Halifax Regional Municipality

Energy Use and Greenhouse Gas Emissions

Baseline Inventory, 2016 &

Business-As-Usual Scenario to 2050

Completed in support of the HalifACT 2050 Community Energy and Climate Action Plan

Completed by:

Sustainability Solutions Group

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Context

Halifax Regional Municipality is currently developing a climate action plan, *HalifACT 2050 - Acting on Climate Together*, to develop a comprehensive climate strategy to significantly reduce community-wide energy use and greenhouse gas (GHG) emissions, and establish long-term adaptation goals that increase resilience to the impacts of climate change.

The report summarizes the results of establishing a baseline GHG emissions inventory for 2016, and a base case projection to 2050, hereinafter referred to as the business-as-usual (BAU) scenario.

The emissions baseline and BAU scenario were developed using an energy and emissions model called CityInSight; this tool will be used in subsequent phases of the work to explore energy and emissions reduction scenarios.

The emissions baseline and BAU scenario applies the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC Protocol) accounting framework, using the municipal boundary of Halifax Regional Municipality as the inventory boundary.

This report is divided into two parts:

Part 1: Energy & Emissions, 2016-2050, includes the results and analysis of:

- A baseline energy and greenhouse gas (GHG) emissions inventory for 2016;
- An energy and GHG emissions business-as-usual (BAU) scenario, to 2050.

Part 2: Data, Methods & Assumptions, discusses the data, methods, assumptions and simulation tool used to develop the baseline inventory and BAU scenario.

Executive Summary

The population of Halifax Regional Municipality (HRM) is projected to grow by 30 % between 2016 and 2050, adding approximately 131,200 new residents. This growth is expected to be accompanied by 31,400 new jobs, and 49,400 new households, which will drive demand for new residential and non-residential floor space. This growth will also drive additional demands for energy, transportation, water and wastewater treatment, and generate additional waste.

As the population continues to grow, the BAU projections indicate that community-wide energy demand will decrease by 4.2%, from 55.2 million GJ to 52.8 million GJ between 2016 and 2050. Emissions will decline by 33%, from 5,784,000 tCO2e in 2016, to 3,880,000 tCO2e in 2050.

Per capita energy is projected to decline by 26%, from 125 GJ/cap in 2016 to 92 GJ/cap in 2050, while per capita emissions are projected to decline by 48%, from 13.1 tCO2e/cap in 2016 to 6.8 tCO2e/cap in 2050.

While population continues to grow, the BAU projections indicate that emissions have a decreasing trajectory. This decrease is primarily driven by: improvements to the emissions associated with provincial electrical generation, vehicle fuel efficiency standards and uptake of electric vehicles in the transportation sector; reduced energy demands for space heating in new and existing buildings due to a decrease in heating degree days projected to occur as the climate continues to warm; minor incremental increases in building efficiency standards for new buildings; and a marginal switch to electricity in the buildings and transportation sector.

High level observations of these results that inform low carbon modelling include:

- Switching to electricity provides a significant emissions reduction opportunity.
- New electricity generation capacity from renewables will be needed.
- Retrofitting the existing building stock will be critical.
- New construction standards will be key to limit emissions of a growing region.
- Electrifying transportation and shifting modes to transit and active transportation will be fundamental.
- Recovering energy from waste and wastewater present further opportunities for emissions reduction.
- Under a BAU, HRM is expected to benefit from variables outside of the Municipality's direct control, in particular the fuel efficiency standards and the greening of the provincial grid; however, the Municipality can not solely rely on these factors to reduce emissions.

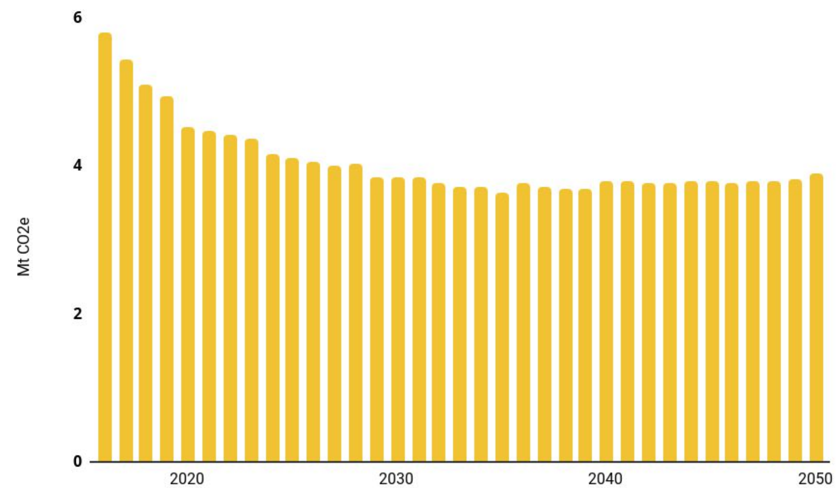


Figure 1. Projected BAU emissions for HRM (tCO2e), 2016-2050.

Part 1:

Energy & Emissions, 2016-2050

Demographics

Population

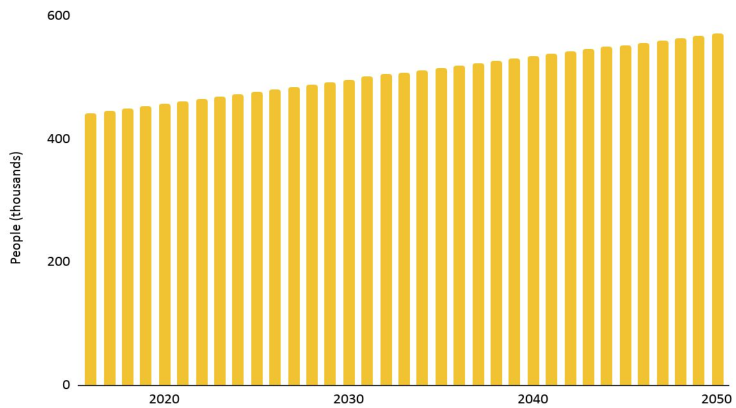


Figure 2. Projected population, 2016-2050.

Halifax's population in 2016 amounted to approximately 441,400 people. This is projected to grow steadily to approximately 572,600 people by 2050; a total growth of 30% over that period.

Employment

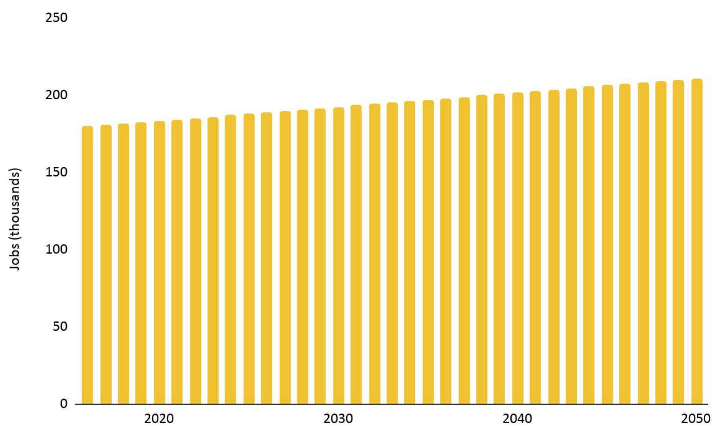


Figure 3. Projected employment, 2016-2050.

Employment in Halifax is projected to grow by 17%, increasing from 179,900 jobs in 2016 to 211,300 jobs in 2050, an increase of over 31,400 jobs.

Households

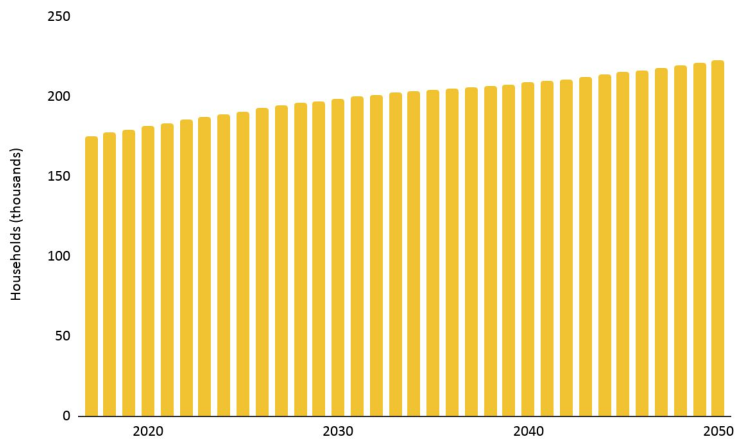


Figure 4. Projected households, 2016-2050.

In 2016, there were 173,325 households in Halifax. An additional 49,400 households are projected to be added, for a total of approximately 222,725 by 2050.

Community Energy

Energy by sector

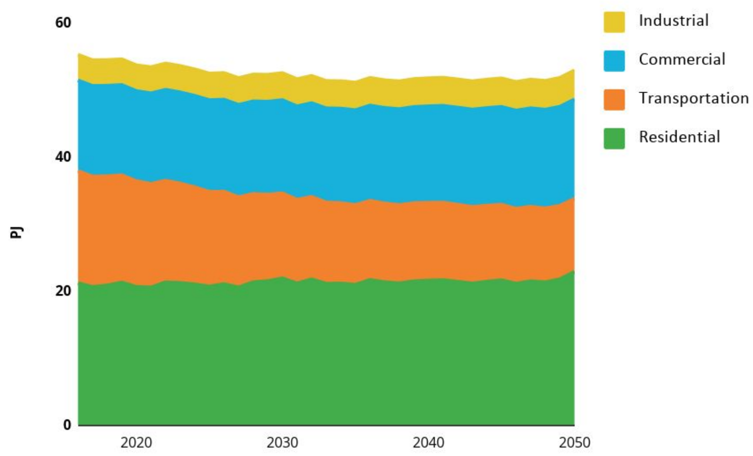


Figure 5. Projected BAU energy consumption (PJ) by sector, 2016-2050.

Energy by fuel

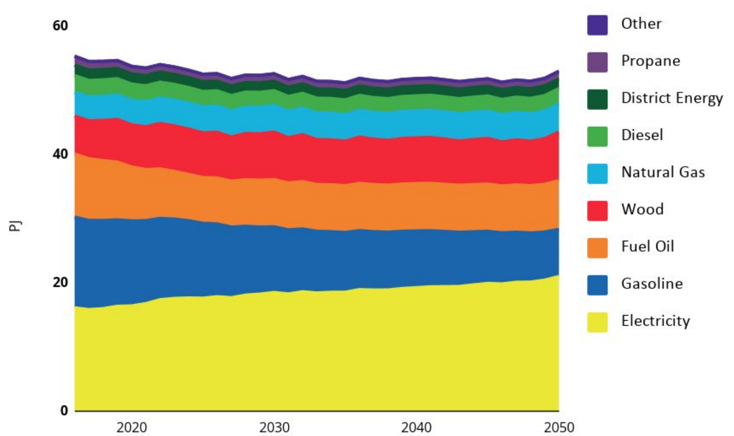


Figure 6. Projected BAU energy consumption (PJ) by fuel, 2016-2050.

Community wide energy consumption for Halifax is projected to decrease slightly from approximately 55.2 million GJ in 2016, to 52.8 million GJ in 2050, representing a decrease of 4.2% over the period.

A decrease in energy consumption in the transportation sector occurs through to 2030, due mostly to improved fuel efficiency standards in vehicles, and an incremental uptake of electric vehicles, which also contributes to the increase in electricity consumption.

Slight increases in energy consumption in the residential and commercial buildings sector occur through to 2050, consistent with projected population and buildings growth. Improved building efficiency standards and codes for new buildings, as well as a decrease in heating degree days (which are projected to occur as the climate continues to warm), result in marginally smaller increases in energy consumption in residential and commercial buildings even as the building stock continues to grow to 2050 with the growing population.

All sectors except for transportation show increased energy consumption from 2016 to 2050, with the greatest increases in the industrial sector (12.9% increase) and the commercial sector (9.6% increase).

Electricity shows the largest increases from 2016 to 2050, with increasing reliance on electricity for transportation and space heating and cooling. Fuel oil and gasoline consumption declines over the study period with the switch to electricity.

Refer to Table 1 for tabulated results of energy by sector and fuel.

Local Energy Production

In 2016, approximately 1,629,400 GJ of energy was generated through district energy (which produces heating and cooling through the consumption of natural gas, fuel oil, and electricity), and 5,900 GJ of solar PV and wind (which produces electricity). It was assumed that this locally generated energy was consumed within the buildings sector in Halifax. The BAU assumes only a slight increase in solar PV and wind generation to 2050, with the other sources held constant.

Per Capita Energy

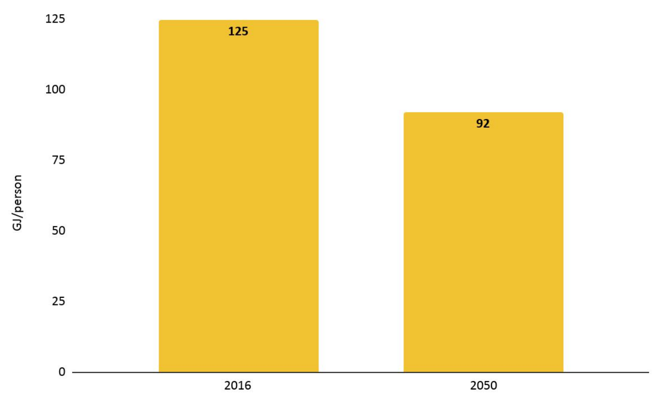


Figure 7. Projected BAU energy per capita (GJ/person), 2016 & 2050.

While overall energy consumption in Halifax is projected to increase by 2050, on a per capita basis, Halifax residents are projected to use approximately 26% less energy in 2050 compared with 2016, decreasing from 125 GJ/person in 2016 to 92 GJ/person in 2050.

Table 1. Community energy consumption tabulated results, 2016 & 2050 (BAU).

