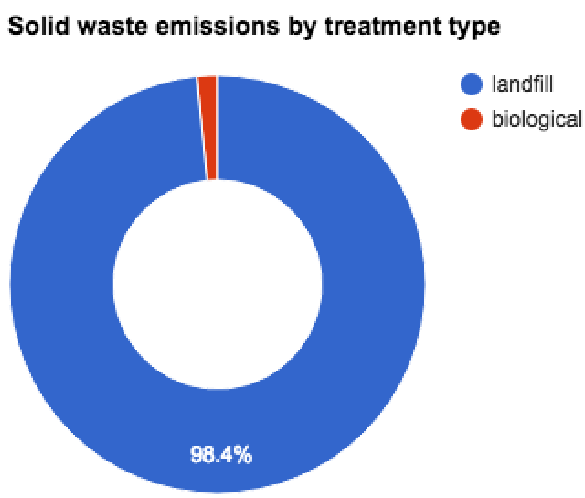
Tonnage of waste ≈ 1,017,340 tonne

Figure 22. Waste tonnage composition, 2011.



Tonnage of waste ≈ 1,017,340 tonne

Figure 23. Waste tonnage by treatment types, 2011.



Solid waste emissions ≈2,065,800 tonne CO2e

Figure 24. Solid waste emissions by source, 2011.

Wastewater

Wastewater emissions amount to 355,300 tonne CO2e, which makes up 15% of total waste emissions for the city (Figure 21). These emissions are as a result of the wastewater treatment of approximately 441,200,000 cubic meters of wastewater that is treated at the Ashbridges, Highland, Humber, and North Toronto wastewater treatment plants.

4. BAP Modelling Process

The Build As Planned (BAP) scenario is a projection over the time period from 2012 to 2050 designed to illustrate energy use and greenhouse gas emissions for the City of Toronto, if no additional policies, actions or strategies are implemented (above those that are currently underway).

The development of the BAP involved a comprehensive review of city policies in the relevant domains, identification of projections that have been developed for specific sectors, a review of Provincial policies, and more than a dozen interviews and discussions with City departments on their plans and activities.

The results of this work are summarized in the following sections and a bibliography of documents reviewed is attached at the end of this document.

The following hierarchy of decision-making was used for developing the Build as Planned scenario:

1. Calibrate model and develop 2011 baseline using observed data and filling in gaps with assumptions where necessary;
2. Input existing projected quantitative data to 2050 where available:
    a. Population, employment & households projections from City by transportation zone
    b. Build out (buildings) projections from City by transport zone
    c. Transport modelling from City
3. Where quantitative projections are not carried through to 2050 (eg. completed to 2041), extrapolate the projected trend to 2050.
4. Where specific quantitative projections are not available, develop projections through:
    a. Analysing current on the ground action in the City (reviewing actions plans, engagement with staff etc.), and where possible, quantifying the action;
    b. Analysing existing policy that has potential impact for the city, and where possible, quantifying the potential impact.

4.1 The city is divided into zones

Zones allow for the exploration of what happens in a smaller unit of geography, as well as providing a structure to describe how people move from one location to another. The 625 transport zones in Toronto were used as the primary unit of analysis (Figure 25); transportation zones are used extensively by the City for projections and analysis.

Figure 25: Transport zones in Toronto

4.2 Population

How many people?

The population projection provided by the City of Toronto was developed for the SmartTrack analysis and is aligned with the Provincial Growth Plan forecast. In the SmartTrack family of scenarios, the population and employment projection used is labelled “Low” and does not include SmartTrack transit options. The projection is categorized by age and sex year over year, and begins with the base year of 2011.

Figure 26 includes the population by four different age categories over time- notice how a spike in the number of two year olds in 2014 is reflected 20 years later in 2024 in the 22 year old category. In addition to following these bumps over time, the scenario also makes assumptions for fertility, mortality, immigration and emigration. In terms of impact on greenhouse gas emissions, the age composition of the population influences the floor space required; for example, a bump in the number of school-aged children drives floor space for schools. In total, the population is projected to increase from 2.721 million in 2011[1] to 3.40 million in 2041. Figure 27 illustrates the resident population as well as the student population (which is 101,500) by 2050.

As TransformTO extends until 2050, CityInSight's cohort-survival population model was used to project the population from 2041 to 2050 - keeping assumptions for immigration, emigration, fertility rates and mortality rates constant or trend-projected - by which point the population increases to 3.497 million.

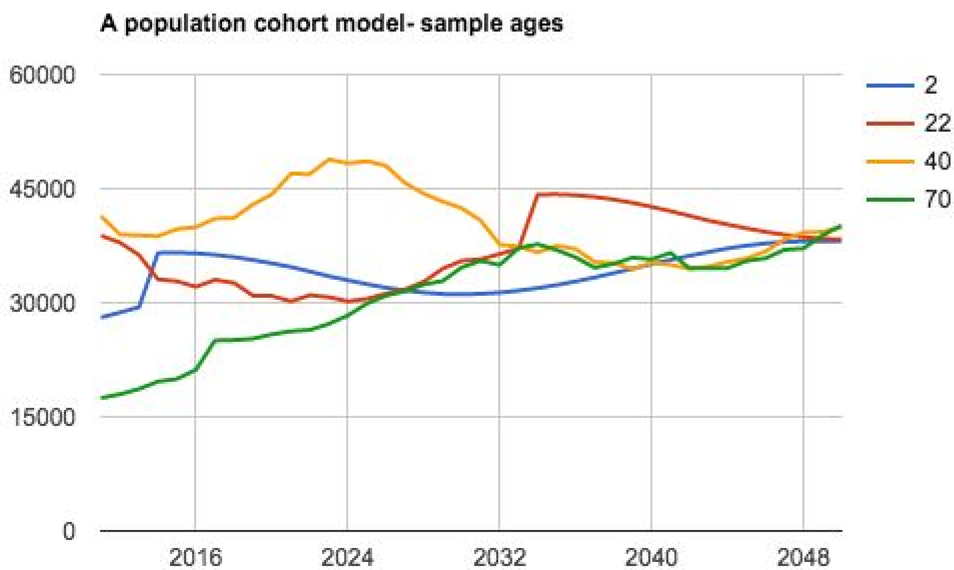


Figure 26: Population over time for different age categories

[1] This estimate accounts for census undercount and external students.

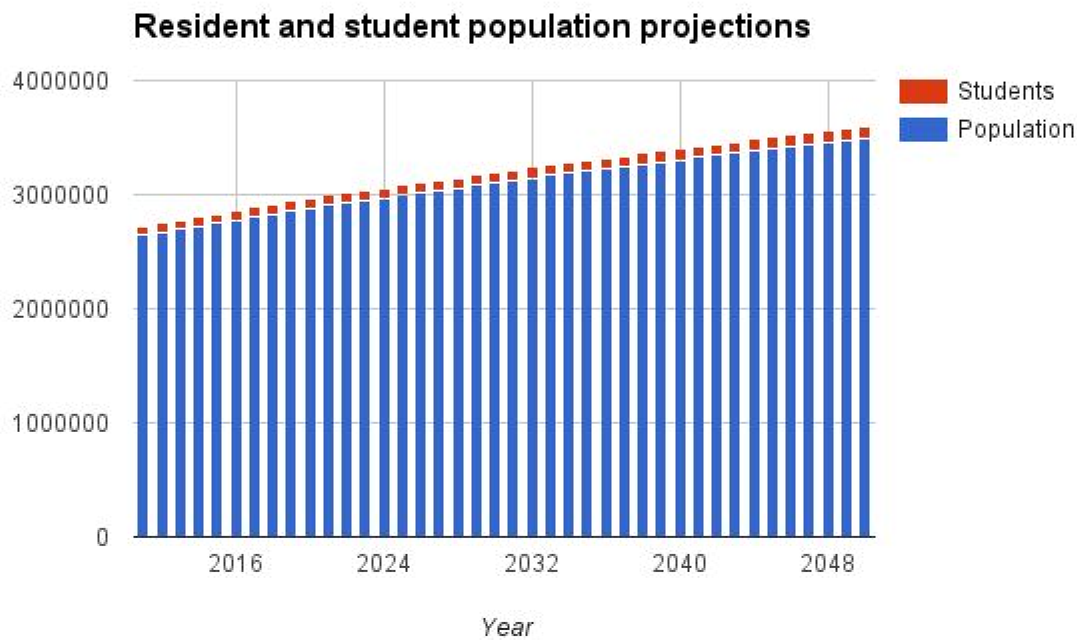


Figure 27: Projected total population

Where do people live?

The “Low” scenario converts the projected population into apartments and ground-related housing by traffic zone according to the existing housing stock, potential housing supply and the land-use policies of the Official Plan (pre 2014 Feeling Congested update). In order to provide more detail on the categories of buildings, in the BAP scenario, new dwellings in each transportation zone were distributed amongst dwelling types according to the same proportion of the existing dwelling mix in that zone. For example, the projection provided by the City provides the categories of ground-related dwellings and apartments and these categories are further segregated into the categories that CityInSight uses according to the pre-existing mix of residential buildings types in a zone.

Figure 28 shows new density added to the City by 2050 by apartments buildings of greater than 5 stories. There is a concentration of new development downtown and new development in the Port Lands is also evident; a smaller concentration of new density is found in North York. In comparison, Figure 29 indicates that there are very few single family dwellings added (Note that the same scale applies to both figures). Approximately 95% of new dwellings units between 2011 and 2050 are expected to be apartments, with just under 85% of total new units in apartments greater 5 stories (Figure 29).

