HALIFAX REGIONAL MUNICIPALITY

LOW-CARBON TECHNICAL REPORT

MARCH 2020

PREPARED BY:

SSG SUSTAINABILITY SOLUTIONS GROUP

whatIf?

About this document

This report was developed by SSG as a technical resource to support and inform the development of the City of Halifax's Climate Action Plan, HalifACT 2050. The primary purpose of the technical work undertaken was to identify an emissions reduction pathway for Halifax. This report details the results of that analysis and includes a set of recommendations for inclusion in the HalifACT 2050 plan to reduce emissions and adapt to a changing climate.

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Executive Summary

As both local and global greenhouse gas emissions continue to increase, the planet continues to warm, resulting in changes to local and global climate systems. Localized downscaled climate projections for the region indicate that Halifax can expect to see higher annual and seasonal average temperatures, higher maximum or peak temperatures, more heat waves, increased annual precipitation, increases in extreme precipitation, and increases in the intensity and frequency of some extreme events, including storms, flooding, and wildfires.

These hazards pose risks for people, infrastructure and the built environment, natural systems and resources, economies, livelihoods and safety. As the climate continues to change, Halifax faces increased risks and impacts. Amongst others, this includes: damage to physical infrastructure, reduced fresh water quality and quantity, risks to agriculture and food systems, threats to biodiversity and ecosystem resilience, risks to fisheries and forestry, adverse impacts on physical and mental health, increased demands on emergency services, financial impacts to businesses and economies, and risks related to the capacity of government to effectively provide public services.

Significantly reducing emissions and preparing for these impacts are critical for Halifax to thrive in a changing climate.

In 2016, the community of Halifax emitted approximately 5.8 MtCO2e. Under a business-as-usual scenario (ie. no additional policies, actions or strategies to address energy and emissions are implemented towards 2050, other than those currently underway or planned), this is projected to decrease by 33% to 3.9 MtCO2e by 2050.

To be in line with limiting average global temperature rise to below 1.5℃, the benchmark establish by the Intergovernmental Panel on Climate Change (IPCC), Halifax needs to reduce its emissions to 1.4 MtCO2e by 2030 (75% by 2030 from 2016), and to zero or net-zero MtCO2e by 2050 (100% by 2050 from 2016); and limit its cumulative emissions, or "carbon budget", to 37 MtCO2e between 2020-2050.

This requires a steep and rapid (rather than gradual) decline in emissions, specifically in the next 10 years, and requires rapid and far-reaching transitions in energy, urban and infrastructure systems (including transportation, buildings, and land use), and industrial systems. Significant and transformative action in the immediate near-term is critical.

Using the 1.5℃ targets and pathway as a benchmark, a steep emissions reduction scenario (LC3) was developed to establish a basis for the scale and pace of emissions reduction action required to meet this target. A series of emissions reduction actions across a variety of sectors was modelled, including for buildings, energy supply, transportation, water, wastewater, and solid waste.

Results indicate that by implementing LC3, 95% of emissions can be reduced by 2050, and cumulative emissions limited to 45 $MtCO_2e$ between 2020-2050. While LC3 includes significant efforts to improve energy efficiency and shifts to renewable sources with current-day technology, 5% of emissions remain in 2050, and the 1.5°C carbon budget is exceeded by 8 Mt CO_2e.

The ability to address the remaining 5% will improve in the next 30 years as new technologies and other fuel sources (such as hydrogen) are developed. While improvements in technology towards 2050 will contribute to limiting cumulative emissions, the timing of action is much more important. Deploying current-day technology on a bigger scale, over a shorter period of time, in the very near future, has a much larger impact on limiting cumulative emissions than waiting to implement changes.

Achieving emissions reductions of this scale is technically feasible and economically viable. While significant capital investments are required in the near-term, these will generate considerable operating, maintenance, and energy costs savings over time, generate revenues from local renewables, and generate significant new employment; all of which stimulate local economic development and reduce economic leakage.

Ensuring that the transition is equitable and just is paramount.

Not all people will be affected equally by climate change. Certain groups, communities, or populations, will be disproportionately affected due to their increased exposure and sensitivity to climate risks, or lack of adaptive capacity to deal with the impacts. Similarly, not all will be able to contribute to the significant action and investment required to decarbonize.

Given limited resources, it is therefore imperative to prioritize action for the most vulnerable and affected members of our communities, many of whom are already suffering from a range of challenges, and ensuring the equitable distribution of those resources and prioritize those most vulnerable to climate.

Investing to reduce emissions and prepare for the impacts of climate change in the near-term is critical. Every dollar invested proactively can save as much as four to six dollars on recovery; whereas the cost of inaction will only grow over time. Delaying action in the near-term will lead to higher and unpredictable costs in the long-term, placing an additional burden on future generations who will already be on the frontlines of a climate change.

CONTEXT

Introduction

Global climate change

Human-induced climate change poses risks to health, economic growth, safety, livelihoods and the natural world. The latest climate science estimates that an increase in average global temperatures by 2℃ could lead to extreme temperatures, unprecedented droughts and storms, destructive sea level rise in coastal regions, and impacts to living organisms across a spectrum of ecosystems and environments, including for human life. The Intergovernmental Panel on Climate Change (IPCC) expects that limiting warming to 1.5℃ may provide a greater buffer against this potential damage, although there will still be a risk to human and natural systems. Already, there are observable changes to climate both in Canada and abroad.

Limiting average global temperature rise to below 1.5℃ will require dramatic emissions reductions. According to global climate models, global emissions reductions need to be in the order of 25% by 2030, and net zero emissions by 2050 to meet the 1.5℃ warming target. This corresponds to a remaining global carbon budget of 420 GtCO2e that can be emitted by 2050; by the end of 2017, 2,230 GtCO2e were emitted globally.

Canada

Canada has a unique responsibility to take on meaningful emissions reductions. Its per capita emissions are among the highest in the world, exceeded only by the USA, Saudi Arabia and Australia. Canada is also already experiencing double the average rate of global warming.

The Government of Canada has formally committed to reducing its GHG emissions by 30% below 2005 levels by 2030 (under the Paris Agreement), and 80% below 2005 levels by 2050.

Although Canada's mid-century target does not call for net zero emissions and is therefore currently inconsistent with 1.5℃ degree warming, Canada has verbally committed to 1.5℃. The Liberal minority government elected in late 2019 campaigned on a net zero emissions target by 2050, with legally binding five-year milestones. As of January 2020, the target has yet to be adopted.

Canada's strategy for supporting emissions reductions is detailed in the Pan Canadian Framework on Clean Growth and Climate Change (PCF), produced in 2016. From the PCF, Canada has implemented a national carbon pricing system, consultations on a clean fuel standard, and methane regulations for oil and gas operations. In addition, there have been billions in funding for public transportation, as well as other initiatives funded through the Investing in Canada Infrastructure Program. The PCF also committed to the development of a net zero carbon building standard by 2030, toward which efforts are currently ongoing.

Despite the initiatives under PCF, Canada is not on track to meet its 2030 target, possibly reaching only 19% emissions reductions by 2030. Canada is among four other G20 countries that are falling well behind on their emissions reduction targets.

Nova Scotia

Nova Scotia recently adopted its emissions reduction targets of 53% emissions reductions below 2005 by 2030, and net zero emissions by 2050. These ambitious targets were spurred in part because the province already exceeded Canada's 2030 target in 2017.

Nova Scotia's achievements can be attributed to a provincially legislated emissions cap for power facilities beginning in 2010, and continuing until 2030. The share of coal-powered electricity has been reduced from 76% in 2007 to 52% in 2018 of total generation. Coal capacity is being increasingly replaced with renewable sources. Nova Scotia Power is also required to invest in energy efficiency through Efficiency Nova Scotia, the provincial efficiency utility established in 2011. In 2018, Efficiency Nova Scotia programming helped avoid 92 ktCO2e. Nova Scotia's Cap and Trade program was implemented in 2019 and is the province's contribution to the federal carbon pricing system. Cap and Trade applies to electricity importers, industrial facilities, natural gas distributors and petroleum product providers.

Notwithstanding the above, Nova Scotia's per capita emissions remain high compared with other provinces due to the use of coal, although this is expected to continually drop under the emissions caps in the Greenhouse Gas Regulations.

Halifax

HalifACT 2050: Acting on Climate Together is the Municipality's long-term climate action plan to reduce emissions and help communities adapt to a changing climate. It is an update and consolidation of two existing priority plans; the 2014 Regional Plan Community, Energy Plan (2007; 2016) and the Corporate Plan to Reduce GHG Emissions 2012-2020 (2011), and includes both climate adaptation and mitigation considerations.

On January 29, 2019, the Regional Council of Halifax declared a climate emergency, emphasising that climate change is a serious and urgent threat, called for the incorporation of climate targets and actions needed to achieve net-zero carbon emissions before 2050 into plan, and the establishment of a carbon budget for emissions commensurate with limiting warming to 1.5˚C.

While the development of HalifACT 2050 began earlier in spring of 2018, the plan is intended to respond to Council's subsequent climate emergency declaration.

Current state

Changing climate

Halifax's climate is changing. As both local and global greenhouse gas emissions continue to increase, the planet continues to warm, resulting in changes to local and global climate systems. Localized downscaled climate projections for the region indicate that Halifax can expect to see, amongst others, higher annual and seasonal average temperatures, higher maximum or peak temperatures, more heat waves, increased annual precipitation, increases in extreme precipitation, and increases in the intensity and frequency of some extreme events, including storms, flooding and wildfires. Refer to the *Climate Adaptation Baseline Report f*or further details on climate projections.

Change	1976-2005	2051-2080		
	Mean	Low	Mean	High
Typical hottest summer day	29.6 °C	30.7 °C	33.6 °C	36.6 °C
Typical coldest winter day	-21.3 °C	-18.8 °C	-14.6 °C	-10.7 °C
Number of +25 °C days per year	18	40	66	92
Number of +20 °C nights per year	0	1	10	27
Annual precipitation	1440 mm	1324 mm	1571 mm	1849 mm
Number of below-zero days per year	145	71	92	115
Frost-free season (days)	170	191	217	243

Figure 1. Climate projections for Halifax, RCP8.5, Climate Atlas of Canada.

Climate hazards arise from the climate system and result from natural climate variability and change caused by human action (anthropogenic emissions that are driving climate change).

Climate hazards can be either climate-related physical events, such as extreme weather events, or longer-term climate change trends, such as increasing average temperatures and sea level rise. A summary of climate change driven hazards events and longer-term trends expected in Halifax is shown in Figure 2. Many of these climate hazards are projected to increase in variability, frequency, and intensity as a result of projected changes in climate.

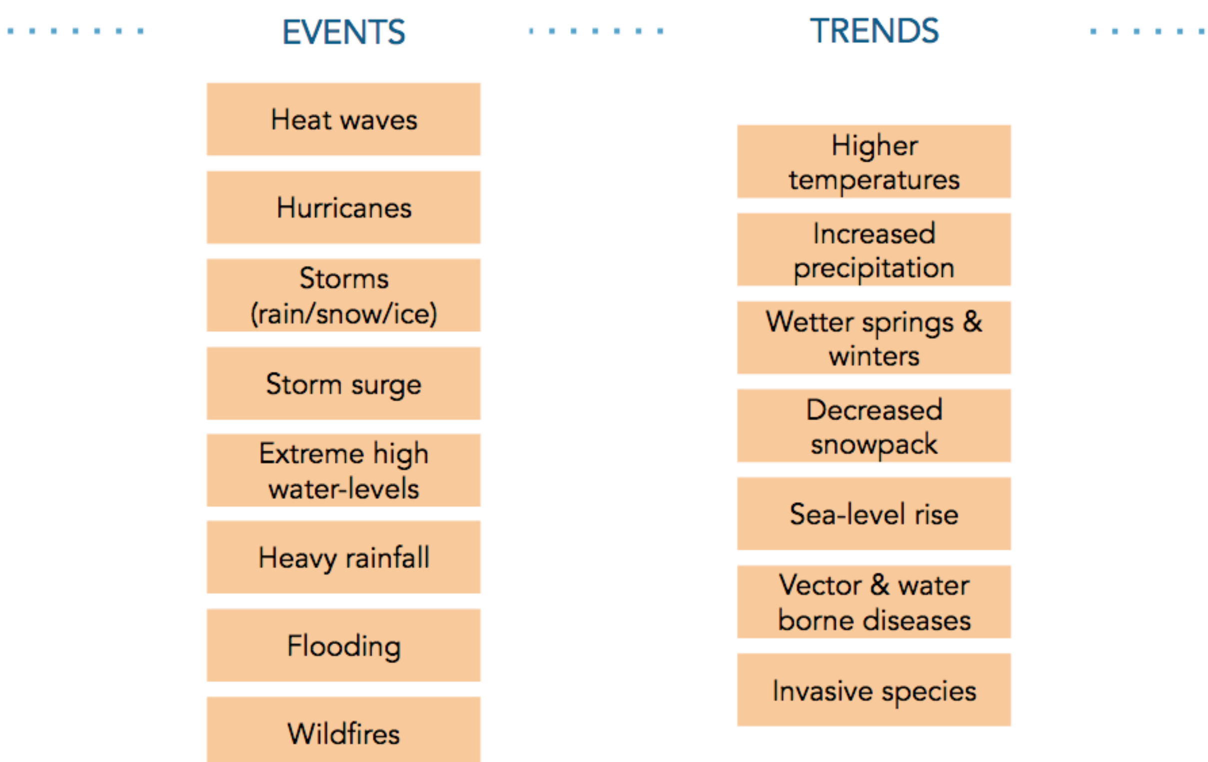


Figure 2. Climate hazard events and trends.

These hazards pose risks for people, infrastructure and the built environment, natural systems and resources, economies, livelihoods and safety; this includes health impacts, damage to property, disruption in critical infrastructure systems, business and service interruptions, increasing demand for health and emergency management services, inhibiting mobility and access to services, impacts on water quality and quantity, and impacts for food production and distribution.

The risks and impacts that Halifax faces from a changing climate include:

- **Physical infrastructure** (buildings, transportation (roads, bridges, railways), energy supply, ICT, water & WW infrastructure etc.):
    - Damage from extreme weather events such as heavy precipitation, hurricanes/high winds, storms, and flooding;
    - Damage to coastal infrastructure & property from inundation, saltwater intrusion, and coastal erosion due to sea-level rise and storm surges;
    - Increased probability of power outages and grid failures;

- Increasing risk of cascading infrastructure failures.

- **Water supply**:
  - Reduced water quality and quantity (declining or less regular water supply) due to changing precipitation patterns, diminishing snowpack, earlier or more variable spring runoff, increasing temperatures, inundation and saltwater intrusion from sea level rise and storm surge.

- **Food systems**:
  - Risks to agriculture and food systems, including adverse impacts on agricultural crops (decreased crop yield and decreased nutritional quality of crops grown), increased food prices, contaminated water and food supplies, increases in new and existing pests and diseases, and damage and disruption to food supply and distribution infrastructure from extreme events.

- **Ecosystems**:
  - Threats to biodiversity, ecosystem resilience, and the ability of ecosystems to provide a range of benefits to people (such as environmental regulation, provision of natural resources, habitat, and access to culturally important activities and resources).

- **Natural resources industries**:
  - Risks to fisheries and fish stocks, including declining fish stocks and less productive/resilient fisheries due to changing marine and freshwater conditions, ocean acidification, invasive species, and pests;
  - Risks to forestry, including declining forest health and lower production of timber and forest products due to changing weather patterns, increasing frequency of extreme weather events, increasing range of invasive species and/or pests, and growing prevalence of wildfires.

- **Human health and wellbeing**:
  - Adverse impacts on physical and mental health due to hazards such as extreme weather events, heatwaves, lower ambient air quality, and increasing ranges of vector-borne pathogens.

- **Emergency services**:
  - Increased demands on emergency services (full-time and volunteer emergency service personnel and non-government organisations) from extreme weather events, along with decreased recovery times as events happen more frequently and or concurrently.

- **Economy and business**:

- Risk of financial impacts to businesses and organizations from direct damage or interruptions to assets, operations, supply chain, transport needs, and employee safety;
- Financial performance may also be affected by changes in water availability, sourcing and quality, and grid reliability.

- **Governance and capacity**:
  - Risks related to the capacity of government to effectively provide public services, manage and respond to climate risks, and maintain the public's trust, including new or increased obligations on government policies, programs, and budgets.

Greenhouse gas emissions

Business-as-usual (BAU) emissions

A baseline greenhouse gas (GHG) emissions inventory for 2016, and a base case business-as-usual (BAU) reference scenario to 2050 was modelled to determine existing GHG emissions, and projected GHG emissions out to 2050 for the Halifax Regional Municipality (community-wide).

The BAU scenario illustrates the anticipated emissions associated with population and employment growth projections for HRM, if no additional policies, actions or strategies to address energy and emissions are implemented towards 2050, other than those currently underway or planned (eg. BAU includes Nova Scotia Power's projected/currently planned projects to reduce emissions of the electricity grid out to 2050).

- Under a BAU scenario, emissions are expected to decrease from 5.8 MtCO2e in 2016 to 3.9 MtCO2e in 2050 (-33%) (Figure 3);
- Per capita emissions are projected to decrease from 13.1 tCO2e/person in 2016 to 6.8 tCO2e/person in 2050 (-48%);
- The majority of the emissions reductions in the BAU are expected as a result of the projected decarbonization of the provincial electricity grid, improved fuel efficiencies in vehicles towards 2035,

marginal electrification of the transportation sector, and a decrease in space heating energy demand as a result of a warming climate.
Refer to the *Baseline and Business-as-usual Report f*or further details on the baseline inventory and BAU.

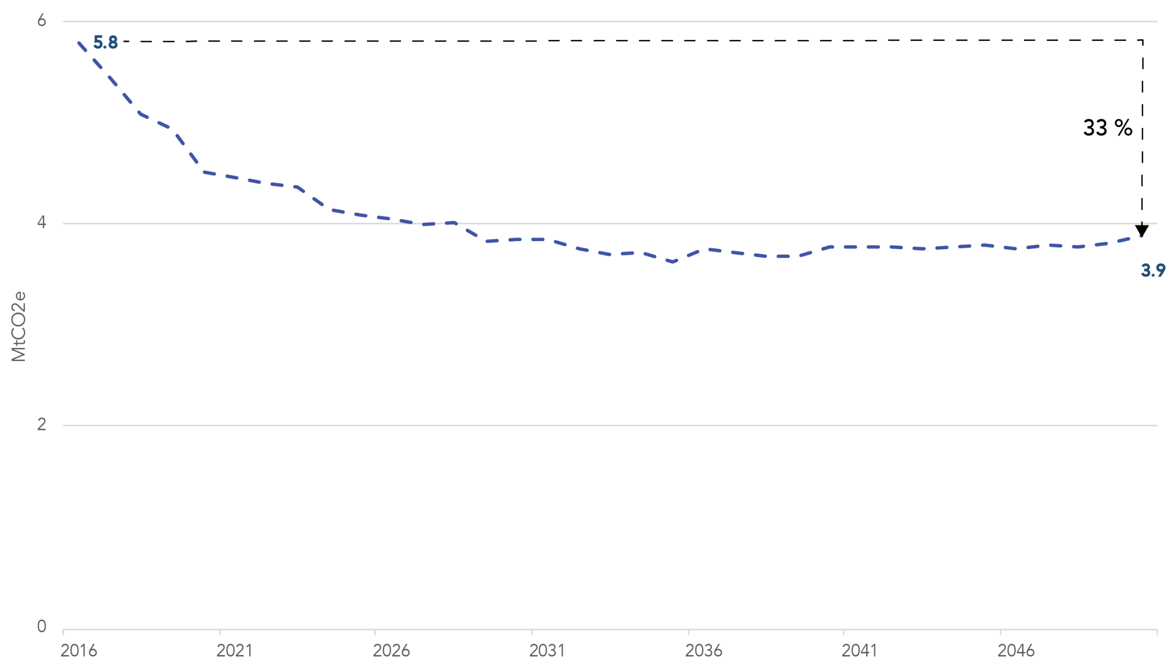


Figure 3. Projected BAU emissions (MtCO2e), 2016-2050

Aligning with the Paris Agreement and 1.5°C

The Paris Agreement's long-term temperature goal is to reduce greenhouse gas emissions to keep the increase in global average temperature to well below 2 °C above pre-industrial levels, and to pursue efforts to limit the increase to 1.5 °C, recognizing that this would substantially reduce the risks and impacts of climate change.

Subsequently, the Special Report on Global Warming of 1.5°C (SR15), published by the Intergovernmental Panel on Climate Change (IPCC) in October 2018, indicates that climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth are projected to increase with global warming of 1.5°C and increase further with 2°C. As such, limiting warming to 1.5°C has become the new benchmark for determining needed emissions reduction pathways and carbon budgets. SR15 indicates that limiting global warming to 1.5°C with no or limited overshoot **requires rapid and far-reaching transitions** in energy, land, urban and infrastructure systems (including transport and buildings), and industrial systems.

Emissions reduction targets for 2030 and 2050 were developed to establish a benchmark for Halifax to align with limiting global temperature increase to 1.5°C. These benchmark targets were established using C40 Cities' targets for cities globally, which sets a target of 2.9 tCO2e per capita by 2030, and 0 tCO2e per capita by 2050. This results in an emissions target of 1.4 MtCO2e by 2030 (reduction of 75% by 2030 from 2016), and zero or net-zero MtCO2e by 2050 (reduction of 100% by 2050 from 2016) for Halifax (Figure 4).

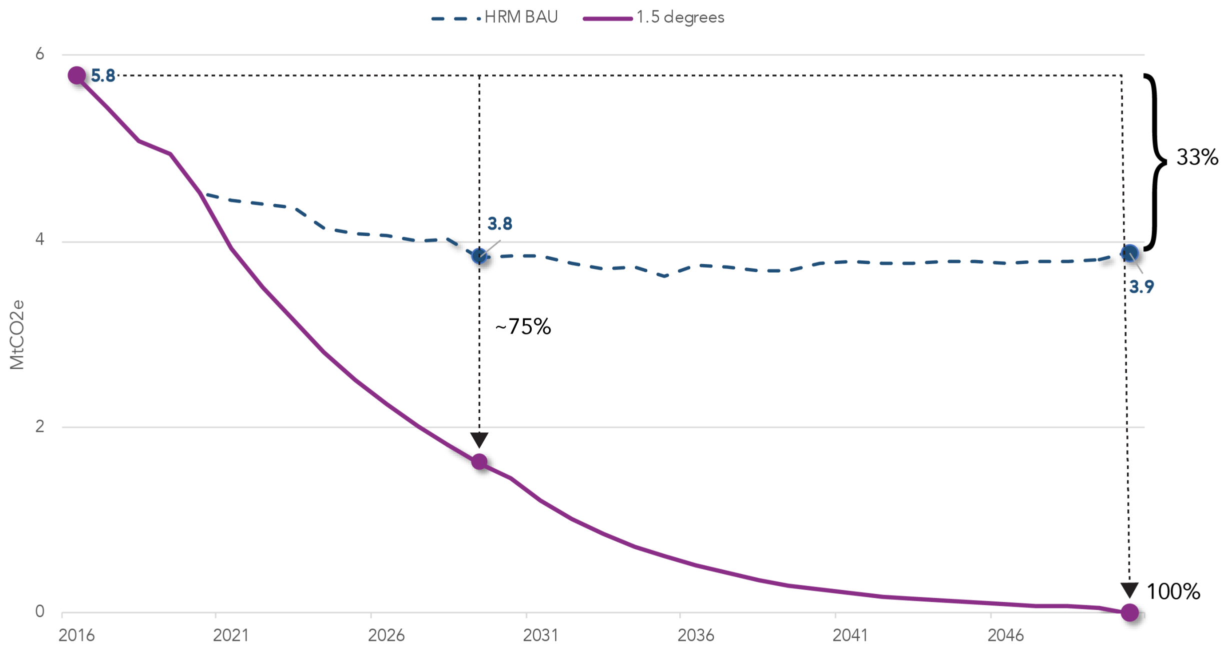


Figure 4. Percentage reductions to align with 1.5C.

These targets were further used to establish a carbon budget for Halifax. A carbon budget is the total amount of carbon dioxide equivalent (or cumulative emissions) that can be emitted to the atmosphere to remain within the 1.5°C threshold. Under the 1.5°C pathway (Figure 5), this equates to a carbon budget of 37 MtCO2e between 2020-2050. That is, to align with 1.5°C, Halifax cannot cumulatively emit more than 37 MtCO2e between now and 2050.

Under the BAU scenario, cumulative emissions in Halifax are projected to reach 121 MtCO2e, significantly higher than the 1.5°C budget. In the absence of immediate and significant efforts to reduce emissions, Halifax will exceed the 1.5°C budget by 2028.

Figure 5. Cumulative carbon [carbon budget] 2020-2050 (Mt CO2e) for HRM BAU and 1.5C.

The application of targets and a carbon budget for Halifax to align with 1.5°C illustrate two key messages:

- **The pathway matters.** It is not just about the end [2050] target, but the pathway that is taken to get there, as the cumulative emissions that add up along the way play a significant role.
- **It's not just the scale of effort, but the speed.** Aligning with 1.5°C requires a steep (rather than gradual) decline in emissions, specifically in the next 10 years. The importance of this period cannot be overstated. **Significant and transformative action in the immediate near-term is imperative.**

Modelling

MODELLING

Introduction

Modelling was undertaken to explore potential emissions reduction scenarios for Halifax to support the development of the HalifACT2050 plan. Three scenarios were modelled, each with increasing ambition and 2050 targets. During the scenarios modelling exercise (alongside the analysis of the 1.5°C benchmark targets and carbon budget, and through large stakeholder support for a net-zero by 2050 target), it became evident that a steep decline scenario was required to align with the 1.5°C pathway. This ambition is depicted in the third scenario (LC3), and forms the basis for the detailed actions and recommendations in this report.

Modelling approach

Emissions reductions modelling was undertaken using CityInSight, an integrated energy and emissions model developed by SSG and whatIf? Technologies, and the same model used for developing the baseline and BAU energy and emissions profile.

Three emissions reduction scenarios (LC1, LC2, and LC3) were developed through establishing a series of emissions reductions actions and assigning modelling assumptions to each action in terms of scale and timing of deployment; for example: *starting in 2020, increase solar photovoltaic (PV) installations, so that by 2050, xx MW is installed*. The level of ambition increases from LC1 to LC3 through either scaling up the level of action (e.g. increasing MW of solar PV), deploying the action or achieving the target sooner (e.g. by 2040 or 2030), or both.