Energy by sector (GJ)	**2016**	**share 2016**	**2050 (BAU)**	**share 2050**	**% +/ 2016-2050**
Commercial	13,508,700	24.5%	14,801,100	28.0%	9.6%
Industrial	3,827,400	6.9%	4,320,400	8.2%	12.9%
Residential	21,114,700	38.3%	22,823,400	43.2%	8.1%
Transportation	16,708,000	30.3%	10,873,200	20.6%	-34.9%
Total	**55,158,800**		**52,818,000**		**-4.2%**
Energy by fuel (GJ)	**2016**	**share 2016**	**2050 (BAU)**	**share 2050**	**% +/ 2016-2050**
Diesel	2,596,900	4.7%	2,390,600	4.5%	-7.9%
District Energy	1,629,400	3.0%	1,517,800	2.9%	-6.9%
Electricity	15,969,500	29.0%	20,864,700	39.5%	30.7%
Fuel Oil	9,818,700	17.8%	7,578,400	14.3%	-22.8%
Gasoline	14,138,300	25.6%	7,341,300	13.9%	-48.1%
Natural Gas	3,692,900	6.7%	4,378,500	8.3%	18.6%
Other[1]	1,600	0.0%	1,700	0.0%	3.5%
Propane	1,386,200	2.5%	1,178,000	2.2%	-15.0%
Wood	5,925,300	10.7%	7,566,900	14.3%	27.7%
Total	**55,158,800**		**52,818,000**		**-4.2%**
Energy per capita (GJ/cap)	**125**		**92**		**-26%**

[1] Other fuels include biomass, biodiesel and ethanol.

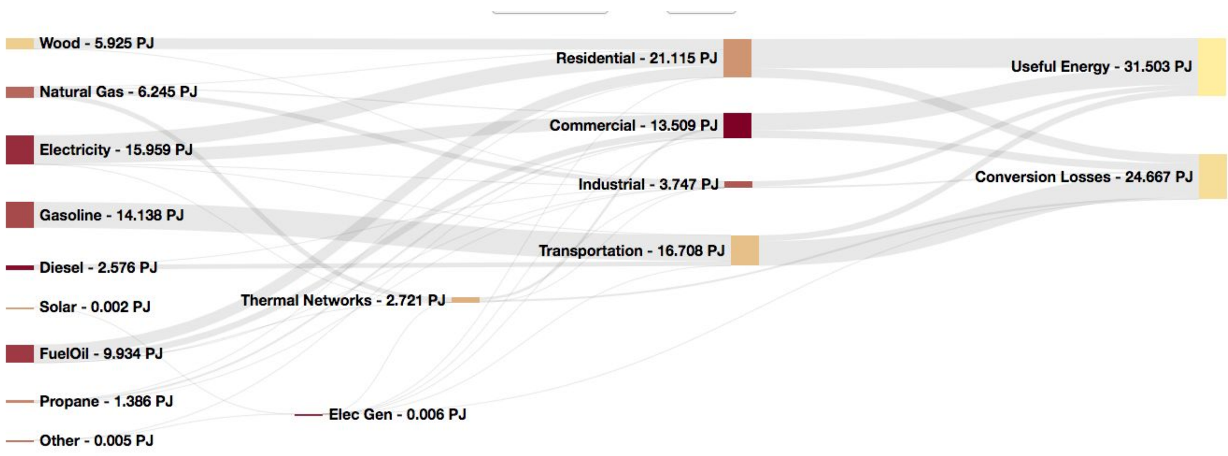


Figure 8. Energy flow, 2016.

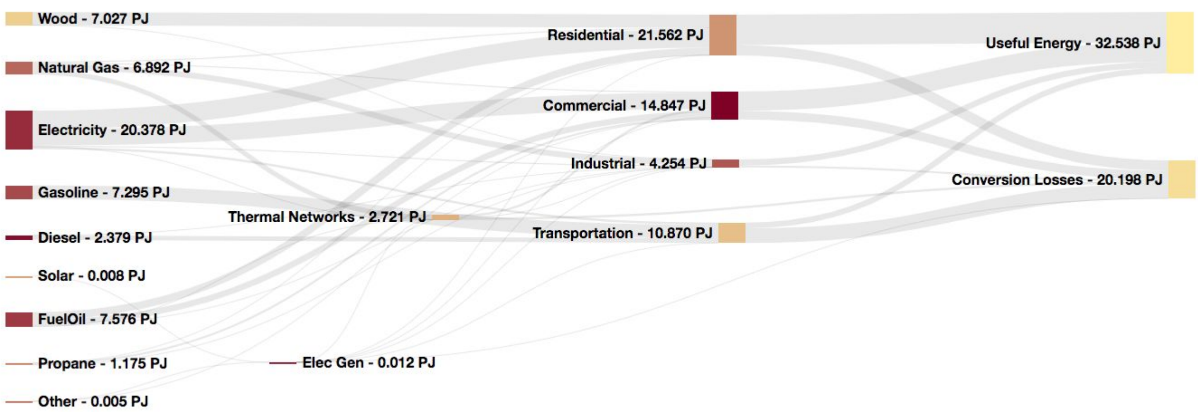


Figure 9. Energy flow, 2050 (BAU).

Energy flow and conversion

The sankey diagrams alongside depict the energy flow by fuel and sector through Halifax in 2016 and 2050 respectively.

Overall, energy demand remains fairly constant to 2050, with a slight increase in the commercial and industrial sectors, and decrease in the transportation sector.

There is an increase in useful energy between 2016 and 2050, accompanied by a reduction in conversion losses; the ratio of useful energy to conversion losses in 2016 is 1.28:1, compared with 1.61:1 in 2050. This is mostly as a result of increases in efficiency in the transportation and buildings sectors, alongside a shift to electricity.

Community Emissions

Emissions by sector

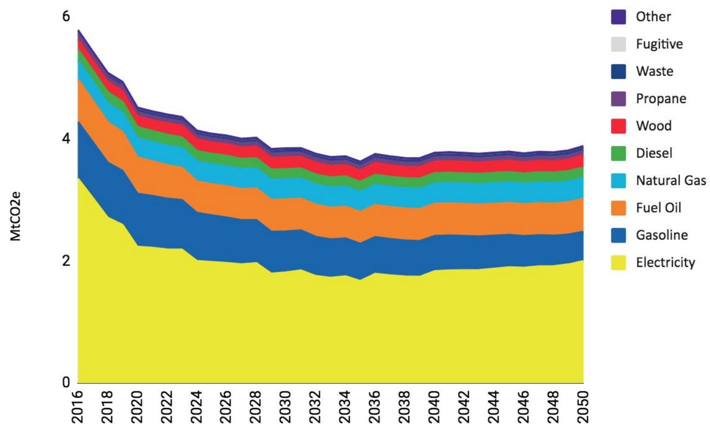


Figure 10. Projected BAU emissions (MtCO2e) by sector, 2016-2050.

Emissions by source

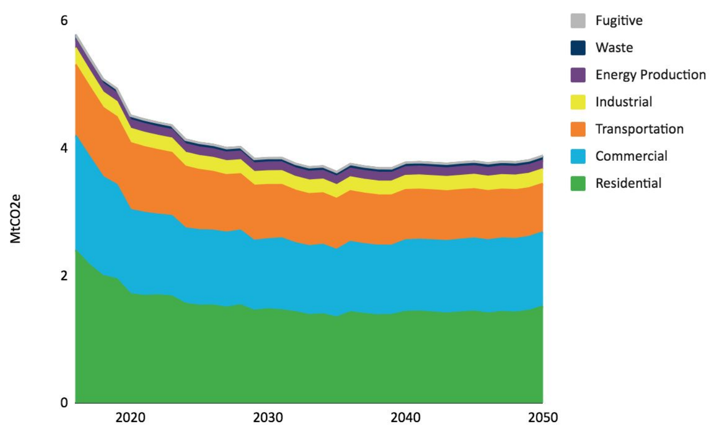


Figure 11. Projected BAU emissions (MtCO2e) by source, 2016-2050.

Community wide emissions are projected to decrease from 5.8 MtCO2e in 2016 to 3.9 MtCO2e in 2050, a 33% decrease over that period. The stepwise decrease in emissions is a result of switching to lower-carbon fuels for electricity generation across Nova Scotia. Electricity generation is responsible for 58% of emissions in 2016, so improvements in this have wide-reaching impacts on overall emissions produced in Halifax.

Gasoline shows a 49% decrease in emissions from 2016 to 2050, mostly due to improved fuel efficiency standards in vehicles, which results in a steady decline in gasoline use, as well as an incremental uptake of electric vehicles over the same time period. It is not as a result of decreased vehicle kilometres travelled, which increases by 12.5% from 2016 to 2050.

In the buildings sector, a small shift away from fuel oil results in a decrease in emissions. This is accompanied by higher electricity consumption in the buildings sector; however, overall emissions decrease as the provincial electricity grid emissions intensity decreases.[2]

Post 2032, emissions in Halifax are projected to start increasing; this is mostly from the transportation sector as increases in vehicle kilometres travelled start to outpace any gains in fuel efficiency, as well as the tapering of a grid electricity emissions intensity decreases, which are assumed to remain constant from 2040 onwards.

Emissions in the waste sector increases by 4.2% between 2016 and 2050. The BAU assumes no further actions (other than what is currently underway, such as the Centre Plan and Integrated Mobility Plan) to reduce waste emissions, and as such, increases in this sector are primarily driven by population growth.

Refer to Table 3 for tabulated results of emissions by sector and source.

[2] See Part 2 for assumptions on projected grid electricity emissions factor.

Per Capita Emissions

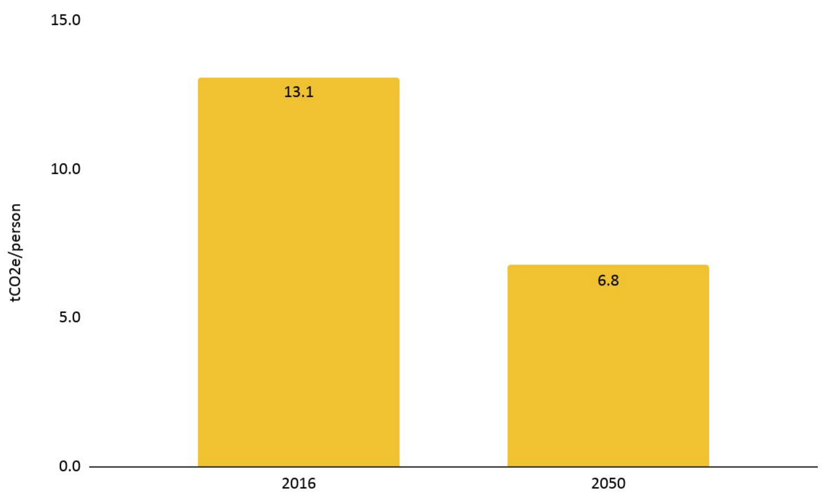


Figure 12. Projected BAU emissions per capita (tCO2e/person), 2016 & 2050.

Similarly to per capita energy, per capita emissions are projected to decrease from 13.1 tCO2e/person in 2016 to 6.8 tCO2e/person in 2050, resulting in an overall decrease of 48%.

Table 2. Per capita emissions, 2016 and 2050 (BAU).

Emissions by sector (tCO2e)	2016	2050 (BAU)	% +/- (2016-2050)
Emissions per capita (tCO2e/person)	**13.1**	**6.8**	**-48%**

Table 3. Community emissions tabulated results, 2016 & 2050 (BAU).

Emissions by sector (tCO2e)	2016	share 2016	2050 (BAU)	share 2050	% +/- (2016-2050)
Commercial	1,802,600	31.2%	1,164,100	30.0%	-35.4%
Energy Production	137,000	2.4%	136,500	3.5%	-0.3%
Fugitive[3]	3,000	0.1%	3,300	0.1%	10.9%
Industrial	261,800	4.5%	229,400	5.9%	-12.4%
Residential	2,395,100	41.4%	1,512,900	39.0%	-36.8%
Transportation	1,114,500	19.3%	760,800	19.6%	-31.7%
Waste	69,800	1.2%	72,800	1.9%	4.2%
Total	**5,783,700**		**3,879,900**		**-32.9%**
Emissions by source (tCO2e)	**2016**	**share 2016**	**2050 (BAU)**	**share 2050**	**% +/- (2016-2050)**
Diesel	186,200	3.2%	171,400	4.4%	-8.0%
Electricity	3,349,300	57.9%	1,997,100	51.5%	-40.4%
Fugitive	695,100	12.0%	541,200	14.0%	-22.1%
Fuel Oil	3,000	0.1%	3,300	0.1%	10.9%
Gasoline	930,200	16.1%	479,500	12.4%	-48.5%
Natural Gas	308,200	5.3%	341,800	8.8%	10.9%
Propane	84,800	1.5%	72,100	1.9%	-15.0%
Waste	69,800	1.2%	72,800	1.9%	4.2%
Wood	157,000	2.72%	200,600	5.2%	27.7%
Total	**5,783,700**		**3,879,900**		**-32.9%**

[3] 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.

Buildings Sector Energy

Buildings energy by fuel

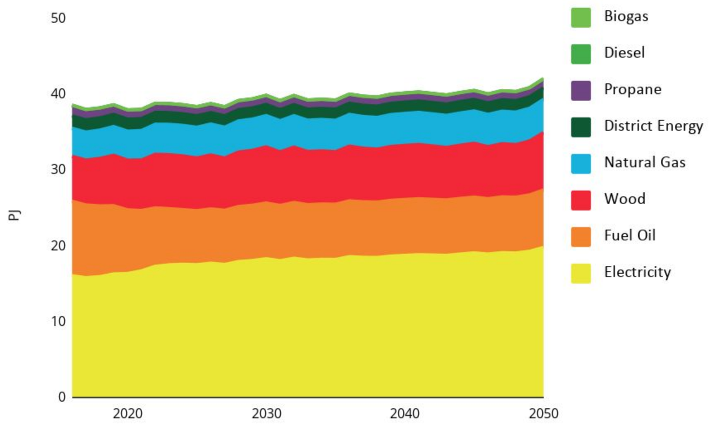


Figure 13. Projected BAU buildings energy use (GJ) by fuel, 2016-2050.