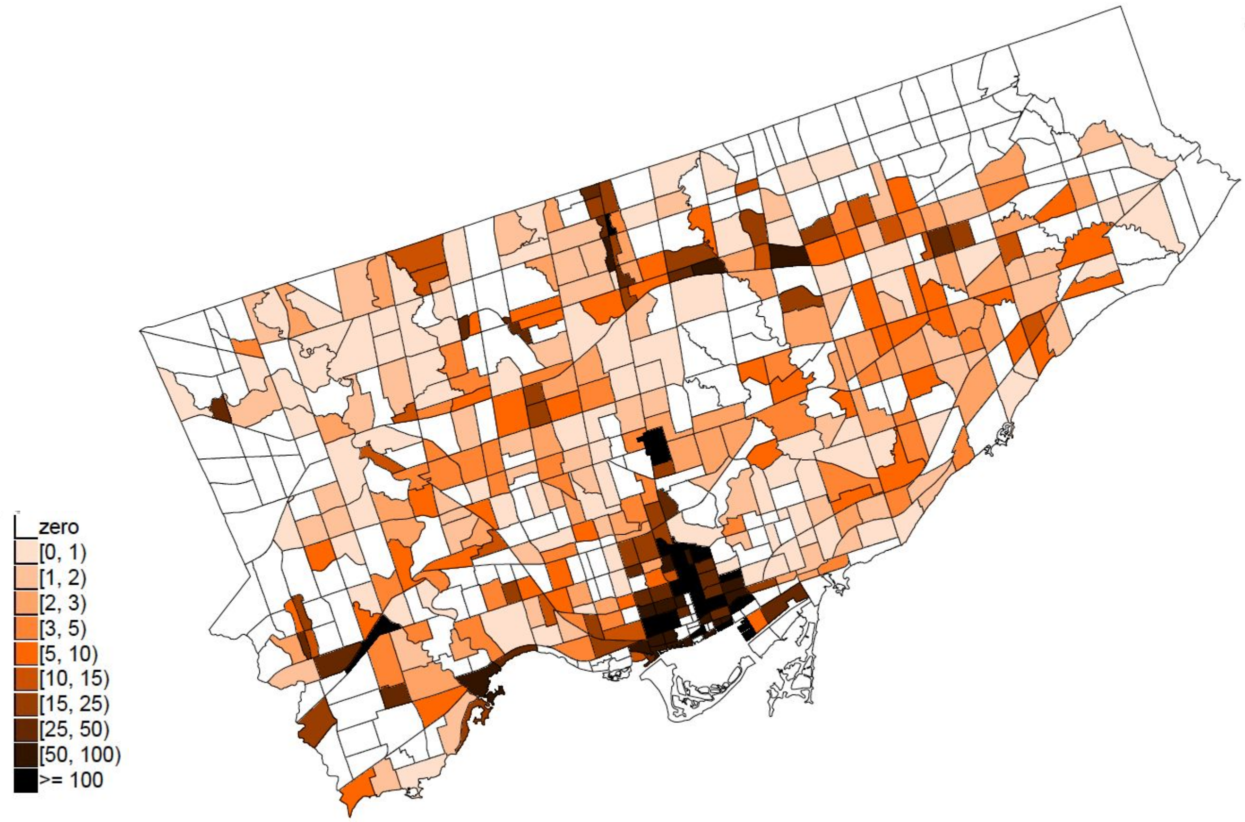


Figure 28: Additional apartments > 5 stories from 2016 to 2050 (dwelling units/hectare)

Figure 29: Additional single family dwellings from 2012 to 2050 (dwelling units/hectare)

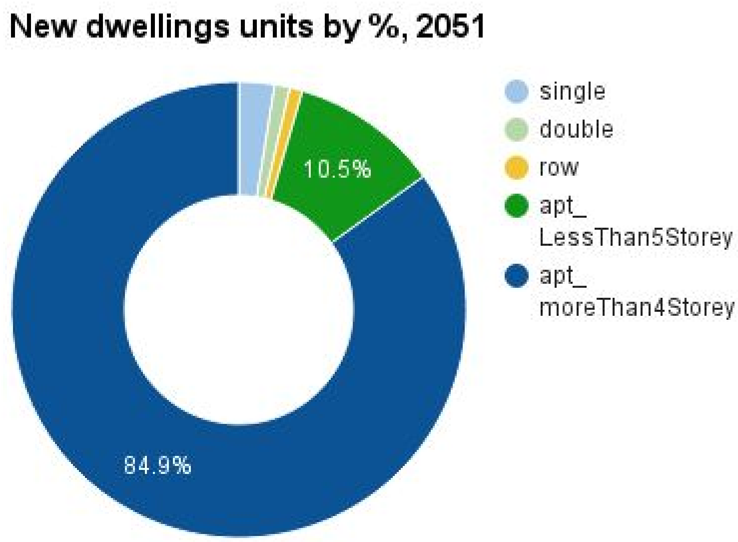


Figure 30: Shares of cumulative new dwelling units by 2050 (%)

4.3 Employment

How many jobs? What kind of jobs?

Employment projections are derived from work conducted by Strategic Projections Inc. for the City of Toronto's Employment Uses Policy Study (2012); the "Medium" scenario was used, which reflects the projections from the Provincial Growth Plan. The City's projections began with 2011 numbers from the National Household Survey (Statistics Canada), and adjustments were made using 2006 census data and municipal employment surveys. Employment is projected to increase from 1.572 million in 2011 to 2.69 million in 2050 in the City's projections scenario (Figure 31).

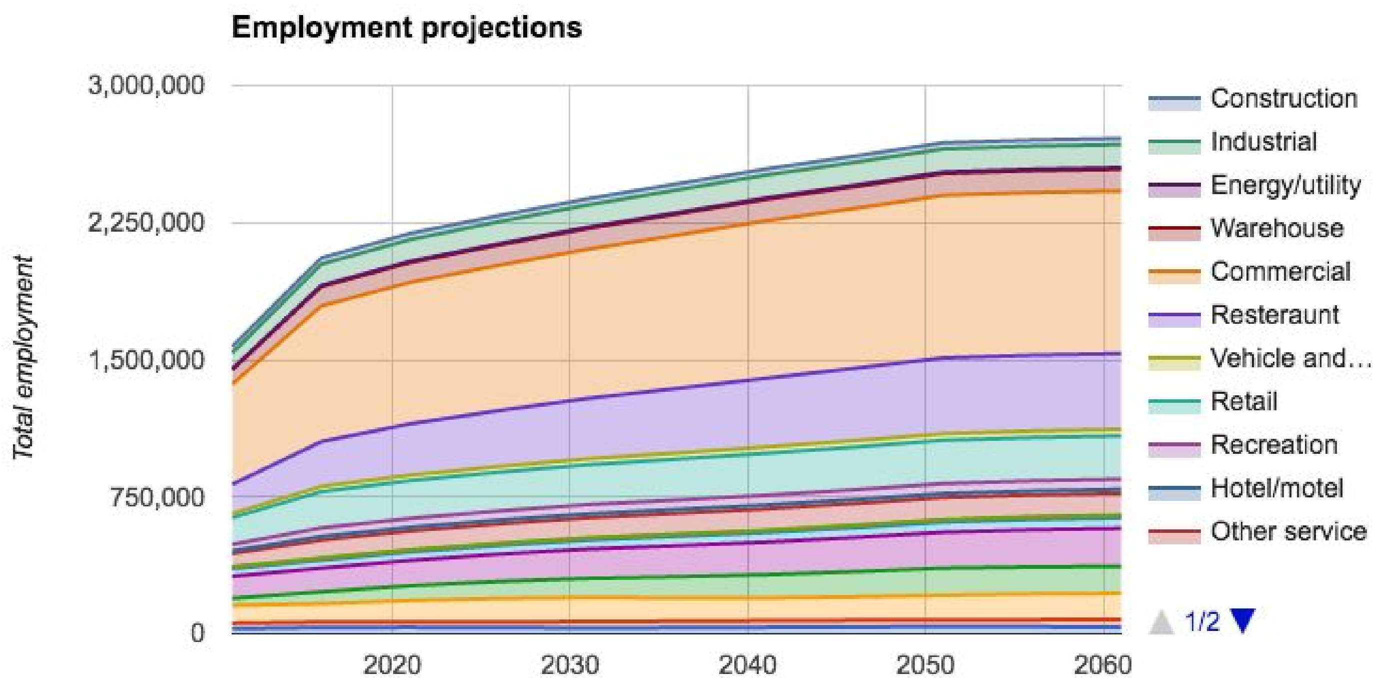


Figure 31: Jobs by category, 2011 to 2050

Where are the jobs?

The employment projections provided by the City use three categories for places of work: work at home; usual place of work and no usual place of work. Jobs in the first two categories were allocated to transportation zones, but jobs in the third category cannot be tied to a particular place. Once total jobs were allocated to zones, they were parcelled out to different types of jobs based on the 2011 mix for that zone, as the job projections only included total number of jobs (they did not include a breakdown of job types to 2041). Therefore, if a zone was 80% office employment in 2011, that zone would continue to have 80% office employment in 2021, 2031 and so on.

The City made additional adjustments to this forecast, particularly for the Port Lands area, due to planned redevelopment. Floor space was then allocated based on an area/employee ratio for each employment type, again derived from historical ratios. Figure 32 illustrates the starting point in 2011 for floor space density of museums and art galleries, one of 46 different buildings types, as an example of the detail at which the analysis is undertaken. Note that the scale is not linear; in other words, the dark colours represent a much greater density of floor space than the lighter colours.

The analysis does not include any assumptions for job removals. As jobs drive floor spaces, it is likely that the results slightly overstate required floor space.