Emissions reduction actions, discussed further in *Modelled actions, assumptions and results for LC3*, were explored across five major areas: buildings; energy supply; transportation; water and wastewater; and, solid waste.

Reduce, Improve, Switch, Generate

The development of actions and the approach to modelling is informed by a framework of Reduce, Improve, Switch, Generate. Adapted from similar approaches such as Reduce-Reuse-Recycle (from the waste sector), and Avoid-Shift-Improve (from the transportation sector), it provides guidance on an overall approach to community energy and emissions planning.

In general, emissions reductions are realized through actions that ***reduce*** energy use (e.g. behaviour change, envelope improvements), those that ***improve*** the use of energy (e.g. appliance efficiencies, lighting), and those that ***switch*** from the use of carbon-intensive fuels to less or zero carbon intensive fuels (e.g. electric vehicles). When a steep decline in emissions is needed, actions in all three areas are a necessary step; accompanying this will the need to ***generate*** local renewable low or zero carbon energy.

The logic of the approach is that reducing and improving energy use not only reduces emissions directly, but also reduces the size of renewable energy generation that will be needed, especially when accompanied by significant fuel switching; a necessary step towards deep carbonization.

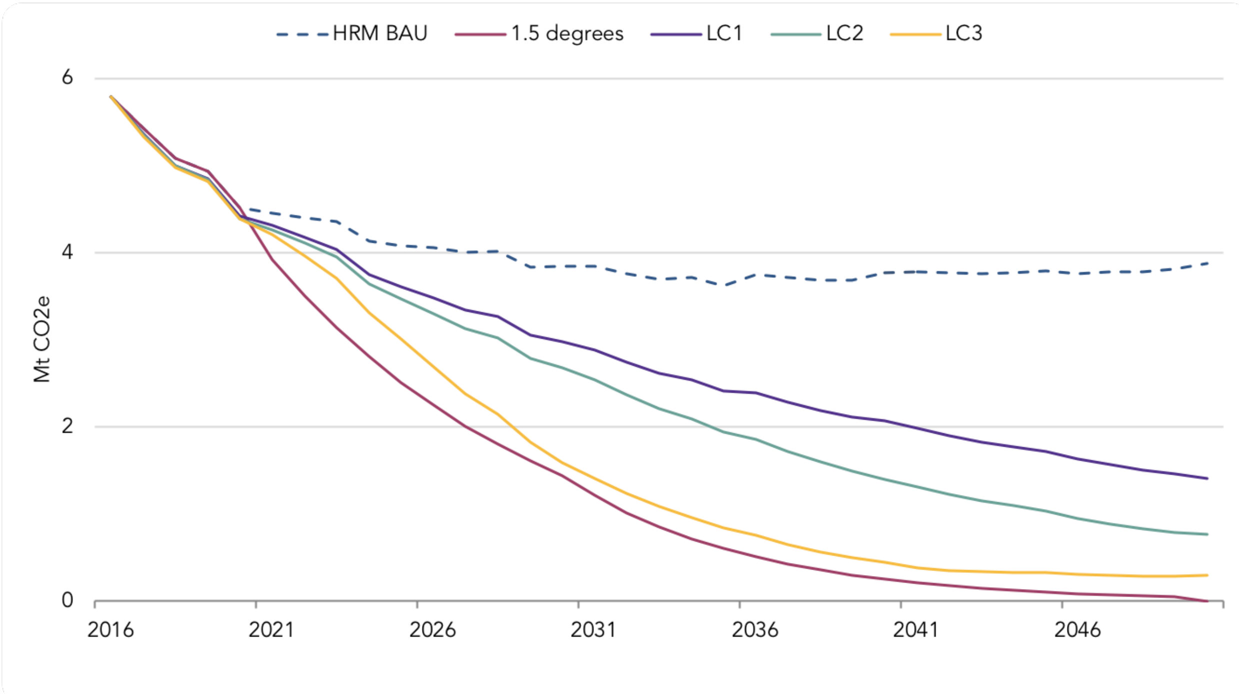
Results

Scenario results

The results of the three scenarios, along with the BAU and 1.5°C benchmark pathway are shown in Figure 6. While LC1 and LC2 achieve annual emission reductions of 76% and 87% respectively by 2050, they remain short off the 1.5°C benchmark target. The emissions decline pathways of these two scenarios are more gradual, resulting in significant cumulative emissions. Under LC1, approximately 82 Mt CO2e are emitted between 2020 and 2050, over 2.2 times larger than the 1.5°C carbon budget of 37 Mt CO2e (Figure 7). Under LC2, 68 Mt CO2e are emitted.

Under LC3, 95% of emissions are reduced by 2050, with 45 MtCO2e of cumulative emissions from 2020-2050. LC3 includes significant efforts to improve energy efficiency and shifts to renewable sources with current-day technology; however, 5% of emissions remain in 2050, and the 1.5°C carbon budget is exceeded by 8 Mt CO2e.

The ability to address the remaining 5% will improve in the next 30 years as new technologies and other fuel sources (such as hydrogen) are developed. While improvements in technology towards 2050 will contribute to limiting cumulative emissions, the timing of action is much more important. Deploying current-day technology on a bigger scale, over a shorter period of time, in the very near future, is the key to limiting cumulative emissions.



	% reduction 2016-2050	MtCO2e in 2050
LC1	76%	1.4
LC2	87%	0.8
LC3	95%	0.3
1.5C	100%	0

Figure 6. Emissions trajectories (Mt CO2e) and resulting 2050 percentage reductions for Halifax: BAU, LC1, LC2, LC3, and 1.5C, 2016-2050.

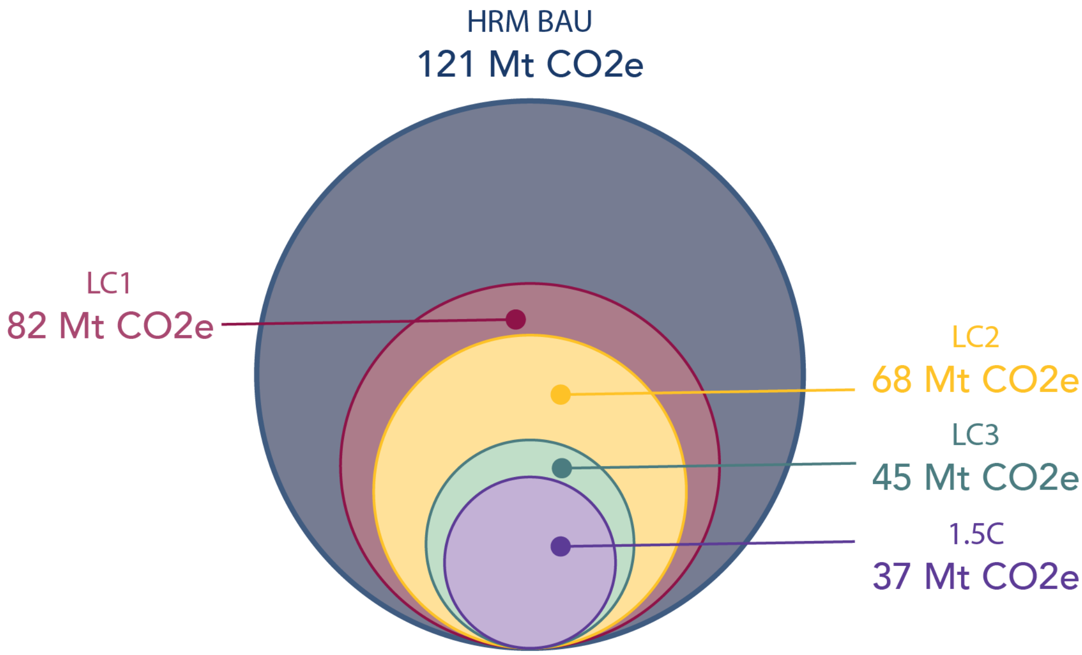


Figure 7. Cumulative carbon [carbon budget] 2020-2050 (Mt CO2e) for HRM BAU, LC1, LC2, LC3, and 1.5C.

Modelled actions, assumptions, and results for LC3

A list of modelled actions, the associated technical modelling assumptions, and emissions reduction results by action theme are shown in Table 1. Figure 8, referred to as a wedge diagram, illustrates the emissions reduction impacts of the LC3 scenario actions relative to the BAU scenario. Emissions reductions from each action are represented by colours (or colour wedges), while remaining GHG emissions are represented by the grey area.

A detailed list of actions and associated modelling assumptions for the LC3 scenario is included in Appendix B

Table 1. Relative emissions reduction in 2050 by modelled action category.

Action theme	**Assumption**	**Emissions reduction in 2050 (kt CO2e)**
Retrofit existing buildings		1,470
Retrofit existing residential buildings	Deep retrofit 100% of all existing residential buildings by 2040	910
Retrofit existing non-res buildings	Deep retrofit 100% of all existing non-residential buildings by 2040	560
Rooftop solar PV & storage		**670**
Rooftop solar pv & storage - residential	800 MW by 2030	350
Rooftop solar pv & storage - non-residential	500 MW by 2030	320
Utility scale renewables		**580**
Wind	280 MW	240
Ground mount solar pv	200 MW by 2030 + 100MW between 2030-2050	180
District energy	Switch 100% of existing DE to renewable sources by 2050 & expand new renewable fueled DE	160
Net-zero new construction		**360**
Net-zero new buildings - non-residential	New residential construction net-zero by 2030	190
Net-zero new buildings - residential	New non-residential construction net-zero by 2030	180

Low carbon transportation		**280**
Electrify personal, commercial & municipal vehicles	100% new personal and commercial vehicles sales are EV post 2030 Municipal fleet 100% EV by 2030	280
Low carbon transit & active transportation		**70**
Transit & active transportation infrastructure	Infrastructure built to deliver IMP mode share targets by 2030	70
Industrial efficiency		**80**
Industrial energy use	Improve industrial operational efficiency 75% by 2040	80
Water & wastewater		**50**
Water & WW treatment & pumping energy	Reduce water & WW treatment & pumping energy use 50% by 2050	25
WW biogas recovery	80% wastewater through anaerobic digestion by 2030	25
Waste		**30**
Waste reduction, diversion & biogas recovery	100% diversion by 2050 Reduce generation 30% by 2050 100% organics to anaerobic digestion	30
	Total emissions reduction in 2050	**3,590**
	BAU emissions in 2050	3,890
	Remaining emissions reduction in 2050	300

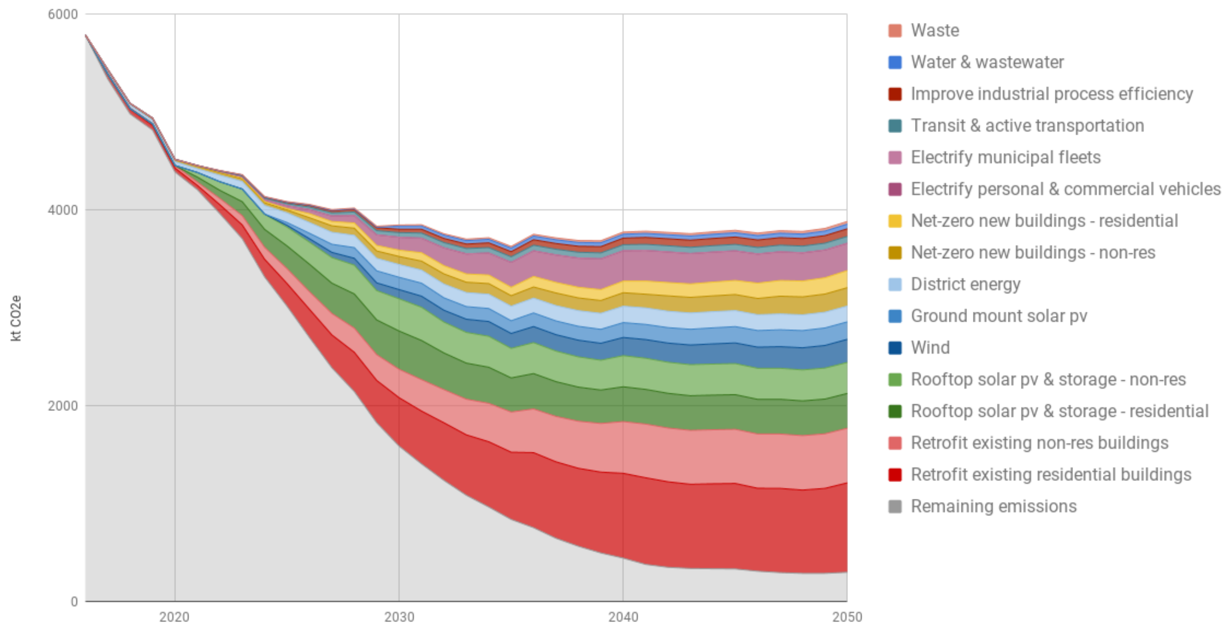


Figure 8. Wedge diagram showing emissions reduction by action area to 2050 in the LC3 scenario.

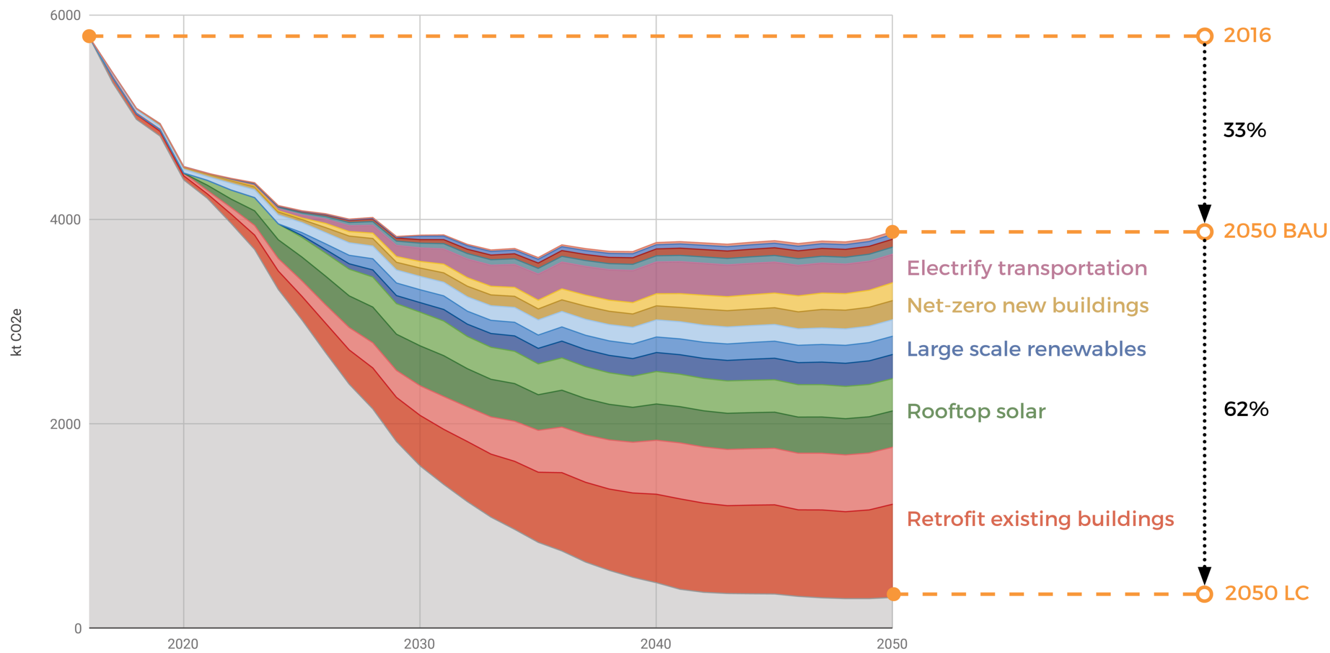


Figure 9. Wedge diagram showing the relative emission reduction (kt CO2e) by action area and percentage reduction to 2050 in the LC3 scenario.

LC3 energy and emissions outcomes

Energy

In the LC3 scenario, by 2050 fuel and electricity consumption decrease by 65% from the 2016 base year levels. (Figure 10, Table 2).

The largest reductions are in the residential and transportation sectors, with decreases of 71% and 74%, respectively, resulting from retrofitting, net-zero new construction, and low-carbon transportation actions.

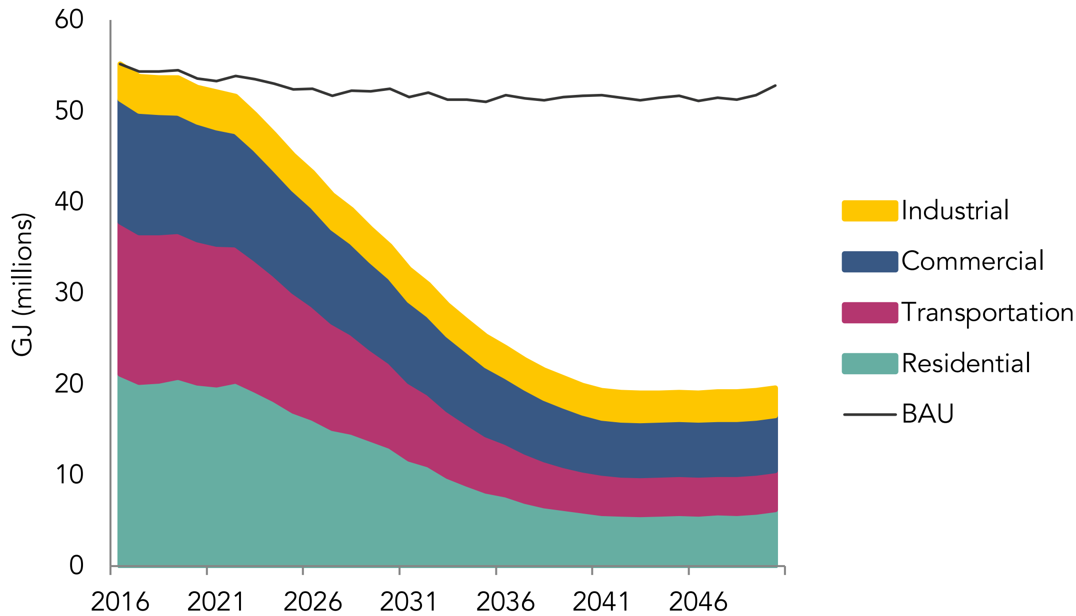


Figure 10. LC3 energy consumption (PJ) by sector, 2016-2050.

Buildings are the largest energy consumer in Halifax, totally 38,451 TJ in 2016 (70% of community energy use). Actions in the LC3 scenario include deep energy retrofits for residential and non-residential buildings, switching space and water heating systems to electricity, implementing green building standards to improve energy efficiency of new buildings, and improving industrial process energy use. These actions collectively decrease building energy use to 15,242 TJ in 2050, 60% below 2016 levels (Figure 4, Table 2).

The transportation sector is the second highest energy consumer, accounting for 30% of energy use, or 16,708 TJ in 2016. Actions in the LC3 scenario, which include an expedited uptake of electric vehicles, increasing walking, cycling and transit mode shares through transit and active transportation infrastructure, result in a 74% decrease in energy consumption to 4,292 TJ by 2050 (Figure 4, Table 2). Improvements to vehicle efficiency standards drive some of the decrease in transportation energy use in personal vehicles and more in commercial vehicles, but the majority of energy savings are a result of electrification of personal and commercial vehicles and the complete electrification of the municipal vehicle fleet.

Fuel sources in 2016 are primarily electricity (29%), gasoline (26%), and fuel oil (18%). Diesel, natural gas, propane, wood, and other sources make up the remainder. In the LC3 scenario, electricity becomes the dominant energy source (76%).

Annual electricity consumption remains relatively constant between 2016 and 2050 as actions to reduce electricity consumption and improve efficiencies (eg. retrofits) stay on par with those that fuel switch to electricity (eg. electric vehicles), resulting in a balanced total demand over time.

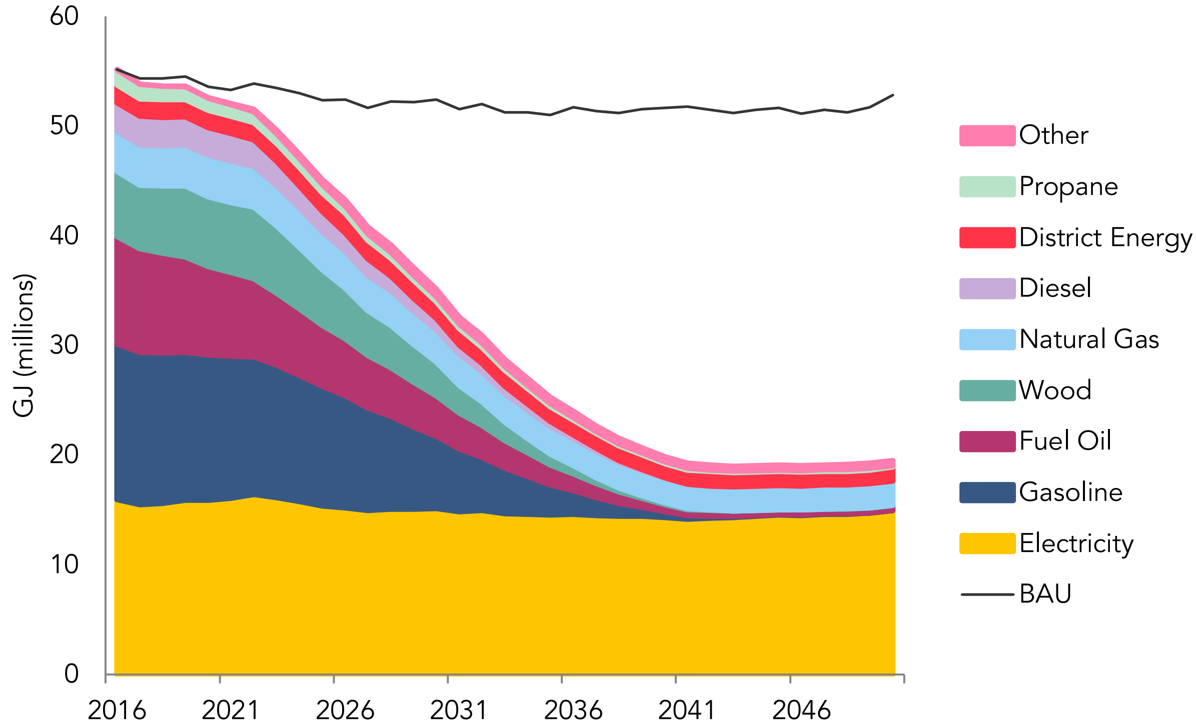


Figure 11. LC3 energy consumption (PJ) by fuel, 2016-2050.

Table 2. LC3 community energy consumption tabulated results, 2016 & 2050 (BAU).

	2016		2050 LC3		[+/-] % 2016-2050
	GJ	share	GJ	share	
Energy by fuel					
Diesel	2,597,000	5%	17,000	0%	-99%
District Energy	1,629,000	3%	1,255,000	6%	-23%
Electricity	15,970,000	29%	14,941,000	76%	-6%
Fuel Oil	9,819,000	18%	459,000	2%	-95%
Gasoline	14,138,000	26%	29,000	0%	-100%
Natural Gas	3,693,000	7%	2,186,000	11%	-41%
Other	2,000	0%	492,000	3%	-
Propane	1,386,000	3%	145,000	1%	-90%
Wood	5,925,000	11%	10,000	0%	-100%
Total	55,159,000		19,534,000		-65%
Energy by sector					
Commercial	13,509,000	24%	6,046,000	31%	-55%
Industrial	3,827,000	7%	3,009,000	15%	-21%
Residential	21,115,000	38%	6,187,000	32%	-71%
Transportation	16,708,000	30%	4,292,000	22%	-74%
Total	55,159,000		19,534,000		-65%

Emissions

As energy demand is decreased under LC3 implementation, so too are GHG emissions; LC3 achieves a 95% reduction from 2016 levels in 2050, with 300 kt CO2e in annual emissions remaining in 2050 (Figure 12, Table 3).

Residential and transportation emissions are all but phased out by 2050, while commercial buildings and waste emissions are reduced to very little. Remaining emissions in 2050 result from the industrial sector, where some natural gas use remains, and emissions from grid electricity use across all sectors.

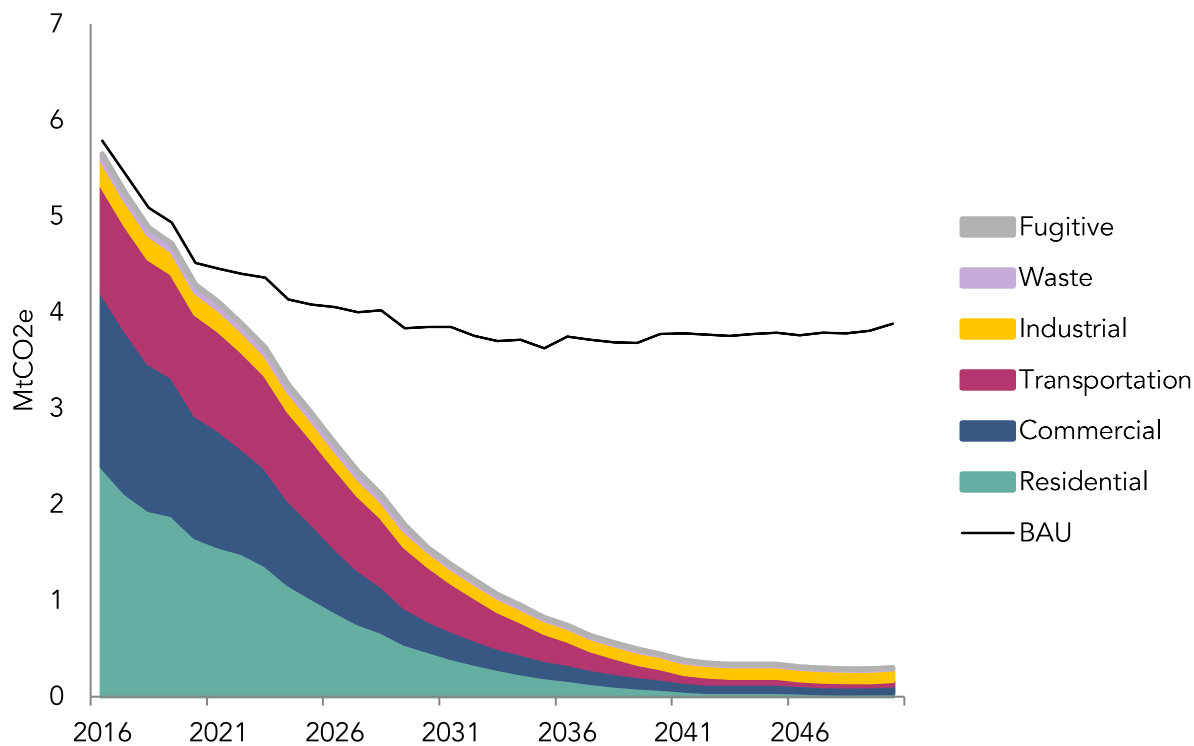


Figure 12. LC3 emissions (MtCO2e), by sector, 2016-2050.