Buildings energy by end use

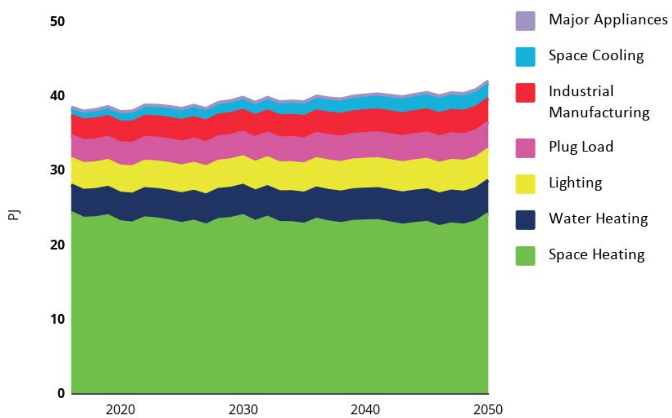


Figure 14. Projected BAU buildings energy use (GJ) by end use, 2016-2050.

Building energy use amounted to 38.5 million GJ in 2016, and is projected to grow to just under 41.9 million GJ by 2050, an increase of 9.1 %.

Increases in energy consumption in the residential and commercial buildings sector occur through to 2035, consistent with projected population and buildings growth. Improved building efficiency standards and codes for new buildings, as well as a decrease in heating degree days (which are projected to occur as the climate continues to warm), result in a slight decrease in energy consumption post 2035, even as the building stock continues to grow to 2050. This is primarily as a result of a decrease in space heating requirements with a warming climate, offset slightly by an increase in cooling demand.

In 2016, electricity accounts for 42% of the energy consumption, and fuel oil accounts for a further 26%. The residential sector is the largest consumer, accounting for 55% of the total energy consumed by buildings. The majority (63%) of energy consumed for all buildings types is for space heating.

Buildings energy by building type & fuel

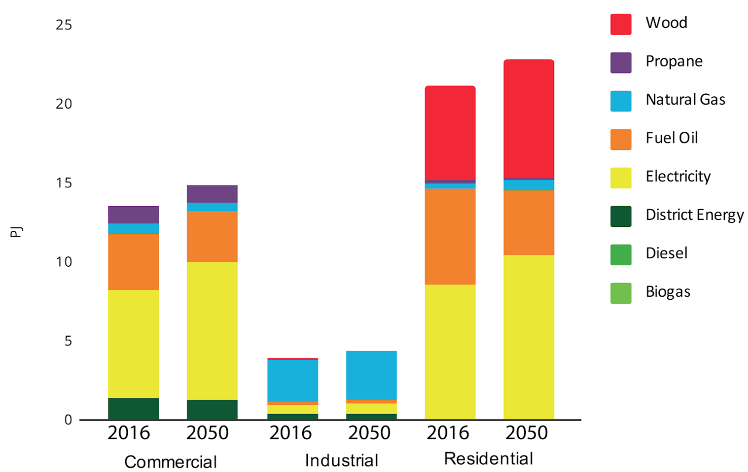


Figure 15. Projected BAU buildings energy use (GJ) by building type and fuel, 2016 & 2050.

Buildings energy by building type & end use

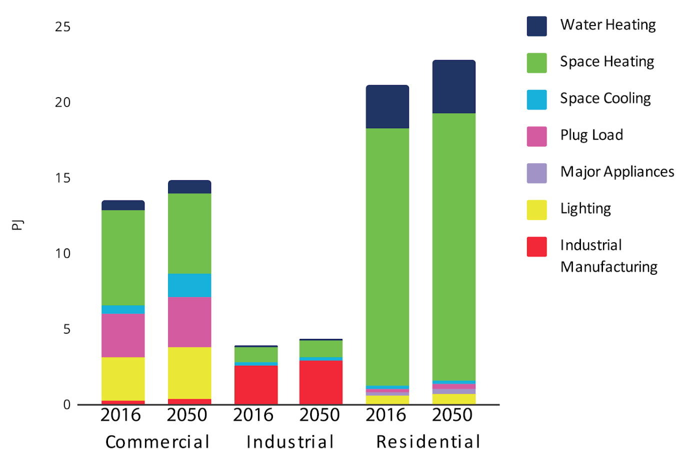


Figure 16. Projected BAU buildings energy use (GJ) by building type and end use, 2016 & 2050.

In 2016, residential buildings energy demand is dominated by space heating requirements (80%), followed by water heating (14%); electricity is the dominant fuel, accounting for 41% of residential energy demand, followed by fuel oil (29%) and wood (28%). Fuel oil decreases to 18% of the energy used by 2050, with no other major relative changes for other fuel types.

Commercial buildings are also dominated by space heating (47%), but have higher demands for plug load and lighting in comparison with residential buildings. Electricity increases from 51% of the total energy used to 59% by 2050, and the other fuels maintain consistent ratios.

The increase in residential energy demand is tempered by efficiencies in all building types, resulting in slight decreases in the relative energy demand for space heating. Space cooling demands for commercial buildings increases by 2050 due to the increased number of cooling degree days projected with a warming climate.

Per household energy

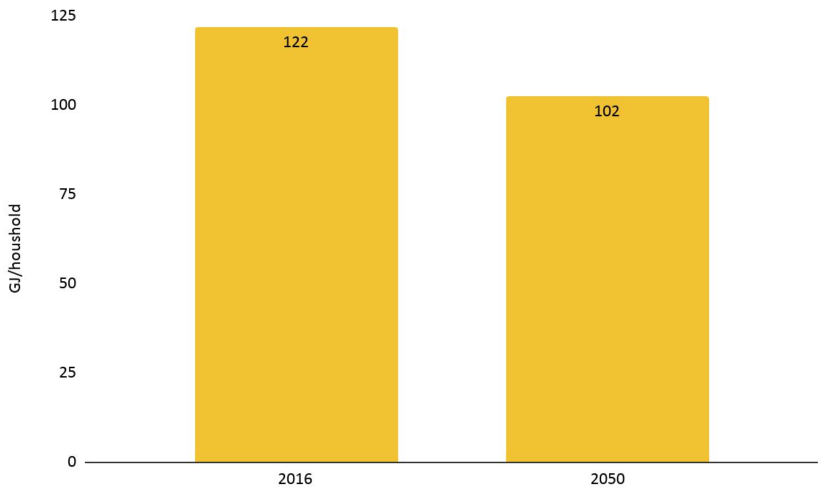


Figure 17. Projected BAU residential energy per household (GJ/household), 2016 & 2050.

While energy consumption in the residential sector is projected to increase by 8.1% between 2016 and 2050, on a per household basis, Halifax residents are projected to use approximately 16% less energy, decreasing from 122 GJ/household in 2016 to 102 GJ/household in 2050.

Table 4. Buildings sector energy tabulated results, 2016 & 2050 (BAU).

Buildings energy (GJ) by building type	2016	share 2016	2050 (BAU)	share 2050	% +/- (2016-2050)
Residential	21,114,700	54.9%	22,823,400	54.4%	8.1%
Commercial	13,508,700	35.1%	14,801,100	35.3%	9.6%
Industrial	3,827,400	10.0%	4,320,400	10.3%	12.9%
Total	**38,450,800**		**41,944,900**		**9.1%**

Buildings energy (GJ) by fuel	2016	share 2016	2050 (BAU)	share 2050	% +/- (2016-2050)
Biogas	1,600	0.0%	1,700	0.0%	3.5%
Diesel	27,500	0.1%	28,400	0.1%	3.3%
District Energy	1,629,400	4.2%	1,517,800	3.6%	-6.9%
Electricity	15,969,200	41.5%	19,695,100	47.0%	23.3%
Fuel Oil	9,818,700	25.5%	7,578,400	18.1%	-22.8%
Natural Gas	3,692,900	9.6%	4,378,500	10.4%	18.6%
Propane	1,386,200	3.6%	1,178,000	2.8%	-15.0%
Wood	5,925,300	15.4%	7,566,900	18.0%	27.7%
Total	**38,450,800**		**41,944,900**		**9.1%**

Buildings energy (GJ) by end use	2016	share 2016	2050 (BAU)	share 2050	% +/- (2016-2050)
Industrial Manufacturing	2,695,500	7.0%	3,165,000	7.5%	17.4%
Lighting	3,570,200	9.3%	4,184,900	10.0%	17.2%
Major Appliances	253,400	0.7%	349,700	0.8%	38.0%
Plug Load	3,074,300	8.0%	3,617,400	8.6%	17.7%
Space Cooling	881,700	2.3%	2,017,400	4.8%	128.8%
Space Heating	24,264,600	63.1%	24,141,200	57.6%	-0.5%
Water Heating	3,711,000	9.7%	4,469,200	10.7%	20.4%
Total	**38,450,800**		**41,944,900**		**9.1%**

Buildings Sector Emissions

Buildings emissions by source

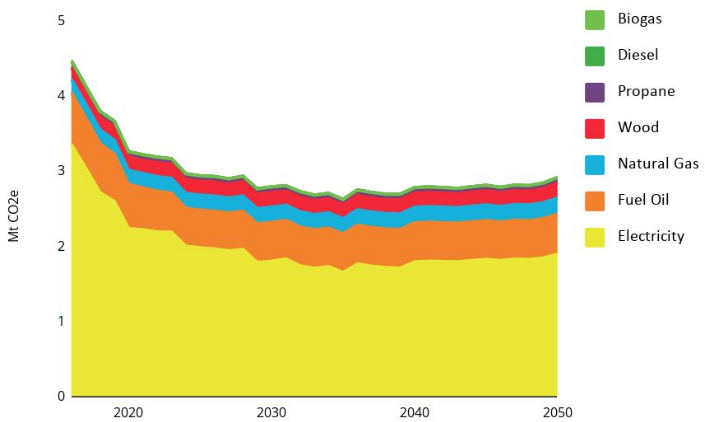


Figure 18. Projected BAU buildings emissions (kt CO2e) by source, 2016-2050.

Buildings emissions by end use

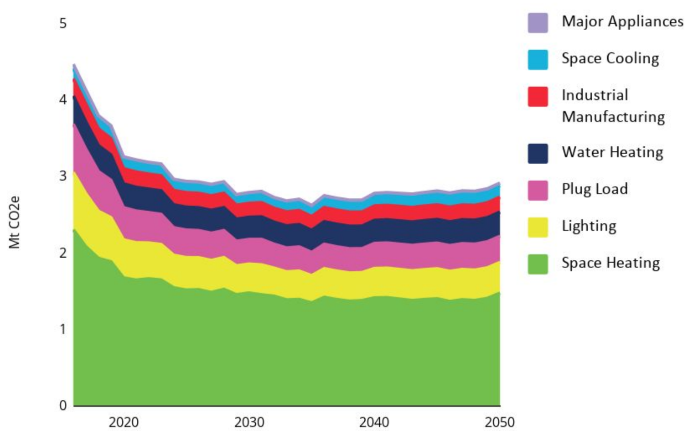


Figure 19. Projected BAU buildings emissions (kt CO2e) by end use, 2016-2050.

Emissions in the buildings sector decrease from 4.46 Mt CO2e in 2016 to 2.91 Mt CO2e, a decrease of 35% over the period.

Buildings emissions are dominated significantly by electricity, accounting for 75% of emissions in 2016. Changes in the grid electricity supply in Nova Scotia, as well as improvements in buildings, results in a 44% decrease in emissions from electricity use by 2050.

Switching from fuel oil and propane to electricity reduces emissions by 22% and 15% from 2016 to 2050, respectively. The remaining fuel types show a slight increase in emissions over the study period, but represent smaller portions of the total emissions.

What is clear is that the emissions from electricity generation are a major component of the total emissions for buildings in Halifax, and improvements to the grid emissions show immediate reductions in buildings emissions.

Emissions from space heating and lighting decrease by 36% and 47% respectively between 2016 and 2050, primarily as a result of improved efficiencies, switching to electricity, and a decrease in heating degree days.

Buildings emissions by building type & source

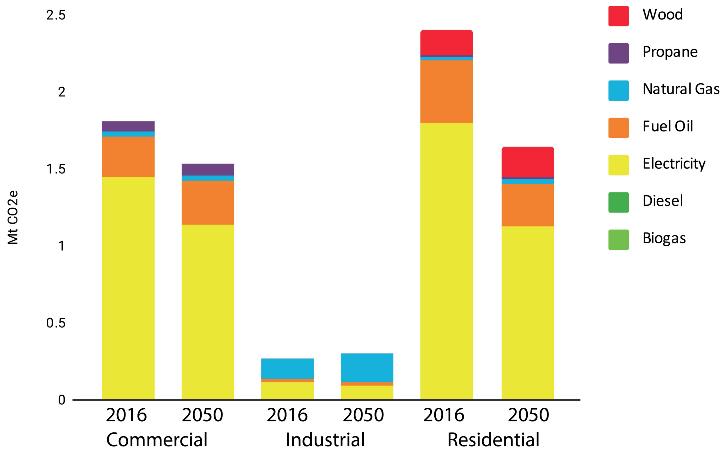


Figure 20. Projected BAU buildings emissions (kt CO2e) by building type and source, 2016 & 2050.

Buildings emissions by building type & end use

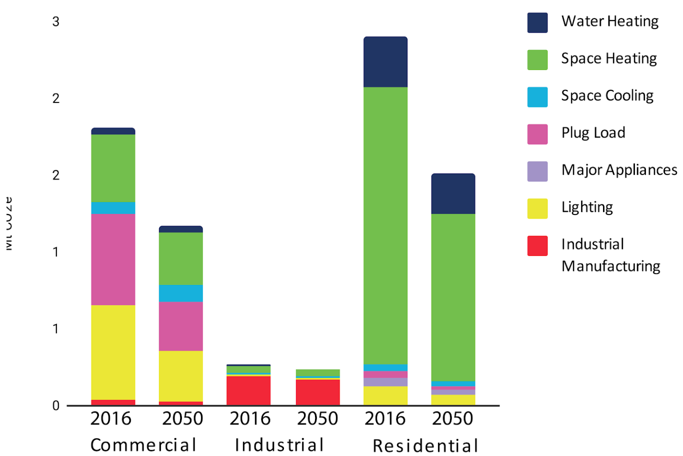


Figure 21. Projected BAU buildings emissions (kt CO2e) by building type and end use, 2016 & 2050.