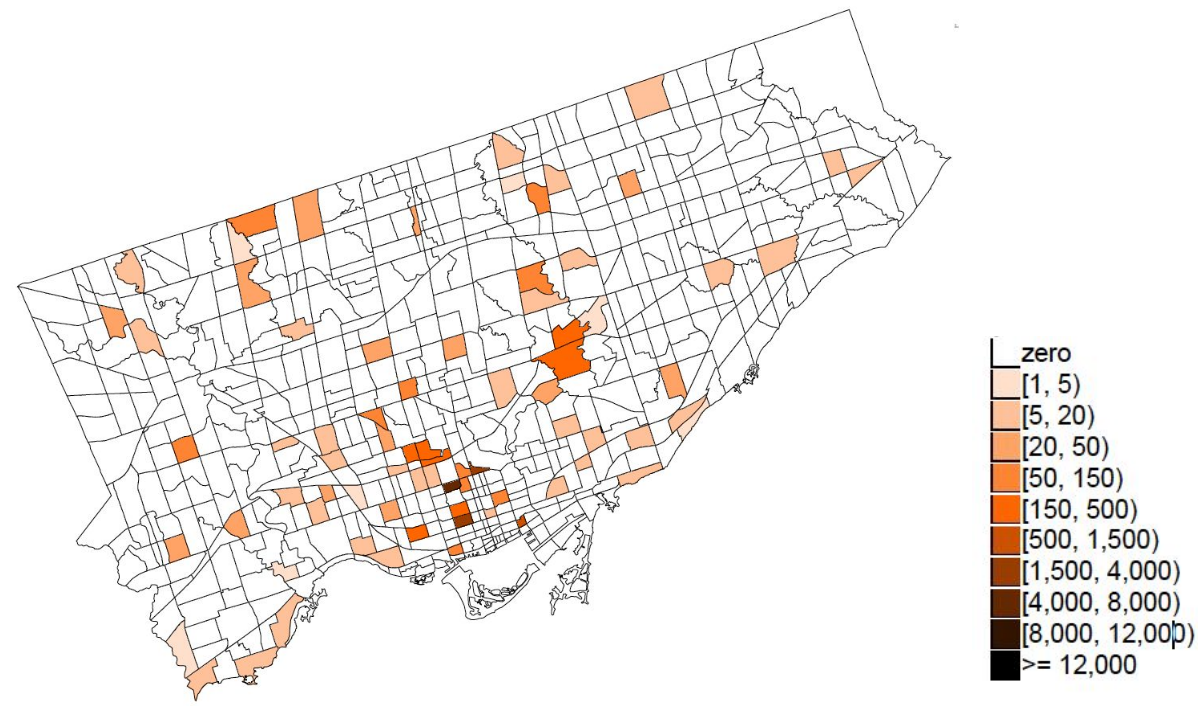


Figure 32: Sample of building type: density of floor space for museums and art galleries, 2011 (m2/ha).

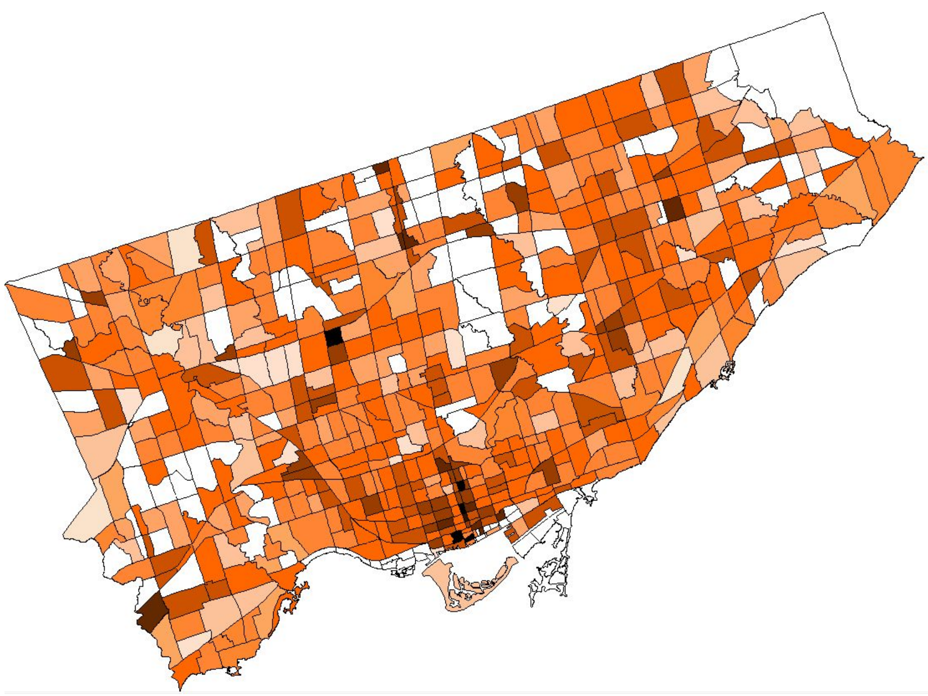


Figure 33: Sample of retail floorspace projection, 2050 (m2/ha).

4.4 Energy consumption

How much energy do buildings use?

In addition to the type of buildings, a key consideration is their energy performance. Buildings are divided into two categories; new construction and existing buildings. The City of Toronto currently has specific requirements for the energy performance of new buildings under the Toronto Green Standard, which was updated in 2014 to Version 2. Existing buildings, however are not required to achieve specific energy performance levels. A certain percentage of buildings are retrofitted each year and must upgrade energy performance to the current building code requirements when they do so. Additionally buildings are retrofitted in order to achieve conservation programming targets required by the Province.

The City of Toronto, as a result of the Toronto Green Standard program, has detailed energy performance data on buildings, classified by type, with additional analysis undertaken by the Toronto Atmospheric Fund[2]. This information was used to develop physical characteristics for residential and non-residential building types considered in this analysis, which was then calibrated against observed energy data provided by the electricity and natural gas utilities in 2011. These physical characteristics, for example thermal performance of the building envelope, were then adjusted to achieve energy use intensities for different building types that address each of the performance levels described in Table 2.

Table 2: Buildings energy performance assumptions.

Standard	Application	2010-2013	2014-2050
Toronto Green Standard Tier 1	Part 9 buildings with > 5 dwelling units and all Part 3 buildings	85% of new construction	Starts at 85% of new construction and declines to 0% by 2050.
Toronto Green Standard Tier 2		15% uptake of Tier 2 v1 for new construction	Starts at 15% uptake of Tier 2 v2 increasing to 100% by 2050 for new construction
Ontario Building Code	Part 9 buildings with < 5 units including single family dwellings.	Ontario Building Code-EnerGuide 80 (beginning in 2012)	Incrementally increase efficiency and renewable generation to achieve net zero carbon emissions by 2030 as indicated in the Ontario Climate Action Plan.
Ontario Building Code	Existing buildings	Apply retrofits that reduce electricity consumption by 1% per year and natural gas by 0.75% per year[3]. Retrofitted buildings meet Ontario Building Code (2012) energy efficiency requirements.	

Major appliances, plug load, lighting and space conditioning

Residential energy use was modelled by evolving a technology stock that is deployed to provide the demanded 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 3.

[2] City of Toronto. (2016). Green Standard Tier 1 Energy Data Consolidated (unpublished).

[3] Acadia Centre. (2014). *Energy efficiency: Engine of economic growth in Canada: A macroeconomic modeling & tax revenue impact assessment*. Retrieved from http://acadiacenter.org/wp-content/uploads/2014/11/ENEAcadiaCenter_EnergyEfficiencyEngineofEconomicGrowthinCanada_EN_FINAL_2014_1114.pdf

Table 3: Stocks of equipment that consume energy

Major appliances ● Refrigerator ● Freezer ● Dishwasher ● Clothes washer ● Clothes dryer (electricity or natural gas) ● Range (electricity, natural gas or propane)	Lighting ● Incandescent ● Compact flourescent ● Fluorescent ● Halogen ● LED	Space heating ● Oil furnace (normal, mid or high efficiency) ● Gas (normal, mid or high efficiency) ● Electric ● Heat pump (electric or gas) ● Geothermal ● Wood ● LPG ● Coal and other ● Wood/electric ● Wood/oil ● Solar/electric ● Solar/gas ● Solar/oil ● Gas/electric ● Oil/electric
Plug load (minor appliances)	Space cooling ● Central ● Heat pump ● Room	

In all cases (except for minor appliances) the 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)[4]. Historical trends in the adoption of new technologies and energy consumption were then projected into the future in order to simulate ongoing improvements in energy efficiency of appliances and heating or cooling equipment. In the case where legislation has established performance targets, these trends were overruled and targets from the legislation were used, for example in the case of lighting efficiency, incandescent light bulbs were phased out by 2017[5].

What about the influence of climate?

Energy use in Toronto 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 is adjusted according to the number of heating and cooling degree days identified in a projection for the City. Because the projection only includes the time periods of 2000-2009 and 2040-2049, a trend line was interpolated between those two periods[6] (Figure 34).

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[4] 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

[5] Government of Canada. (2013, October 5). Regulations amending the energy efficiency regulations. Retrieved September 14, 2016, from http://canadagazette.gc.ca/rp-pr/p1/2013/2013-10-05/html/reg6-eng.html

[6] SENES Consultants Ltd. (2011). *Toronto's future weather and climate driver study: Volume 2- data tables (200-2009 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

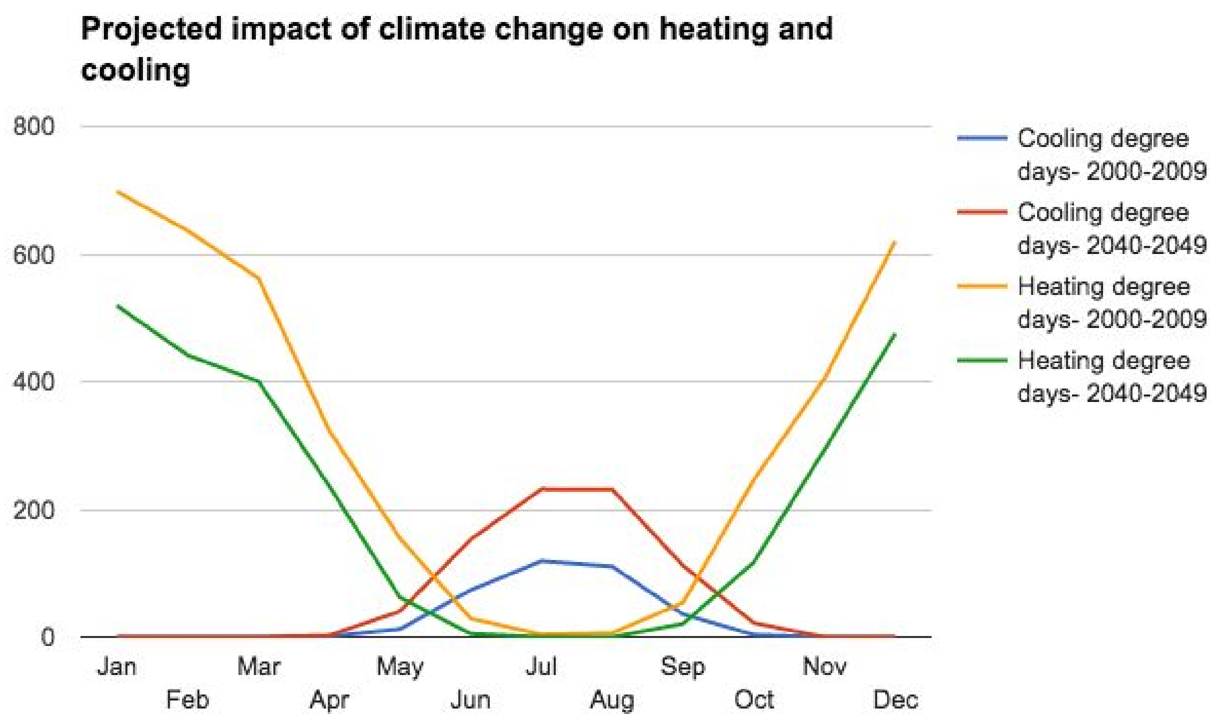

Figure 34: Heating and cooling degree days in 2000-2009 and 2040-2049

4.5 Transportation

How do people get around?