The LC3 scenario significantly reduces energy demand across all sectors, alongside a major shift to electricity. In 2016, emissions from electricity represent 58% of total emissions. By 2050, emissions from electricity decrease significantly (-96%). This is partly as a result of the currently projected decrease in the emissions intensity of the provincial electrical grid, but also as a result of the significant increase in local renewable electricity generation (solar PV and wind) in LC3. While emissions from electricity are decreased significantly towards 2050, electricity continues to represent the largest source of emissions (45%). Continued decarbonization of the provincial electricity grid, beyond what is currently planned, will be necessary to continue to reduce this source of emissions.

Detailed results for energy and emissions by sector and fuel under the LC3 scenario are included in Appendix A.

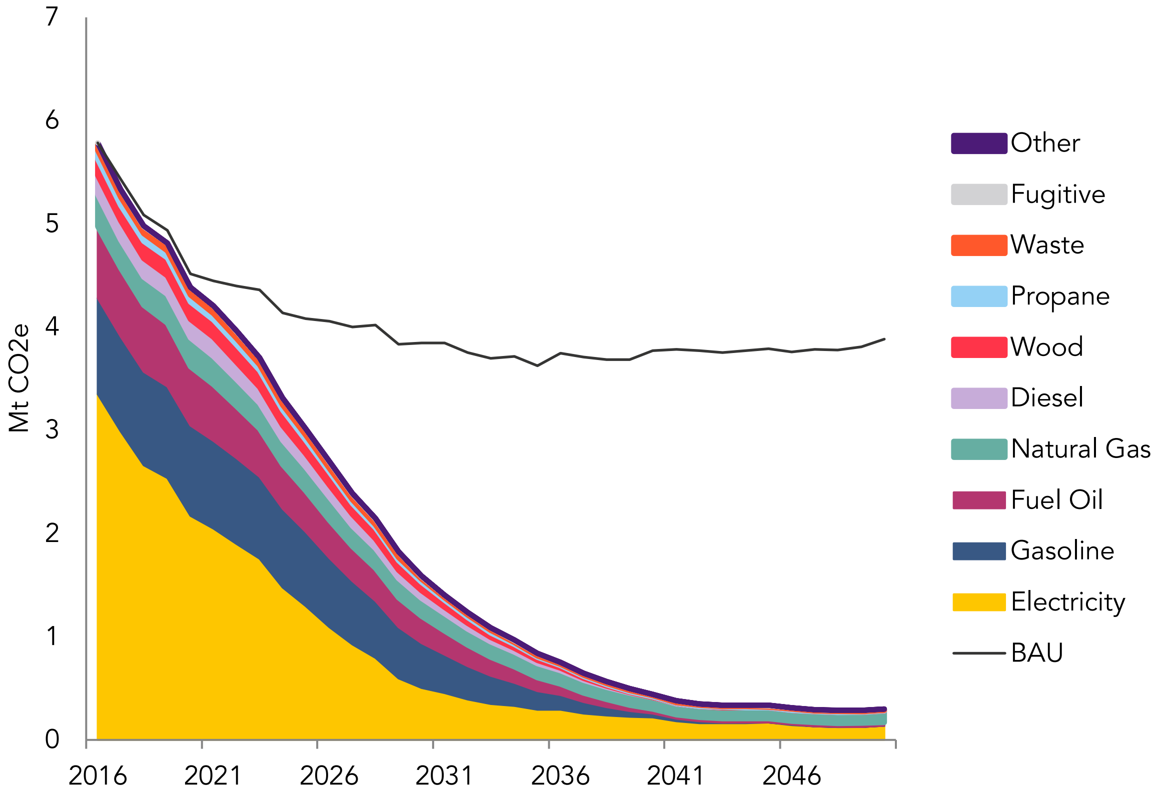


Figure 13. LC3 emissions (MtCO2e), by fuel, 2016-2050.

Table 3. LC3 community emissions tabulated results, 2016 & 2050 (BAU).

	2016		2050 LC3		[+/-] % 2016-2050
	kt CO2e	share	kt CO2e	share	
Emissions by sector					
Commercial	1,800	31%	80	25%	-96%
Energy Production	140	2%	0	0%	-100%
Fugitive	-	0%	0	0%	-65%
Industrial	260	5%	120	40%	-54%
Residential	2,400	41%	50	15%	-98%
Transportation	1,110	19%	50	16%	-96%
Waste & wastewater	70	1%	10	3%	-86%
Total	5,780		300		-95%
Emissions by source					
Diesel	190	3%	0	0%	-99%
Electricity	3,350	58%	140	45%	-96%
Fuel Oil	700	12%	30	11%	-95%
Fugitive	-	0%	0	0%	-65%
Gasoline	930	16%	0	1%	-100%
Natural Gas	310	5%	110	36%	-65%
Other	-	0%	0	0%	-
Propane	80	1%	10	3%	-90%
Waste & wastewater	70	1%	10	3%	-86%
Wood	160	3%	0	0%	-100%
Total	5,780		300		-95%

Financial analysis

High-level financial analysis was undertaken to identify the costs, savings, net present value, and marginal abatement costs of the modelled actions. In both the BAU and LC3 scenarios, expenditures are made and savings occur; the financial information presented here shows the incremental additional expenditures required and savings resulting from the implementation of the LC3 scenario over those that are expected to be incurred BAU scenario.

Costs and Savings Summary

Costs and savings modelling considers upfront capital expenditures, operating and maintenance costs (including fuel and electricity), and carbon pricing. Table 4 summarizes expenditure types that were evaluated. Expenditures that were not included, due to lack of data or other limiting factors, include costs for other non-fleet related transit infrastructure, EV charging infrastructure, infrastructure to reduce water and wastewater energy use, and costs to reduce waste generation and recovery (eg. anaerobic digestion).

Table 4. Categories of *expenditures* evaluated.

Category	Description
Residential buildings	Cost of dwelling construction and retrofitting (incl. equipment); operating and maintenance costs (non-fuel).
Residential fuel	Energy costs for dwellings and residential transportation.
Residential emissions	Costs resulting from a carbon price on GHG emissions from dwellings and transportation.
Non-residential buildings	Cost of building construction and retrofitting (incl. equipment); operating and maintenance costs (non-fuel).
Non-residential fuel	Energy costs for commercial buildings, industry and transport.
Non-residential emissions	Costs resulting from a carbon price on GHG emissions from commercial buildings, production and transportation.
Energy production emissions	Costs resulting from a carbon price on GHG emissions for fuel used in the generation of electricity and heating.
Energy production fuel	Cost of purchasing fuel for generating local electricity, heating or cooling.
Energy production equipment	Cost of the equipment for generating local electricity, heating or cooling.
Energy production revenue	Revenue derived from the sale of locally generated electricity or heat.
Personal, commercial & municipal/transit vehicles	Cost of vehicle purchase; operating and maintenance costs (non-fuel).
Vehicle fuel	Energy costs for transportation fuel
Vehicle emissions	Costs resulting from a carbon price on GHG emissions from transportation.
Water and waste treatment	Cost of water, waste and wastewater treatment operations
Water and waste emissions	Costs resulting from a carbon price on GHG emissions from water, waste and wastewater operations.

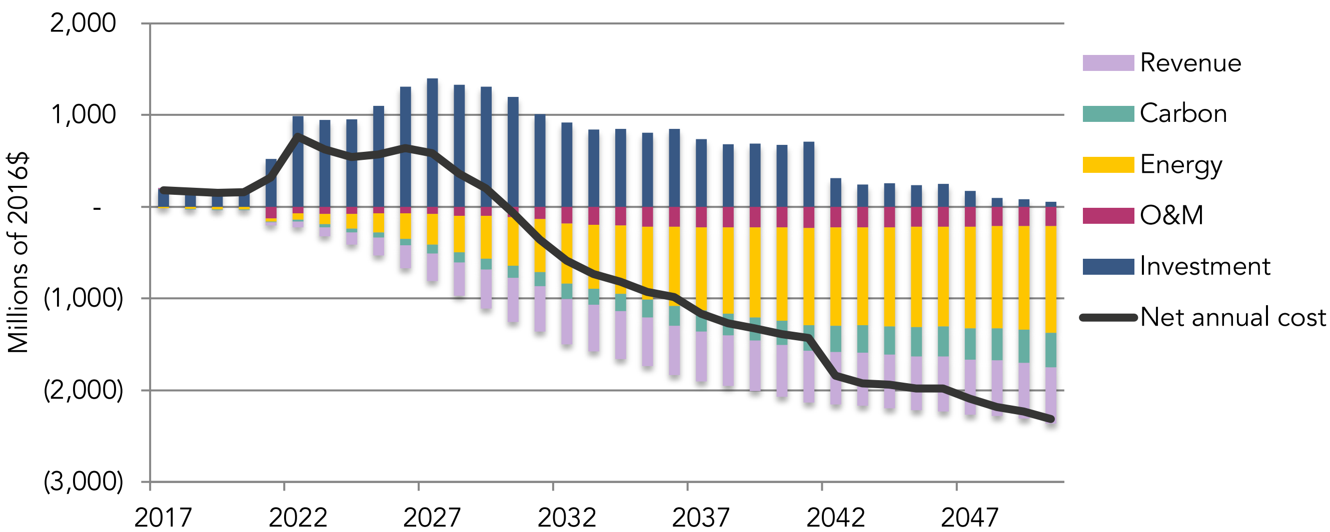


Figure 14. Summary of annual LC3 costs (above x-axis) and savings (below x-axis) relative to the BAU scenario.

Figure 14 summarizes modelled annual costs and savings of LC3 over those in the BAU scenario. Costs vary year-over-year as investments in retrofits, solar PV, electric vehicles, and other elements are made. Majority of costs are incurred towards 2030, in-line with the need to act and invest intensely in low carbon action over the next 10 years. Thereafter, annual costs start to decline towards 2040, and trickle off towards 2050, as efforts taper off.

Building mechanical systems and electric vehicles operations and maintenance savings grow over the next thirty years as systems become more efficient and electricity powered, requiring less servicing and replacement. Energy cost savings grow substantially as energy savings are realized from more efficient buildings and vehicles, as well as increased transit use and active transportation (more affordable trips than those made by car).

The rooftop solar PV, ground mount solar PV, and wind generation systems generate substantial revenues for their owners and operators. As more systems are implemented over the time period, the total annual revenues of these systems increase.

Carbon pricing in the LC3 increases the value of fuel and electricity savings, modestly in the first half of the time period but more significantly in later years as the price increases. Federal carbon pricing is currently valued at $20 per tonne of emissions and is scheduled to increase to $50/tonne by 2022. Commitments beyond 2022 have not yet been made, but it is estimated that carbon pricing will be over $100/tonne by 2050.

By 2050, cumulative LC3 implementation costs total $22.1B, with a net present value of $14.9B (at a discount rate of 3%). Total net savings reach $22.3B, with a net present value of $8.7B (Table 5, Figure 15). Savings in each category increase over time as energy efficiency and energy generation actions increasingly result in avoided energy costs, avoided operations and maintenance costs, avoided carbon pricing costs, and increasing energy generation revenues.

Net annual costs rise annually towards 2030, as expenditures outweigh savings. There is an inflection, or break even point, around 2030 where savings, especially from reduced energy costs and revenue from local energy generation, start to outweigh costs.

Table 5: Summary LC3 financial metrics (2016 $ Billions).

	Cumulative costs and savings to 2050 (undiscounted)	Net Present Value (discount rate of 3%)
Costs	$ (22.10B)	$ (14.86B)
O&M savings	$2.94B	$1.63B
Energy cost savings	$21.87B	$11.44B
Carbon price credit	$6.02B	$3.10B
Local generation revenues	$13.57B	$7.36B
Net annual cost/savings	$ 22.3B	$ 8.7B

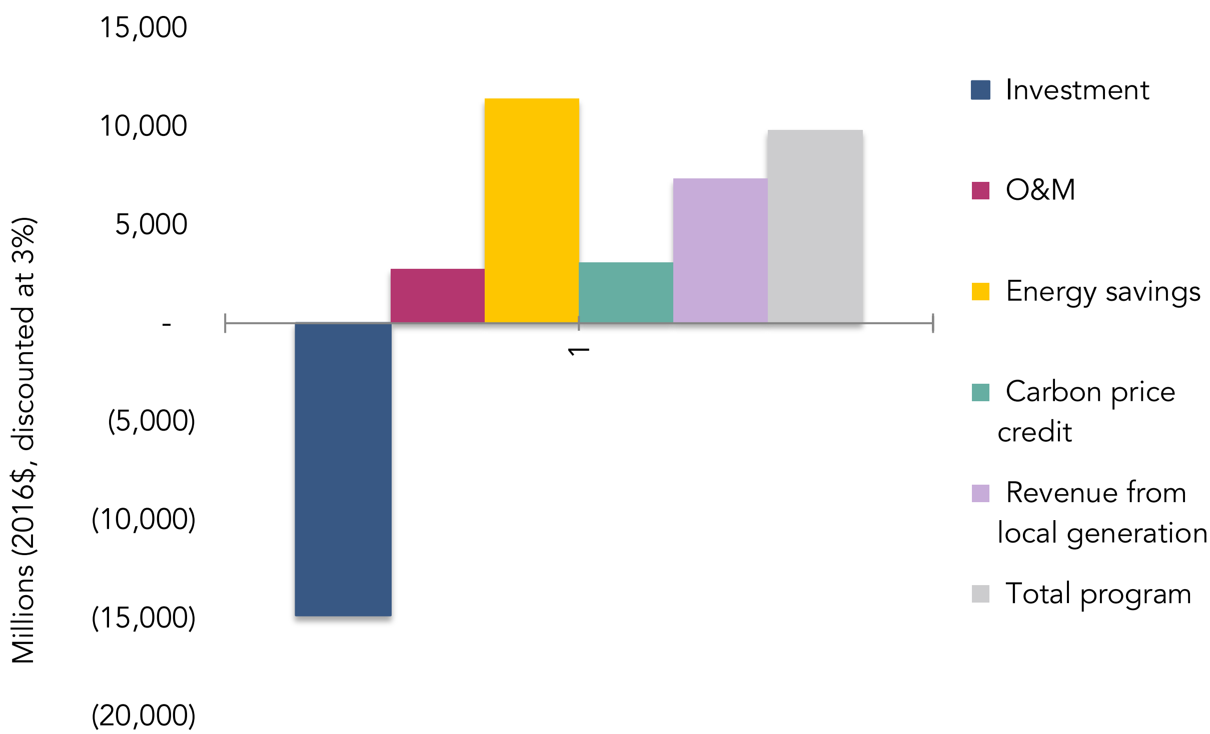


Figure 15. Net present value of costs (negative) and savings (positive) of LC3 over the BAU scenario.

Capital Costs Summary

LC3 capital annual costs are summarized in Figure 16.

Residential retrofits and non-residential retrofit costs dominate capital expenditures and increase over the time period, as more and more buildings are retrofit for energy efficiency, tapering off after 2040 as the majority of retrofits are completed.

Local energy generation investments, specifically rooftop solar PV, are strong over the first 10 years of implementation, then steady for the last 20 years as ground mount solar PV and wind systems continue to be installed towards 2050.

After peaking in the late 2020s, personal vehicle costs steadily decrease as EV ownership grows, until a crossover point in 2048 when net savings begin. The analysis assumes that the cost of electric vehicles will be lower than internal combustion engines by the middle of 2040, a conservative projection.

Transit fleet expansion and electrification, and active transportation costs occur primarily between 2022 and 2031, but continue to occur over the whole 30-year period.

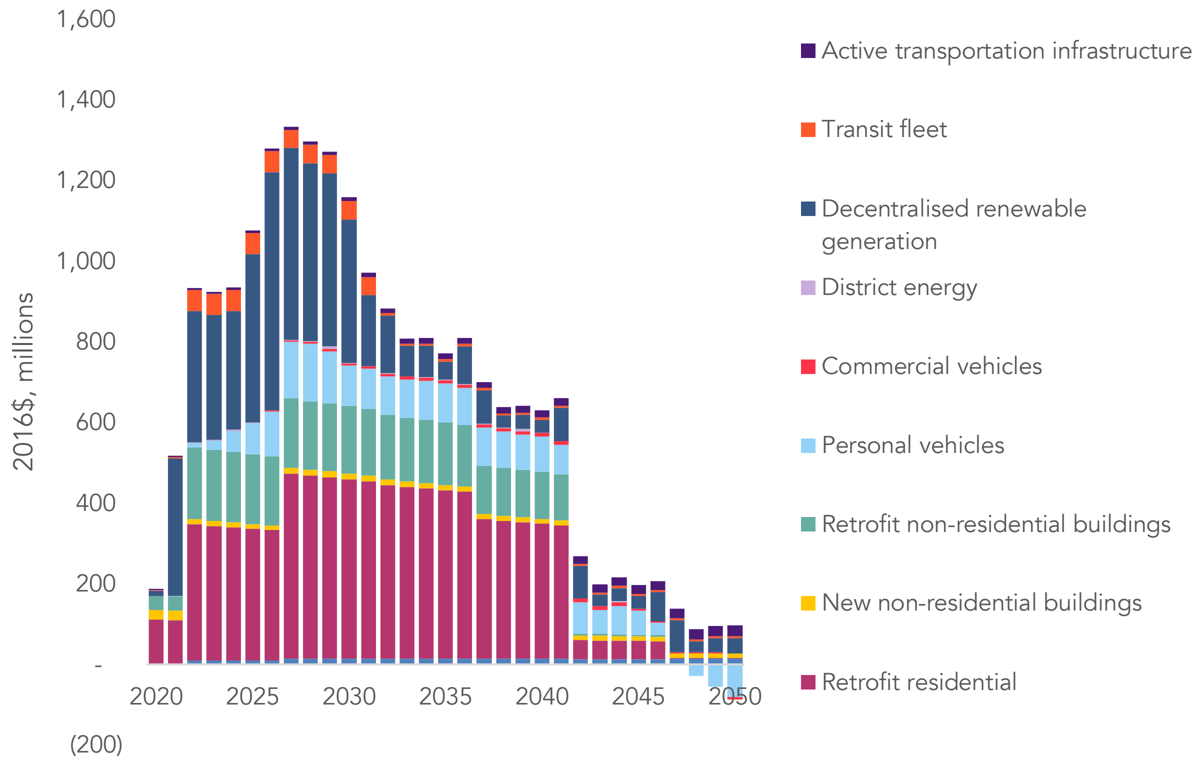


Figure 16. Annual incremental LC3 capital costs over BAU capital costs.

Energy Costs

Figure 17 depicts the expected total energy (fuel and electricity) costs for LC3 versus the BAU scenario.

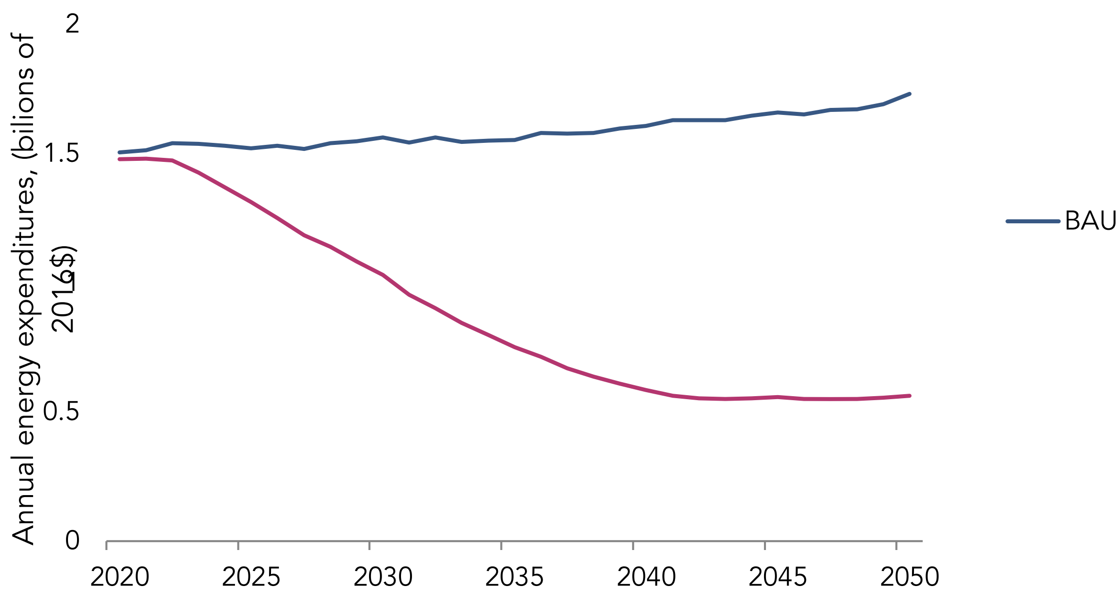


Figure 17. Estimated total annual energy costs for the BAU scenario (blue) and LC3 (green).

LC3 energy costs decrease mostly towards 2030 as retrofits are undertaken, solar PV installations come online, transit is expanded, and electric vehicles uptake increases; decreases in energy costs level off in the 2040s when most energy efficiency efforts have been achieved.

In 2016, total energy costs paid by the residents, businesses, and all other organizations in Halifax totalled $1.50 billion; in the BAU scenario, these are projected to increase to $1.73 billion by 2050. Under LC3 implementation, energy costs are reduced to approximately $565 million in 2050, a 62% decrease compared with 2016, and a third of what they would otherwise be in 2050 in the BAU. Cumulatively, this results in a total of $21.9 billion in avoided energy costs between 2020 and 2050.

Under LC3 implementation, electricity comes to dominate total energy spending as vehicles and building heating systems are electrified through retrofits (Figure 18). Gasoline, diesel and fuel oil spending are all but phased out by the early 2040s.

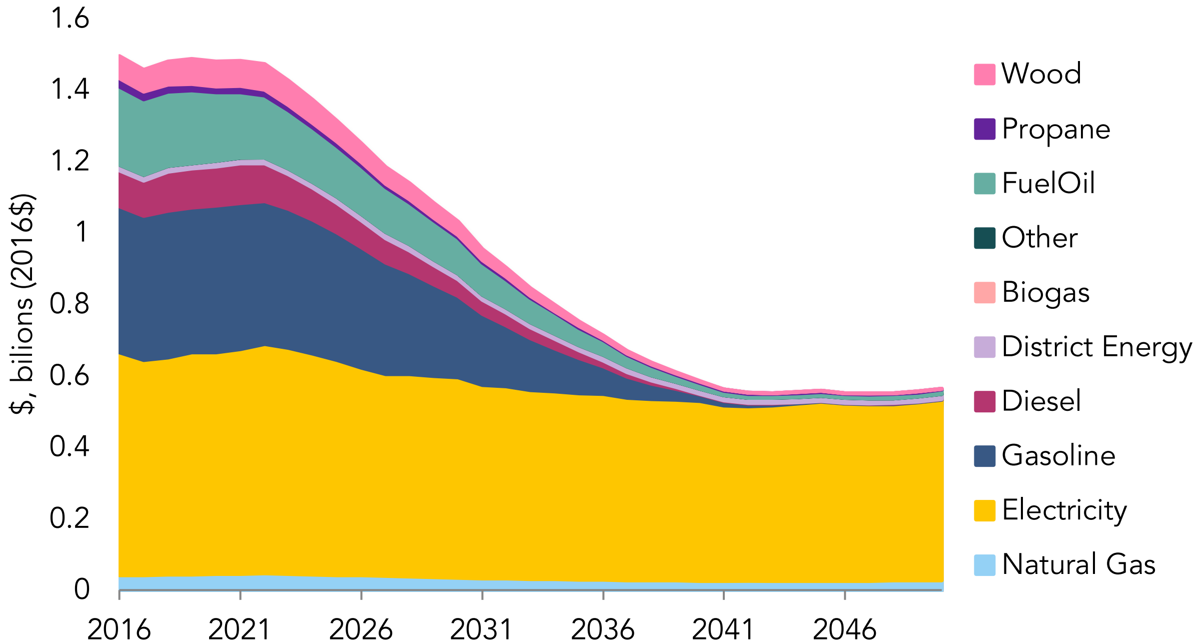


Figure 18. Total LC3 annual energy costs by energy source.

Employment

LC3 capital expenditures result in increased employment. Employment factors for each sector were used to translate each million dollars of activity resulting from LC3 actions into full-time equivalent jobs (Figure 19). The LC3 scenario is estimated to generate approximately 170,000 person years of employment between 2020 and 2050, an average of 5,500 annually, compared to the BAU scenario.

Majority of jobs are in the residential and non-residential building sector, with significant retrofits (including heat pumps and water heating systems) targeted between 2020 and 2040. Local renewable generation jobs increase significantly towards 2030 with significant solar PV installs in the first 10 years, tapering off slightly towards 2040 with continued efforts in community scale solar PV and wind. Some automotive repair jobs are lost (2048-2050) as the requirement for maintenance of electric vehicles is expected to decline.