Emissions in the residential and commercial buildings sectors decrease from 2016 to 2050 by 37% and 35% respectively, primarily as a result of changes to the provincial energy supply that reduce emissions associated with energy generation, and a decrease in space heating demand.

In the industrial sector emissions decrease by 12% over the same period, as manufacturing energy demand (primarily provided through natural gas) continues to grow to 2050, resulting in a lower relative reduction in emissions for this sector.

Per household emissions

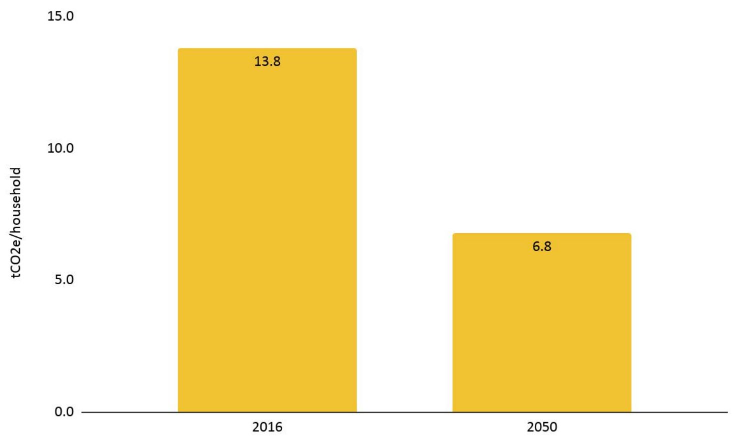


Figure 22. Projected BAU residential emissions per household (tCO2e/household), 2016 & 2050.

On a per household basis, residential emissions are projected to decrease by 51%, from 13.8 tCO2e/hh to 6.8 tCO2e/hh.

Table 5. Buildings sector emissions tabulated results, 2016 & 2050 (BAU).

Buildings emissions (tCO2e) by building type	2016	share 2016	2050 (BAU)	share 2050	% +/- (2016-2050)
Residential	2,395,100	53.7%	1,512,900	52.1%	-36.8%
Commercial	1,802,600	40.4%	1,164,100	40.1%	-35.4%
Industrial	261,800	5.9%	229,400	7.9%	-12.4%
Total	**4,459,400**		**2,906,500**		**-34.8%**

Buildings emissions (tCO2e) by fuel	2016	share 2016	2050 (BAU)	share 2050	% +/- (2016-2050)
Biogas	-	0.0%	-	0.0%	2.1%
Diesel	2,000	0.0%	2,100	0.1%	3.3%
Electricity	3,348,500	75.1%	1,884,900	64.9%	-43.7%
Fuel Oil	686,200	15.4%	532,300	18.3%	-22.4%
Natural Gas	180,900	4.1%	214,500	7.4%	18.6%
Propane	84,800	1.9%	72,100	2.5%	-15.0%
Wood	157,000	3.5%	200,600	6.9%	27.7%
Total	**4,459,400**		**2,906,500**		**-34.8%**

Buildings emissions (tCO2e) by end use	2016	share 2016	2050 (BAU)	share 2050	% +/- (2016-2050)
Industrial Manufacturing	225,700	5.1%	194,700	6.7%	-13.7%
Lighting	748,600	16.8%	400,500	13.8%	-46.5%
Major Appliances	53,100	1.2%	33,500	1.2%	-37.0%
Plug Load	631,800	14.2%	342,700	11.8%	-45.8%
Space Cooling	134,300	3.0%	149,900	5.2%	11.6%
Space Heating	2,297,700	51.5%	1,468,400	50.5%	-36.1%
Water Heating	368,100	8.3%	316,800	10.9%	-13.9%
Total	**4,459,400**		**2,906,500**		**-34.8%**

Transportation Sector Energy

Transportation energy by fuel

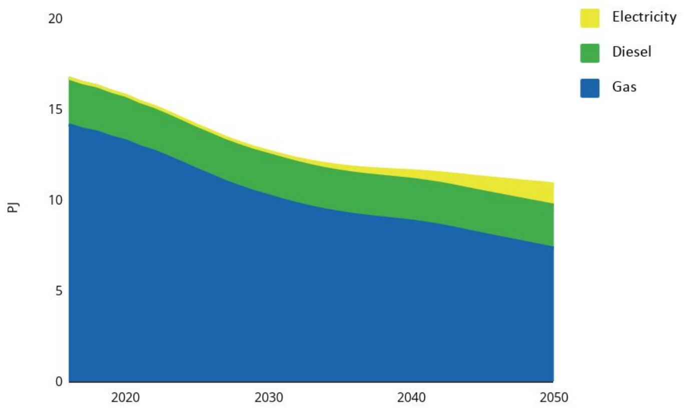


Figure 23. Projected BAU transportation energy use (PJ) by fuel, 2016-2050.

Transportation energy by vehicle type

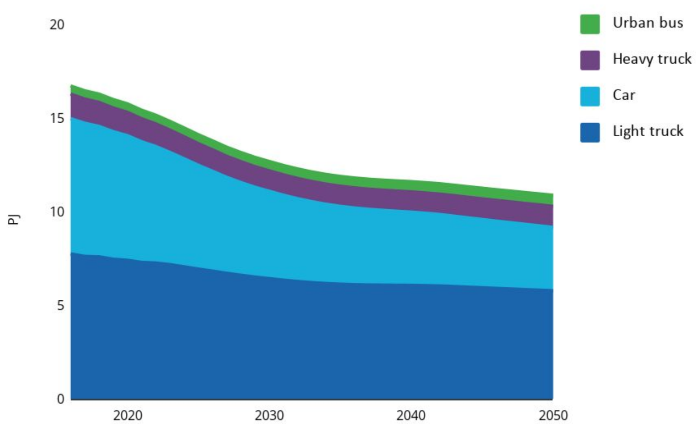


Figure 24. Projected BAU transportation energy use (GJ) by vehicle type, 2016-2050.

Transportation energy in 2016 amounts to approximately 16.7 million GJ, of which 85% is supplied through gasoline, with diesel representing the remaining 15%. The total transportation energy consumption is projected to decrease to 10.9 million GJ in 2050, a decrease of 35% over the period.

There is a noticeable decline in energy demand in the transportation sector between 2016 and 2035; this is primarily as a result of the projected fuel efficiency standards for vehicles assumed in the BAU and uptake of electric vehicles (EV) ; it is not as a result of a decrease in vehicle kilometres travelled (VKT), which increases by 12.5% from 2016 to 2050.

Vehicle fuel consumption rates in the BAU are set to reflect the implementation of the U.S. Corporate Average Fuel Economy (CAFE) fuel standard for light duty vehicles and phase 1 and phase 2 of EPA HDV fuel standards for medium and heavy duty vehicles.

Post 2035, transportation energy flattens out slightly to 2050. During this period, the projected vehicle fuel efficiencies start to taper off, that is, there are not major increases or gains in efficiency post 2035. At this point, the ongoing increase in VKT, which is driven by population and buildings growth from 2016 to 2050, start to compete with the gains made from efficiencies in the vehicle stock. The BAU assumes that mode shares remain constant from 2016 to 2050.

Between 2016 and 2050, there is a slight shift away from cars to light trucks, as SUVs become a more prominent choice of vehicle.

Transportation energy by vehicle type & fuel

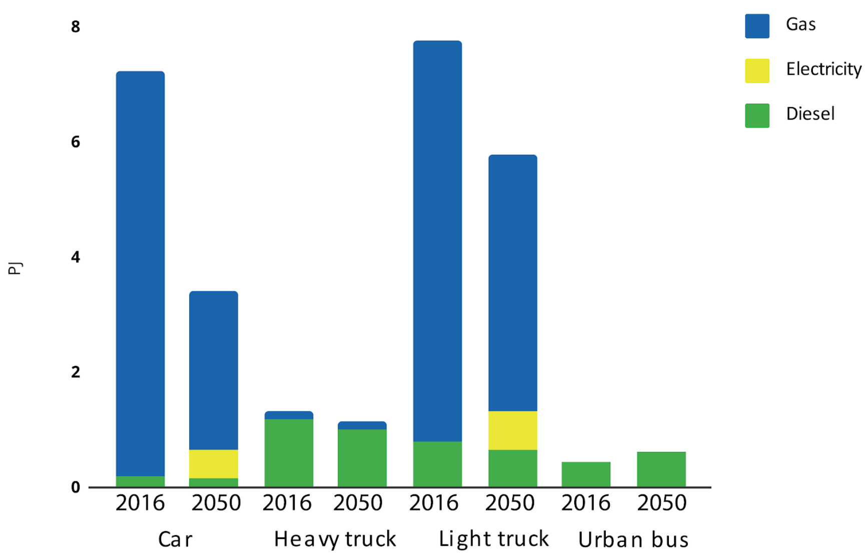


Figure 25. Projected BAU transportation energy use (GJ) by vehicle type and fuel, 2016-2050.

Between 2016 and 2050, there is a noticeable decline (53%) in energy demand for cars in comparison with other vehicle types. This is driven predominantly by vehicle fuel efficiency, but also as a result of a shift from cars to light trucks. Light truck stock energy demand also decreases as a result of fuel efficiency, but not at the same rate, as light truck vehicles become more prominent.

Table 6. Transportation sector energy tabulated results, 2016 & 2050 (BAU).

Transportation energy (GJ) by fuel	2016	share 2016	2050 (BAU)	share 2050	% +/- (2016-2050)
Diesel	2,569,400	15.4%	2,362,200	21.7%	-8.1%
Electricity	300	0.0%	1,169,700	10.8%	365543.0%
Gasoline	14,138,300	84.6%	7,341,300	67.5%	-48.1%
Total	**16,708,000**		**10,873,200**		**-34.9%**
Transportation energy (GJ) by vehicle type	**2016**	**share 2016**	**2050 (BAU)**	**share 2050**	**% +/- (2016-2050)**
Car	7,221,700	43.2%	3,384,600	31.1%	-53.1%
Heavy truck	1,310,000	7.8%	1,122,900	10.3%	-14.3%
Light truck	7,742,100	46.3%	5,775,600	53.1%	-25.4%
Bus	434,200	2.6%	590,000	5.4%	35.9%
Total	**16,708,000**		**10,873,200**		**-34.9%**

Transportation Sector Emissions

Transportation emissions by source

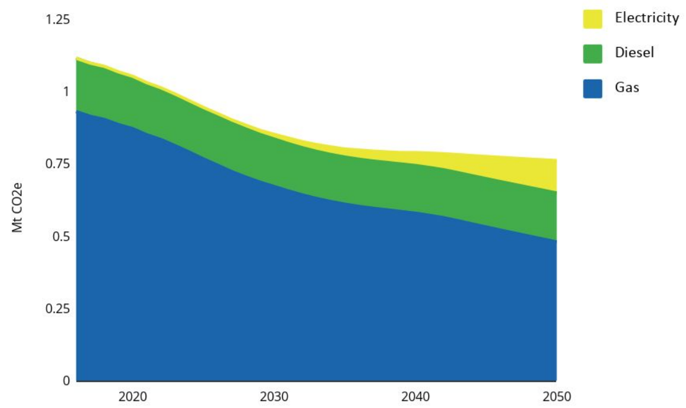


Figure 26. Projected BAU transportation emissions (kt CO2e) by source, 2016-2050.

Transportation emissions by vehicle type

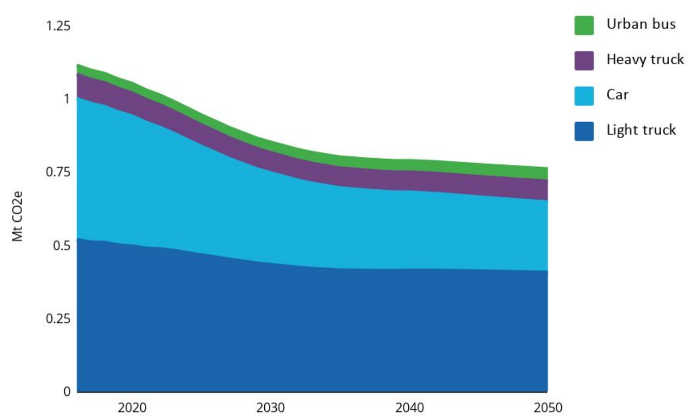


Figure 27. Projected BAU transportation emissions (kt CO2e) by vehicle type, 2016-2050.

Transportation emissions follow a similar trajectory as transportation energy demand; emissions decline from 1.11 MtCO2e in 2016 to 0.76 MtCO2e in 2050, a decrease of 32% over the period.

While electric cars increase to 15% of transportation emissions by 2050, gasoline remains the predominant source of transportation emissions, accounting for 84% in 2016 and 63% in 2050.

Similar to transportation energy, emissions reductions are predominantly driven by improved vehicle fuel efficiencies, and the increased use of electric vehicles.

Transportation emissions by source & vehicle type

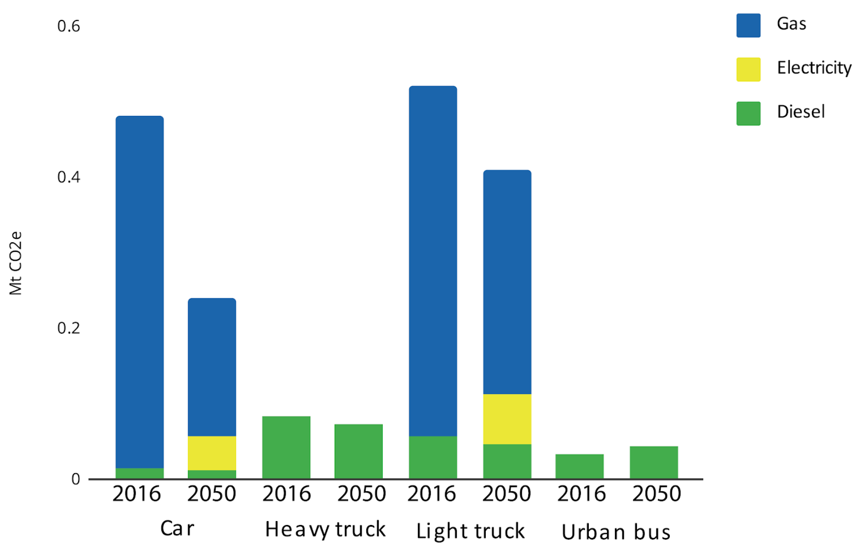


Figure 28. Projected BAU transportation emissions (ktCO2e) by source and vehicle type, 2016-2050.