The City provided modelled origin-destination matrices for each of the transportation zones, which describe how many trips start and end in each zone by trip purpose and mode out until 2041. Base year trips were generated from the Transportation Tomorrow Survey[7] and are categorised as home-to-work, home-to-school, home-to-other and non-home-based. Figure 35 shows that home to work trips are significantly longer than any other trip types within the City boundary.

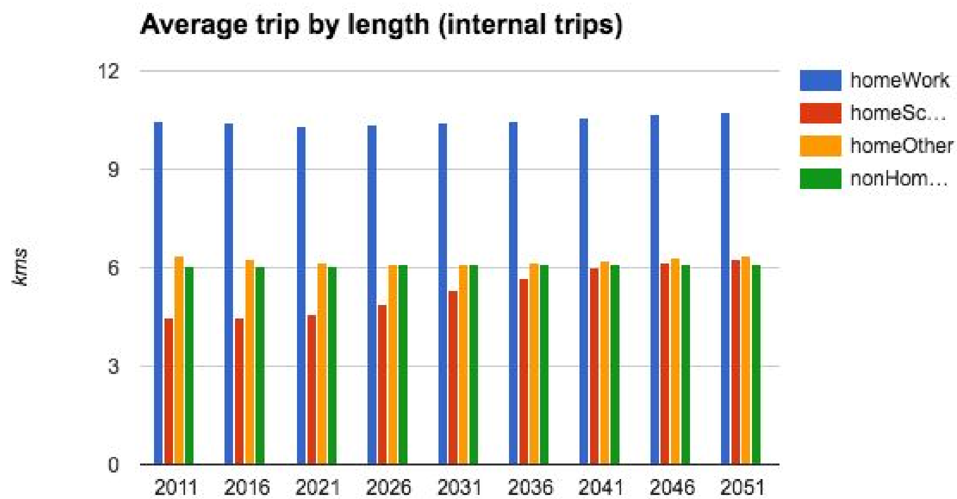

Figure 35: Trip length by type, internal trips (2011-2050)

External trips are much longer than internal trips (Figure 36), however in general over the time period, external trips account for less than half of the per resident VKT.

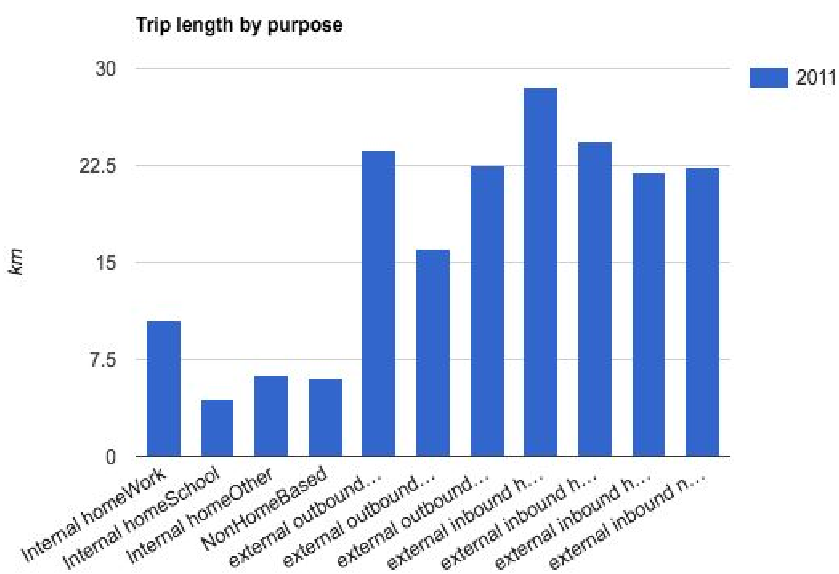

Figure 36: Trip length by type, internal and external trips (2011)

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[7] Government of Ontario. (2016). Transportation tomorrow survey. Retrieved September 12, 2016, from http://www.transportationtomorrow.on.ca/

Trips were generated according to the number of people living and employed in each zones. Mode of travel was selected depending on the destination and the accessibility to different modes for that destination as well as other factors, within the City's transportation model. Figure 37 and 38 illustrate the vehicular mode share across the city and, with results in 2050 showing a slight decline in many of the transportation zones outside of the city core as new transit options come online.

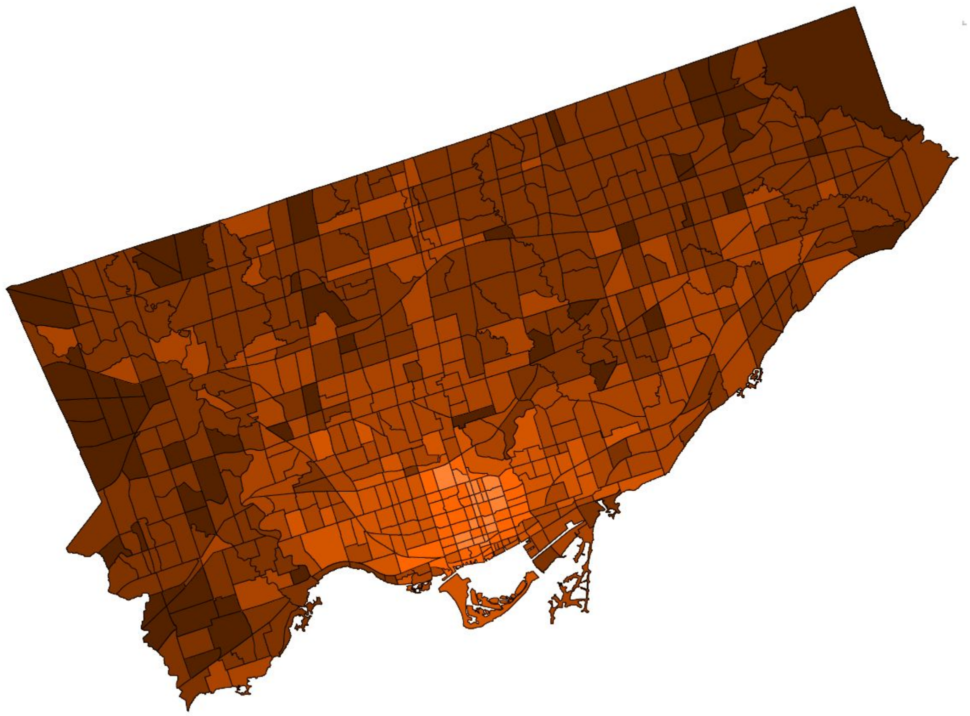

Figure 37: Vehicular mode share by zone (internal trips only), 2011.

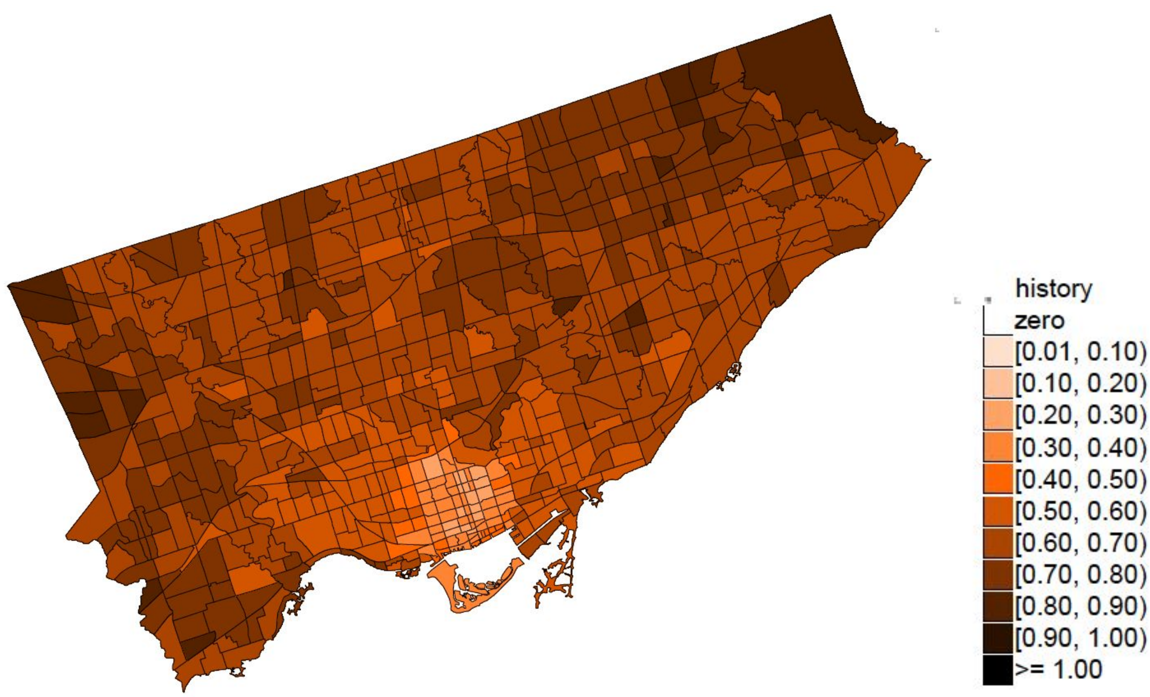

Figure 38: Vehicular mode share by zone (internal trips only), 2050.