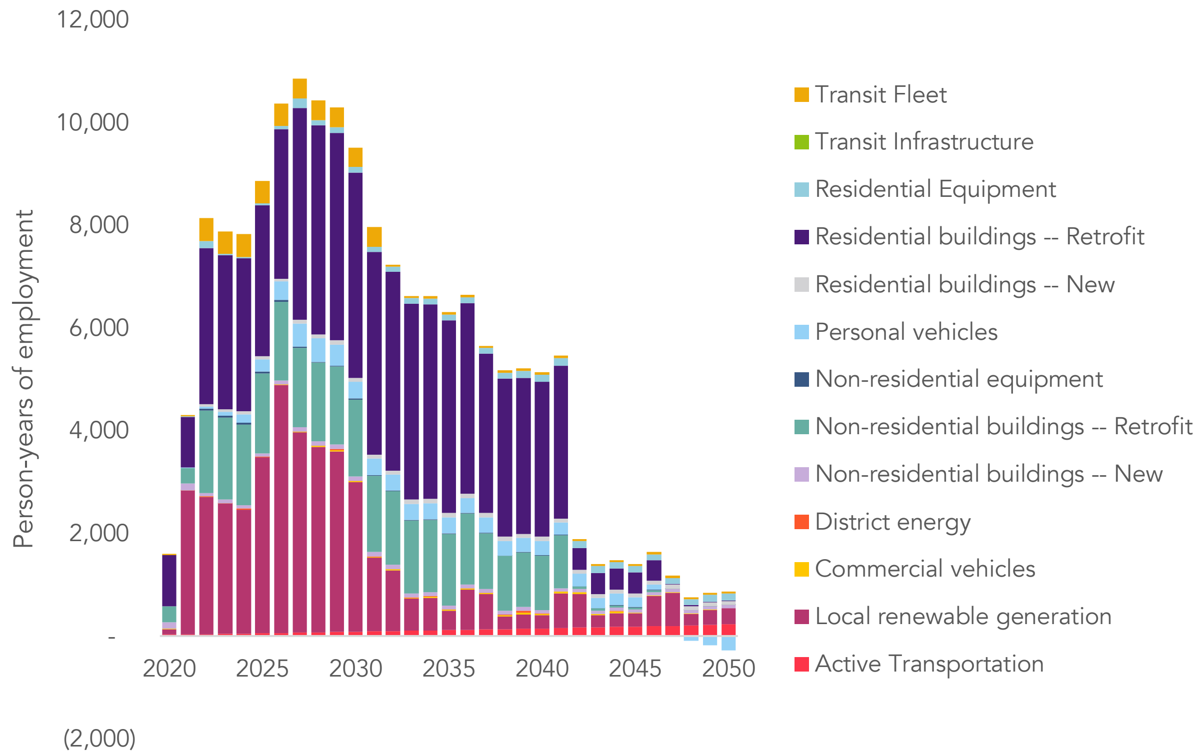


Figure 19. Employment generated by LC3 implementation.

Recommended Actions

RECOMMENDED ACTIONS

Actions summary

	Action name	*Target/objective*
DECARBONIZED & RESILIENT INFRASTRUCTURE		
Efficient buildings		
1	Net-zero and climate resilient new construction	NET-ZERO NEW CONSTRUCTION BY 2030
2	Residential and non-residential deep retrofit program	RETROFIT ALL EXISTING BUILDINGS BY 2040
3	Industrial coalition and support program	IMPROVE INDUSTRIAL PROCESS EFFICIENCY BY 75% BY 2040
Renewable energy		
4	Rooftop solar PV and energy storage program	INSTALL 1,300 MW OF ROOFTOP SOLAR PV WITH STORAGE BY 2030
5	Community scale solar PV and wind generation	SIGNIFICANTLY EXPAND LOCAL COMMUNITY-SCALE RENEWABLE ENERGY GENERATION: - 300 MW GROUND MOUNT SOLAR PV BY 2050 - 280 MW WIND BY 2050 - 100% RENEWABLE DISTRICT ENERGY BY 2050
6	District energy	
7	Provincial electricity grid decarbonization	
Low carbon transportation		
8	Transit and active transportation infrastructure	PLAN AND BUILD THE TRANSIT AND ACTIVE TRANSPORTATION INFRASTRUCTURE NEEDED TO ACHIEVE THE 2030 MODE SHARE TARGETS IN THE INTEGRATED MOBILITY PLAN
9	Personal and commercial vehicle electrification	BY 2030, 100% OF NEW VEHICLE SALES ARE ELECTRIC
10	EV planning and policy	
Greening government operations		
11	Net zero municipal operations	ACHIEVE NET ZERO MUNICIPAL OPERATIONS BY 2030
Water		
12	Net zero water and wastewater operations	ACHIEVE NET ZERO WATER AND WASTEWATER OPERATIONS BY 2030

#	Action	Goal
13	Water supply strategy	FUTURE PROOF WATER SYSTEMS AND SUPPLY
14	Stormwater management plan and program	
Critical infrastructure and services		
15	High level risk assessment (HLRA)	REDUCE RISK TO CRITICAL INFRASTRUCTURE
16	HRM critical infrastructure risk and vulnerability analysis	
17	Zero emissions back-up power	
18	Inspection procedures	
19	Standards for new infrastructure	
Natural areas and green infrastructure assets		
20	Green Network and Urban Forest Master Plans	PROTECT, RESTORE, MAINTAIN AND EXPAND NATURAL AREAS AND GREEN INFRASTRUCTURE ASSETS
21	Region-wide naturalization program	
22	Tree planting and re-greening program	
Planning		
23	Land use planning	PLAN AND BUILD A LOW CARBON RESILIENT REGION
24	Planning for district energy and microgrids	
25	Land protection and conservation	
26	Green space planning	
Coastal preparedness		
27	Detailed risk and vulnerability analysis of coastal, waterfront, and shoreline areas	BETTER PREPARE FOR CLIMATE RELATED COASTAL CHANGES AND IMPACTS
28	Coastal-specific adaptation strategy	
PREPARED AND CONNECTED COMMUNITIES		
Emergency management		

29	Integrate climate into emergency management planning	BETTER PREPARE FOR INCREASED CLIMATE-RELATED EMERGENCIES
30	Develop climate event evacuation plans: flooding, wildfire and coastal storm surge	
Community capacity		
31	Neighbourhood resilience and disaster support hubs	ENHANCE THE CAPACITY OF NEIGHBOURHOODS TO PREPARE FOR AND RECOVER FROM CLIMATE EVENTS
32	Local resident emergency training	
33	Neighbourhood action planning	
34	Broad, deep and collaborative engagement	ENGAGE DEEPLY AND COLLABORATIVELY
Food		
35	Food action plan	IMPROVE FOOD SECURITY AND FOOD SYSTEMS RESILIENCE
Business and economy		
36	Workforce and technology development for building decarbonization and resilience	PREPARE AND LEVERAGE BUSINESS FOR THE TRANSITION
37	Resilient decarbonized businesses program	
COORDINATED GOVERNANCE & LEADERSHIP		
Mainstreaming climate into municipal operations		
38	Integrate climate into financial decision-making	INTEGRATE CLIMATE THINKING INTO MUNICIPAL DECISION-MAKING AND GOVERNANCE
39	New mechanisms for financing climate action	
40	Green municipal investments	
Governance and capacity for action		
41	Governance	ESTABLISH GOVERNANCE AND CAPACITY FOR COLLABORATIVE, FLEXIBLE AND DISTRIBUTED CLIMATE ACTION
42	Capacity	
Monitoring and reporting		

43	Annual indicators report	MONITOR AND REPORT ON CLIMATE ACTION AND IMPACT
Carbon accounting		
44	Carbon offsets framework	GET READY FOR NEUTRALITY AND STEP UP THE CARBON SCOPE
45	Consumption-based emissions	
46	Embodied carbon	

Climate vulnerability and social equity

The success or failure in moving towards a decarbonized and climate resilient future will be measured not just by how quickly we are able to reduce emissions and adapt to the impacts of climate change, but by how just and equitable the transition is.

Not all people will be affected equally by climate change. Certain groups, communities, or populations, will be disproportionately affected due to their increased exposure and sensitivity to climate risks, or lack of adaptive capacity to deal with the impacts. Similarly, not all will be able to contribute to the significant action and investment required to decarbonize.

Given limited resources, it is therefore imperative to prioritize action for the most vulnerable and affected members of our communities, many of whom are already suffering from a range of inequities and challenges. These include, amongst others, those who live or work in hazard prone areas, persons who experience homelessness or live in poor quality housing or living conditions, the elderly and very young, and those with disabilities and pre-existing illnesses.

Climate vulnerability is inextricably linked to social equity. Low income persons, racialized groups, immigrants and refugees, non-english speakers, and Indigenous peoples (amongst others) face physical, social and structural barriers in accessing services and social supports, and frequently face discrimination. This directly influences their ability to seek and receive help, in addition to influencing health and income. Alongside both historic and growing social and economic inequities, and continued systemic and institutional inequities, this continues to exacerbate vulnerability to climate change.

It is imperative for Halifax, in its efforts to address climate change, that it prioritize action for those most vulnerable to climate change, and consider social equity at all levels of decision-making and implementation.

What does this mean? It means that in identifying, prioritizing and implementing actions that reduce emissions and climate risk, HRM and partners will ensure the equitable distribution of resources and prioritize those most vulnerable to climate. This includes developing and designing policies and programs that achieve equitable outcomes; for example, creating benefits/incentives for those that need it most.

At the same time, HRM and partners will continue to address the systemic drivers of social inequity, seeking to eliminate inequities that are increasing climate vulnerability.

Actions descriptions

The following section includes a set of recommendations for HRM that enable the emissions reductions actions associated with LC3, and to prepare for the impacts of climate change. They are grouped according to sector or theme and numbered for reference, not priority.

Efficient buildings

NET-ZERO NEW CONSTRUCTION BY 2030

1. Net-zero & climate resilient new construction

Starting in 2020, develop, adopt and apply a net-zero and climate resilient program for new construction that:

- Sets standards and requirements for energy efficiency, renewable energy generation, climate resilience and thermal survivability, EV charging, indoor air quality, and solid waste for new residential and non-residential construction, and **scales up over time so that by 2030, all new construction is net-zero**, and is designed and built to withstand future climate conditions;
- Is applied to all new residential and non-residential development and construction (at the building scale and large development site scale) through the development permit and/or rezoning process; and,
- Is applied to new construction of municipal buildings.

The program can parallel the Toronto Green Standard (TGS) and New York City Climate Resilience Design Guidelines. TGS is aligned with Passive House standards for energy efficiency and provides a clear pathway for significantly increasing the performance of new buildings, and includes an incentive program for offsetting part or all of the incremental costs of increased performance. Halifax can build directly on the City of Toronto and City of New York's experience, avoiding considerable start-up costs. In order to apply the TGS, Halifax will need to have the necessary provisions in their Official Plan and site plan control by-laws. The TGS model does not apply to single family dwellings, so a new approach would be required for this component of the building stock.

RETROFIT ALL EXISTING BUILDINGS BY 2040

2. Residential and non-residential deep retrofit program

Starting in 2020, develop a retrofit program(s) and toolkit to enable and fast-track energy and climate resilience retrofits in the residential and non-residential sector, so that **by 2040, 100% of existing buildings undergo deep retrofits.** Deep retrofits include reducing both thermal and electrical energy demand by 50% respectively, electrifying heating and water systems, and “future-proofing” buildings to be more resilient to climate impacts, including active and passive cooling solutions.

The deep retrofits program is envisioned as a partnership with HRM, provincial and federal government, utilities, industry, higher education, non-profits, and the private sector. The program would:

- Develop a financing package through a PACE or LIC mechanism, combined with incentives from other levels of government and utilities, investment raised through a combination of community bonds and green bonds, a revolving fund, and/or private funding;
- **Develop/design the program/financing package to achieve equitable outcomes**; that is, the application of the program may require enhanced benefits/incentives for those that need it most, rather than treating everyone, as well as prioritizing retrofits for those buildings that house those most vulnerable to climate impacts (eg. nursing homes and social housing);
- Develop a technical retrofit guideline or standard to be applied/support deep retrofits across an array of buildings types (incl. heritage) that includes considerations for energy efficiency, renewable energy, climate resilience and thermal survivability, EV charging, indoor air quality, and solid waste (incl. energy & resilience audit to help identify improvements).

Although many buildings will require similar types of retrofits, tailoring of the approach will be required. Building energy and resilience assessments are a good way to determine the most effective technical retrofit approach.

It will be fundamental that the program prioritize those most vulnerable to the impacts of climate change, and ensure equitable outcomes. Among other co-benefits, deep retrofits will play a significant role in improving indoor air quality and living conditions, reducing the impacts of extreme heat and other climate events, and reducing energy costs.

Retrofits can be targeted to groups of buildings, such as neighbourhoods or sectors (restaurants, grocery stores, etc) to pool risk and develop larger, more sophisticated projects. Renewable energy including district energy, solar PV, energy storage and ground-source heat pumps could be included in the program for larger scale projects.

Given the scale and pace of retrofits, it will be important for the retrofit program to adopt an adaptive management approach; evaluating ongoing performance, challenging status quo thinking, and changing or adapting parameters of the program as needed.

With buildings being the largest consumer of energy and source of emissions in Halifax (Tables 3), widespread deep retrofits of residential and non-residential buildings over the next 20 years provide the largest emissions reductions of all actions modelled in LC3 (Figure 8 and 9).

IMPROVE INDUSTRIAL PROCESS EFFICIENCY 75% BY 2040

3. Industrial coalition & support program

With partners, **develop an industrial coalition and support program** that brings together industry and partners in the form of a "coalition of the willing" that seeks to reduce emissions in the industrial sector through **improving industrial process efficiency by 75% by 2040**.

The coalition, supported and resourced by a HRM industrial support office, is intended to: develop a strategy to decarbonize industry; identifies and establishes partnerships (industry/industry, NGO/industry) and voluntary agreements; encourages monitoring & reporting; develops and maintains industrial emissions data; and, coordinates reduction initiatives (competitions, funding, incentives etc.).

Renewable energy

INSTALL 1,300 MW OF ROOFTOP SOLAR PV WITH STORAGE BY 2030

4. Rooftop solar PV and energy storage program

Starting in 2020, significantly scale up or revamp the existing Solar City program, or create a new program to enable and fast-track rooftop solar PV installations and energy storage, with a target of installing 1,300 MW solar PV by 2030.

Similar to deep retrofits, the program would develop a financing package through a PACE or LIC mechanism, combined with incentives from other levels of government and utilities, investment raised through a combination of community bonds and green bonds, a revolving fund, and/or private funding; and could be combined with the deep retrofit program (#2).

Under the current parameters and program design of the existing Solar City program, only 4.1 MW of rooftop solar PV has been installed since the program's launch in 2016. The pace and scale of the program would need to ramp up significantly to align with the targets; this will likely necessitate a reconfiguration of the program, including current financial and legal mechanisms, to enable wide scale uptake. Additionally, the program should be expanded to include battery and/or thermal energy storage to reduce potential impacts on the electricity grid, and increase resilience to climate impacts such as power outages.

Similar to the deep retrofit program, the revised solar program needs to: be developed and designed to achieve equitable outcomes; prioritize those most vulnerable to the impacts of climate change; consider large scale application to pool risk, and adopt an adaptive management approach.

SIGNIFICANTLY EXPAND LOCAL COMMUNITY-SCALE RENEWABLE ENERGY GENERATION:
- 300 MW GROUND MOUNT SOLAR PV BY 2050
- 280 MW WIND BY 2050
- 100% RENEWABLE DISTRICT ENERGY BY 2050

5. Community-scale solar PV and wind generation

With partners (including community groups and utilities), **develop and participate in a local community renewable energy co-operative or energy coalition** entity that coordinates and advances the development of utility scale renewable energy generation, using an entrepreneurial approach. In addition to the renewable energy mandate, the coalition would:

- Have a mandate to develop local expertise, stimulate the local economy and provide energy security and resilience;
- Advocate for, develop, commission and finance projects, depending on which strategy is appropriate to a particular context, with greater flexibility than existing utilities;
- Be technology agnostic, working on solar, wind, energy storage and/or district energy;
- Coordinate and establish funding/financing, including incentives from other levels of government and the utilities, investment raised through a combination of community bonds and green bonds, a revolving fund, and/or private funding.

6. District energy initiative

With partners, **establish a district energy initiative or coalition** (eg. UNEP District Energy in Cities Initiative) that brings together district energy owners and operators in the form of a "coalition of the willing" that seeks to decarbonize existing district energy systems. The initiative, supported by Halifax, develops a strategy to **fuel switch existing district energy systems to 100% renewable sources by 2050** or earlier, and works with HRM to plan for and expand low or zero carbon district energy systems in high density areas (see further #23 Planning for district energy and microgrids).

7. Provincial electricity grid decarbonization

Actively support, advocate and partner with Nova Scotia Power, the Province and others to decarbonize the provincial electricity grid.

The ability of Halifax to reduce its emissions and achieve net zero by 2050 is largely underpinned by, and dependent upon, the decarbonization of the provincial electricity grid.

Emissions from grid electricity are currently projected to decrease towards 2050 as fossil fuels used to generate electricity are reduced, and other renewable sources such as hydro (Muskrat Falls) come online. The LC3 scenario includes background assumptions about the emissions intensity of the provincial grid that is reflective of these plans toward 2050. This reduction in emissions intensity of the grid will significantly benefit Halifax; however, it will nonetheless remain relatively carbon intense by 2050.

As many energy consuming activities electrify towards 2050, a necessary step towards a net zero future, it will be fundamental to ensure that these end uses are fueled by low or zero carbon electricity. A 100 percent clean, renewable energy supply is a baseline condition for reaching carbon neutrality. In part, this will require Halifax to significantly increase local renewable generation (as noted in #4 and #5), but it will rely heavily on the continued decarbonization of the provincial electricity grid, beyond what is currently planned.

Low carbon transportation

PLAN AND BUILD THE TRANSIT AND ACTIVE TRANSPORTATION INFRASTRUCTURE NEEDED TO ACHIEVE THE 2030 MODE SHARE TARGETS IN THE INTEGRATED MOBILITY PLAN

8. Transit and active transportation infrastructure

By 2030, build out the transit and active transportation infrastructure needed to (at a minimum): achieve the 2030 mode share targets by area as set out in the Integrated Mobility Plan (IMP); increase build out to achieve higher mode share targets out to 2050; and, do this hand-in-hand with land use planning that supports alternate modes of transportation.

Halifax's IMP sets a regional vision for mobility and helps to direct future investment in transportation demand management, transit, active transportation, and the roadway network; and it also sets out mode share targets for 2030. However, it does not include an associated transit and active transportation infrastructure build out plan that will enable those mode share targets to be met. And, while the Centre Plan is now in effect, growth in the region continues to sprawl.

This continued sprawl creates lock-in. As low density growth continues outward, the number and distance of vehicle trips increases, alongside the decreasing viability of efficient and effective transit service. Low density sprawl not only locks-in patterns of travel behaviour, it essentially locks-out opportunities for transit, and increases servicing costs for the municipality. The more the region sprawls, the harder it becomes to influence mode share, both now and in the future.

Building transit and active transportation infrastructure networks in Halifax will be fundamental to not just reducing emissions in the transportation sector, but to ensuring that people and goods can move efficiently and effectively throughout the region, especially as the population continues to grow. Providing access and a range of mobility choices will also be important as the climate changes, ensuring that residents and businesses can continue to access services and continue operations during climate events for example.

Additionally, reduced congestion and increased use of transit and active transportation increase physical activity and improve air quality; further improving physical and mental health outcomes that contribute to reducing climate vulnerability.

Significant investment will likely be required to achieve the IMP mode share targets. At the same time, reducing continued sprawl through land use planning and policy will be fundamental to enable efficient and effective transit and active transportation networks.

BY 2030, 100% OF NEW VEHICLE SALES ARE ELECTRIC

9. Personal and commercial vehicle electrification

Starting in 2020, establish an **electric vehicle joint venture** with partners to **significantly increase the uptake of personal and commercial electric vehicles** (EV) in Halifax. The joint venture will have a mandate to develop and implement a community wide EV strategy (five-year action plan/roadmap) that plans for and catalyzes electric vehicle adoption, including:

- Planning for EV charging infrastructure throughout Halifax to support the full electrification of the transportation sector;
- Coordinating infrastructure investments (including opportunities to combine EV charging infrastructure with renewable energy generation projects);
- Coordinating educational and marketing activities;
- Developing and coordinating subsidies and incentives.

10. EV planning and policy

Prepare for and catalyze EV uptake through HRM planning and policy, including:

- Requiring EV charging infrastructure in new construction and zoning bylaws (tied to #1 New construction);
- Providing funding through incentives, loans, or rebates to install EV chargers in residential and non-residential buildings (which could be combined with #2 Retrofits and/or #4 Rooftop solar PV and storage);
- Establishing an ongoing/updated city-wide database of buildings that have installed EV charging equipment or are EV charger ready;
- Updating relevant bylaws and planning documents to include special provisions for EV charging infrastructure, fees, and assigned/preferred parking spaces (eg. parking, taxi, limousine & shuttle transportation, vehicles for hire);
- Including EV charging considerations and/or requirements in secondary and master planning.

Greening government operations

ACHIEVE NET ZERO MUNICIPAL OPERATIONS BY 2030

11. Net zero municipal operations

Adopt a commitment, develop a detailed and costed infrastructure plan, and finance implementation to achieve net-zero municipal operations by 2030. Municipal operations in this context refers to municipally owned and operated buildings, vehicle and ferry fleets, waste operations, and outdoor lighting.

The commitment and plan should include:

- Net-zero and climate resilient new buildings

Applying net-zero and climate resilient requirements for all new municipal buildings starting in 2020. Any new buildings constructed today that are not net-zero and climate resilient only increase the investments required later on to retrofit and decarbonize, alongside potentially squandering investment if they are not built to withstand the climate of the future;

- Retrofitting existing buildings

  Deep retrofitting and future-proofing all existing HRM buildings by 2030;

- Reducing waste emissions

Developing a waste strategy that reduces per capita residential waste by 30%, diverts 100% of residential and ICI waste from landfill, increases landfill gas capture to generate electricity, and routes 100% of organic waste to anaerobic digester to generate biogas by 2030. This could include exploring options and policy instruments to implement Extended Producer Responsibility (EPR) or eliminate single use products in Halifax, developing HRM procurement policies that foster recycled content and increase market demand for recycled content, and actively develop policies and programs that build and support a local circular economy;

- Electrify municipal fleets

  Electrify all HRM transit and municipal fleet vehicles, including ferries, by 2030;

- Renewable energy generation and purchase

Achieve neutrality through installing HRM-owned and -operated renewable energy generation (eg. solar and wind), and through (in the interim) purchasing locally sources zero carbon energy through a Power Purchase Agreement (PPA) for municipal operations.

Water

ACHIEVE NET ZERO WATER AND WASTEWATER OPERATIONS BY 2030

12. Net zero water and wastewater operations

Adopt a commitment and develop a detailed plan to achieve net-zero water and wastewater operations by 2030, with a minimum 50% reduction in water and wastewater treatment and pumping energy use by 2050.

Strategies that could be applied to reduce energy use and emissions in water and wastewater include:

- Water conservation

Reduce water consumption through leak detection, metering and monitoring, education and behaviour change, water restrictions, water efficient fixtures, water efficient landscaping, and water reuse (eg. rain barrels). Water efficient fixtures should, at a minimum, be part of both new construction standards (#1) and deep retrofits (#2), along with water efficient landscaping and water reuse. This may include developing regulations to support the usage of alternative water sources including greywater and blackwater for non-potable demand. The ‘fit for purpose’ approach to water end use will reduce pressure on the regional supply and delivery of treated drinking water. As water consumption is reduced, so is the energy to treat and pump drinking water, alongside the energy required to treat and pump wastewater, as less wastewater makes its way to the treatment plant. This too reduces the amount of direct emissions associated with wastewater treatment.

- Reducing rainwater in the wastewater system

Reduce or eliminate the amount of rainwater that makes its way into the wastewater system. In Halifax, approximately 40% of the total amount of wastewater that is centrally treated is rainwater. Eliminating this component from the wastewater system would significantly reduce energy for wastewater treatment and pumping, in addition to reducing the risk of overflows during high rainfall events. This could be achieved through a combination of combined sewer separation, disconnecting downspouts, and on-site water retention and attenuation through green roofs, rain water barrels, and permeable paving for example.

- Biogas from wastewater

Expanding biogas recovery from wastewater through anaerobic digestion. Approximately 15% of total annual wastewater generated in Halifax passes through anaerobic digesters (at Mill Cove and Timberlea wastewater treatment facilities). By adding anaerobic digestion at the Halifax and Dartmouth treatment facilities, this could increase to approximately 85% of total annual wastewater flow, representing a significant increase and opportunity to produce biogas.

FUTURE PROOF WATER SYSTEMS AND SUPPLY

13. Water supply strategy

Develop a holistic integrated water supply strategy with climate as its core focus.
Understanding how climate will impact the future of water supply and water use will be fundamental in ensuring secure, sustainable, and well managed water resources for the future of a growing region.

The strategy should include:

- Analyzing in of the impact of future climate on water supply/water resources (including groundwater), water availability (water budget), and water quality. This could be done through a detailed risk and vulnerability assessment that considers, as a minimum, the impacts of increasing temperatures, extreme heat, changing precipitation patterns, diminishing snowpack, earlier or more variable spring runoff, inundation and saltwater intrusion from sea level rise, and storm surge.
- Analyzing/understanding the ability of HRM/Halifax Water to provide water under future conditions, and identify actions needed minimize the effect of climate induced water-related emergencies and hazards. This includes a groundwater management strategy, a water conservation plan (a component of #12), and a drought response plan.

14. Stormwater management plan and program

Develop a holistic integrated stormwater management plan and program with climate as its core focus, to reduce the impacts of extreme rainfall and flooding from a changing climate.

The strategy should focus on reducing stormwater runoff and increasing permeability throughout the region, especially in urbanized areas; continuing to maintain, improve and expand stormwater infrastructure where needed; publicly sharing information about flooding risk; and embracing green infrastructure as a core component of stormwater management.

The strategy should consider:

- Mandatory requirements for on-site stormwater retention and permeability;
- New major storm systems where not present/needed, that are built for a future climate (2050 at a minimum), with a preference for green infrastructure;
- Back-flow preventer program, specifically for basement flooding/sewer back-up;
- Residential and public space re-greening program that works to convert hard surfaces to permeable or green surfaces;
- Modelling and mapping high risk flood areas (pluvial and fluvial) under current and future climate conditions, and making this information publicly available.

Critical infrastructure and services

REDUCE RISK TO CRITICAL INFRASTRUCTURE

Halifax depends upon a complex network of infrastructure; systems that function to produce and deliver a reliable flow of services that are critical to support economic prosperity and social well-being. This includes energy, telecommunications, transportation, water supply, wastewater treatment, solid waste management, buildings, and food systems. These systems are complex, interconnected, do not always work as foreseen, and have weaknesses.