Similarly to energy demand for cars, there is a noticeable decline in emissions for cars between 2016 and 2050; driven by a combination of the implementation of vehicle fuel efficiency standards and an increase in the number of electric vehicles within the car stock.

Emissions for light trucks declines to 2035, but then flattens out to 2050 again. Again, the decline is as a result of vehicle fuel efficiency standards and a shift away from diesel to gasoline and electricity; but post 2035, increases in VKT flatten out these gains.

Table 7. Transportation sector emissions tabulated results, 2016 & 2050 (BAU).

Transportation emissions (tCO2e) by fuel	2016	share 2016	2050 (BAU)	share 2050	% +/- (2016-2050)
Diesel	184,200	16.5%	169,300	22.3%	-8.1%
Electricity	70	0.0%	111,900	14.7%	166783.4%
Gasoline	930,200	83.5%	479,500	63.0%	-48.5%
Total	**1,114,500**		**760,800**		**-31.7%**
Transportation emissions (tCO2e) by vehicle type	**2016**	**share 2016**	**2050 (BAU)**	**share 2050**	**% +/- (2016-2050)**
Car	481,300	43.2%	240,100	31.6%	-50.1%
Heavy truck	83,000	7.5%	71,000	9.3%	-14.5%
Light truck	519,200	46.6%	407,400	53.6%	-21.5%
Urban bus	31,000	2.8%	42,200	5.5%	35.9%
Total	**1,114,500**		**760,800**		**-31.7%**

Waste Sector Emissions

Waste emissions by type

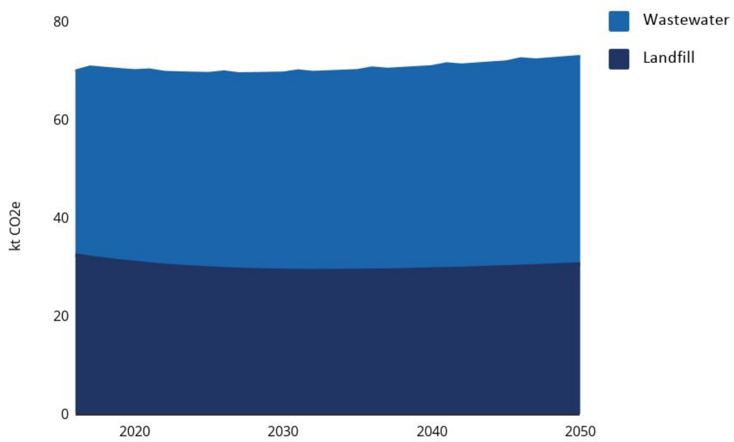


Figure 29. Projected BAU waste emissions (tCO2e), 2016-2050.

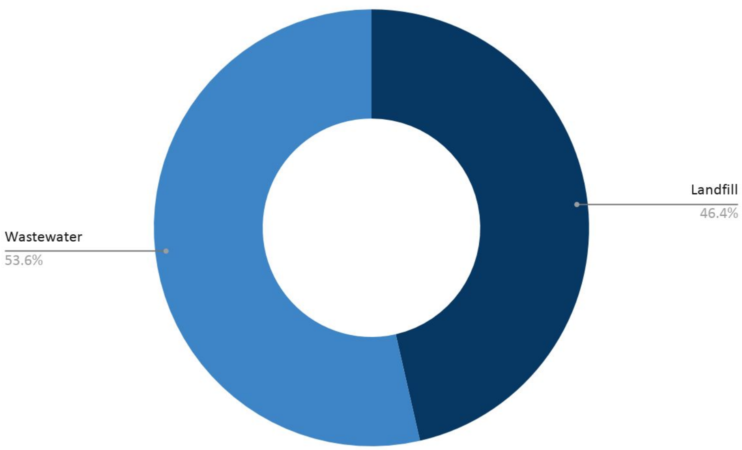


Figure 30. Waste emissions by type, 2016.

Waste sector emissions, which includes emissions from both solid waste and wastewater, account for 70 kt CO2e in 2016, and increase gradually to 73kt CO2e by 2050; an increase of approximately 4.3% over the period. In 2016, approximately 54% of waste emissions were from wastewater.

The increase in waste emissions is primarily driven by an increase in population. The projection assumes no further reduction in the rates of per capita waste production or improvement in treatment facilities.

Summary Analysis

General

The population of Halifax Regional Municipality (HRM) is projected to grow by 30 % between 2016 and 2050, adding approximately 131,200 new residents. This growth is expected to be accompanied by 31,400 new jobs, and 49,400 new households, which will drive demand for new residential and non-residential floor space. This growth will also drive additional demands for energy, transportation, water and wastewater treatment, and generate additional waste.

As the population continues to grow, the BAU projections indicate that community-wide energy demand will decrease by 4.2 %, from 55.2 million GJ to 52.8 million GJ between 2016 and 2050. Emissions will decline by 33%, from 5,784,000 tCO2e in 2016, to 3,880,000 tCO2e in 2050.

Per capita energy is projected to decline by 26%, from 125 GJ/cap in 2016 to 92 GJ/cap in 2050, while per capita emissions are projected to decline by 48%, from 13.1 tCO2e/cap in 2016 to 6.8 tCO2e/cap in 2050.

Table 8. Community energy and emissions summary results, 2016 & 2050 (BAU).

Energy by sector (GJ)	2016	share 2016	2050 (BAU)	share 2050	% +/ 2016-2050
Commercial	13,508,700	24.5%	14,801,100	28.0%	9.6%
Industrial	3,827,400	6.9%	4,320,400	8.2%	12.9%
Residential	21,114,700	38.3%	22,823,400	43.2%	8.1%
Transportation	16,708,000	30.3%	10,873,200	20.6%	-34.9%
Total	**55,158,800**		**52,818,000**		**-4.2%**
Emissions by sector (tCO2e)	**2016**	**share 2016**	**2050 (BAU)**	**share 2050**	**% +/- (2016-2050)**
Commercial	1,802,600	31.2%	1,164,100	30.0%	-35.4%
Energy Production	137,000	2.4%	136,500	3.5%	-0.3%
Fugitive[4]	3,000	0.1%	3,300	0.1%	10.9%
Industrial	261,800	4.5%	229,400	5.9%	-12.4%
Residential	2,395,100	41.4%	1,512,900	39.0%	-36.8%
Transportation	1,114,500	19.3%	760,800	19.6%	-31.7%
Waste	69,800	1.2%	72,800	1.9%	4.2%
Total	**5,783,700**		**3,879,900**		**-32.9%**

[4] 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.

Buildings

Energy consumption in the buildings sector is expected to increase by 9.1%, from approximately 38.5 million GJ in 2016 to 41.9 million GJ in 2050. This is accompanied by a decrease in emissions of 35%, from 4.5 MtCO2e in 2016 to 2.9 MtCO2e in 2050.

The increase in buildings energy demand is mainly driven by a demand for new residential and non-residential floorspace. The trajectory of this increase (9.1%) however, is slightly lower than the increase in population (30%); that is, while buildings energy demand is driven by population growth, and the resulting buildings to support that growth, they are not growing at the same rate. This is as a result of two main driving assumptions within the BAU:

- **New building energy performance requirements:** the BAU assumes that all new construction, in all building sectors, will be 2% more efficient every 5 years starting in 2021.This assumption is held for all building types, and holds the same share of fuels used to heat, cool and operate the buildings as for 2016.

- **Heating and cooling degree days:** The BAU accounts for the influence of projected climate change by including an assumption for heating degree days (HDD) and cooling degree days(CDD).[5] The projection indicates a decrease in heating degree days (HDD), and an increase in cooling degree days (CDD) as the climate continues to warm towards 2050. A decrease in 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) results in a reduction in the amount of energy required for space heating. 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. The overall impact is a net decrease in energy demand for buildings over time as a result of a warming climate; as building energy demand is significantly dominated by space heating, this outweighs any increases in cooling demand.

For the existing building stock, that is, the building stock prior to 2016, no improvements in efficiency were applied in the BAU. The baseline efficiencies for each building type in 2016 were held constant to 2050. As such, any reductions in energy demand in existing buildings is primarily as a result of a decrease in space heating requirements that is driven by a decrease in heating degree days.

The decrease (35%) in emissions in the building sector, compared with the decrease in energy demand (9%), is being driven primarily by a change in the sources for the electricity supplied by the provincial grid. The grid is expected to produce fewer emissions per kWh by adding more renewables, and introducing electricity sourced from the Muskrat Falls hydro dam, starting in 2020, thereby reducing the need for the use of coal-fired electricity generation.

Transport

Energy consumption in the transportation sector is expected to decrease by 35%, from approximately 16.7 million GJ in 2016 to 10.9 million GJ in 2050. This is accompanied by a decrease in emissions of 32%, from 1.14 MtCO2e in 2016 to 760 ktCO2e in 2050.

The decrease in transportation energy demand is being primarily driven by an increase in vehicle fuel efficiencies (through the implementation of fuel efficiency standards)[6], along with an assumed uptake in electric vehicles[7]; it is not being driven by a decrease in vehicle kilometres travelled (VKT), which increases by 12.5% from 2016 to 2050.

The decrease in transportation energy occurs primarily between 2016 and 2035, thereafter it continues to decrease, but at a much slower rate, as a continued in VKT starts to overcome any gains made from vehicle

[5] See Part 2 for assumptions on HDD and CDD.

[6] See Part 2 for assumptions on projected vehicle fuel efficiency standards.

[7] See Part 2 for assumptions on projected uptake of electric vehicles.

fuel efficiencies and a shift towards electric vehicles. Additionally, the BAU that mode shares remain constant from 2016 to 2050.

The decrease in transportation emissions is predominantly driven by improved efficiency for gasoline cars and light trucks, and a marginal switch to electric vehicles.

Waste

Waste emissions increase by 4.3% from 70.0 $ktCO_2e$ in 2016 to 73 $ktCO_2e$ by 2050. Emissions in this sector include those produced from solid waste and wastewater treatment, and are primarily driven by an increase in population. This result is not unexpected, as the BAU assumes no further reduction in the rates of per capita waste production, waste diversion, or improvement in treatment facilities.

Observations and insights for low carbon modelling

Switching to electricity provides a significant emissions reduction opportunity.

- The Provincial electricity grid emissions intensity is projected to decrease over the next few years as some fossil fuel sources are reduced and Muskrat Falls comes online. This creates an emissions reduction opportunity for fuel switching from carbon intensive fuels to increasingly cleaner electricity, particularly from fuel oil and natural gas in the buildings sector, and gasoline and diesel in the transportation sector. However, it is worth noting that while the Nova Scotia grid is decarbonizing incrementally towards 2050, it remains a significant source of emissions in HRM and the province, and continues to have a relatively high grid emissions factor in comparison with other provinces . As a result;

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.

Retrofitting the existing building stock will be critical.

  - In 2016, existing buildings accounted for approximately 70% of community wide energy demand, and produced 73% of all emissions. Towards 2050, this existing building stock will continue to play a major role in energy demand and emissions, and as such provides a significant opportunity for energy and emissions reductions. A broad scale ambitious retrofit program will be critical.

New construction standards will be key to limit emissions of a growing region.

  - Improved performance standards, above the BAU assumptions, will be needed for new construction in order to lessen the upward pressure of an increasing population on the GHG curve. Anything built new that does not meet the highest standards in energy efficiency and achieves net-zero emissions will increase emissions and contribute to the challenge of retrofitting the buildings stock.

Electrifying transportation and shifting modes to transit and active transportation will be fundamental.

- By 2035, increases in vehicle kilometres travelled (VKT) start to negate energy gains realized from vehicle fuel efficiencies; electrifying transportation and shifting modes to transit and active transportation will be fundamental. Shifting modes will require a large focus on the provision of transit infrastructure and densified transit oriented growth patterns to influence a shift to more active modes, reduced trip lengths, and reduced vehicle ownership. As buildings growth occurs incrementally over time, and transit infrastructure can take years to implement, it will be critical for the Municipality to start implementing growth policies and infrastructure funding immediately to get ahead of this. Switching to electric vehicles will be fundamental in achieving earlier emissions reductions in transportation as transit is built over time.

Recovering energy from waste and wastewater present further opportunities for emissions reduction.

- With current solid waste generation and diversion rates, and with existing waste and wastewater treatment processes, emissions from waste will continue to grow with a growing population. Actions to decrease waste and wastewater generation, increase diversion, and improve treatment processes to recover energy from waste and wastewater streams [that is otherwise not being used and is a lost opportunity] will be critical to reducing emissions in this sector.

Under a BAU, HRM is expected to benefit from variables outside of the Municipality's direct control, in particular the fuel efficiency standards and the greening of the provincial grid; however, the Municipality can not solely rely on these factors to reduce emissions.

  - HRM is expected to benefit from the projected reduction in grid electricity emissions intensity as some fossil fuel sources are reduced and Muskrat Falls comes online. However, the Municipality cannot solely rely on the Province's ability these emissions and will need to increase local electricity generation capacity with renewables to ensure that the emissions factor for electricity remains constant or declines.
  - Vehicle fuel efficiency standards are projected to play a major role in decreasing transportation energy demand to 2035. These however, are not within the Municipality's control; the Municipality's will need to focus on other measures to reduce VKT and increase the uptake of electric vehicles to ensure transportation emissions are reduced.