Vehicular travel continues to be the dominant mode until 2050 (Figure 39), accounting for approximately 60% of the trips within the City boundaries, 70% of external inbound trips and 86% of external outbound trips in 2050.

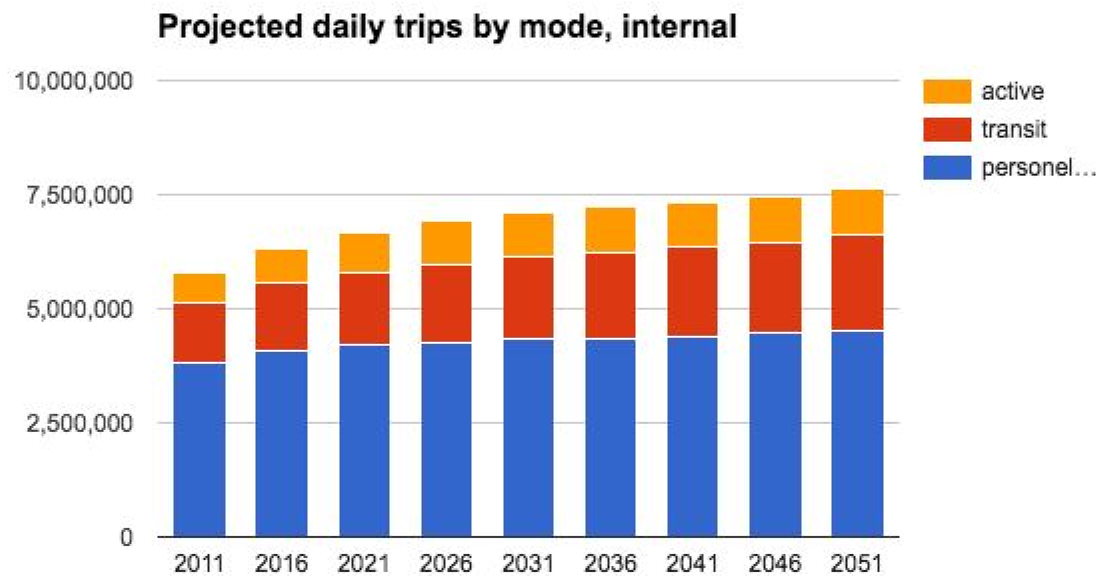

Figure 39: Mode split projections for trips within the City boundary

After the mode was specified, vehicle kilometres travelled (internal and external), were calculated (Figure 40), which, when combined with vehicle types as described below, was translated into energy consumption and GHG emissions.

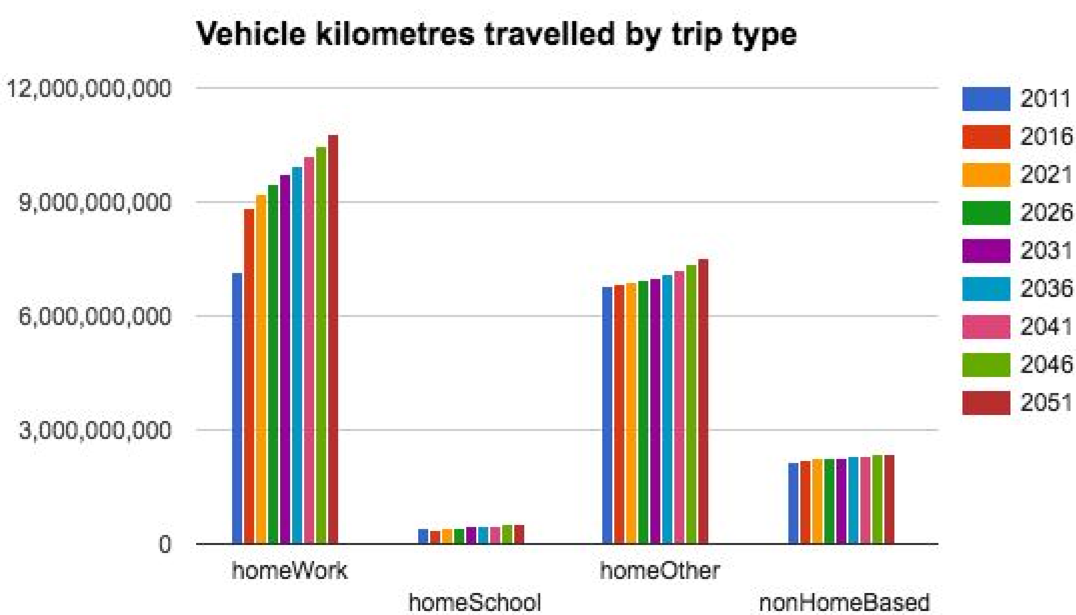

Figure 40: VKT projections by trip type

The City's transportation projections provide a mode share for vehicles, transit and active transportation; however, they do not account for City policies and strategies to support walking or cycling, for example the Toronto Walking Strategy[8] or the Ten Year Cycling Network Plan[9].

What kind of vehicles do people have?

The 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 CANSIM and Natural Resources Canada's Demand and Policy Analysis Division[10], which are then scaled proportionately to Toronto. 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 4.

Table 4: Vehicle types

Personal light duty vehicles ○ Cars ○ SUVs and trucks	Public transit vehicles ○ Buses ○ Subway/LRT ○ Commuter rail	Commercial vehicles Light duty ○ Taxis ○ Delivery vehicles Medium duty ○ "heavy duty" pick-up and vans

Each of these vehicles types is then assigned an engine technology, which can be an internal combustion engine (ICE), an hybrid ICE, a fuel cell, a plug-in hybrid (PIHB), or an electric engine. Subsequently these power sources can be fueled 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 BAP scenario incorporates the implementation of harmonised fuel efficiency standards that apply to Canada including the CAFE Standards for Light-Duty Vehicles, MYs 2022-2025[11] and Phase 1 (2014-2018) and 2 (2018-2027) of Fuel Efficiency and GHG Emission Program for Medium- and Heavy-Duty Trucks[12].

Electric vehicles and plug-in hybrids are assumed to escalate to 4% of new cars and trucks by 2020, climbing to 1 million vehicles in Ontario by 2035. Figure 41 shows the mix of light duty vehicles by fuel type.

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[8] City of Toronto. (2009). *Toronto walking strategy*. Retrieved from http://www1.toronto.ca/City%20Of%20Toronto/Transportation%20Services/Walking/Files/pdf/walking-strategy.pdf
[9] City of Toronto. (2016). *Ten year cycling network plan* (Staff report). Retrieved from http://www.toronto.ca/legdocs/mmis/2016/pw/bgrd/backgroundfile-92811.pdf
[10] 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
[11] 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
[12]For detailed information on the fuel standards, see: http://www.nhtsa.gov/fuel-economy

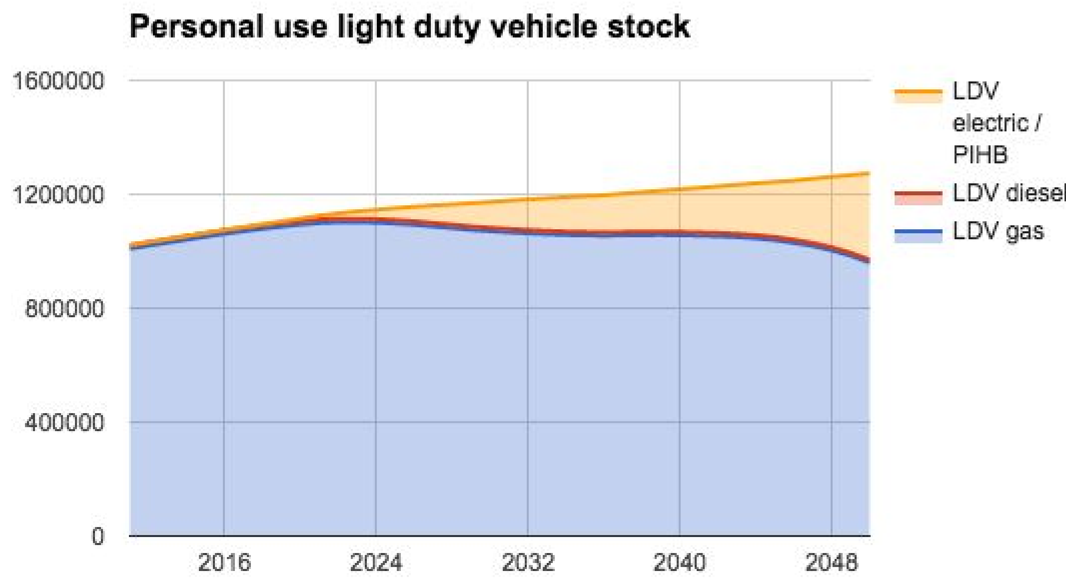


Figure 41: Personal use light duty vehicle stock.

What does the transit system look like?

By 2031, the City's transit system was assumed to include the Scarborough Subway Extension with 3 stops[13] on McCowan Road, GO's Regional Express Rail, Eglinton Crosstown Rail Transit, Finch West Rail Transit, Sheppard East Rail Transit and Toronto-York Spadina Subway Extension. No further expansion in the transit system was assumed between 2031 and 2050. The Toronto Transit Commission subway cars and streetcars were assumed to continue to run on electricity while buses are assumed to be diesel without any improvements in efficiency. The analysis assumes that 86% of GO train VKT will be fueled by electricity beginning in 2031, which is held constant until 2050.

[13] Since this projection was created, the City has decided to move forward with one stop.

4.6 Energy production

How is energy generated?