Growth in Halifax is increasingly putting pressure on existing infrastructure systems, which are in some cases already at or over capacity, are aging rapidly, and are already experiencing impacts of extreme climate events. As climate events become more extreme and occur more frequently, increases in disruption and damage to these infrastructure systems, and the subsequent costs to repair or replace them will increase; along with cascading consequences on the environment, society, and economy that are triggered by failure in these systems.

Already aging infrastructure is likely to age faster than designed for, requiring new investment for replacement ahead of its anticipated lifespan, further exacerbating the infrastructure deficit and state of good repair (SOGR) backlog. In the absence of significant action and investment, the risk to existing and future infrastructure will continue to increase.

For the region to thrive, it is fundamental that its critical infrastructure is able to withstand the impacts of climate change, both in the near and long term. This requires proactively protecting and strengthening infrastructure to ensure it can withstand the shocks and stresses that come with climate change. Through improving the resilience of infrastructure now, the reactive resources needed for event or emergency response are reduced.

Understanding where, what, how, and by how much action and investment is required to reduce the risk to Halifax's critical infrastructure requires a better understanding of the risks and vulnerabilities these systems face in a changing climate.

15. High level risk assessment (HLRA)

Conduct a HLRA with internal and external stakeholders (critical infrastructure owners and operators) to assess the ability **of critical infrastructure systems** (utilities, transportation, water, health facilities and telecoms) to operate in and withstand future climate and extreme weather, with a specific focus on understanding interdependencies between systems.

16. HRM Critical infrastructure risk and vulnerability analysis

In concert with the HLRA, conduct a detailed spatially-based risk and vulnerability analysis of HRM owned and operated critical infrastructure at the asset class and system level. Outcomes of the analysis should include:

- A risk register and infrastructure condition index detailing the condition and level of risk at the asset level;
- Application of the results to inform the developments of programs and projects to reduce the risk and impacts from climate hazards and ensure the continuity of critical services. This could include adapting physical infrastructure, or changes in service management and operations;
- Integration with asset management and capital planning.

In the delivery of programs and projects to reduce risk in critical infrastructure, it will be fundamental to ensure the equitable distribution of resources and prioritize those most vulnerable to climate change.

17. Zero emissions back-up power

Install zero emissions back-up power in HRM owned and operated critical infrastructure, to ensure continuity of service delivery needs during power outages without negatively impacting emissions mitigation efforts.

18. Inspection procedures

Develop inspection procedures for high risk infrastructure to identify resulting damage from extreme events and incorporate this into critical infrastructure retrofit, build-back, or state-of-good-repair work to limit early end-of-life or premature failure.

19. Standards for new infrastructure

Develop and/or update codes and design standards for new municipal and private infrastructure within the context of climate change. Codes and standards for infrastructure should include forward-looking climatic information to ensure that infrastructure is designed and built to be both low or zero-carbon, and more resilient to climate impacts; ensuring it will be able to perform safely and efficiently under future climate conditions, while lessening the upward trend of emissions. This is particularly important for infrastructure with a longer design life or that performs a critical purpose. Codes and standards that are based on historical records urgently need updating for the climate that is coming, and need to consider emissions reductions.

These standards should be applied to all new infrastructure, whether it is infrastructure that is being built to specifically reduce emissions (such as solar PV), or that which is aimed at providing direct or indirect protection from climate hazards (eg. stormwater infrastructure), or any other general infrastructure that is otherwise being built new, or as part of state-of-good-repair (eg. roads).

Where HRM relies on codes and standards that are developed by external standard-setting organizations (such as the Province), HRM should work through the relevant professional organizations to advance the updating of these from a climate perspective. While the updating of existing codes and standards seek to set a new and higher bar for the construction of low carbon climate-resilient infrastructure, they remain nonetheless a baseline. Moving forward, these codes and standards should strive for continuous improvement, being frequently updated as new information and knowledge about the climate develops.

Natural areas and green infrastructure assets

PROTECT, RESTORE, MAINTAIN AND EXPAND NATURAL AND GREEN INFRASTRUCTURE ASSETS

Halifax is urbanizing. With urbanization comes elevated surface and air temperatures due to the presence of heat absorbing materials, reduced evaporative cooling caused by lack of vegetation, and production of waste heat, as well as increased flooding as a result of the increase in impervious surfaces and decrease in vegetation. Combined with projected increases in temperature and changing precipitation patterns, urbanization and the loss of vegetation and permeable surfaces in built up areas is likely to exacerbate these issues.

As natural areas are turned to urban landscapes, ecosystems are destroyed, biodiversity is lost, water quality is reduced, and carbon sequestration capacity removed, resulting in increased emissions. For those areas that remain, they too are under threat from the impacts of climate change, including more frequent and severe storms and hurricanes, drier and hotter growing seasons, more invasive pests, higher risk of wildfires, and warmer winters with a higher occurrence of damaging freeze-thaw cycles.

Natural areas and green infrastructure play a significant role in reducing heat and flooding impacts, primarily through increasing infiltration and reducing runoff, reducing the heat island effect, improving water quality, providing shading and areas for reprieve, as well as increasing carbon sequestration capacity. This includes, but is not limited to, parks, trees, shrubs, urban forests, green roofs and walls, gardens, bioswales, natural channels, watercourses, ponds, and constructed wetlands.

The additional social and environmental benefits of natural areas and green infrastructure, however, particularly for health, are what make it so appealing when compared with other "grey" strategies to address heat (eg. expansion of air conditioning) or flooding (extensive hard stormwater infrastructure systems). Amongst others, natural areas and green infrastructure contribute to improving air quality, providing space for recreation, physical activity and social interaction, improving water quality, reducing noise pollution, reducing energy demand for cooling, providing habitat and enhancing biodiversity, growing food, and generally beautifying a city. Many of these are no-regret measures that can significantly enhance communities.

Today and in a future climate, it is vital for Halifax to protect, restore, maintain, and expand its natural areas and green infrastructure. This includes:

- **Protecting what already exists** through conservation and land use planning:
    - Increasing protected areas (prioritizing ecological corridors, forests, coastal areas, riverines and floodplains, wetlands;
    - Limiting or restricting greenfield development and development in riverine, floodplain, and water source areas;
    - Wildfire protection and prevention;
- Restoring and maintain what already exists through:
    - Sustainable forest management;
    - Woodland management;
    - Restoration of ecosystems and ecosystem surfaces;
    - Invasive species management;
- Expanding natural areas and green infrastructure though:
    - Permanent reforestation and afforestation in urban and rural areas;
    - Integrate natural assets into urban areas through re-greening programs and land use planning.

20. Green Network and Urban Forest

Fund and implement the Green Network Plan and Urban Forest Master Plan. Much work has been put into these plans, and they include and address many aspects of what is noted above. What is needed next is for them to be fully funded and implemented.

Additionally, HRM should include natural areas and green infrastructure as officially designated assets in HRM's Asset Management portfolio.

21. Region-wide naturalization planning

Continue the naturalization program through pilot projects, public education and awareness to support the development of a region-wide naturalization program. Naturalization is an ecological approach to landscape management that enhances biodiversity and improves ecosystem health and resilience in an urban environment. Naturalization reduces maintenance requirements and costs, as systems are self-renewing and resilient, and provides more naturalized space to residents and wildlife. Regional Council provided direction to expand naturalization efforts in parks and rights-of-way areas in January 2019. Both the Urban Forest Master Plan and the Green Network Plan highlight the benefits that are associated with increased naturalization and biodiversity.

22. Tree planting and re-greening program

With partners, develop and implement a region wide tree planting and re-greening program. The program would be a public-private initiative that works to plant trees and re-green existing grey surfaces on both public and private land, including residential and commercial properties. The New York City One Million Trees Initiative is a good example of such an initiative.

In addition to tree planting and re-greening, the program would also have a mandate to:

- Develop local expertise and stimulate the local economy;
- Coordinate education and outreach;
- Coordinate and establish funding/financing, including incentives from other levels of government, private sector, or other innovative municipal financing mechanism.

Planning

As cities expand outward, they convert forested, agricultural and vacant land to suburban and other urbanized uses. Costs increase for the municipality to provide and maintain infrastructure such as roads, pipes, and emergency services. Residents are more likely to be dependent on cars, driving longer distances, adding stress and time to commutes. Once neighbourhoods are built, it is difficult to alter the development pattern, thus locking in transportation patterns, building design, infrastructure, and energy supply for decades to come.

This conversion of "green to grey" is also associated with elevated surface and air temperatures due to the presence of heat absorbing materials, reduced evaporative cooling caused by lack of vegetation, and production of waste heat, as well as increased flooding as a result of the increase in impervious surfaces and decrease in vegetation. Combined with projected increases in temperature and changing precipitation patterns, urbanization and the loss of vegetation and permeable surfaces in built up areas is likely to exacerbate these issues. Additionally, when communities are planned based on historical climate conditions that no longer exist, they make themselves more vulnerable to current and future climate risks.

Land use policy and planning tools, including official plans, secondary plans, zoning, development permits and others, are one of the most cost-effective processes to reduce energy and emissions, and facilitate local climate resilience. Unlike retrofitting buildings or creating new energy systems, directing new development to create complete, compact, connected and resilient neighbourhoods is very low cost.

Well-considered land-use policy also achieves many objectives simultaneously. Infill and compact, complete developments provide greater support for transit services. They also allow more trips to be made through active transportation, as places of work, play, schools, and services are close by. Smaller homes and homes that share walls are much more energy efficient, which reduces energy bills. More walking, cycling and access to green space improves physical and mental health, and allows for more social interaction. Limiting development in hazard-prone or high-risk areas reduces exposure to climate hazards. Protecting natural environments, and enabling the expansion of natural and human-made green infrastructure improves air quality, reduces heat and flooding impacts, reduces the heat island effect, improves water quality, provides shading and areas for reprieve, increases carbon sequestration capacity, and improves health outcomes.

All these elements play a role in energy use and emissions production, and vulnerability to the impacts of climate change.

PLAN AND BUILD A LOW CARBON RESILIENT REGION

23. Land use planning policies and processes

Integrate climate into land use planning policies and processes to reduce the upward trend of emissions associated with growth, and ensure it is more resilient to the impacts of climate change.

That is, implement land use planning that avoids increases in emissions, climate risk and exposure, and avoids locking-in patterns of development that make it both hard to undue, and limit future opportunities to reduce emissions and risk in the future.

This includes:

- Avoiding sprawl and supporting density, infill development and mixed uses that increase building energy efficiency, maximize infrastructure use, enable opportunities for community energy (eg. district energy), provide population density to support neighbourhood services, amenities and reduce social isolation;
- Transportation oriented development approaches to coordinate transit and active transportation options with development densities, including considerations for connectivity and accessibility during emergencies;
- Green space, urban forestry, and requirements for community spaces (further details in 24. Green space planning);
- Limiting development in hazard-prone or high-risk areas to reduce exposure to climate hazards, and ensure new buildings and infrastructure are built to withstand future climate.

As a first step, it is recommended to:

- **Establish a clear set of goals and objectives for climate within Planning** (including those mentioned above at a minimum), **and integrate these from "top to bottom"**, from the Regional Plan through secondary plans to zoning, translating these into targets and requirements appropriate at each level;
- Include climate as an organizing principle in the next update of the Regional Plan.

24. Planning for district energy and microgrids

Plan for the deployment of carbon-neutral district energy and microgrid systems through integrating these considerations early in the land use and infrastructure planning process.

District energy and microgrids form a fundamental building block of decarbonization; they make energy delivery more efficient, improve resilience to power outages, reduce strain on energy infrastructure, and reduce emissions through use renewable sources. District energy is particularly well suited in areas with higher energy use density.

Enabling these systems requires a process that considers energy early in the land-use and infrastructure planning and design process, and identifies opportunities to integrate local energy solutions at a building and neighbourhood-scale. The City of Toronto currently applies this approach through the development of Community Energy Plans that are created as part of Secondary Plans, Precinct Plans or Avenue Studies led by City Planning.

25. Land protection and conservation

Increase land protection and conservation on private lands through partnerships, collaboration, and municipal planning requirements.

For land protection, strategies include protecting green spaces that already exist through conservation and land use planning, restoring and maintaining what already exists through careful management and ecosystem restoration, and expanding natural areas and green infrastructure. Available municipal tools for protection can include amending land use bylaw regulations, open space subdivision, zoning, and through development agreement between the developer and the Municipality. Additional tools that could be explored in partnership with other stakeholders include land donation, easements, and voluntary preservation. The Municipality will continue to strategically acquire lands that provide ecological value and preserve biodiversity. The current Regional Plan review provides an opportunity to strengthen the Municipality's role in acquiring and protecting lands that will both sequester carbon to mitigate climate impacts and increase adaptive capacity.

26. Green space planning

Prioritize the protection and expansion of green spaces through land use planning policies and mechanisms.

Natural areas and green infrastructure are a key ingredient of a low carbon resilient region. It is vital for Halifax to protect, restore, maintain, and expand its natural areas and green infrastructure. This requires a multi-faceted approach that: firstly, protects and enhances that which already exists; secondly, expands these areas through reforestation, afforestation and adding or patching in within the existing built form (eg. re-greening program); and thirdly, through actively planning for green infrastructure and open spaces to be integrated into urban areas as the region grows.

Land use planning policies and tools can play a significant role in achieving these outcomes. Mechanisms to achieve this include:

- Requiring green space, urban forestry, and community space allocation in the development process;

- Limiting or restricting greenfield development in forested, riverine, floodplain, and water source areas;
- Requiring post development carbon neutrality and for greenfield sites (where permitted) through requiring new trees (or other green components) and offsets to equal pre-development carbon sequestration capacity.

Coastal preparedness

BETTER PREPARE FOR CLIMATE RELATED COASTAL CHANGES AND IMPACTS

Halifax's coast, waterfront and shoreline areas are at increased risk of climate impacts; specifically, increasing risk of damage to coastal infrastructure, property, and natural areas and assets from inundation, saltwater intrusion, and coastal erosion due to sea-level rise, storm surge and extreme events.

27. Detailed risk and vulnerability analysis of coastal, waterfront, and shoreline areas

Conduct a detailed spatially-based risk and vulnerability (R&V) analysis of Halifax's coastal, waterfront, and shoreline areas, including the impact to infrastructure, property, and natural areas and assets from climate change, including coastal processes related to sediment transport, water chemistry, erosion, and sea level rise.

28. Coastal-specific adaptation strategy

Building on the results of the R&V analysis above, develop a coastal-specific adaptation strategy with coastal communities, property and infrastructure owners, and other levels of government, including Develop Nova Scotia. The strategy should include, at a minimum:

- Adaptation measures for key historical, cultural and heritage properties;
- Adaptation measures to reduce the risk of impact to existing critical infrastructure;
- Restrictions on coastal development, including coastal setbacks and 'no-development zones';
- Requirements for new buildings and infrastructure in coastal/waterfront/shoreline areas (where permitted) to include and address/respond to sea level rise, extreme water levels and storm surge in planning, design and construction.

Emergency management

BETTER PREPARE FOR INCREASED CLIMATE-RELATED EMERGENCIES

The impacts of climate change are expected to affect the emergency management sector's capacity to support preparedness, response and recovery efforts. As extreme events increase, so will the demands on full-time and volunteer emergency service personnel and non-government organisations. Demands are likely to increase for both chronic stresses, such as higher average temperatures, and acute shocks, specifically extreme events such as heat waves and flooding, as a result of growing impacts on human health, which include:

- increased risk of injuries and mortality resulting from extreme weather;
- increased risk of temperature-related morbidity and mortality;
- increased respiratory and cardiovascular conditions exacerbated by poor air quality;
- increased food and water-borne contamination;
- increased incidence of vector-borne illnesses.

These impacts are expected to be greater for those who are considered more vulnerable to climate, including: seniors; children; those experiencing social isolation; individuals with chronic conditions, disabilities, or both; and, socially or economically marginalized individuals; and may worsen existing health inequalities by increasing the health burden on these already vulnerable groups.

Currently established planning, coping and response mechanisms for such events based on past vulnerabilities are unlikely to suffice for what is to come. Ensuring that emergency management has the capacity, through training, resourcing, and coordinated communication to respond is critical.

It is important to note that there is a direct connection between putting in place infrastructure and services that reduce the risk of an emergency occurring from emergency events, and the level of emergency services needed. While emergency management needs to plan for an increase in extreme climate events, ongoing investment to increase the resilience of infrastructure and provide supportive service is needed alongside to help alleviate these growing demands.

29. Integrate climate into emergency management planning

- **Ensure systematic, transparent and up-to-date plans for emergency management** that incorporate/integrate climate considerations; this includes taking stock of the impact that increased frequency and severity of climate-related events will have on emergency management operations to identify gaps and/or changes that may be needed for operations, including resourcing, training, tools and financing;
- **Integrate climate risk and vulnerability mapping with climate vulnerable population information** to better understand and identify locations, groups and individuals who are more at risk or more vulnerable to climate-related events, and may require additional or special assistance;
- **Develop a registration system** for individuals who need help or want to be checked on;
- **Develop a heat response plan** to address the growing public health risks of increasing extreme heat;
- **Develop evacuation plans** for flooding, wildfire and coastal storm surge;
- **Review HRM's ability to provide for the needs of extreme event evacuees** and other populations displaced by extreme weather and climate events;
- **Update Community Emergency Response Training (CERT)** curriculum to incorporate climate-change hazards (eg. heatwaves).

30. Improve emergency management communication and coordination

- Convene a coalition of emergency, social service, health agencies and other organizations to:
  - Identify gaps and needs for delivery of services specific to the challenges posed by extreme weather;
  - Improve communications and coordination between organizations responsible for various sectors (e.g. EMO, NS Power, Red Cross, telecommunications etc.), including on-call volunteers;
- **Develop new internal and external institutional alliances** (with non-traditional partners) to increase resiliency and prepare for and respond to events;
- **Improve communication with the general public** prior to, during, and after events, including the use of multiple languages and media to improve access to information;
- Ensure back-up for communication systems.

Community capacity

ENHANCE THE CAPACITY OF NEIGHBOURHOODS TO PREPARE FOR AND RECOVER FROM CLIMATE EVENTS

More resilient neighbourhoods make a more resilient city. Neighbourhoods that invest in connections, capacity, and resources on a sustained basis are not only better able to withstand times of crises, but also address many of the chronic socio-economic stresses that increase climate vulnerability. Building infrastructural and social capacity at the neighbourhood level not only empowers neighbourhoods to be more independently resilient, but contributes to the resilience of the region as a whole.

31. Neighbourhood resilience and disaster support hubs

Create Disaster Support Hubs or Community Resilience Hubs for community self-sufficiency. Form partnerships with neighbourhood-based organizations and businesses to develop Neighbourhood Resilience Hubs and programs that support residents and the neighbourhood to better prepare and respond to climate change. Hubs should be leveraged as both areas of reprieve during extreme events (such as a cooling space during a heat wave, or disaster assistance and supply hub during a hurricane), but also as locations that can be used to develop social capacity and connectedness; a key ingredient in building social resilience.

32. Local resident emergency training

Train local residents to plan for and respond to emergencies through making emergency management and CERT training widely available to residents and businesses. Extreme climate events are projected to increase, increasing demands on emergency management services. In many cases, emergency management will not be enough. Training that builds and enhances emergency management capabilities will allow residents and business owners to become more self-sufficient, to provide support to fellow residents, and to provide additional support to first responders. Increasing the number of Haligonians with emergency management training, specifically in neighbourhoods that are more vulnerable to extreme climate events, will help build much needed capacity in those neighbourhoods and in turn enhance Halifax's capacity to be more resilient to extreme events.

33. Neighbourhood action planning

Undertake bi-annual (at a minimum) climate planning sessions with neighbourhood organizations to develop local climate plans and coordinate mitigation and adaptation efforts. Those affected by climate decisions should not only be directly engaged in shaping those decisions, but in collaboratively identifying the solutions. Deciding with, not for, is at the foundation of this equitable and community driven approach, which is particularly relevant for climate vulnerable populations. Inclusivity in the process, whereby a wide range of stakeholders are engaged, is key to ensuring that a broad range of perspectives are applied.

ENGAGE DEEPLY AND COLLABORATIVELY

Climate change is a "wicked" problem that cannot be addressed by one or even a few perspectives. It requires a diversity of worldviews and perspectives to develop novel approaches and diverse ways of thinking in order to address the urgency and complexity of the issue. It also requires knowledge to be shared, and widespread awareness of the issues and challenges. Broad, deep and collaborative engagement, education and capacity building is fundamental in addressing climate change.

34. Broad, deep and collaborative engagement

➢ Indigenous and African Nova Scotian communities

Work purposefully, meaningfully, and collaboratively, with Indigenous community leaders and groups, and other groups seeking reconciliation, including African Nova Scotian communities, in the continued development and implementation of HalifACT2050.

➢ Education and awareness

- Develop and deliver awareness and education programs across a suite of climate issues and topics, including (but certainly not limited to): information about programs and incentives; where and how to take action at home and work; emergency management during events; water conservation; reducing energy consumption etc.
- Create a Climate Ambassador program and partner with local schools to develop a school curriculum on climate change and resilience building

➢ Actively ***work*** with partners and other institutions

Take an active leadership role in working with and learning from local partners and institutions, engaging with neighbouring municipalities and regions, other municipalities provincially and nationally, and participating in international networks.

Food

IMPROVE FOOD SECURITY AND FOOD SYSTEMS RESILIENCE

Climate change poses increased risks to agriculture and food systems, including adverse impacts on agricultural crops (decreased crop yield and decreased nutritional quality of crops grown), increased food prices, contaminated water and food supplies, increases in new and existing pests and diseases, and damage and disruption to food supply and distribution infrastructure from extreme events.

Additionally, food production and distribution contribute significantly to increasing emissions through, including through methane produced by livestock (mainly cattle), manure and fertilizers, pasture management, energy for agricultural vehicles and machinery, conversion of forests, grasslands and other carbon 'sinks' into cropland, and energy used in food processing, transport, packaging and retail.

35. Food action plan

Fund and implement the Food Action Plan, and include climate as a core component. In December 2019, Halifax Regional Council endorsed the Halifax Food Charter in principle and committed to supporting the development of a Food Action Plan with the Halifax Food Policy Alliance. Including climate as a key component of this plan, and funding its implementation, presents a great opportunity for improving food systems resilience, reducing emissions from food, and building food security, especially for those most vulnerable to the impacts of climate change. As such, as part of the Food Action Plan's development, it is recommended to include:

- A vulnerability assessment of the city's food system from a changing climate, including the impact on food supply and distribution during extreme events, holding climate vulnerable populations and social equity paramount,
- Strategies that seek to reduce the emissions associated with food production and distribution, including changes to diets, food waste reduction, and local production and consumption.

Business and economy

PREPARE AND LEVERAGE BUSINESS FOR THE TRANSITION

36. Workforce and technology development for building decarbonization and resilience

The transition to a low carbon and climate resilient future will require and generate a significant amount of professional and skilled labour positions, alongside revitalizing local economies. Under LC3 implementation, approximately 170,000 person years of employment are expected to be generated between 2020 and 2050, an average of 5,500 annually, compared to the BAU scenario. This does not include employment associated with adapting to the impacts, such as future proofing critical infrastructure, which would significantly increase this number. Preparing for and catalyzing this need is vital.

With partners (including academic institutions and private sector), **expand workforce and technology development programs and funding** to grow skills and trades for building decarbonization and resilience.

37. Resilient decarbonized businesses program

With partners, **develop a resilient decarbonized businesses program** that supports businesses to reduce their emissions and prepare for climate impacts. The program would engage with and support businesses to analyze and understand their and operational energy consumption and emissions (including supply chains); develop strategies to reduce and improve energy use and fuel switching; assess the vulnerability of their business and business continuity to the impacts of climate change, and develop strategies to reduce their risk. The program would also facilitate partnerships and learning between businesses and sectors.

Mainstreaming climate into municipal operations

INTEGRATE CLIMATE THINKING INTO MUNICIPAL DECISION-MAKING AND GOVERNANCE

Climate change is having and will continue to have a financial impact on Halifax. Decarbonizing and adapting to the impacts of climate change will require significant investment, and mobilizing funding commensurate with the challenge will be a struggle at many levels. But the cost of inaction will only grow over time. Every dollar invested proactively can save as much as four to six dollars on recovery. Many policy makers do not yet recognize the choice they face between paying predictable costs today for mitigation and adaptation, compared to delaying action and paying higher and unpredictable costs later to try and cope with the impacts of climate change.

This challenge will require municipal government to establish new mechanisms for financing climate action, while simultaneously rethinking their own municipal fund investment strategies. Additionally embedding climate resilience considerations into financial decision-making will be key to ensuring these investments are not “malinvested”; that they contribute to reducing emissions and reducing risk for more broadly throughout the region.

38. Integrate climate into financial decision-making

Integrate climate into municipal financial decision-making through:

- Climate-related financial disclosures

Report climate-related financial disclosures annually in alignment with the Task Force on Climate-related Financial Disclosures (TCFD) framework. TCFD has developed a voluntary, consistent climate-related financial risk disclosure framework that considers the physical, liability and transition risks associated with climate change. As of 2018, the City of Vancouver has included climate-related financial disclosures in its annual financial report.

- Cost of carbon

Include a cost of carbon and social cost of carbon in financial analysis, capital and business planning. This would include the application of a cost of carbon, aligned with Provincial and Federal pricing at a minimum, in assessing the cost-effectiveness of HRM plans, projects and operations. Additionally, a social cost of carbon (SCC) should be applied. The social cost of carbon is a measure of the broader societal and economic harm of emissions and climate impacts, expressed as the dollar value of the total damages from emitting one ton of carbon dioxide into the atmosphere.

- Carbon budget

Adopt a municipal carbon budget for HRM and report annually. A carbon budget is a key governance tool for achieving emissions reduction targets. It essentially sets an emissions budget in a similar manner to a municipal budget. Just as a financial budget has a ceiling on how much money can be spent, a climate budget sets a ceiling on the volume of carbon dioxide that can be emitted in the same year. In 2016, the City of Oslo adopted a carbon budget as an integral component of the overall city budget, and has continued to successfully implement it. In Oslo, this governance instrument transported the issue from the periphery of environmental departments to the center of attention and mainstreamed it into daily operations and decision-making.