Part 2:

Data, Methods & Assumptions

Emissions Framework, Scope & Factors

Modelling Tool

Modelling Process

Sensitivity Analysis

Part 2: Emissions Framework, Scope, and Factors

Emissions Accounting Framework & Scope

Category	Description	Comment	Source
Accounting Framework	Global Protocol for Community-Scale GHG Emission Inventories (GPC)		Global Protocol for Community-Scale GHG Emission Inventories (GPC) Accessed at http://www.ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities
Emissions scope	Scope 1, 2 and partial scope 3	GPC scope definition: 1) All GHG emissions from sources located within the city boundary. 2) All GHG emissions occurring as a consequence of the use of grid supplied electricity, heat, steam and/or cooling within the Municipality boundary. 3) All other GHG emissions that occur outside the Municipality boundary as a result of activities taking place within the Municipality boundary.	See *GPC Emissions Scope Table* in Appendix 1rt for detailed list of scope items included in HRM emissions inventory.
Sectors	Stationary energy (buildings) Transportation Waste		See *GPC Emissions Scope Table* in Appendix 1 for detailed list of sectors and sub-sectors included in HRM emissions inventory.
Boundary	Municipal Boundary of Halifax Regional Municipality		
Reporting	GPC BASIC & partial BASIC+		See Section *4.4 GPC reporting framework* in GPC.
Transportation methodology	GPC induced activity method		See Section *7.3.1 Transportation methodology options* in GPC.
Baseline year	2016		
Projection year	2050	5 year increments are modelled from the 2016 baseline year. 2021 will represent the first simulation period/year. Projections will extend to 2050. Due to the 5-yr increment, the last simulation year will be 2051. Results will be interpolated back for 2050.	

Greenhouse gases	Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N20) are included. GWP: CO_2 = 1 CH_4 = 34 N_2O = 298	Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6) and nitrogen triflouride (NF_3) are not included. Emissions are expressed in CO_2 equivalents (CO_2e) per global warming potential (GWP) factors; GWPs have been updated in the IPCC 5th Assessment Report to include climate-carbon feedback.	Myhre, G. et al., 2013: *Anthropogenic and Natural Radiative Forcing*. Table 8.7. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

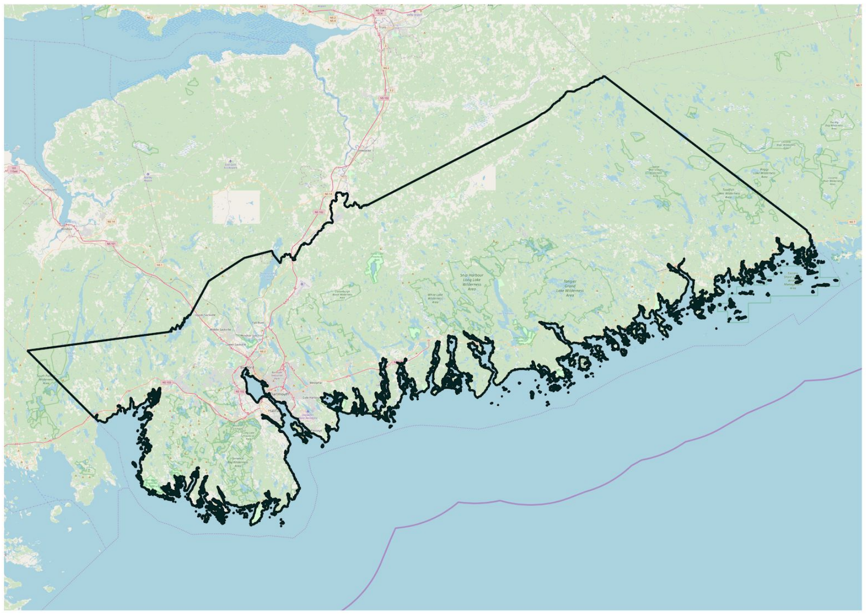


Figure 35. Municipal Boundary of Halifax.

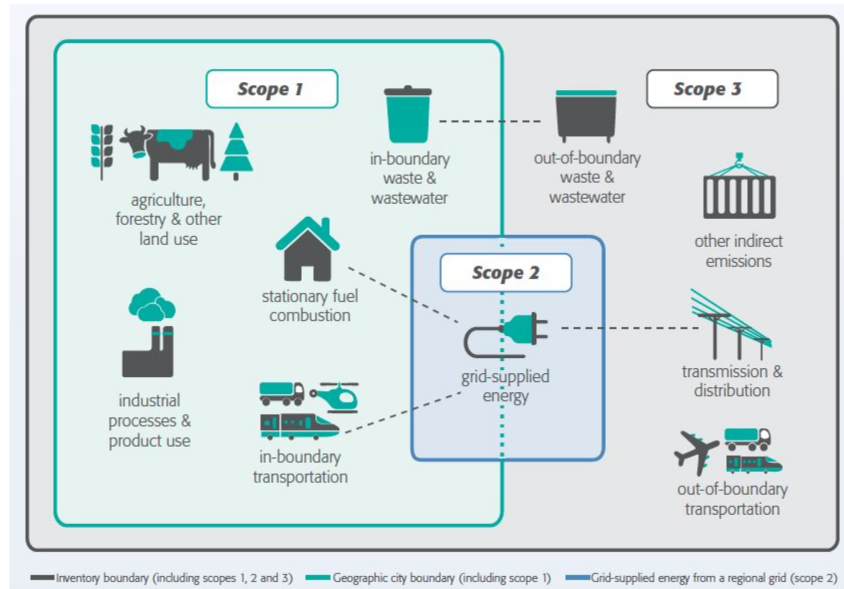


Figure 36. GPC scope boundaries.

Emissions Factors

Category	Description	Comment
Natural gas	49 kg CO2e/GJ	Environment and Climate Change Canada. *National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada*. Part 2. Tables A6-1 and A6-2, Emission Factors for Natural Gas.
Electricity	2016: CO_2: 700.0 g/kWh CH_4: 0.03 g/kWh N_2O: 0.01 g/kWh 2050: CO_2: 363.9 g/kWh CH_4: 0.03 g/kWh N_2O: 0.01 g/kWh	National Energy Board. (2016). *Canada's Energy Future 2018.* Government of Canada. Retrieved from https://www.cer-rec.gc.ca/nrg/ntgrtd/ftr/2018/pblctn-eng.html
Gasoline	g/L CO_2: 2316 CH_4: 0.14 N_2O: 0.022	Environment and Climate Change Canada. *National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada.* Part 2. Table A6–12 Emission Factors for Energy Mobile Combustion Sources (Tier 2)
Diesel	g/L CO_2: 2690.00 CH_4: 0.051 N_2O: 0.22	Environment and Climate Change Canada. *National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada.* Part 2. Table A6–12 Emission Factors for Energy Mobile Combustion Sources (Advanced Control)
Fuel oil	Residential g/L CO_2: 2560 CH_4: 0.026 N_2O: 0.006 Commercial g/L CO_2: 2753 CH_4: 0.026 N_2O: 0.031 Industrial g/L CO_2: 2753 CH_4: 0.006 N_2O: 0.031	Environment and Climate Change Canada. *National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada.* Part 2. Table A6–4 Emission Factors for Refined Petroleum Products

Wood	Residential g/kg CO_2: 1539 CH_4: 12.9 N_2O: 0.12 Industrial CO_2: 840 CH_4: 0.09 N_2O: 0.06	Environment and Climate Change Canada. *National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada.* Part 2. Table A6–32 Emission Factors for Biomass
Propane	g/L Transport CO_2: 1515.00 CH_4: 0.64 N_2O: 0.03 Residential CO_2: 1515.00 CH_4 : 0.027 N_2O: 0.108 All other sectors CO_2: 1515.00 CH_4: 0.024 N_2O: 0.108	Environment and Climate Change Canada. *National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada.* Part 2. Table A6–3 Emission Factors for Natural Gas Liquids Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Waste	Landfill emissions are calculated from first-order decay of degradable organic carbon deposited in landfill. Derived emission factor in 2016 = 0.015 kg CH_4/tonne solid waste (assuming 70% recovery of landfill methane); 0.050 kg CH_4/tonne solid waste not accounting for recovery.	Landfill emissions: *IPCC Guidelines Vol 5*. Ch 3, Equation 3.1
Wastewater	CH_4: 0.48 kg CH_4/kg BOD N_2O: 3.2 g / (person * year) from advanced treatment 0.005 g /g N from wastewater discharge	CH_4 wastewater: *IPCC Guidelines Vol 5*. Ch 6, Tables 6.2 and 6.3; MCF value for anaerobic digester N_2O from advanced treatment: *IPCC Guidelines Vol 5*. Ch 6, Box 6.1 N_2O from wastewater discharge: *IPCC Guidelines Vol 5*. Ch 6, Section 6.3.1.2

Modelling

For this project, CityInSight will be used as the main modelling tool.

About CityInSight

CityInSight is an integrated energy, emissions and finance model developed by Sustainability Solutions Group and whatIf? Technologies.

It is an integrated, multi-fuel, multi-sector, partially-disaggregated energy systems, emissions and finance model for cities. The model enables bottom-up accounting for energy supply and demand, including renewable resources, conventional fuels, energy consuming technology stocks (e.g. vehicles, appliances, dwellings, buildings) and all intermediate energy flows (e.g. electricity and heat).

Energy and GHG emissions are derived from a series of connected stock and flow models, evolving on the basis of current and future geographic and technology decisions/assumptions (e.g. EV penetration rates). The model accounts for physical flows (i.e. energy use, new vehicles by technology, vehicle kilometres travelled) as determined by stocks (buildings, vehicles, heating equipment, etc).

CityInSight incorporates and adapts concepts from the system dynamics approach to complex systems analysis. For any given year within its time horizon, CityInSight traces the flows and transformations of energy from sources through energy currencies (e.g. gasoline, electricity, hydrogen) to end uses (e.g. personal vehicle use, space heating) to energy costs and to GHG emissions. An energy balance is achieved by accounting for efficiencies, conservation rates, and trade and losses at each stage in the journey from source to end use.

Characteristic	Rationale
Integrated	CityInSight is designed to model and account for all sectors that relate to energy and emissions at a city scale while capturing the relationships between sectors. The demand for energy services is modelled independently of the fuels and technologies that provide the energy services. This decoupling enables exploration of fuel switching scenarios. Physically feasible scenarios are established when energy demand and supply are balanced.
Scenario-based	Once calibrated with historical data, CityInSight enables the creation of dozens of scenarios to explore different possible futures. Each scenario can consist of either one or a combination of policies, actions and strategies. Historical calibration ensures that scenario projections are rooted in observed data.
Spatial	The configuration of the built environment determines the ability of people to walk and cycle, accessibility to transit, feasibility of district energy and other aspects. CityInSight therefore includes a full spatial dimension that can include as many zones - the smallest areas of geographic analysis - as are deemed appropriate. The spatial component to the model can be integrated with city GIS systems, land-use projections and transportation modelling.
GHG reporting framework	CityInSight is designed to report emissions according to the GHGProtocol for Cities (GPC) framework and principles.
Economic impacts	CityInSight incorporates a full financial analysis of costs related to energy (expenditures on energy) and emissions (carbon pricing, social cost of carbon), as well as operating and capital costs for policies, strategies and actions. It allows for the generation of marginal abatement curves to illustrate the cost and/or savings of policies, strategies and actions.

Model Structure

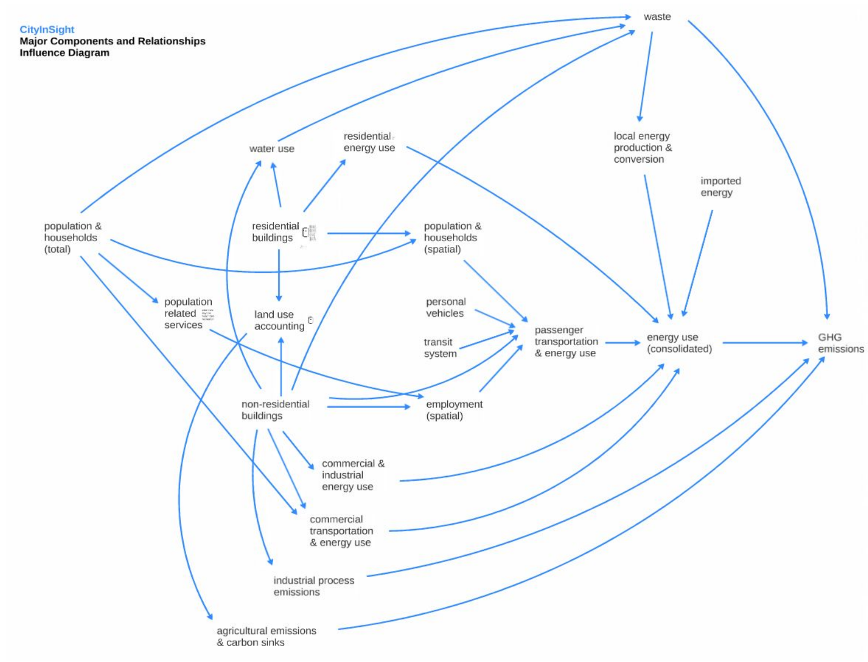
The major components of the model, and the first level of modelled relationships (influences), are represented by the blue arrows in Figure 2. Additional relationships may be modelled by modifying inputs and assumptions - specified directly by users, or in an automated fashion by code or scripts running “on top of” the base model structure. Feedback relationships are also possible, such as increasing the adoption rate of non-emitting vehicles in order to meet a particular GHG emissions constraint.

The model is spatially explicit. All buildings, transportation and land use data is tracked within the model through a GIS platform, and by varying degrees of spatial resolution. A zone type system is applied to break up a large areas into smaller configurations. This enables consideration of the impact of land-use patterns and urban form on energy use and emissions production from a baseline year to future dates using GIS-based platforms. CityInSight’s GIS outputs can be integrated with the Municipality’s mapping systems.

Stocks and flows

For any given year various factors shape the picture of energy and emissions flows, including: the population and the energy services it requires; commercial floorspace; energy production and trade; the deployed technologies which deliver energy services (service technologies); and the deployed technologies which transform energy sources to currencies (harvesting technologies). The model makes an explicit mathematical relationship between these factors - some contextual and some part of the energy consuming or producing infrastructure - and the energy flow picture.

Some factors are modelled as stocks - counts of similar things, classified by various properties. For example, population is modelled as a stock of people classified by age and gender. Population change over time is projected by accounting for: the natural aging process, inflows (births, immigration) and outflows (deaths, emigration). The fleet of personal use vehicles, an example of a service technology, is modelled as a stock of vehicles classified by size, engine type and model year - with a similarly-classified fuel consumption intensity. As with population, projecting change in the vehicle stock involves aging vehicles and accounting for major inflows (new vehicle sales) and major outflows (vehicle discards). This stock-turnover approach is applied to other service technologies (e.g. furnaces, water heaters) and also harvesting technologies (e.g. electricity generating capacity).