The future trajectory for energy generation was derived from a national energy model developed by whatIf? Technologies called CanESS, which analyses the energy system nationally and by province. CanESS was calibrated against historical data, including on population, economy, residential energy use, commercial energy use, transportation energy use, industrial energy use, resource production, and energy production, so that when the model is run over historic time, the energy use and emissions outputs match the energy use by sector and by fuel as reported in the Report on Energy Supply and Demand from Statistics Canada[14]. Other data sources used in the calibration process include additional CANSIM tables, the Energy Efficiency Trends Analysis Table, the National Inventory Report from Environment Canada[15] and expert estimates when observed data was not available.

Figure 42 illustrates energy use by sector in GJ; the dominant sector is commercial buildings. Figure 43 illustrates the dominance of natural gas, which, in residential buildings, is used for space heating (Figure 44). A decrease in gasoline consumption is caused by improved fuel efficiency standards combined with an incremental uptake of electric vehicles, which also contributes to the increase in electricity consumption.

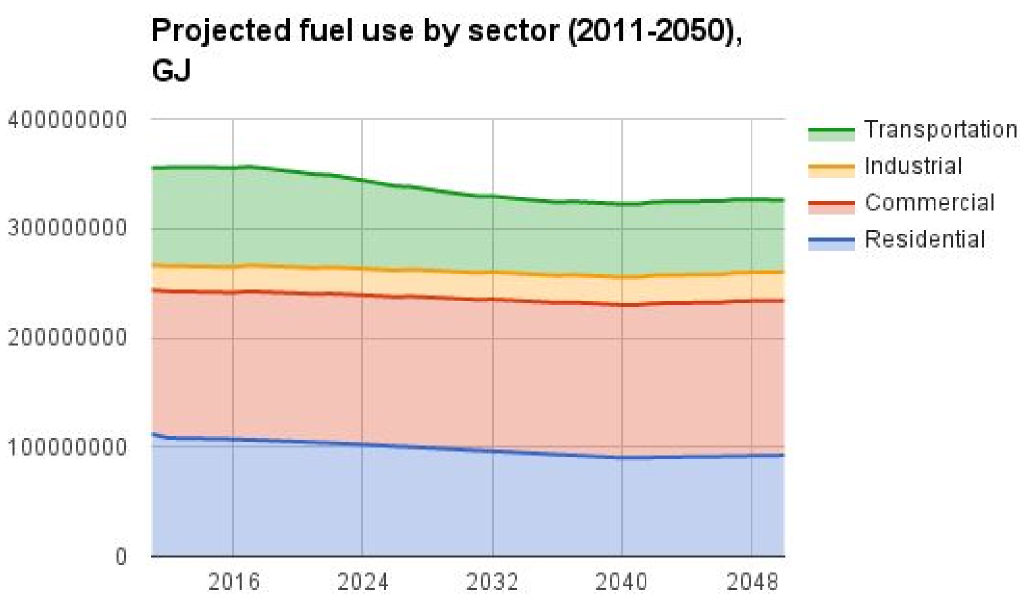


Figure 42: Projected energy use by sector, GJ (2011-2050).

[14] 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
[15] Government of Canada. (2016). *National inventory report 1990-2014: Greenhouse gas sources and sinks in Canada- Part 1*.

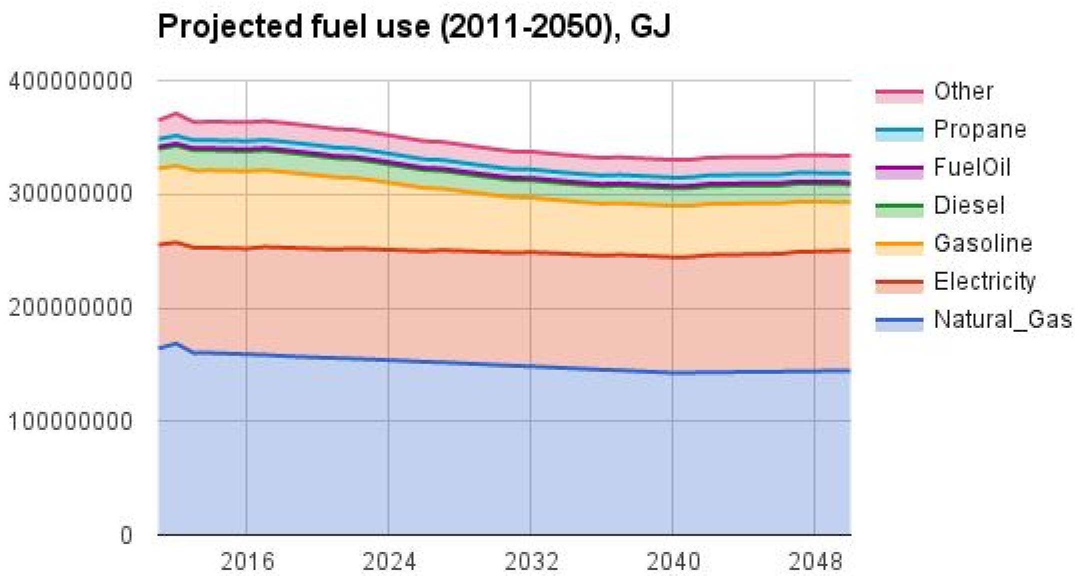


Figure 43: Projected energy use by fuel type, GJ, (2011-2050).

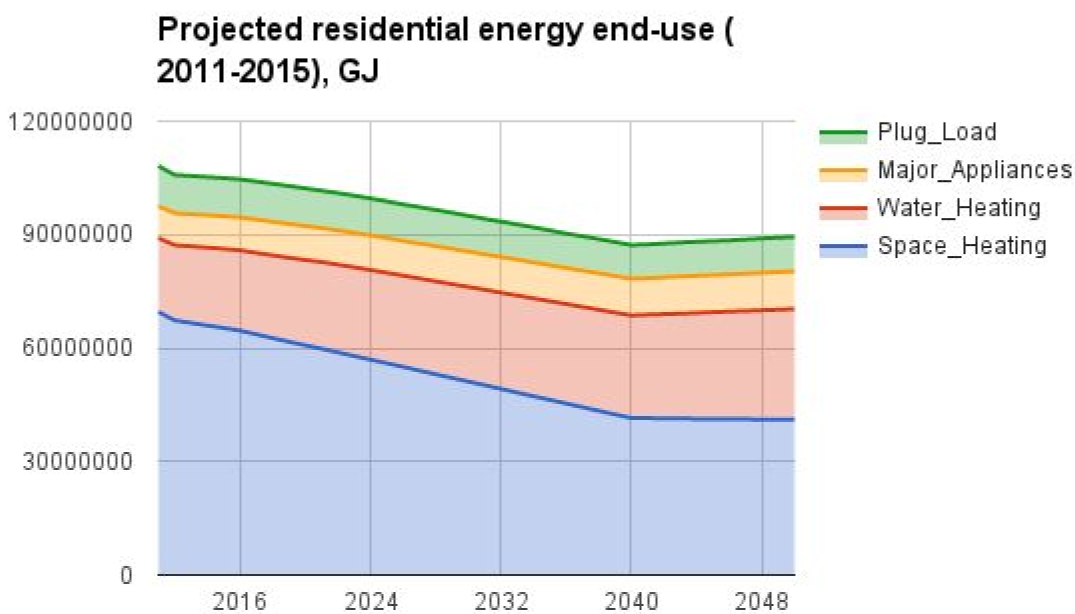


Figure 44: Projected energy use by end-use in the residential sector, GJ (2011-2050).

In order to develop the BAP projection, each of the model inputs for the energy system was either fixed at the level of the last year in history (currently 2013), or alternatively if there was a clear trend in the historic data, that trend is used to project into the future. The projection is typically not linear, but was rather a saturation projection where the trend was levelled off after a certain number of years, depending on the relevant variable.

The electrical grid

The historical data for the electrical grid is obtained from a variety of sources including Statistics Canada's 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 BAP scenario, the electricity generation input variables were set on the basis of NEB's Energy Future 2016, beginning in 2015[16]. A subsequent comparison with electricity capacity data for each generation technology from IESO[17] 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 5) 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 5: Emissions factor comparison between the National Inventory Report and CanESS

Year / kg CO2e/mWh	NIR	CanESS
2012	95	101
2013	66	70
2014	41	33

For current and future generation capacity, coal capacity was phased out in 2014, Pickering units are decommissioned between 2022- and 2024, while refurbishments of the remaining nuclear facilities mostly occurs in the 2020s. Wind, solar and also 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 45 illustrates the projected emissions factor for the electricity grid in Ontario.

[16] 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
[17] IESO (2016) *MODULE 4:Supply Outlook*. Retreived from http://ieso.ca/Documents/OPO/MODULE-4-Supply-Outlook-20160901.pptx