- Capital planning

Apply a climate lens to capital planning to ensure HRM capital financial decisions are climate-informed. In 2018, Infrastructure Canada started requiring the application of a Climate Lens assessment for certain projects applying for funding under Infrastructure Canada's Investing in Canada Infrastructure Program (ICIP), Disaster Mitigation and Adaptation Fund (DMAF) and Smart Cities Challenge. Assessments are required to include two components: a GHG mitigation assessment, which measures the anticipated GHG emissions impact of an infrastructure project; and, a climate change resilience assessment, which employs a risk management approach to anticipate, prevent, withstand, respond to, and recover from a climate change-related disruption or impact. A guidance document for how to carry out these assessments has been published by Infrastructure Canada.

- Asset management

Include the financial impacts of climate risks and emissions in asset management and service delivery planning through integrating climate to asset management at HRM, and evaluate levels of service standards in the context of a changing climate. The intended outcome is to better understand and account for the emissions associated with HRM assets and services, along with the physical and financial impacts climate will have on the condition, performance and longevity of HRM assets and service delivery, in order to identify and prioritize needs for investment, both in the near and long term.

39. New mechanisms for financing climate action

Decarbonizing and adapting to the impacts of climate change will require significant investment, and mobilizing funding commensurate with the challenge will be a struggle at many levels. Under current funding models, Canadian municipalities do not have the resources they need to pay for climate change related projects. This challenge will require municipal government to explore and establish new mechanisms for financing **climate action**, including private sources of finance. Climate financing tools work exploring include:

- **Green bonds**, which are debentures, the proceeds of which are earmarked for projects with an environmental benefit;
- **Environmental impact bonds** which allow governments to pay for performance-based policy interventions while transferring performance risk onto private investors;
- **Catastrophe bonds** that transfer risk to capital markets when insurance policies do not cover the risks associated with catastrophic events;
- **Green banks**, which are financial institutions that specialize in the provision of financing for projects with environmental benefits; and,
- **Revolving funds**, which provide financing for climate related projects that result in ongoing cost savings that replenish the fund.

Additionally, it is worth exploring how these types of funding mechanisms, along with others such as TCFD (#36) and municipal investing (#38), further influence costs of borrowing and insurance premiums for the HRM and residents/businesses more broadly, attract private investment needed for climate action, and establish Halifax as a preferred location for climate finance and clean technology.

40. Green municipal investments

Incorporate Environmental, Social, Governance (ESG) principles, specifically as they relate to climate, into management of HRM's municipal funds, including operating funds, and pension and trust funds. This includes investing HRM funds in portfolios that maintain strong ESG practices, and are disclosing their climate-related financial risk.

Governance and capacity for action

ESTABLISH GOVERNANCE AND CAPACITY FOR COLLABORATIVE, FLEXIBLE AND DISTRIBUTED CLIMATE ACTION

41. Governance

Leading on climate action at HRM will require a sustained and broad approach; one that focuses on institutionalizing climate thinking throughout the organization, building human and technical resource capacity internally, driving the implementation of HalifACT2050, and engaging with and working alongside external partners. Establish governance for collaborative, flexible, and distributed action will be key to achieving these outcomes.

To facilitate this, a coordinated, collaborative and distributed effort is required. Fundamentally, there needs to be an entity responsible and accountable for this delivery. The **establishment of a central (to HRM) Climate Office**, that reports directly to the CAO, **with a distributed network of coordinated support** is well suited to this role. It would directly support HRM divisions and decision-makers to integrate climate into their work; develop decision support and communications tools; actively build staff and technical capacity; implement the actions in HalifACT2050; and, participate and work more collaboratively with external partners to deliver action across the region. In this context, a Climate Office would act as the focal point for climate at HRM, including acting as a clearinghouse for climate data and information at HRMs while also facilitating, coordinating and driving climate action within Halifax more broadly.

42. Capacity

Significantly increase staff capacity for implementation. Integrating climate throughout the HRM organization, while implementing HalifACT2050 at HRM and with partners will require a significant increase in staff capacity. In concert with the development of a central climate entity above, it is recommended to staff the central entity with a minimum of ten (10) FTE's, and a distributed network of twenty (20) FTE's. The distributed network would report dually to the central climate entity and to their divisions, and be responsible for driving climate action in their division, while acting as the divisional climate specialist. This network would include staff in Planning, Asset Management, Waste, Transportation, Buildings, Halifax Water, Finance, Legal, Procurement, Emergency Management, Social Services, and others. Staff in the central entity would lead delivery of HalifACT 2050 actions not directly included in existing divisions (eg. retrofitting existing residential buildings), along with delivery of the plan more broadly; monitoring progress and report directly to the CAO and council; leading engagement and communication internally and externally, including working with higher orders of government; managing climate data and information; and building human and technical resource capacity.

Monitoring and reporting

MONITOR AND REPORT ON CLIMATE ACTION AND IMPACT

43. Annual indicators report

Develop an Annual Indicators Report and report annually. The indicators report is intended not only to measure and report on the progress of HalifACT2050 actions implementation, but the impact these are having for emissions and risk reduction, the capacity of HRM as an organization, and the climate more broadly. Indicators in the Annual Indicators Report are intended to provide both a macro picture and detailed insight as to which activities are providing results. Ultimately, the most foundational indicator of impact will be annual emissions.

The Annual Indicators Report should include a combination of quantitative and qualitative indicators across three main areas that seek to answer a set of high level questions:

- **Climate and climate events indicators**: How is the climate changing? What are the impacts of that change?
- **Action implementation and effectiveness indicators**: What is the status and progress of actions implementation? Are the actions achieving their objectives? Are emissions reducing in Halifax? Is Halifax more prepared for climate change?
- **Capacity and learning indicators**: What is the capacity of HRM to address climate change? Is HRM making climate-informed decisions ? Is HRM learning and incorporating the knowledge gained?

Table 4 includes a set of sample indicators for each of the categories above. In identifying and selecting indicators, HRM should consider using indicators that:

- Use a process-based approach: A process-based approach seeks to illustrate trends rather than specific outcomes. By using process indicators, it is possible to consider whether the direction of travel is correct given the current information;
- Ability to tell a story: A good indicator represents a number of different inputs and outcomes so that it provides a quick snapshot of a complex situation;
- Availability of data: HRM already prepares a wide range of indicators on different issues. Where possible, these indicators should be included to minimize the additional work involved in annual reporting.

Table 4: Sample indicators by category.

Climate and climate events indicators	
Climate indicator	Average annual temperature
	Number of days with heat warnings
	Number of weather warning events by type (rainfall, snowfall, freezing rain and wind warnings)
Climate impact indicator	Total $ insurance claims due to climate event
	Direct cost to HRM from climate event
	Deaths and hospital admissions from extreme heat
Action implementation and effectiveness indicators	
Action implementation indicators	Has the retrofit program been established?
	Has a detailed risk and vulnerability assessment of HRM's assets been completed?
	Number of homes retrofitted
	Number of solar panels installed
	Number of Halifax residents engaged
	Number of trees planted, tree canopy and % of impervious surfaces
	Number of HRM assets future-proofed
Action effectiveness indicators	Community wide GHG emissions
	HRM municipal GHG emissions & carbon budget
	Energy costs/savings
	Climate events financial costs/avoided costs

Capacity and learning indicators	
	Number of staff actively working on climate
	Number of staff trained on climate or with a climate change-related professional certification
	Number of capital projects that applied a climate lens
	Number of capital projects that included a cost of carbon and social costs of carbon

Carbon accounting

GET READY FOR NEUTRALITY AND STEP UP THE CARBON SCOPE

44. Carbon offsets framework

Develop a values-based framework for carbon offsets. Under LC3 implementation, 95% of emissions are reduced by 2050, but 5% of emissions remain, and the 1.5°C carbon budget is exceeded by 8 Mt CO2e. Addressing this remainder will likely improve in the next 30 years, but offsets may still need to be considered. In this light, HRM should develop a **values-based framework for carbon offsets that includes** guidelines for carbon offsets for future policies and programs, and explores a local carbon offsets market.

45. Consumption-based emissions

Develop a consumption based inventory. The energy and emissions quantified in this report are those associated with the energy used and emissions produced within the geographical boundary of the Halifax Regional Municipality, according to the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), which is otherwise referred to as a "sector-based" approach. This is currently the standard protocol for cities globally. However, this approach does not account for the emissions associated with goods and services that are generated and produced outside of Halifax, but used or consumed in Halifax; such as food and clothing for example. These are referred to as "consumption-based emissions".

According to C40, consumption-based emissions, or upstream emissions, may represent more than double the emissions from local energy use in buildings, transportation and waste. Addressing these will be vital to reducing emissions more broadly in Halifax. As a first step, HRM should develop a consumption-based inventory to support action and investment to address this growing issue.

46. Embodied carbon

Include embodied carbon in new construction standards for buildings. Embodied emissions include those associated with construction material extraction, manufacturing, and transportation to site, on-site construction processes, as well as building maintenance, repair, refurbishment, and decommissioning (end-of-life including demolition, recycling, and landfill). As buildings become more efficient and energy sources become lower or zero carbon (through LC3 implementation), annual operational emissions will decrease over time, while embodied emissions will remain largely unaddressed, and are likely to become the dominant source of building emissions.

Addressing the construction phases that will most likely be responsible for the bulk of life cycle emissions in the future, requires policies to be developed now that tackle embodied carbon and work to offset the carbon debt associated with construction. Additionally, policies aimed at reducing embodied carbon can address emissions in the building and construction sector that are not yet being tackled by other carbon policies, and can do so in the timeframes needed to meet reduction targets.

Glossary

Glossary

1.5°C warmer worlds	Projected worlds in which global warming has reached and, unless otherwise indicated, been limited to 1.5℃ above pre-industrial levels. There is no single 1.5℃ warmer world, and projections of 1.5℃ warmer worlds look different depending on whether it is considered on a near-term transient trajectory or at climate equilibrium after several millennia, and, in both cases, if it occurs with or without overshoot. Within the 21st century, several aspects play a role for the assessment of risk and potential impacts in 1.5℃ warmer worlds: the possible occurrence, magnitude and duration of an overshoot; the way in which emissions reductions are achieved; the ways in which policies might be able to influence the resilience of human and natural systems; and the nature of the regional and sub-regional risks. Beyond the 21st century, several elements of the climate system would continue to change even if the global mean temperatures remain stable, including further increases of sea level.
Adaption	In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects. **Transformational adaptation.** Adaptation that changes the fundamental attributes of a socioecological system in anticipation of climate change and its impacts.
Adaptive capacity	The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.
Air pollution	Degradation of air quality with negative effects on human health or the natural or built environment due to the introduction, by natural processes or human activity, into the atmosphere of substances (gases, aerosols) which have a direct (primary pollutants) or indirect (secondary pollutants) harmful effect.
Anthropogenic	Resulting from or produced by human activities.

Anthropogenic emissions	Emissions of greenhouse gases (GHGs), precursors of GHGs and aerosols caused by human activities. These activities include the burning of fossil fuels, deforestation, land use and land-use changes (LULUC), livestock production, fertilisation, waste management and industrial processes.
Carbon budget	This term refers to three concepts in the literature: (1) an assessment of carbon cycle sources and sinks on a global level, through the synthesis of evidence for fossil fuel and cement emissions, land-use change emissions, ocean and land CO2 sinks, and the resulting atmospheric CO2 growth rate. This is referred to as the global carbon budget; (2) the estimated cumulative amount of global carbon dioxide emissions that is estimated to limit global surface temperature to a given level above a reference period, taking into account global surface temperature contributions of other GHGs and climate forcers; (3) the distribution of the carbon budget defined under (2) to the regional, national, or sub-national level based on considerations of equity, costs or efficiency.
Carbon dioxide	A naturally occurring gas, CO2 is also a by-product of burning fossil fuels (such as oil, gas and coal), of burning biomass, of land-use changes (LUC) and of industrial processes (e.g., cement production). It is the principal anthropogenic greenhouse gas (GHG) that affects the Earth's radiative balance. It is the reference gas against which other GHGs are measured and therefore has a global warming potential (GWP) of 1.
Carbon price	The price for avoided or released carbon dioxide (CO2) or CO2-equivalent emissions. This may refer to the rate of a carbon tax, or the price of emission permits. In many models that are used to assess the economic costs of mitigation, carbon prices are used as a proxy to represent the level of effort in mitigation policies.
Carbon sequestration	The process of storing carbon in a carbon pool.
Climate change	Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change

	(UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.' The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes.
Climate-resilient pathways	Iterative processes for managing change within complex systems in order to reduce disruptions and enhance opportunities associated with climate change.
Climate target	Climate target refers to a temperature limit, concentration level, or emissions reduction goal used towards the aim of avoiding dangerous anthropogenic interference with the climate system.
Cumulative emissions	The total amount of emissions released over a specified period of time.
Decarbonisation	The process by which countries, individuals or other entities aim to achieve zero fossil carbon existence. Typically refers to a reduction of the carbon emissions associated with electricity, industry and transport.
Discounting	A mathematical operation that aims to make monetary (or other) amounts received or expended at different times (years) comparable across time. The discounter uses a fixed or possibly time-varying discount rate from year to year that makes future value worth less today (if the discount rate is positive). The choice of discount rate(s) is debated as it is a judgement based on hidden and/or explicit values.
Energy efficiency	The goal of a given country, or the global community as a whole, to maintain an adequate, stable and predictable energy supply. Measures encompass safeguarding the sufficiency of energy resources to meet national energy demand at competitive and stable prices and the resilience of the energy supply; enabling development and deployment of technologies; building sufficient infrastructure to generate, store and transmit energy supplies; and ensuring enforceable contracts of delivery.

Equality	A principle that ascribes equal worth to all human beings, including equal opportunities, rights, and obligations, irrespective of origins.
Equity	Equity is the principle of fairness in burden sharing and is a basis for understanding how the impacts and responses to climate change, including costs and benefits, are distributed in and by society in more or less equal ways. It is often aligned with ideas of equality, fairness and justice and applied with respect to equity in the responsibility for, and distribution of, climate impacts and policies across society, generations, and gender, and in the sense of who participates and controls the processes of decision-making. **Intergenerational equity**. Equity between generations that acknowledges that the effects of past and present emissions, vulnerabilities and policies impose costs and benefits for people in the future and of different age groups.
Exposure	The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected
Extreme weather event	An extreme weather event is an event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., drought or heavy rainfall over a season)
Feasibility	The degree to which climate goals and response options are considered possible and/or desirable. Feasibility depends on geophysical, ecological, technological, economic, social and institutional conditions for change. Conditions underpinning feasibility are dynamic, spatially variable, and may vary between different groups.
Flood	The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas that are not normally submerged. Floods include river (fluvial) floods, flash

	floods, urban floods, pluvial floods, sewer floods, coastal floods, and glacial lake outburst floods.
Food security	A situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.
Fossil fuels	Carbon-based fuels from fossil hydrocarbon deposits, including coal, oil, and natural gas.
Green infrastructure	The interconnected set of natural and constructed ecological systems, green spaces and other landscape features. It includes planted and indigenous trees, wetlands, parks, green open spaces and original grassland and woodlands, as well as possible building and street-level design interventions that incorporate vegetation. Green infrastructure provides services and functions in the same way as conventional infrastructure.
Greenhouse gas (GHG)	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself and by clouds. This property causes the greenhouse effect. Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary GHGs in the Earth's atmosphere. Moreover, there are a number of entirely human-made GHGs in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO2, N2O and CH4, the Kyoto Protocol deals with the GHGs sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.
Impacts	The consequences of realized risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure, and vulnerability. Impacts generally refer to effects on lives; livelihoods; health and well-being; ecosystems

	and species; economic, social and cultural assets; services (including ecosystem services); and infrastructure. Impacts may be referred to as consequences or outcomes, and can be adverse or beneficial.
Livelihood	The resources used and the activities undertaken in order to live. Livelihoods are usually determined by the entitlements and assets to which people have access. Such assets can be categorised as human, social, natural, physical or financial.
Local knowledge	Local knowledge refers to the understandings and skills developed by individuals and populations, specific to the places where they live. Local knowledge informs decision-making about fundamental aspects of life, from day-to-day activities to longer-term actions. This knowledge is a key element of the social and cultural systems which influence observations of, and responses to climate change; it also informs governance decisions.
Lock-in	A situation in which the future development of a system, including infrastructure, technologies, investments, institutions, and behavioural norms, is determined or constrained ('locked in') by historic developments.
Methane (CH4)	One of the six greenhouse gases (GHGs) to be mitigated under the Kyoto Protocol and is the major component of natural gas and associated with all hydrocarbon fuels. Significant emissions occur as a result of animal husbandry and agriculture, and their management represents a major mitigation option.
Mitigation measures	In climate policy, mitigation measures are technologies, processes or practices that contribute to mitigation, for example, renewable energy (RE) technologies, waste minimization processes and public transport commuting practices.
Net zero emissions	Net zero emissions are achieved when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period. Where multiple greenhouse gases are involved, the quantification of net zero emissions depends on the climate metric chosen to compare emissions of different gases (such as global warming potential, global temperature change potential, and others, as well as the chosen time horizon)
Paris Agreement	The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) was adopted on

	December 2015 in Paris, France, at the 21st session of the Conference of the Parties (COP) to the UNFCCC. The agreement, adopted by 196 Parties to the UNFCCC, entered into force on 4 November 2016 and as of May 2018 had 195 Signatories and was ratified by 177 Parties. One of the goals of the Paris Agreement is 'Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels', recognising that this would significantly reduce the risks and impacts of climate change.
Pathways	The temporal evolution of natural and/or human systems towards a future state. Pathway concepts range from sets of quantitative and qualitative scenarios or narratives of potential futures to solution-oriented decision-making processes to achieve desirable societal goals. Pathway approaches typically focus on biophysical, techno-economic, and/or socio-behavioural trajectories and involve various dynamics, goals and actors across different scales. **1.5°C pathway.** A pathway of emissions of greenhouse gases and other climate forcers that provides an approximately one-in-two to two-in-three chance, given current knowledge of the climate response, of global warming either remaining below 1.5°C or returning to 1.5°C by around 2100 following an overshoot. **Adaptation pathways.** A series of adaptation choices involving trade-offs between short-term and long-term goals and values. These are processes of deliberation to identify solutions that are meaningful to people in the context of their daily lives and to avoid potential maladaptation.
Policies	Policies (for climate change mitigation and adaptation). Policies are taken and/or mandated by a government – often in conjunction with business and industry within a single country, or collectively with other countries – to accelerate mitigation and adaptation measures.
Remaining carbon budget	Estimated cumulative net global anthropogenic CO2 emissions from the start of 2018 to the time that anthropogenic CO2 emissions reach net zero that would result, at some probability, in limiting global warming to a given level, accounting for the impact of other anthropogenic emissions.
Resilience	The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or

	reorganizing in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation.
Risk	The potential for adverse consequences where something of value is at stake and where the occurrence and degree of an outcome is uncertain. In the context of the assessment of climate impacts, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Risk results from the interaction of vulnerability (of the affected system), its exposure over time (to the hazard), as well as the (climate-related) hazard and the likelihood of its occurrence.
Scenario	A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships. Note that scenarios are neither predictions nor forecasts, but are used to provide a view of the implications of developments and actions.
Social costs	The full costs of an action in terms of social welfare losses, including external costs associated with the impacts of this action on the environment, the economy (GDP, employment) and on the society as a whole.
Inequality	Uneven opportunities and social positions, and processes of discrimination within a group or society, based on gender, class, ethnicity, age, and (dis) ability, often produced by uneven development. Income inequality refers to gaps between the highest and lowest income earners within a country and between countries.
Uncertainty	A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, incomplete understanding of critical processes, or uncertain projections of human behaviour.)
United Nations Framework	The UNFCCC was adopted in May 1992 and opened for signature at the 1992 Earth Summit in Rio de Janeiro. It entered into force in March 1994 and as of May 2018 had 197 Parties (196 States and the

Convention on Climate Change (UNFCCC)	European Union). The Convention's ultimate objective is the 'stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.' The provisions of the Convention are pursued and implemented by two treaties: the Kyoto Protocol and the Paris Agreement.
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.
Well-being	A state of existence that fulfils various human needs, including material living conditions and quality of life, as well as the ability to pursue one's goals, to thrive, and feel satisfied with one's life. Ecosystem well-being refers to the ability of ecosystems to maintain their diversity and quality.

Appendix A:
LC3 Scenario Results

Community Energy

Energy by sector

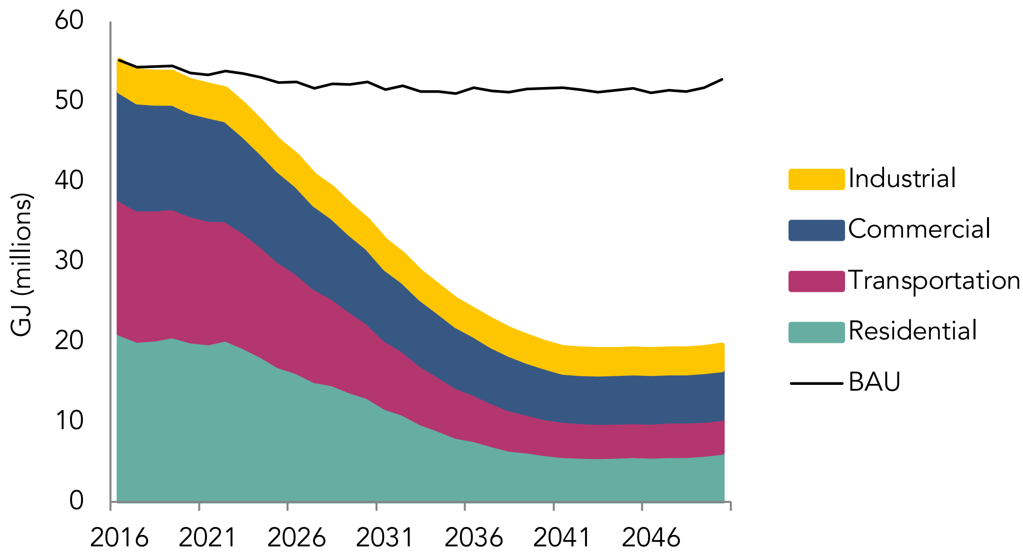


Figure A1. Projected LC3 energy consumption (million GJ) by sector, 2016-2050.

Energy by fuel

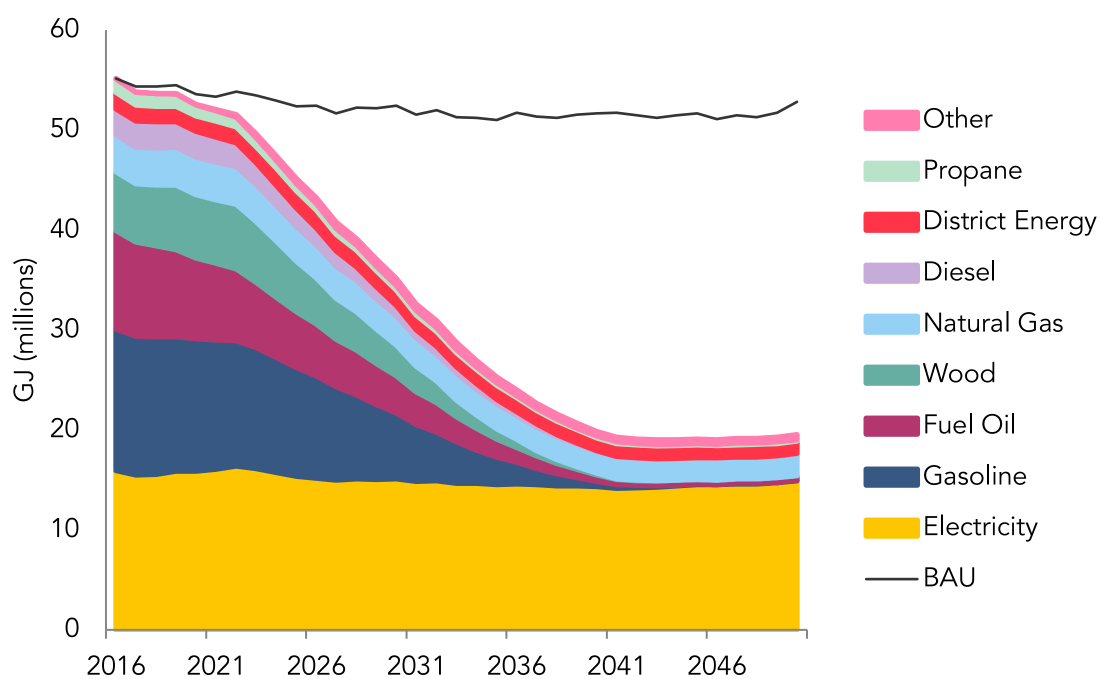


Figure A2. Projected LC3 energy consumption (million GJ) by fuel, 2016-2050.

Per Capita Energy

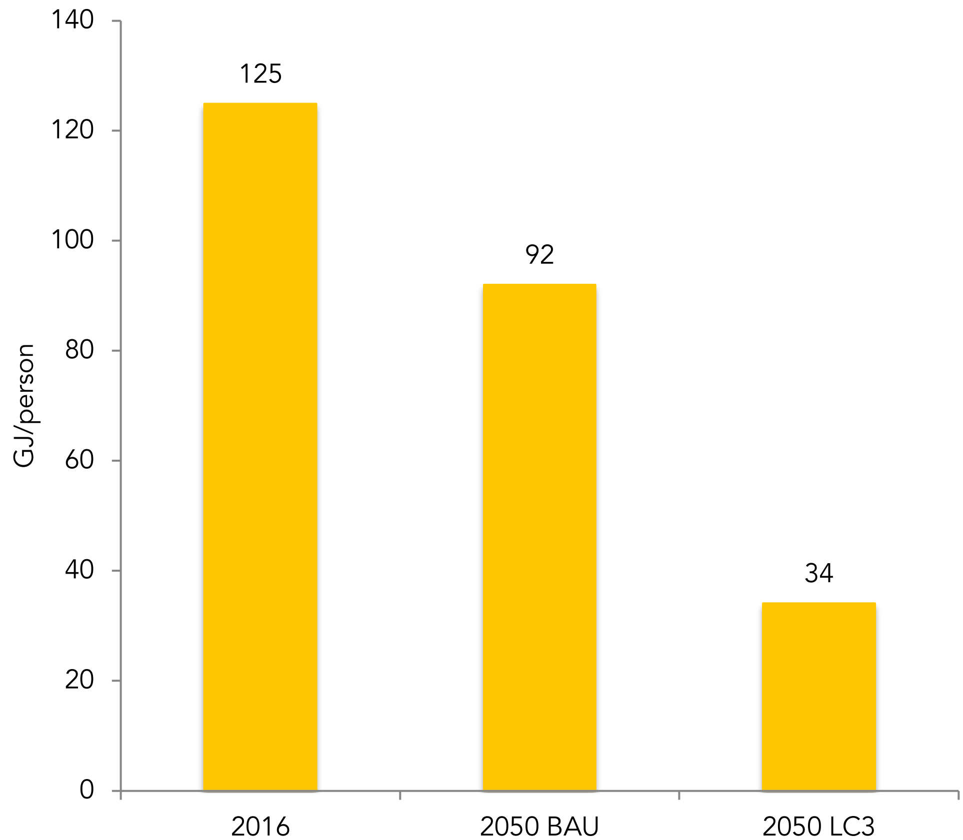


Figure A3. Projected BAU and LC3 energy per capita (GJ/person), 2016 & 2050.