Representation of CityInSight’s structure.

Sub-models

Population and demographics

Municipality-wide population is modelled using the standard population cohort-survival method, disaggregated by single year of age and gender. It accounts for various components of change: births, deaths, immigration and emigration. The age structured population is important for analysis of demographic trends, generational differences and implications for shifting energy use patterns. In CityInSight these numbers will be calibrated against existing projections developed for the Municipality.

Residential buildings

Residential buildings are spatially located and classified using a detailed set of 30+ building archetypes capturing footprint, height and type (single, double, row, apt. high, apt. low), in addition to year of construction. This enables a "box" model of buildings and the estimation of surface area. Coupled with thermal envelope performance and degree-days the model calculates space conditioning energy demand independent of any particular space heating or cooling technology and fuel. Energy service demand then drives stock levels of key service technologies (heating systems, air conditioners, water heaters). These stocks are modelled with a stock-turnover approach capturing equipment age, retirements, and additions - exposing opportunities for efficiency gains and fuel switching, but also showing the rate limits to new technology adoption and the effects of lock in. Residential building archetypes are also characterized by number of contained dwelling units, allowing the model to capture the energy effects of shared walls but also the urban form and transportation implications of population density.

Non-residential buildings

These are spatially located and classified by a detailed use/purpose-based set of 50+ archetypes, and the floorspace of these non-residential building archetypes can vary by location. Non-residential floorspace produces waste and demand for energy and water, and also provides an anchor point for locating employment of various types.

Spatial population and employment

Municipality-wide population is made spatial by allocation to dwellings, using assumptions about persons-per-unit by dwelling type. Spatial employment is projected via two separate mechanisms: population-related services and employment, which is allocated to corresponding building floorspace (e.g. teachers to school floorspace); and floorspace-driven employment (e.g. retail employees per square metre)

Passenger Transportation

The model includes a spatially explicit passenger transportation sub-model that responds to changes in land use, transit infrastructure, vehicle technology, travel behavior change and other factors. Trips are divided into four types (home-work, home-school, home-other, and non-home-based), each produced and attracted by different combination of spatial drivers (population, employment, classrooms, non-residential floorspace). Trips are distributed - that is, trip volumes are specified for each zone of origin and zone of destination pair. For each origin-destination pair trips are shared over walk/bike (for trips within the walkable distance threshold), public transit (for trips whose origin and destination are serviced by transit) and automobile. Following the mode share step, along with a network distance matrix, a projection of total personal vehicles kilometres travelled (VKT) is produced. The energy use and emissions associated with personal vehicles is calculated by assigning VKT to a stock-turnover personal vehicle model. The induced approach is used to track emissions. All internal trips (trips within the boundary) are accounted for, as well as half of the trips that terminate or originate within the boundary. This approach allows the region to better understand its impact on the peripheries and the region.

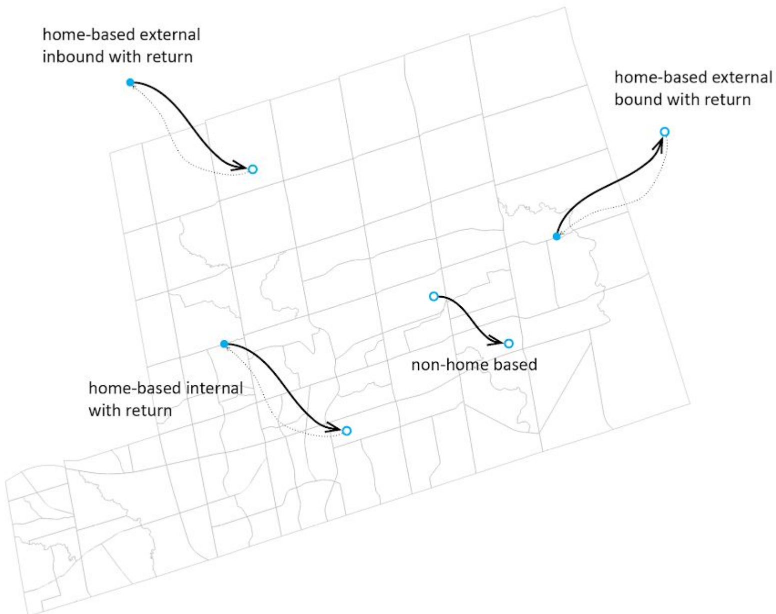


Figure 38. Conceptual diagram of trip categories.

Waste

Households and non-residential buildings generate solid waste and wastewater, and the model traces various pathways to disposal, compost and sludge including those which capture energy from incineration and recovered gas. Emissions accounting is performed throughout the waste sub-model.

Energy flow and local energy production

Energy produced from primary sources (e.g. solar, wind) is modelled alongside energy converted from imported fuels (e.g. electricity generation, district energy, CHP). As with the transportation sub-model, the district energy supply model has an explicit spatial dimension and represents areas served by district energy networks.

Finance and employment

Energy related financial flows and employment impacts - while not shown explicitly in Figure 37 - are captured through an additional layer of model logic. Calculated financial flows include the capital, operating and maintenance cost of energy consuming stocks and energy producing stocks, including fuel costs. Employment related to the construction of new buildings, retrofit activities and energy infrastructure is modelled. The financial impact on businesses and households of the strategies is assessed. Local economic multipliers are also applied to investments.

Scenario Development

CityInSight is designed to support the use of scenarios as a mechanism to evaluate potential futures for communities. A scenario is an internally consistent view of what the future might turn out to be—not a forecast, but one possible future outcome. A good set of scenarios is both plausible and surprising but scenarios can also be misleading if, for example, there are too few so that one scenario is "good" and the other "bad".

Another consideration is to ensure that the name of the scenario does not bias the audience. Lastly, scenarios must represent serious considerations defined not only by planning staff, but also by community members.

Scenarios are generated by identifying population projections into the future, identifying how many additional households are required and then applying those additional households according to existing land-use plans and/or alternative scenarios. A simplified transportation model evaluates the impact of the new development on transportation behaviour, building types, agricultural and forest land and other variables.

Business-As-Usual Scenario

The Business-As-Usual (BAU) scenario will offer a scenario moving towards the year 2050.

Methodology:

1. Calibrate model and develop 2016 baseline using observed data and filling in gaps with assumptions where necessary;
2. Input existing projected quantitative data to 2050 where available:
    - Population, employment & households projections from Municipality by transport zone;
    - Build out (buildings) projections from Municipality by transport zone (if available);
    - Transport modelling from Municipality;
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:
    - Analysing current on the ground action in the Municipality (reviewing actions plans, engagement with staff etc.), and where possible, quantifying the action;
    - Analysing existing policy that has potential impact for the Municipality, and where possible, quantifying the potential impact.

A list of BAU data sources and assumptions can be found in the BAU Data and Assumptions Table, below.

Data and Assumptions

	Data/Assumption	Source	Summary approach/methodology
DEMOGRAPHICS			
Population & employment			
Population & employment	Population: 418,484 (2016), 475,588 (2031) and 546,428 (2051). Employment: 238,545 (2016), 257,719 (2031) and 282,005 (2050).	City of Halifax; population & employment projections to 2031 by zone. *2031 CP Population Housing and Employment.xlsx*	Population and employment projections by zone to 2050 are applied and spatially allocated in the model. 2016 population number includes estimated census undercount. Post 2031 projections and spatial allocation were not available from the Municipality. The population and employment trends for 2017-2031 were extrapolated to get totals for 2050. Spatial allocation of post 2031 population and employment was distributed according to similar patterns of growth exhibited between 2017-2031.
BUILDINGS			
New buildings growth			
Building growth projections	No data from Municipality or other. Derived by the model.		Buildings floorspace (residential & non-residential) by zone to 2050 was derived using the population and employment projections provided by the Municipality. New residential floorspace (households/dwellings) is derived by allocating new dwellings based on the existing persons per unit. New dwellings by type are allocated to zones: - if zone already has dwellings, the existing dwelling type share is used for new builds - if zone does not have dwellings, existing dwelling type share from nearby zones is used for new builds - if population in a zone is projected to decrease, dwellings are removed - all greenfield New non-residential floorspace is derived by allocating new non-residential floorspace according to gross floor area per employee/job. New non-residential floorspace by type is allocated to zones - if zone already has employment, the existing employment sector shares are used along with gross floor area per employee - if zone does not have any employment, the employment shares from nearby zones are used along with gross floor area per employee - if employment in a zone decreases, non-residential buildings are removed - greenfield vs. infill designation is based on the zone. Zones classified as Suburban or Rural have greenfield development, zones classified as Urban, Intensive Employment, Institutional Employment, Downtown Core obtain infills or increased density.

New buildings energy performance			
Residential	New construction 2% more efficient every 5 years starting in 2021.		The modelling for all new construction assumes a 2% improvement every 5 years.
Multi-residential	New construction 2% more efficient every 5 years starting in 2021.		
Commercial & Institutional	New construction 2% more efficient every 5 years starting in 2021.		
Industrial	New construction 2% more efficient every 5 years starting in 2021.		
Existing buildings energy performance			
Residential	Existing building stock efficiency unchanged; efficiency held constant from 2016-2050.		Baseline efficiencies for each building type are derived in the model through calibration with observed data; for existing buildings, no improvements in efficiency are applied.
Multi-residential			
Commercial & Institutional			
Industrial			
End use			
Space heating	Fuel shares for end use unchanged; held from 2016-2050.	Canadian Energy Systems Analysis Research. Canadian Energy System Simulator. http://www.whatiftechnologies.com/caness	Within the model, the starting point for fuel shares by end use is an Ontario average value for the given building type, which comes from CanESS. From there, the fuel shares are calibrated to track on observed natural gas and electricity use. Once calibrated, end use shares are held constant through the BAU.
Water heating			
Space cooling			
Projected climate impacts			
Heating & cooling degree days	Heating degree days (HDD) decrease and cooling degree days (CDD) increase from 2016-2050.	https://climateatlas.ca/data/city/463/hdd_2060_45 and https://climateatlas.ca/data/city/463/cooldd_2060_45	To account for the influence of projected climate change, energy use was adjusted according to the number of heating and cooling degree days.

Grid electricity emissions			
Grid electricity emissions factor	2016: 700 gCO2e/kWh 2040: 317 gCO2e/kwh 2050: 317 gCO2e/kwh	National Energy Board. (2018). Canada's Energy Future 2018. Government of Canada. Retrieved from https://www.cer-rec.gc.ca/nrg/ntgrtd/ftr/2018/pblctn-eng.html Environment Canada National inventory 2018 https://unfccc.int/documents/65715	A projection of the emissions associated with the import of electricity into HRM from the provincial electricity grid was created on the basis of NEB/CER's Energy Future 2018. This outlook contains a projection of provincial generation by fuel type, as well as a projection of interprovincial trade. Combined with emission factors by fuel type derived from Environment Canada's National Inventory Report 2019, this leads to a projection of grid emission factors for imported electricity for HRM. After small adjustments to align the NEB interprovincial trade numbers with Nova Scotia Power's three year rate stability plan for the period covering 2020-2022, and a comparison of the resulting emission intensities with the NS emission caps as modeled in Plexo by Synapse in their analysis for NSP (https://irp.nspower.ca/files/key-documents/background-materials/Synapse-Final-Report-Generation-Optimization-and-Utilization-May-1-2018.pdf), the resulting curve shows a gradual decline of emission intensity from 700 kg CO2e / MWh in 2016 to 317 kg CO2e / MWh in 2040, after which the intensity is held constant.
ENERGY GENERATION			
Local energy generation			
Solar PV	Renewables and solar for baseline and BAU sourced from NSPI data. Installations up to 2016 used in the baseline, 2017-2018 used for first two simulation years. Then held constant	*20190131 NSPI to UARB Enhanced Net Metering Report Att 1 ELECTRONIC.xlsx*	Solar capacity is updated with 2017-2018 data, then held constant to 2050.
TRANSPORTATION			
Transit			
Expansion of transit	Transit mode share held constant to 2050.		No change in transit mode share assumed 2016-2050; that is, some level of additional/expanded transit service is assumed to take place in order to achieve a constant transit mode share across the city as it continues to grow.
Electric vehicle transit fleet	No electrification of transit vehicle fleet assumed 2016-2050.		No electrification of transit vehicle fleet assumed 2016-2050.
Active			
Cycling & walking infrastructure	Active mode share held constant to 2050.		No change in active transportation mode share assumed 2016-2050; that is, some level of additional/expanded active transportation infrastructure is assumed to take place in order to achieve a constant active mode share across the city as it continues to grow.
Private & commercial vehicles			

Vehicle kilometers travelled	Baseline calibrated against origin-destination matrix modelled by the Municipality. BAU VKT projected by the model based on projected spatial buildings, population and employment.	*HRM 2031 Centre Plan OD Tables.xlsx*	Vehicle kilometres travelled projections are driven by buildings projections. The number and location of dwellings and non-residential buildings over time in the BAU drive the total number of internal and external person trips. Person trips are converted to vehicle trips using the baseline vehicle occupancy. Vehicle kilometres travelled is calculated from vehicle trips using the baseline distances between zones and average external trip distances.
Vehicle fuel efficiencies	Vehicle fuel consumption rates reflect the implementation of the U.S. Corporate Average Fuel Economy (CAFE) Fuel Standard for Light-Duty Vehicles, and Phase 1 and Phase 2 of EPA HDV Fuel Standards for Medium- and Heavy-Duty Vehicles.	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 http://www.nhtsa.gov/fuel-economy	Fuel efficiency standards are applied to all new vehicle stocks starting in 2016.
Vehicle share	Personal vehicle stock share changes between 2016-2050. Commercial vehicle stock unchanged 2016-2050.	CANSIM and Natural Resources Canada's Demand and Policy Analysis Division.	The total number of personal use and corporate vehicles is proportional to the projected number of households in the BAU.
Electric vehicles	20% of vehicles on the road in 2044 is an electric vehicle	NS Charging Network Insights & Grid Impact of Residential Charging, NSCC EnergyDATA Workshop Feb 2019, Sanjeev Pushkarna, Nova Scotia Power	Track on low EV scenario page 4 (=20% of vehicles on the road in 2044 is an electric vehicle), exponential growth continued to 2050.
WASTE			
Waste generation	Existing per capita waste generation rates unchanged.		Waste generation per capita held constant form 2016-2050.
Waste diversion	Existing waste diversion rates unchanged.		Waste diversion rates held constant form 2016-2050.
Waste treatment	Existing waste treatment processes unchanged.		No change in waste treatment processes assumed 2016-2050.