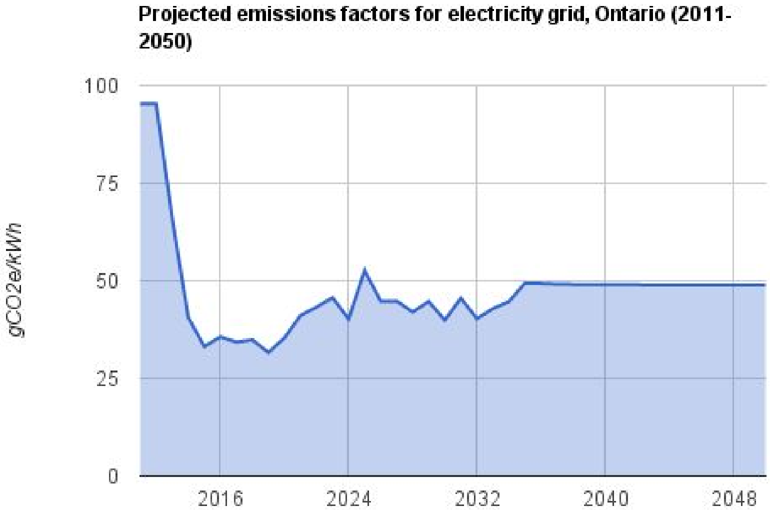
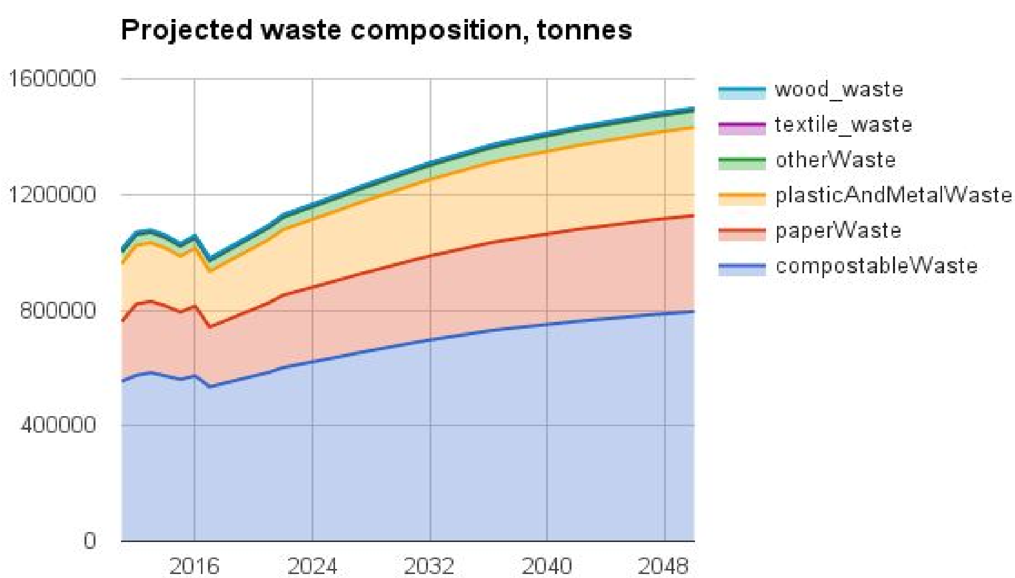


Figure 45: Projected emissions factor for electricity grid, Ontario (2011-2050)

4.7 Waste

How much waste is produced?

The Long Term Waste Strategy was approved by City Council in July, 2016, which established a target of 70% diversion of residential waste by 2026, and of materials collected by the City from industrial, commercial and institutional customers[18]. An overall target is the diversion of 200,000 tonnes by 2026. The baseline residential and non-residential waste generation projections (2014-2050) were used from a Technical Memo that informed the Long Term Waste Strategy[19].



[18] City of Toronto. (2016). *Long-term waste management strategy*. Retrieved from http://www.toronto.ca/legdocs/mmis/2016/pw/bgrd/backgroundfile-94038.pdf

[19] HDR. (2015). *Technical memorandum no.2 Needs assesssment: Vision & guiding principles; gaps, challenges and/or opportunities; and long-term projections*. City of Toronto. Retrieved from http://www1.toronto.ca/City%20Of%20Toronto/Solid%20Waste%20Management%20Services/Long%20Term%20Waste%20Strategy/Tech%20Memorandum%20No%202%20-%20FINAL%20-%20AODA.pdf

Figure 46: Projected waste composition, tonnes (2011-2050)

The City is planning to generate renewable natural gas from Keele Valley Landfill, Disco Road Organics Processing Facility and Dufferin Organics Processing Facility. The BAP scenario assumed that Keele, Disco and Dufferin are in operation by 2020 and Green Lane Landfill is in operation by 2025. In total these facilities generate approximately 1 million GJ of fuel per year[20].

5. BAP Results

Figure 47 shows the total projected GHG emissions in MT for the City of Toronto from 2011 to 2050. Emissions fall from 20.31 MT CO2e in 2011 to just over 17.13 MT in 2020 and then decline slightly to plateau around 15 MT out until 2050. The immediate dip after 2011 can be attributed to the phase out of coal in the electricity system as well as reduced use of natural gas for electricity generation. A steadier and more prolonged decline results from the fuel efficiency standards combined with an incremental uptake of electric vehicles.

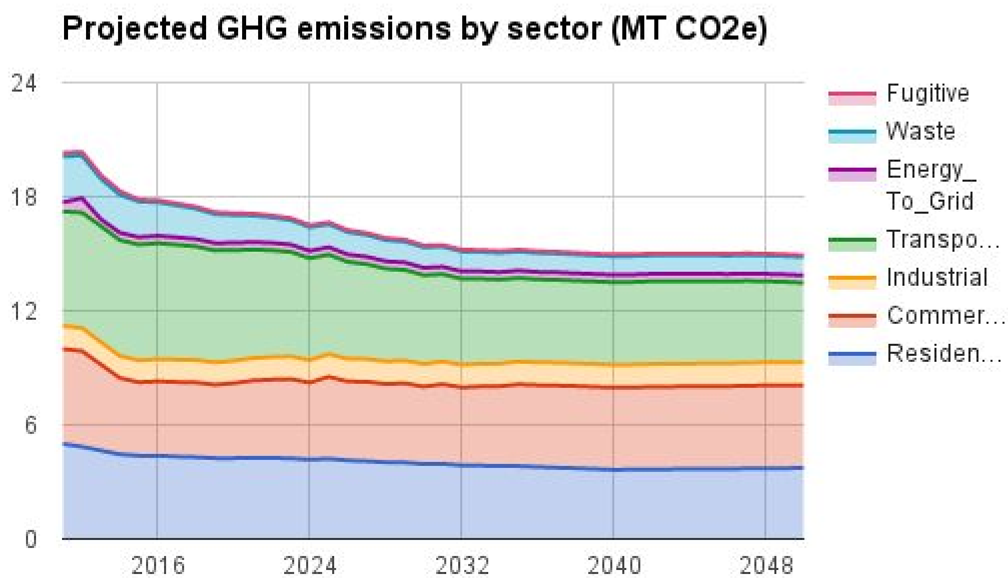


Figure 47: Projected GHG emissions by sector (MT CO2e)

The impact of coal phaseout is apparent in the GHG emissions from each fuel type for residential buildings (Figure 48), and even more dramatically for commercial buildings (Figure 49). The opportunity for emissions reductions by fuel switching from natural gas to electricity is also highlighted, particularly in residential buildings.

[20] City of Toronto. (2016, April). Authority to enter into renewable natural gas projects. Retrieved July 16, 2016, from http://www.toronto.ca/legdocs/mmis/2016/pw/bgrd/backgroundfile-92679.pdf

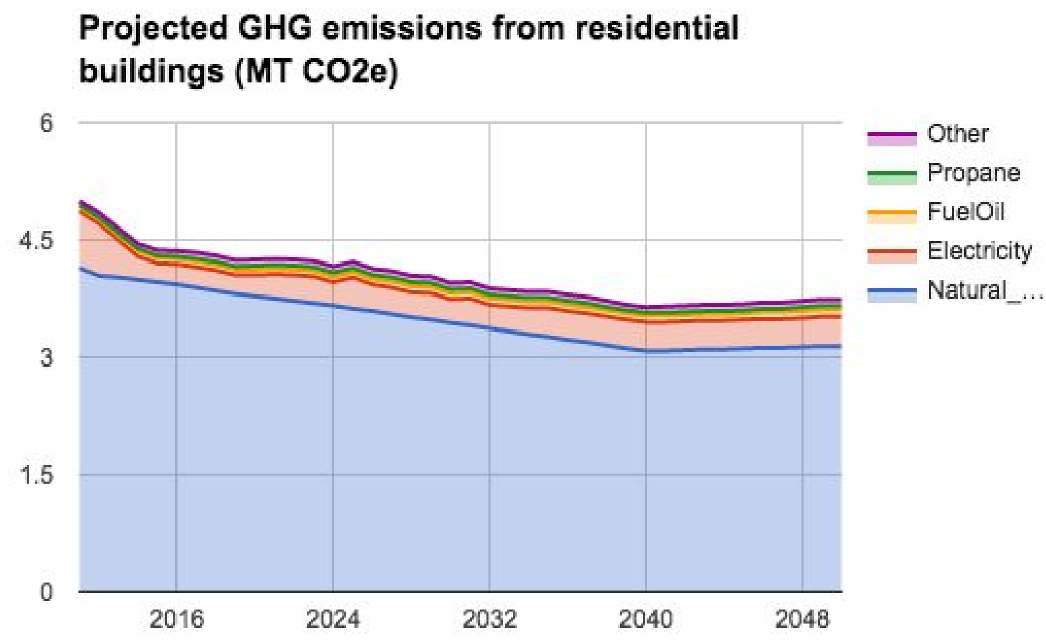


Figure 48: Projected GHG emissions for residential buildings (MT CO2e)

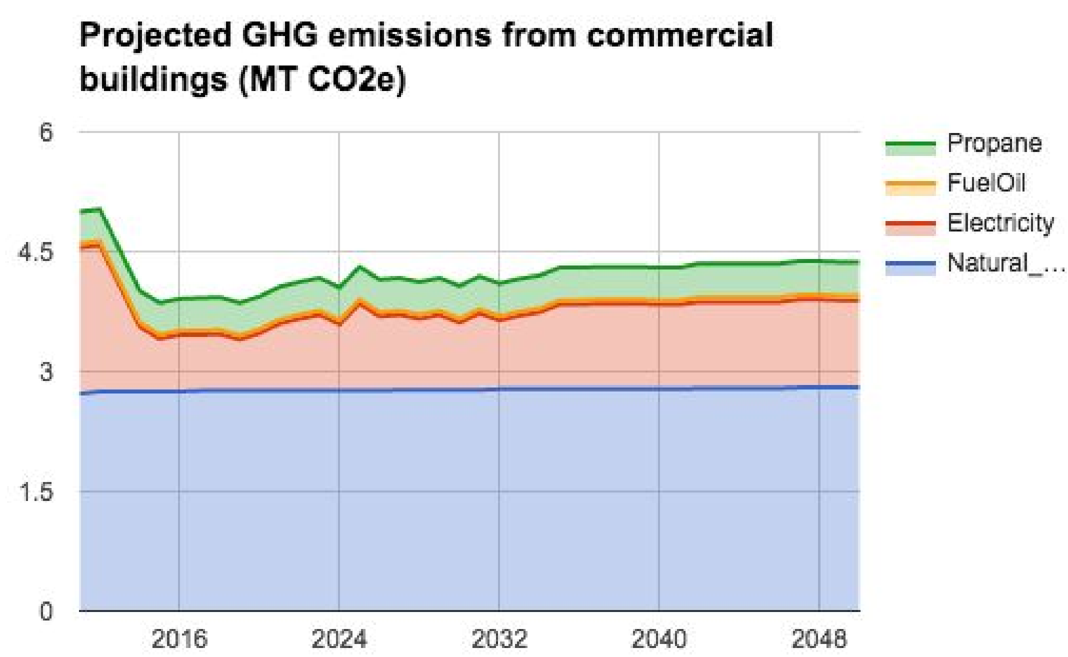


Figure 49: Projected GHG emissions from commercial buildings (MT CO2e)