Table A1. Community energy consumption by sector and fuel, for 2016 BAU, and 2050 BAU and LC3

Energy by sector (GJ)	2016	share 2016	2050 (BAU)	share 2050	2050 (LC3)	share 2050	% +/- 2016-2050 LC	% +/- 2050 BAU-2050 LC
Commercial	13,508,700	24.5%	14,801,100	28.0%	6,046,200	31%	-55.2%	-59.2%
Industrial	3,827,400	6.9%	4,320,400	8.2%	3,009,100	15%	-21.4%	-30.4%
Residential	21,114,700	38.3%	22,823,400	43.2%	6,186,700	32%	-70.7%	-72.9%
Transportation	16,708,000	30.3%	10,873,200	20.6%	4,292,200	22%	-74.3%	-60.5%
Total	55,158,800		52,818,000		19,534,200		-65%	-63%
Energy by fuel (GJ)	**2016**	**share 2016**	**2050 (BAU)**	**share 2050**	**2050 (LC3)**	**share 2050**	**% +/- 2016-2050 LC**	**% +/- 2050 BAU-2050 LC**
Diesel	2,596,900	4.7%	2,390,600	4.5%	17,400	0%	-99.3%	-99.3%
District Energy	1,629,400	3.0%	1,517,800	2.9%	1,254,700	6%	-23.0%	-17.3%
Electricity	15,969,500	29.0%	20,864,700	39.5%	14,941,200	76%	-6.4%	-28.4%
Fuel Oil	9,818,700	17.8%	7,578,400	14.3%	458,600	2%	-95.3%	-93.9%
Gasoline	14,138,300	25.6%	7,341,300	13.9%	29,400	0%	-99.8%	-99.6%
Natural Gas	3,692,900	6.7%	4,378,500	8.3%	2,186,400	11%	-40.8%	-50.1%
Other	1,600	0.0%	1,700	0.0%	492,200	3%	30047.9%	28852.9%
Propane	1,386,200	2.5%	1,178,000	2.2%	144,700	1%	-89.6%	-87.7%
Wood	5,925,300	10.7%	7,566,900	14.3%	9,600	0%	-99.8%	-99.9%
Total	55,158,800		52,818,000		19,534,200		-65%	-63%
Energy per capita (GJ/cap)	**125**		**92**		**34**		**-73%**	**-63%**

Community Emissions

Emissions by sector

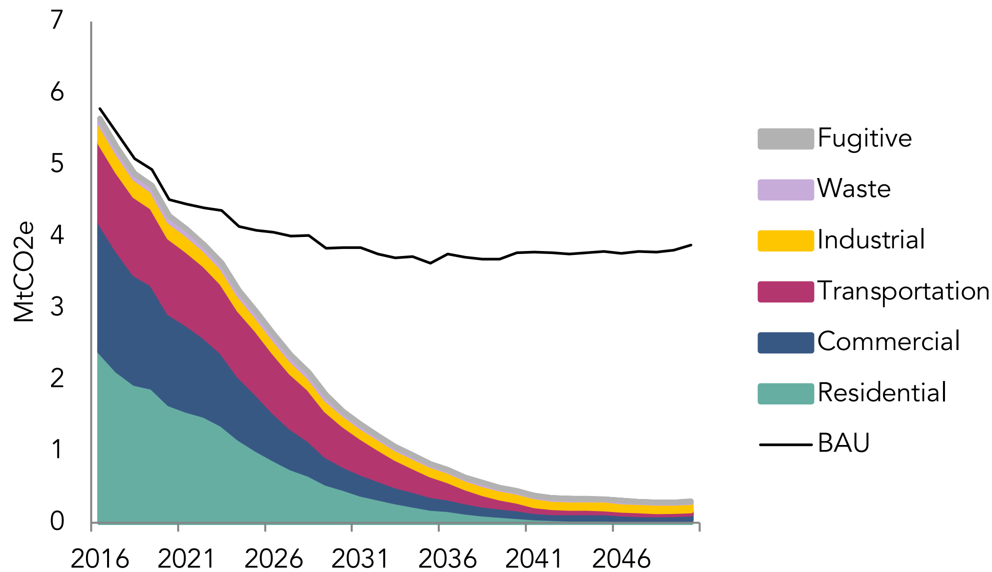


Figure A4. Projected LC3 emissions (MtCO2e) by sector, 2016-2050.

Emissions by source

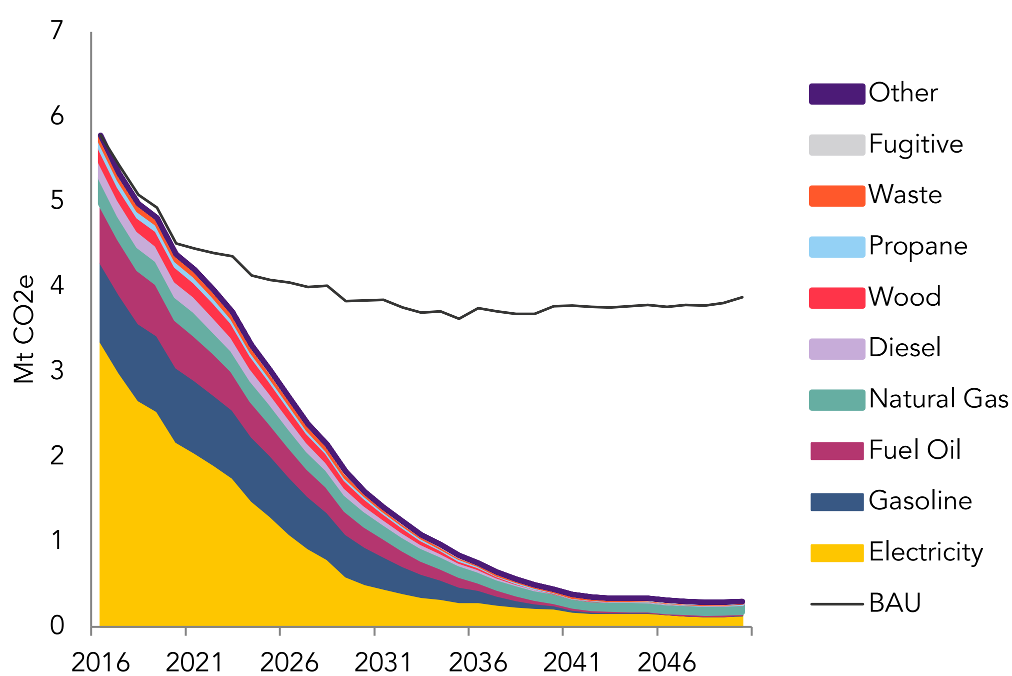


Figure A5. Projected LC3 emissions (MtCO2e) by source, 2016-2050.

Per Capita Emissions

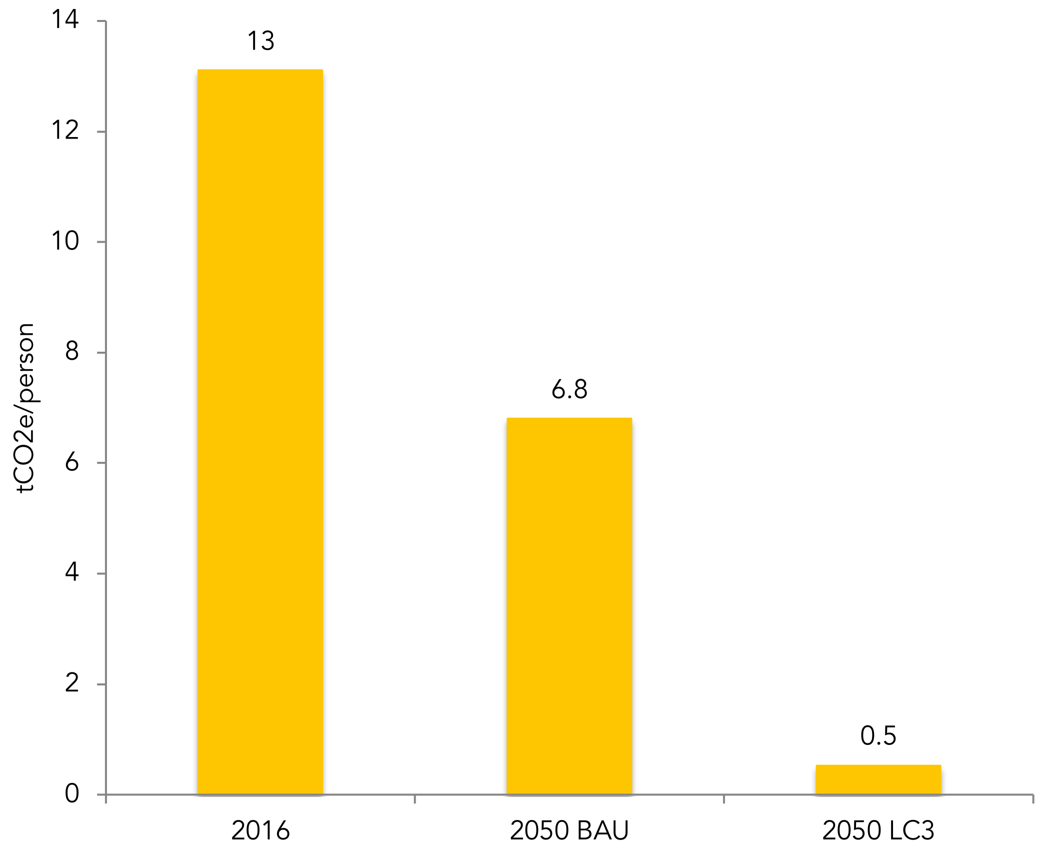


Figure A6. Projected 2016, 2050 BAU and 2050 LC3 emissions per capita (tCO2e/person), 2016 & 2050.

Table A2. Community emissions by sector and fuel, for 2016 BAU, and 2050 BAU and LC3

Emissions by sector (tCO2e)	2016	share 2016	2050 (BAU)	share 2050	2050 (LC)	share 2050	% +/- 2016-2050 LC	% +/- 2050 BAU-2050 LC
Commercial	1,802,600	31.2%	1,164,100	30.0%	75,900	25.4%	-95.8%	-93.5%
Energy Production	137,000	2.4%	136,500	3.5%	130	0.0%	-99.9%	-99.9%
Fugitive	3,000	0.1%	3,400	0.1%	1,050	0.4%	-65.2%	-69.1%
Industrial	261,800	4.5%	229,400	5.9%	119,300	39.9%	-54.4%	-48.0%
Residential	2,395,100	41.4%	1,512,900	39.0%	45,300	15.1%	-98.1%	-97.0%
Transportation	1,114,500	19.3%	760,800	19.6%	47,600	15.9%	-95.7%	-93.7%
Waste	69,800	1.2%	72,800	1.9%	9,900	3.3%	-85.8%	-86.4%
Total	5,783,700		3,879,900		299,200		-94.8%	-92.3%
Emissions by source (tCO2e)	**2016**	share 2016	**2050 (BAU)**	share 2050	**2050 (LC)**	share 2050	**% +/- 2016-2050 LC**	**% +/- 2050 BAU-2050 LC**
Diesel	186,200	3.2%	171,400	4.4%	1,300	0.4%	-99.3%	-99.2%
Electricity	3,349,300	57.9%	1,997,100	51.5%	135,500	45.3%	-96.0%	-93.2%
Fuel Oil	695,100	12.0%	541,200	14.0%	33,400	11.2%	-95.2%	-93.8%
Fugitive	3,000	0.1%	3,400	0.1%	1,050	0.4%	-65.2%	-69.1%
Gasoline	930,200	16.1%	479,500	12.4%	1,950	0.7%	-99.8%	-99.6%
Natural Gas	308,200	5.3%	341,800	8.8%	107,100	35.8%	-65.2%	-68.7%
Other	0	0.0%	0	0.0%	90	0.0%	19198.0%	
Propane	84,800	1.5%	72,100	1.9%	8,800	3.0%	-89.6%	-87.8%
Waste	69,800	1.2%	72,800	1.9%	9,900	3.3%	-85.8%	-86.4%
Wood	157,000	2.7%	200,600	5.2%	-	0.0%	-100.0%	-100.0%
Total	5,783,700		3,879,900		299,200		-94.8%	-92.3%
Emissions per capita (tCO2e/person)	**13**		**6.8**		**0.5**		**-96.0%**	**-92.6%**

Buildings energy by fuel

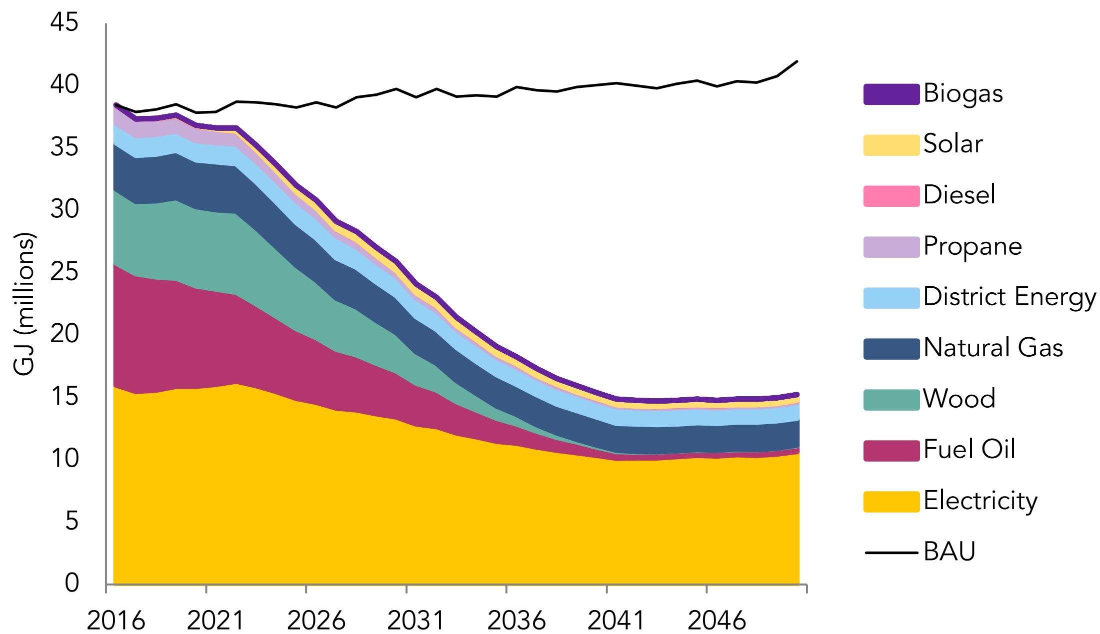


Figure A7. Projected LC3 buildings energy use (million GJ) by fuel, 2016-2050.

Buildings energy by end use

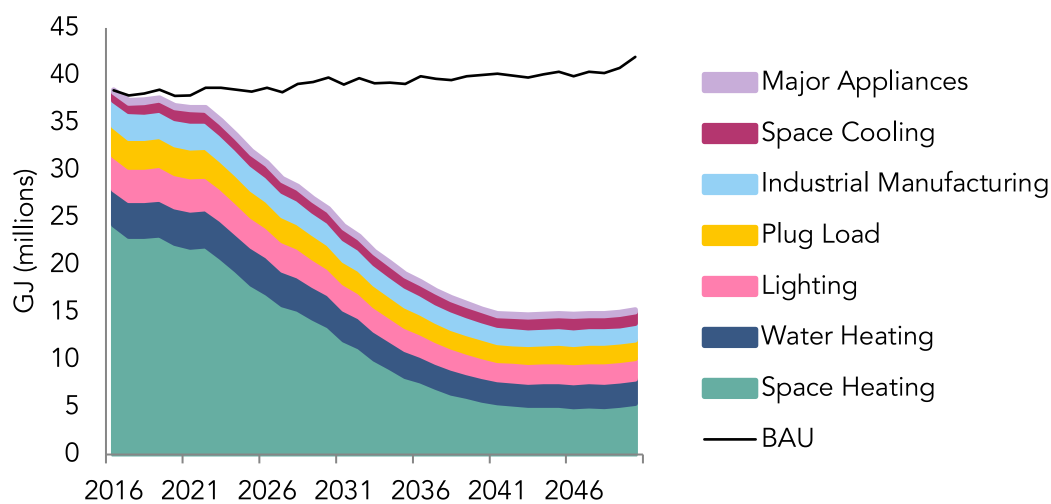


Figure A8. Projected LC3 buildings energy use (million GJ) by end use, 2016-2050.

Buildings energy by building type & fuel

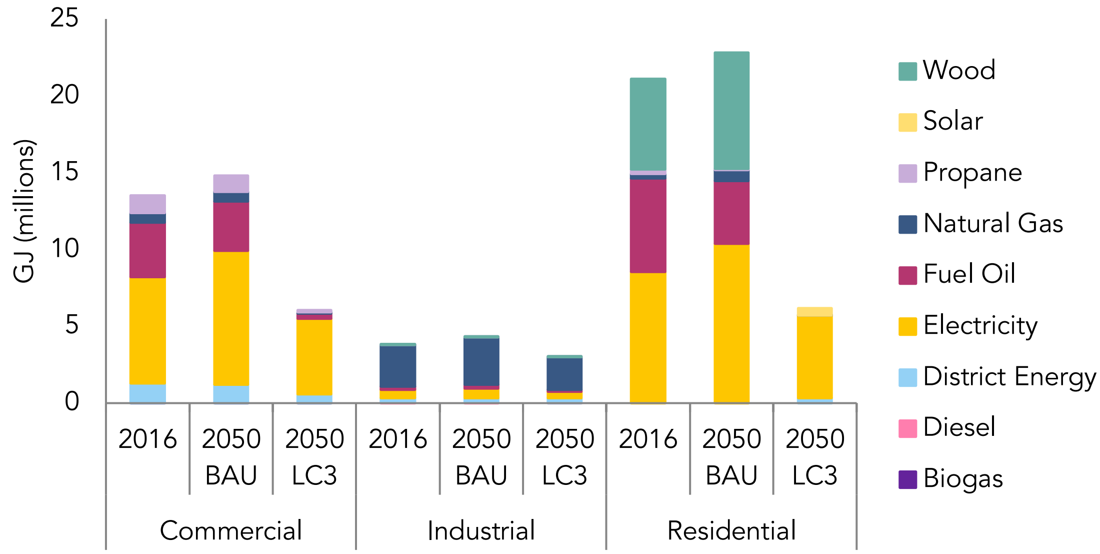


Figure A9. Projected buildings energy use (million GJ) by building type and fuel, 2016, 2050 BAU and 2050 LC3.

Buildings energy by building type & end use

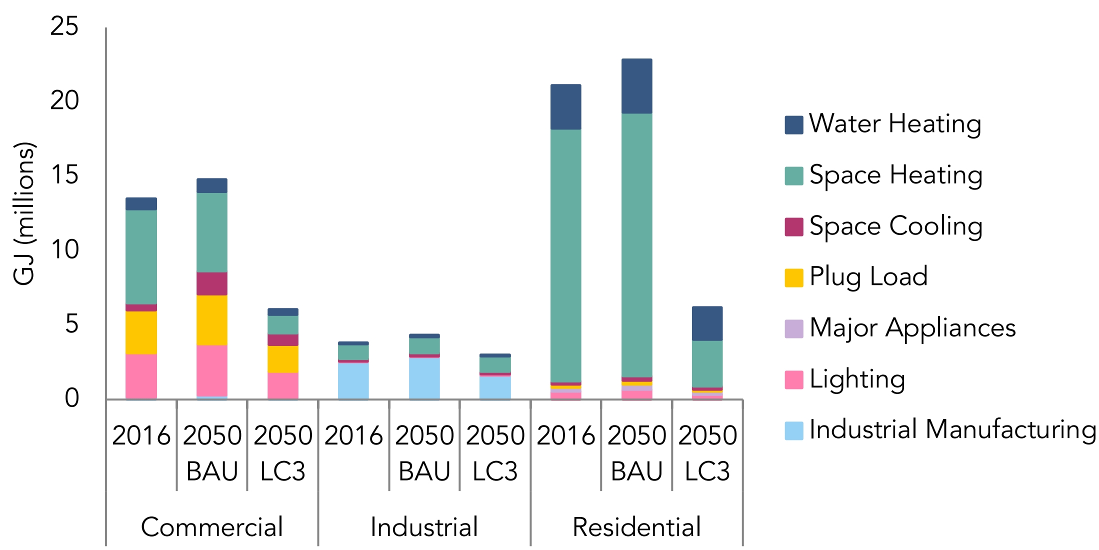


Figure A10. Projected BAU buildings energy use (million GJ) by building type and end use, 2016, 2050 BAU and 2050 LC3.

Per household energy

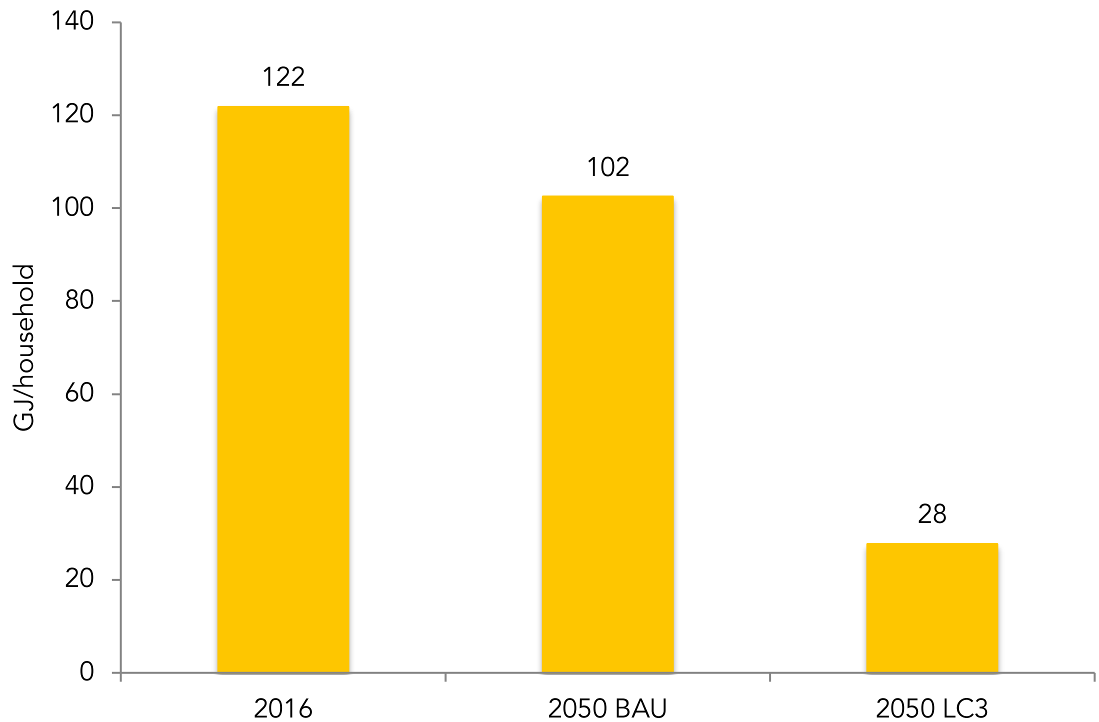


Figure A11. Projected residential energy per household (GJ/household), 2016, 2050 BAU and 2050 LC3.

Table A3. Building sector energy tabulated results, 2016, 2050 BAU and 2050 LC3.