Sensitivity Analysis

The BAU scenario illustrates the projected emissions for HRM built upon the assumptions as described in this report. In that light, the BAU reflects what is anticipated to occur in the future if the assumptions as described are realized.

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 internally 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 may be contributing significantly to the BAU scenario), in order to be better informed about the implications of future options.

The process used applies a judgement-based “one-at-a-time”[1] exploration of variables within a scenario. The results should not be viewed as an evaluation of fully considered alternative futures, rather, it is an exploration revealing how a selected output (i.e. emissions) responds to changes in selected inputs (e.g. # residential units).

Variables and Results

Sensitivity analysis was applied to the BAU scenario. Several variables were identified for sensitivity analysis; the assumptions and results of each are described in Table S-1, and depicted in Figures S-1 & S-2. The impact , expressed in GJ for energy and kt CO2e for emissions, shows the absolute difference relative to the BAU in 2050.

[1] 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.

Discussion

For energy, changes in BAU assumptions for heating degree days (HDD) have the most impact on BAU energy consumption, along with the uptake of electric vehicles and vehicle kilometres travelled.

The assumptions for heating degree days appear to be muting the impact of a growing population on energy and emissions in the BAU. 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), and the population projections used in the BAU are not adjusted (as described above), the results indicate an increase in energy (+3.8%) and emissions (+3.3%); which is higher than the energy and emissions impact of increased population growth assumptions with decreasing HDD assumed in the BAU. Meaning, that the energy increase generally expected from a growing population is being outweighed by a decrease in energy demand that is decreasing [specifically for space heating] as a result of a warming climate.

For emissions, changes in the BAU assumptions for grid electricity emissions intensity have the most significant impact on the BAU emissions trajectory. Emissions from electricity make up 58% of total emissions 2016; this decreases slightly to 52% by 2050 in the BAU, predominantly as a result of a decrease in the grid electricity emissions intensity factor assumed in the BAU. This analysis indicates that if the grid emissions factor decreases faster than that assumed in the BAU, to approximately 50% of the projected emissions factor by 2050, then HRM’s community wide emissions would reduce by approximately 26%.

In a scenario that represents a large shift towards electricity (eg. in a low carbon scenario), the impact of the grid emissions factor will play an even larger role. It will be fundamental, and a large opportunity, in that type of scenario, for the emissions of both existing and new capacity to remain low; as this would have a significant impact on emissions reductions. , or the electrification approach will be at risk from a greenhouse gas emissions perspective.

Table S-1. BAU sensitivity analysis variables and results.

			ENERGY Impact: relative to BAU in 2050		EMISSIONS Impact: relative to BAU in 2050	
			+/- GJ	+/- %	+/- kt CO2e	+/- %
Variable	Modeling assumption	Comment	**BAU Energy 2050 = 52.8 million GJ**		**BAU Emissions 2050 = 3.9 Mt CO2e**	
Demographics and buildings						
Decrease population & employment	-10% dwelling units with reduced population by 2050 -10% non-residential floorspace with reduced employment by 2050	Considers the impact of slower population and building growth than currently projected.	-340,200	-0.6%	-24,200	-0.6%
Increase population & employment	+10% dwelling units with increased population by 2050 +10% NR floorspace with increased employment by 2050	Considers the impact of faster population and building growth than currently projected.	340,400	0.6%	24,200	0.6%
Heating degree days (HDD)						
Hold HDD fixed	Keep number of heating degree days fixed at baseline value.	Considers the impact of the climate not warming as fast as currently projected, ie. stays constant.	2,067,200	3.9%	126,100	3.3%
Decrease HDD + increase CDD	Incrementally decrease number of heating degree days, so that by 2050, there are 10% less HDD compared with BAU. Incrementally increase the number of cooling degree days, so that by 2050, there are 10% more CDD compared with BAU	Considers the impact of the climate warming faster than currently projected.	-2,939,900	-5.6%	-179,100	-4.6%
Grid electricity emissions factor (EF)						
Decrease EF	Decrease EF to 182 g CO2e/kWh in 2050 (50% decrease compared with BAU 364 g CO2e/kWh in 2050).	Considers the impact of the grid cleaning up faster than currently assumed in BAU (per NSP/NEB)	0	0.0%	-998,600	-25.7%
Increase EF	Increase EF to 546 g CO2e/kWh in 2050 (50% increase compared with BAU 364 g CO2e/kWh in 2050).	Considers the impact of the grid not cleaning as fast as currently assumed in BAU (per NSP/NEB)	0	0.0%	998,600	25.7%
Electric Vehicle (EV) adoption						
Decrease in EV uptake in personal use vehicles	Apply NSP extra low EV scenario (= half of low, which is used in BAU) This implies EV makes up 10% (instead of 20%) of the stock in 2044, and 16% in 2050 (instead of 31%)	Considers the impact of a slower uptake of EVs than currently projected in the BAU.	924,200	1.7%	46,000	1.2%
Increase in EV uptake in personal use vehicles	Apply NSP medium EV scenario, which is double NSP low. Increase 2044 EV number of personal use vehicle stocks by 10 percent points (from approx. 10% in BAU to 20%); increase 2050 EV number of personal use vehicle stocks by	Considers the impact of a faster uptake of EVs than currently projected in the BAU.	-1,835,700	-3.5%	-91,200	-2.3%

	31% points (from approx. 31% in BAU to 62%).					
Vehicle kilometres travelled (VKT)						
Increase VKT	Gradual increase in passenger vehicle VKT by 25% in 2050.	Considers the impact of changes in VKT that could be influenced by alternative spatial distribution (land use) and transit service expansion.	-1,860,000	-3.5%	-132,200	-3.4%
Decrease VKT	Gradual decrease in passenger vehicle VKT by 25% in 2050.		1,860,000	3.5%	132,200	3.4%
Methane						
Adjust methane GWP from 100-yr (used in BAU) to 20-yr GWP	Adjust EF for CH4 to: GWP20 CH4 (with ccfb) = 86	Global warming potential (GWP) of methane is a much more potent GHG emission over 20 years than over 100 years. Reporting using 100yr GWP underestimates the impact of methane, and some cities (eg. NYC) have adopted using 20yr GWP for methane in their emissions reporting.	0	0.0%	408,300	10.5%

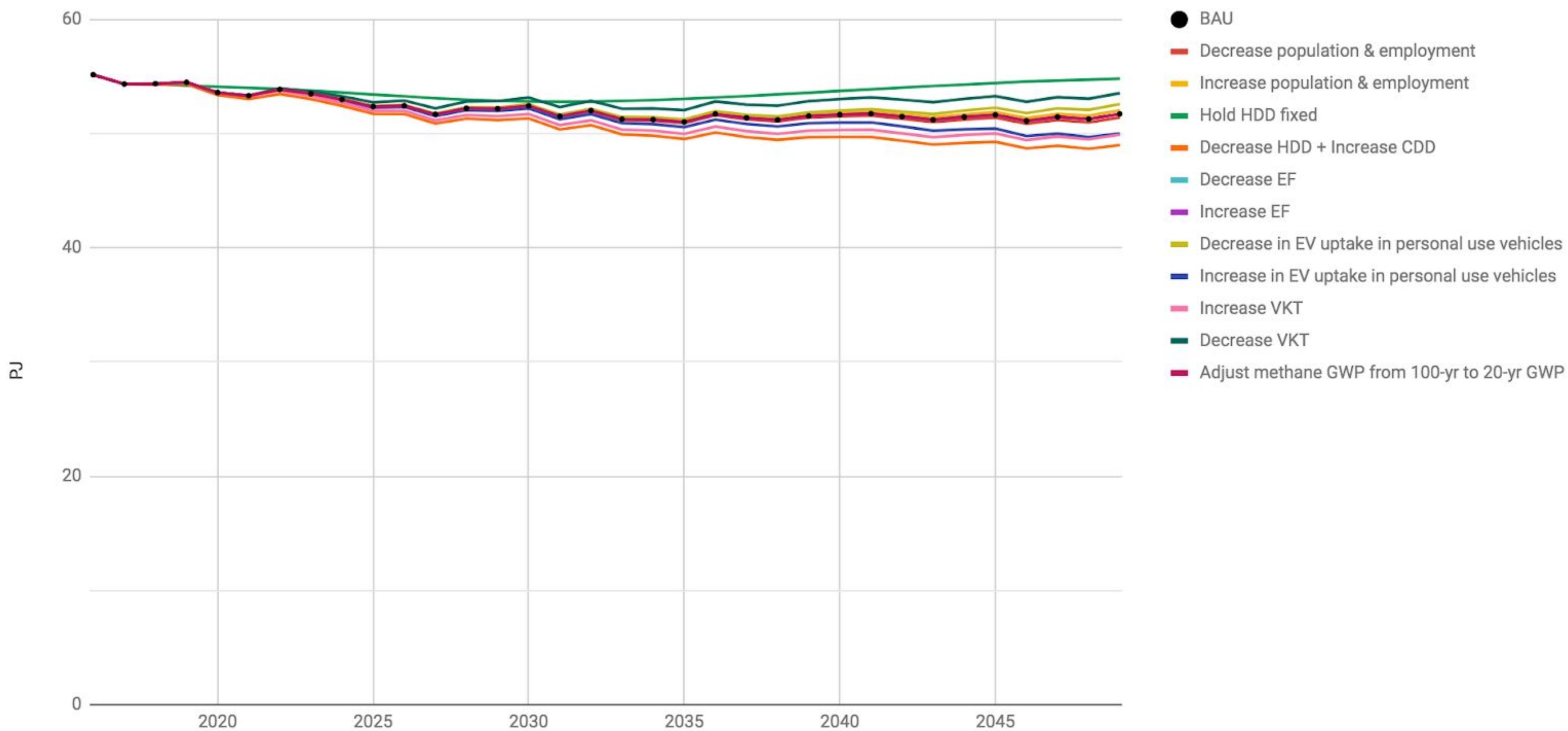


Figure S-1. BAU energy sensitivity, 2016-2050.

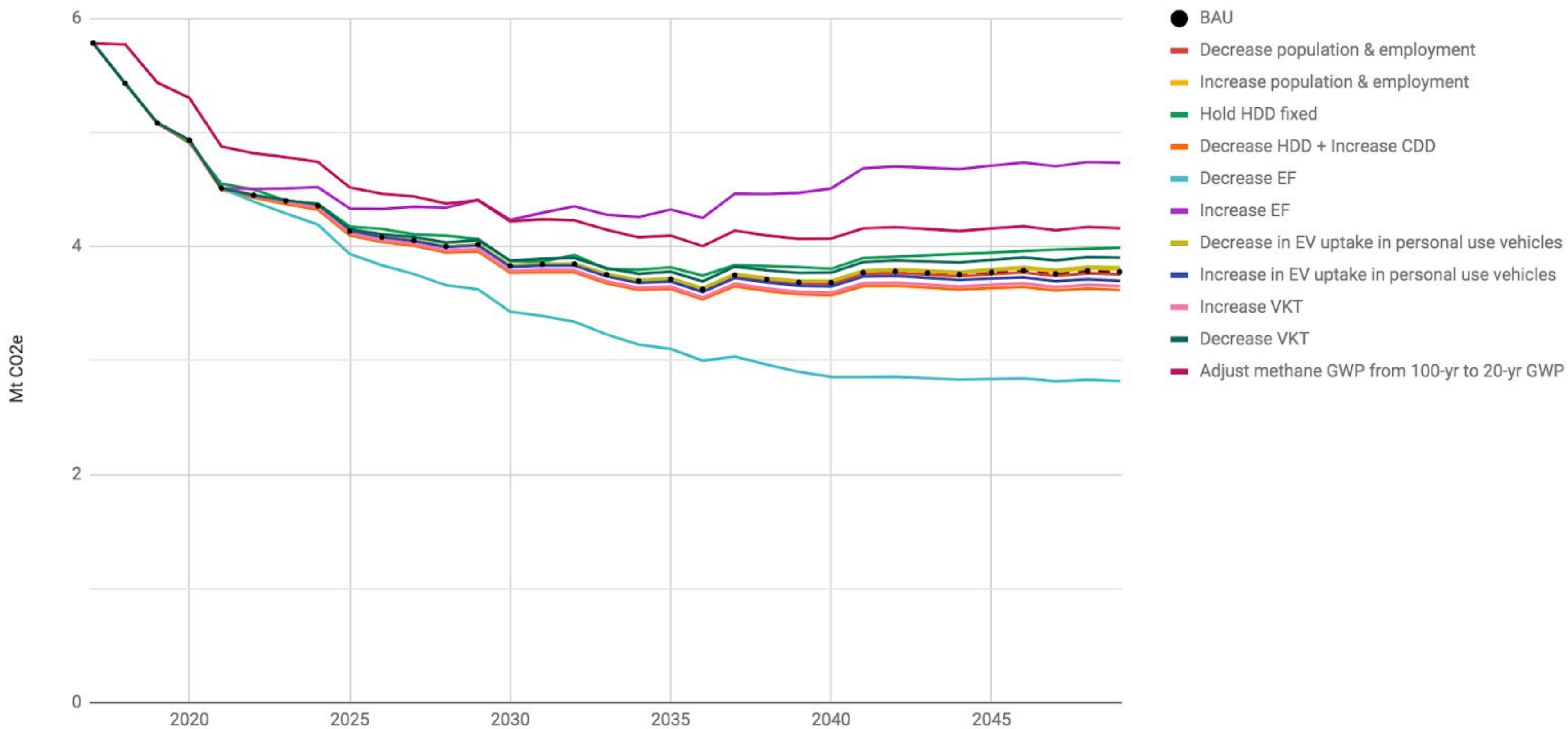


Figure S-2. BAU emissions sensitivity, 2016-2050.