6. BAP Analysis

1. The BAP projections indicate that emissions will amount to 17.1 MT CO_2e in 2020, and 14.9 MT CO_2e in 2050.
2. The BAP projections indicate that the 2020 target will be met, if the assumptions in the BAP (based on currently approved plans and policies) are implemented.
3. While the City's short term target benefits from greening of the Provincial grid and vehicle fuel efficiency standards, the 2050 target represents a major challenge as the remaining major opportunities are more intransigent.
4. The emissions factor for the Provincial grid (electricity) continues to decline. This creates an opportunity for fuel switching for vehicles (private and transit) away from gasoline.
5. Natural gas is the most significant source of emissions; this creates an opportunity for fuel switching to electricity for space heating.
6. Significant efforts to fuel switch to electricity will require new generation with renewables.
7. Existing buildings (pre-2011) have a major impact on GHG emissions; the incremental effect of high efficiency new buildings is small, but decreases the upward pressure of an increasing population on the GHG curve. An ambitious retrofit program will be critical.
8. Vehicular mode share for external trips is ≈70% (inbound) and 86% (outbound); there is an opportunity to shift this mode share. Outside of the downtown core, the vehicular mode share remains relatively high, even for internal trips.
9. Generally, trip lengths are not projected to decline; in spite of a focus on transportation oriented development.
10. Solid waste emissions are driven by the existing landfills, which taper off towards the end of the time period considered.

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Reason for exclusion (if applicable)	Comments	in tonnes CO2	CH4	N2O	Total CO2e	
I		STATIONARY ENERGY SOURCES								
I.1		**Residential buildings**								
I.1.1	1	Emissions from fuel combustion within the city boundary	**Yes**			4,242,607	212	80	4,273,549	
I.1.2	2	Emissions from grid-supplied energy consumed within the city boundary	**Yes**			648,697	138	14	657,502	
I.1.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	**Yes**			72,077	15	2	73,056	
I.2		**Commercial and institutional buildings/facilities**								
I.2.1	1	Emissions from fuel combustion within the city boundary	**Yes**			3,139,276	60	78	3,164,644	
I.2.2	2	Emissions from grid-supplied energy consumed within the city boundary	**Yes**			1,624,456	346	35	1,646,507	
I.2.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	**Yes**			180,495	38	4	182,945	
I.3		**Manufacturing industry and construction**								
I.3.1	1	Emissions from fuel combustion within the city boundary	**Yes**			754,326	15	14	759,148	
I.3.2	2	Emissions from grid-supplied energy consumed within the city boundary	**Yes**			74,799	16	2	75,814	
I.3.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	**Yes**			8,311	2		8,424	
I.4		**Energy industries**								
I.4.1	1	Emissions from energy used in power plant auxiliary operations within the city boundary	**Yes**			356,905	7	6	359,002	
I.4.2	2	Emissions from grid-supplied energy consumed in power plant auxiliary operations within the city boundary	**Yes**			3,673	1		3,723	
I.4.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption in power plant auxiliary operations	**Yes**			408			414	Buildings (stat. energy)
I.4.4	1	Emissions from energy generation supplied to the grid	**Yes**		DE & Portlands Energy Centre	472,267	123	12	480,087	**11,684,816**
I.5		**Agriculture, forestry and fishing activities**								
I.5.1	1	Emissions from fuel combustion within the city boundary	**No**	NR						
I.5.2	2	Emissions from grid-supplied energy consumed within the city boundary	**No**	NR						
I.5.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	**No**	NR						
I.6		**Non-specified sources**								
I.6.1	1	Emissions from fuel combustion within the city boundary	**No**	NR						
I.6.2	2	Emissions from grid-supplied energy consumed within the city boundary	**No**	NR						
I.6.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	**No**	NR						
I.7		**Fugitive emissions from mining, processing, storage, and transportation of coal**								
I.7.1	1	Emissions from fugitive emissions within the city boundary	**No**	NR						
I.8		**Fugitive emissions from oil and natural gas systems**								Fug. emissions
I.8.1	1	Emissions from fugitive emissions within the city boundary	**Yes**			204	5,570		189,582	**189,582**
II		TRANSPORTATION								
II.1		**On-road transportation**								
II.1.1	1	Emissions from fuel combustion for on-road transportation occurring within the city boundary	**Yes**		Includes personal, commercial & buses	4,504,944	419	1,004	4,818,439	
II.1.2	2	Emissions from grid-supplied energy consumed within the city boundary for on-road transportation	**Yes**		No significant EV stock in 2011					
II.1.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	**Yes**		For personal vehicles within GTA only.	1,031,097	119	292	1,122,069	
II.2		**Railways**								
II.2.1	1	Emissions from fuel combustion for railway transportation occurring within the city boundary	**Yes**		Includes GO; excludes Via	45,792	3	18	51,339	
II.2.2	2	Emissions from grid-supplied energy consumed within the city boundary for railways	**Yes**		Includes subway and streetcar	28,442	6	1	28,829	
II.2.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	**Yes**		Only includes transmission & distribution losses; not enough data to estimate transboundary trips	3,160	1		3,203	
II.3		**Water-borne navigation**								
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring within the city boundary	**No**	N/A						
II.3.2	2	Emissions from grid-supplied energy consumed within the city boundary for waterborne navigation	**No**	N/A						
II.3.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	**No**	N/A						
II.4		**Aviation**								
II.4.1	1	Emissions from fuel combustion for aviation occurring within the city boundary	**No**	N/A						
II.4.2	2	Emissions from grid-supplied energy consumed within the city boundary for aviation	**No**	N/A						
II.4.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	**No**	N/A						
II.5		**Off-road**								
II.5.1	1	Emissions from fuel combustion for off-road transportation occurring within the city boundary	**No**	NR						Transport
II.5.2	2	Emissions from grid-supplied energy consumed within the city boundary for off-road transportation	**No**	NR						**6,023,879**
III		WASTE								
III.1		**Solid waste disposal**								
III.1.1	1	Emissions from solid waste generated within the city boundary and disposed in landfills or open dumps within the city boundary	**No**	NR						
III.1.2	3	Emissions from solid waste generated within the city boundary but disposed in landfills or open dumps outside the city boundary	**Yes**				59,787		2,032,754	
III.1.3	1	Emissions from waste generated outside the city boundary and disposed in landfills or open dumps within the city boundary	**No**	NR						
III.2		**Biological treatment of waste**								
III.2.1	1	Emissions from solid waste generated within the city boundary that is treated biologically within the city boundary	**Yes**				637	38	33,039	
III.2.2	3	Emissions from solid waste generated within the city boundary but treated biologically outside of the city boundary	**No**	NR						
III.2.3	1	Emissions from waste generated outside the city boundary but treated biologically within the city boundary	**No**	NR						
III.3		**Incineration and open burning**								
III.3.1	1	Emissions from solid waste generated and treated within the city boundary	**No**	NR						
III.3.2	3	Emissions from solid waste generated within the city boundary but treated outside of the city boundary	**No**	NR						
III.3.3	1	Emissions from waste generated outside the city boundary but treated within the city boundary	**No**	NR						
III.4		**Wastewater treatment and discharge**								
III.4.1	1	Emissions from wastewater generated and treated within the city boundary	**Yes**				9,915	61	355,331	
III.4.2	3	Emissions from wastewater generated within the city boundary but treated outside of the city boundary	**No**	NR						Waste & WW
III.4.3	1	Emissions from wastewater generated outside the city boundary	**No**	NR						**2,421,123**
IV		INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)								
IV.1	1	Emissions from industrial processes occurring within the city boundary	**No**	ID						
IV.2	1	Emissions from product use occurring within the city boundary	**No**	ID						
V		AGRICULTURE, FORESTRY AND LAND USE (AFOLU)								
V.1	1	Emissions from livestock within the city boundary	**No**	NR						
V.2	1	Emissions from land within the city boundary	**No**	NR						
V.3	1	Emissions from aggregate sources and non-CO2 emission sources on land within the city boundary	**No**	NR						
VI		OTHER SCOPE 3								
VI.1	3	Other Scope 3	**No**	N/A						
Reason for exclusion:								**TOTAL**	**20,319,400**	
N/A	Not applicable; Not included in scope									
ID	Insufficient data									
NR	No relevant or limited activities identified									
Other	Reason provided under Comments									

Sector		Total by Scope (tCO2e)				Total	Total by city-induced reporting level (tCO2e)	
		Scope 1	Scope 2	Scope 3	Other Scope 3		BASIC	BASIC+
Stationery Energy	Energy use (all I emissions except I.4.4)	8,745,925	2,383,547	264,839		11,394,311	11,129,472	11,394,311
	Energy generation supplied to the grid (I.4.4)	480,087				480,087		
Transportation (all II emissions)		4,869,778	28,829	1,125,272		6,023,879	4,898,606	6,023,879
Waste	Generated in the city (all III. X.1 and III.X.2)	388,370		2,032,754		2,421,123	2,421,123	2,421,123
	Generated outside city (all III. X.3)							
IPPU (all IV emissions)								
AFOLU (all V emissions)								
Total		14,484,160	2,412,375	3,422,865	0	**20,319,400**	18,449,202	19,839,313
		(All territorial emissions)					*(All BASIC emissions)*	*(All BASIC & BASIC+ emissions)*

Sources required for BASIC reporting (green)
Sources required for BASIC+ reporting (green & blue)
Sources included in Other Scope 3 (orange)
Sources required for territorial but not for BASIC/BASIC+ reporting (pink)
Non-applicable emissions (grey)