Buildings energy (GJ) by building type	2016	share 2016	2050 (BAU)	share 2050	2050 (LC3)	share 2050	% +/- 2016-2050 LC	% +/- 2050 BAU-2050 LC
Residential	21,114,700	54.9%	22,823,400	54.4%	6,186,700	40.6%	-70.7%	-72.9%
Commercial	13,508,700	35.1%	14,801,100	35.3%	6,046,200	39.7%	-55.2%	-59.2%
Industrial	3,827,400	10.0%	4,320,400	10.3%	3,009,100	19.7%	-21.4%	-30.4%
Total	38,450,800		41,944,900		15,242,000		-60.4%	-63.7%
Buildings energy (GJ) by fuel	**2016**	share 2016	**2050 (BAU)**	share 2050	**2050 (LC)**	share 2050	**% +/- 2016-2050 LC**	**% +/- 2050 BAU-2050 LC**
Biogas	1,600	0.0%	1,700	0.0%	1,200	0.0%	-25.0%	-29.4%
Diesel	27,500	0.1%	28,400	0.1%	16,200	0.1%	-41.1%	-43.0%
District Energy	1,629,400	4.2%	1,517,800	3.6%	1,254,700	8.2%	-23.0%	-17.3%
Electricity	15,969,200	41.5%	19,695,100	47.0%	10,679,500	70.1%	-33.1%	-45.8%
Fuel Oil	9,818,700	25.5%	7,578,400	18.1%	458,600	3.0%	-95.3%	-93.9%
Natural Gas	3,692,900	9.6%	4,378,500	10.4%	2,186,400	14.3%	-40.8%	-50.1%
Propane	1,386,200	3.6%	1,178,000	2.8%	144,700	0.9%	-89.6%	-87.7%
Solar	0				491,100	3.2%		
Wood	5,925,300	15.4%	7,566,900	18.0%	9,600	0.1%	-99.8%	-99.9%
Total	38,450,800		41,944,900		15,241,900		-60.4%	-63.7%
Buildings energy (GJ) by end use	**2016**	share 2016	**2050 (BAU)**	share 2050	**2050 (LC)**	share 2050	**% +/- 2016-2050 LC**	**% +/- 2050 BAU-2050 LC**
Industrial Manufacturing	2,695,500	7.0%	3,165,000	7.5%	1,752,000	11.5%	-35.0%	-44.6%
Lighting	3,570,200	9.3%	4,184,900	10.0%	2,149,900	14.1%	-39.8%	-48.6%
Major Appliances	253,400	0.7%	349,700	0.8%	206,500	1.4%	-18.5%	-40.9%
Plug Load	3,074,300	8.0%	3,617,400	8.6%	1,974,800	13.0%	-35.8%	-45.4%
Space Cooling	881,700	2.3%	2,017,400	4.8%	1,164,800	7.6%	32.1%	-42.3%
Space Heating	24,264,600	63.1%	24,141,200	57.6%	5,391,100	35.4%	-77.8%	-77.7%
Water Heating	3,711,000	9.7%	4,469,200	10.7%	2,603,000	17.1%	-29.9%	-41.8%
Total	38,450,800		41,944,900		15,241,900		-60.4%	-63.7%

Buildings Sector Emissions

Buildings emissions by source

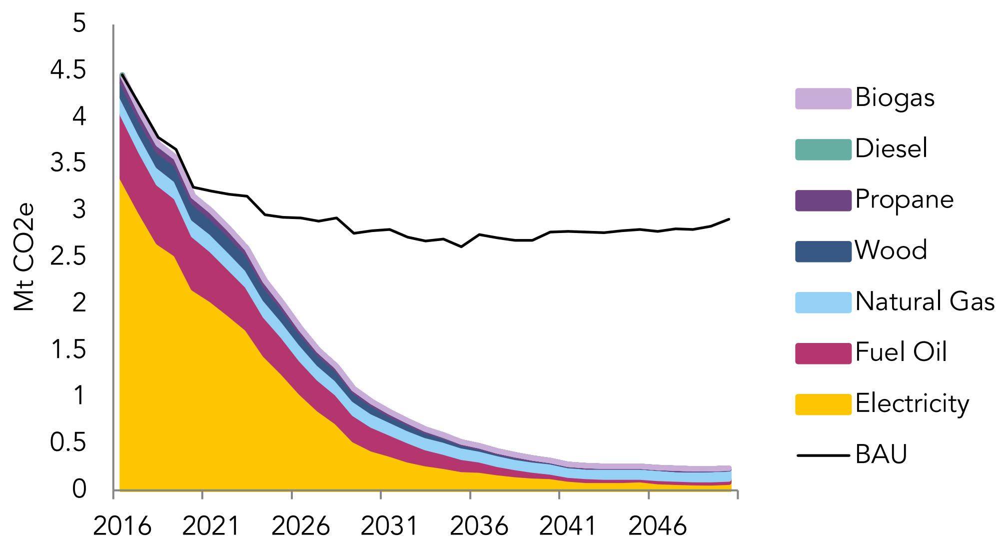


Figure A12. Projected LC3 buildings emissions (Mt CO2e) by source, 2016-2050.

Buildings emissions by end use

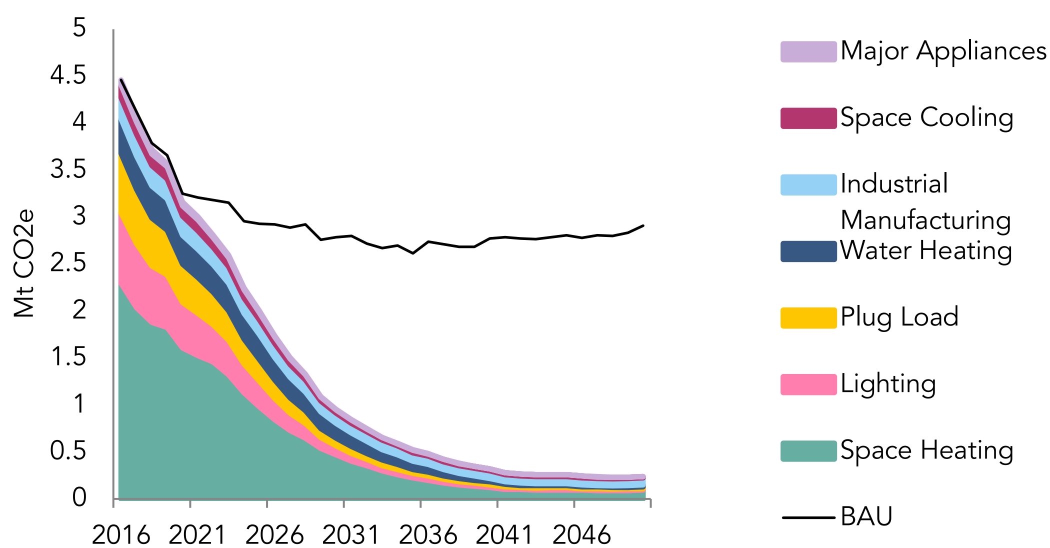


Figure A13. Projected LC3 buildings emissions (Mt CO2e) by end use, 2016-2050.

Buildings emissions by building type & source

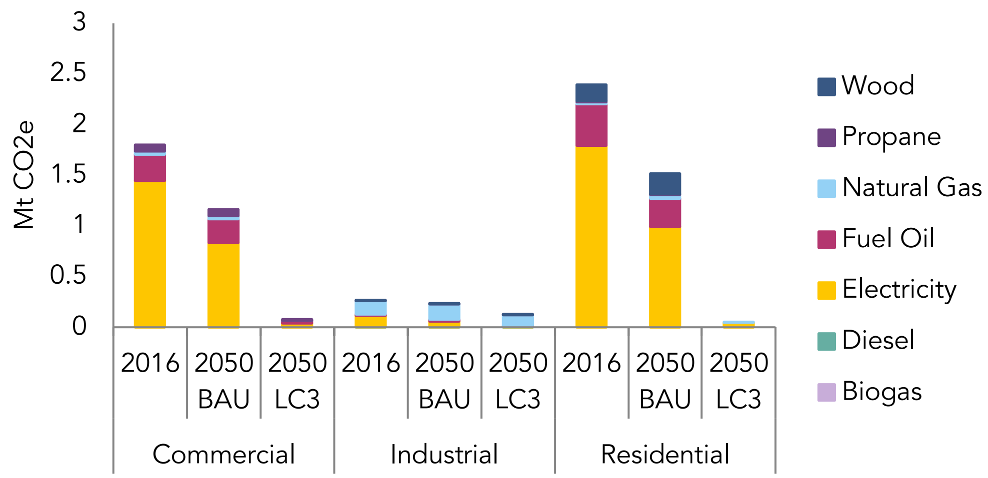


Figure A14. Projected BAU buildings emissions (Mt CO2e) by building type and source, 2016, 2050 BAU and 2050 LC3.

Buildings emissions by building type & end use

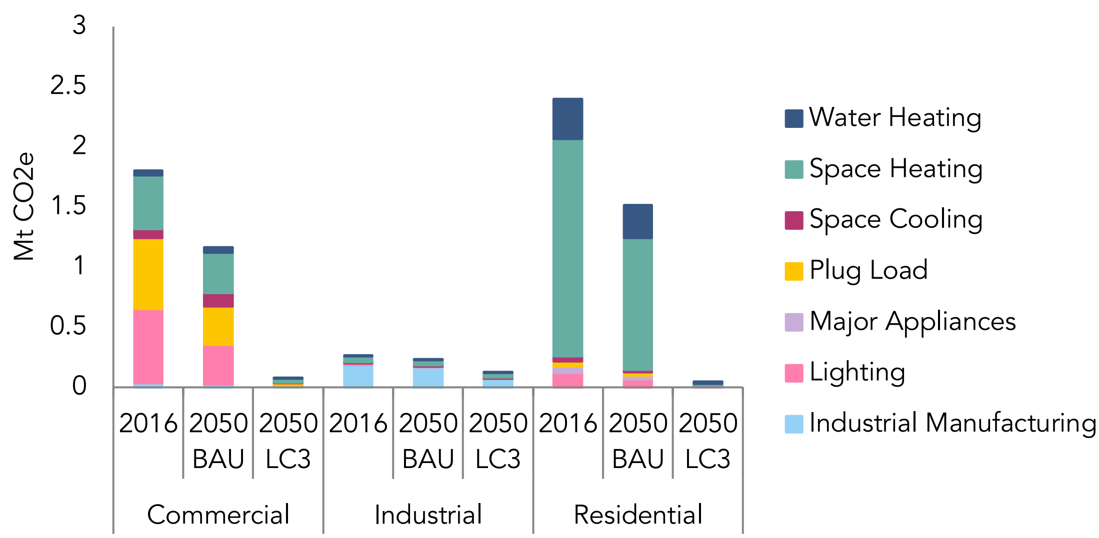


Figure A15. Projected BAU buildings emissions (Mt CO2e) by building type and end use2016, 2050 BAU and 2050 LC3.

Per household emissions

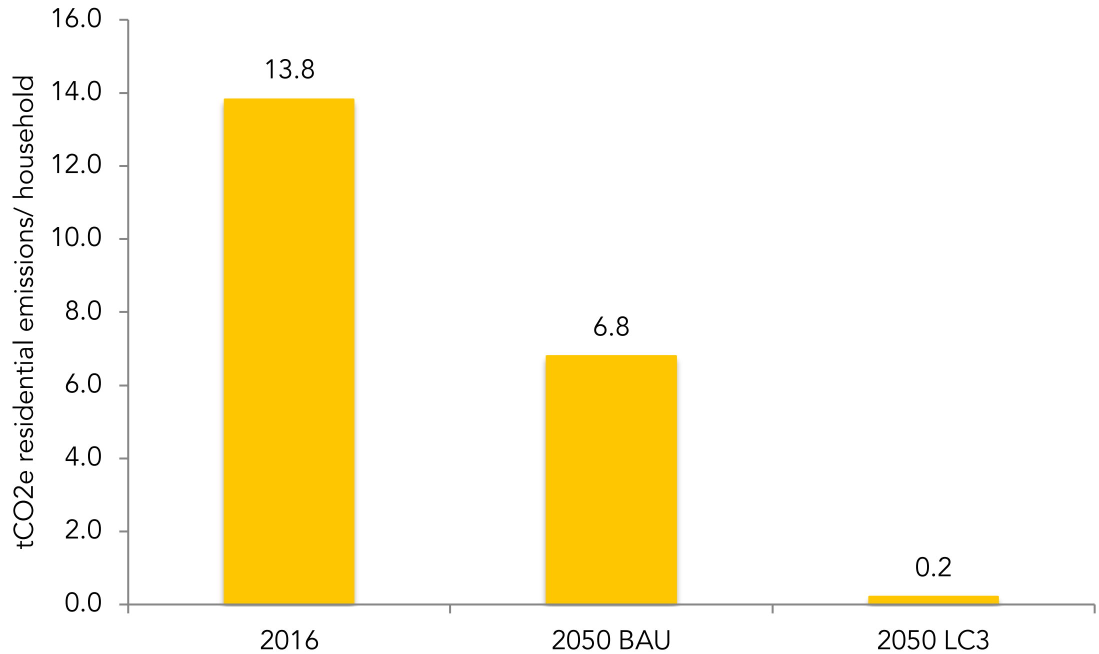


Figure A16. Projected BAU residential emissions per household (tCO2e/household), 2016, 2050 BAU and 2050 LC3.

Table A4. Building sector emissions tabulated results, 2016, 2050 BAU and 2050 LC3.

Buildings emissions (tCO2e) by building type	2016	share 2016	2050 (BAU)	share 2050	2050 (LC3)	share 2050	% +/- 2016-2050 LC	% +/- 2050 BAU-2050 LC
Residential	2,395,100	53.7%	1,512,900	52.1%	45,300	18.8%	-98.1%	-97.0%
Commercial	1,802,600	40.4%	1,164,100	40.1%	75,900	31.6%	-95.8%	-93.5%
Industrial	261,800	5.9%	229,400	7.9%	119,300	49.6%	-54.4%	-48.0%
Total	4,459,400		2,906,500		240,500		-94.6%	-91.7%
Buildings emissions (tCO2e) by fuel	**2016**	share 2016	**2050 (BAU)**	share 2050	**2050 (LC)**	share 2050	**% +/- 2016-2050 LC**	**% +/- 2050 BAU-2050 LC**
Biogas	0	0.0%	0	0.0%	0	0.0%	-27.7%	
Diesel	2,000	0.0%	2,100	0.1%	1,200	0.5%	-41.0%	-42.9%
Electricity	3,348,500	75.1%	1,884,900	64.9%	89,900	37.4%	-97.3%	-95.2%
Fuel Oil	686,200	15.4%	532,300	18.3%	33,400	13.9%	-95.1%	-93.7%
Natural Gas	180,900	4.1%	214,500	7.4%	107,100	44.5%	-40.8%	-50.1%
Propane	84,800	1.9%	72,100	2.5%	8,800	3.7%	-89.6%	-87.8%
Wood	157,000	3.5%	200,600	6.9%	0	0.0%	-100.0%	-100.0%
Total	4,459,400		2,906,500		240,500		-94.6%	-91.7%
Buildings emissions (tCO2e) by end use	**2016**	share 2016	**2050 (BAU)**	share 2050	**2050 (LC)**	share 2050	**% +/- 2016-2050 LC**	**% +/- 2050 BAU-2050 LC**
Industrial Manufacturing	225,700	5.1%	194,700	6.7%	75,200	31.2%	-66.7%	-61.4%
Lighting	748,600	16.8%	400,500	13.8%	18,000	7.5%	-97.6%	-95.5%
Major Appliances	53,100	1.2%	33,500	1.2%	1,800	0.7%	-96.7%	-94.6%
Plug Load	631,800	14.2%	342,700	11.8%	19,100	7.9%	-97.0%	-94.4%
Space Cooling	134,300	3.0%	149,900	5.2%	15,600	6.5%	-88.4%	-89.6%
Space Heating		51.5%	1,468,400	50.5%	92,600	38.5%	-96.0%	-93.7%

	2,297,700							
Water Heating	368,100	8.3%	316,800	10.9%	18,300	7.6%	-95.0%	-94.2%
Total	4,459,400		2,906,500		240,500		-94.6%	-91.7%

Transportation Sector Energy

Transportation energy by fuel

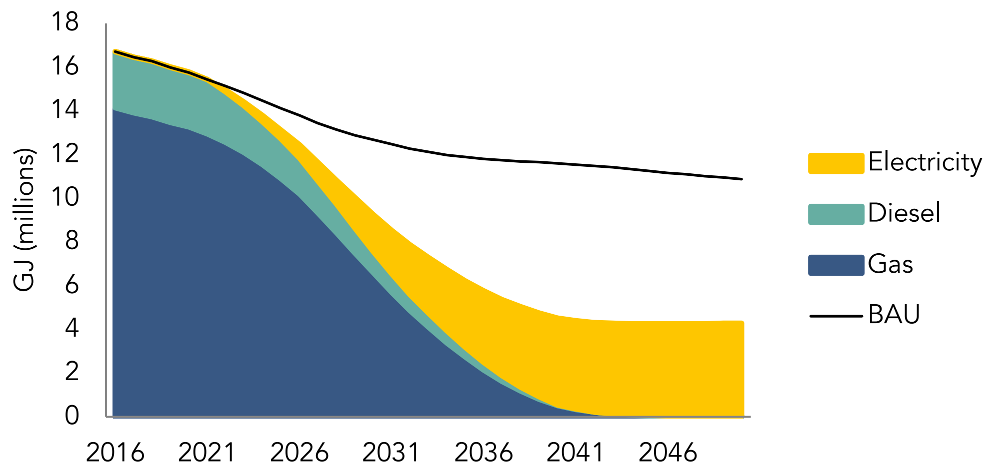


Figure A17. Projected LC3 transportation energy use (million GJ) by fuel, 2016-2050.

Transportation energy by vehicle type

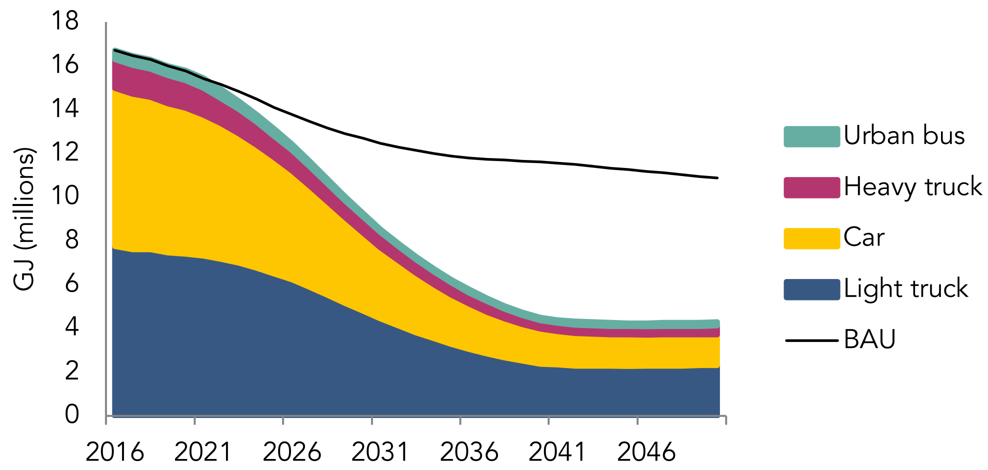


Figure A18. Projected LC3 transportation energy use (million GJ) by vehicle type, 2016-2050.

Transportation energy by vehicle type & fuel

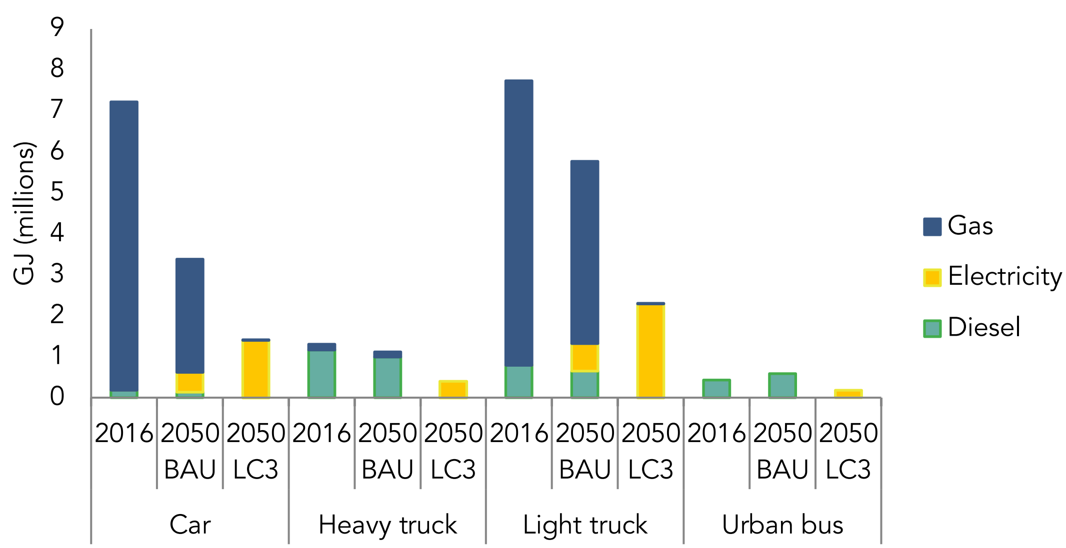


Figure A19. Projected transportation energy use (million GJ) by vehicle type and fuel, 2016, 2050 BAU and 2050 LC3.

Table A5. Transportation sector energy tabulated results, 2016 & 2050 (BAU).

Transportation energy (GJ)	2016	share	2050	share	2050 (LC)	share	% +/- 2016-2050	% +/-

by fuel		2016	(BAU)	2050		2050	LC	2050 BAU-2050 LC
Diesel	2,569,400	15.4%	2,362,200	21.7%	1,100	0.0%	-100.0%	-100.0%
Electricity	300	0.0%	1,169,700	10.8%	4,261,700	99.3%	1332145.4%	264.4%
Gasoline	14,138,300	84.6%	7,341,300	67.5%	29,400	0.7%	-99.8%	-99.6%
Total	16,708,000		10,873,200		4,292,200		-74.3%	-60.5%
Transportation energy (GJ) by vehicle type	**2016**	**share 2016**	**2050 (BAU)**	**share 2050**	**% +/- (2016-2050)**	share 2050	**% +/- 2016-2050 LC**	**% +/- 2050 BAU-2050 LC**
Car	7,221,700	43.2%	3,384,600	31.1%	1,415,500	33.0%	-80.4%	-58.2%
Heavy truck	1,310,000	7.8%	1,122,900	10.3%	393,300	9.2%	-70.0%	-65.0%
Light truck	7,742,100	46.3%	5,775,600	53.1%	2,306,700	53.7%	-70.2%	-60.1%
Bus	434,200	2.6%	590,000	5.4%	176,700	4.1%	-59.3%	-70.0%
Total	16,708,000		10,873,200		4,292,200		-74.3%	-60.5%

Transportation Sector Emissions

Transportation emissions by source

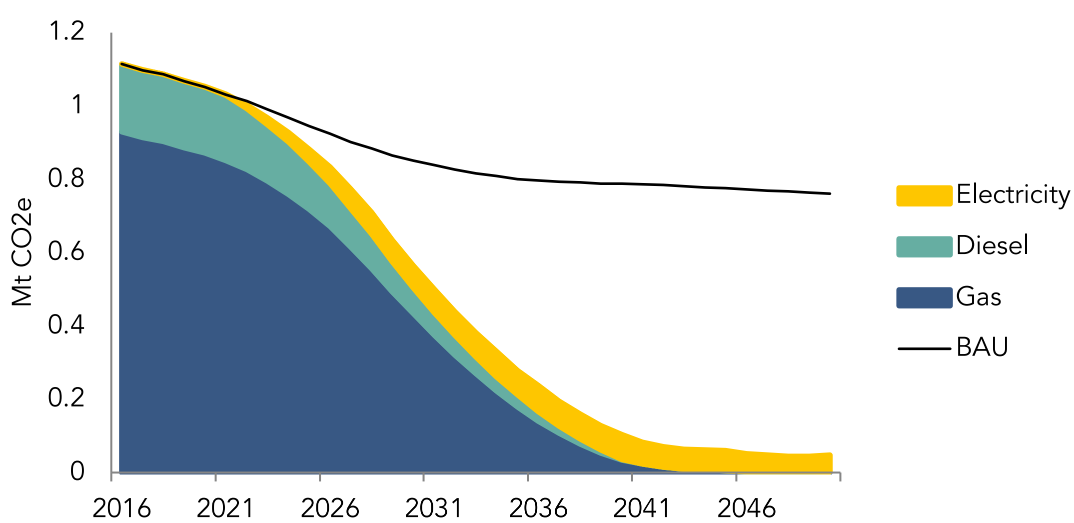


Figure A20. Projected LC3 transportation emissions (Mt CO2e) by source, 2016-2050.

Transportation emissions by vehicle type

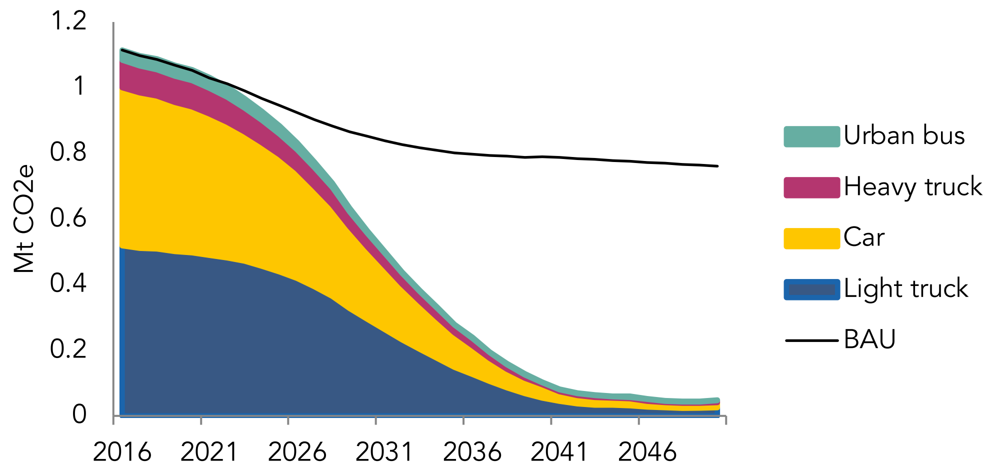


Figure A21. Projected LC3 transportation emissions (Mt CO2e) by vehicle type, 2016-2050.

Transportation emissions by source & vehicle type

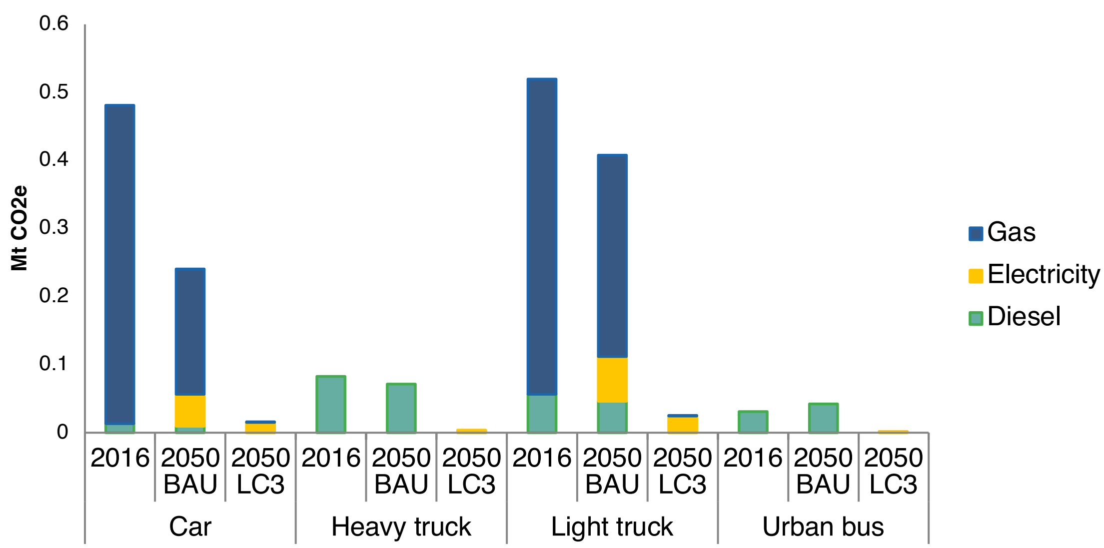


Figure A22. Projected transportation emissions (MtCO2e) by source and vehicle type2016, 2050 BAU and 2050 LC3.

Table A6. Transportation sector emissions tabulated results, 2016, 2050 BAU and 2050 LC3.

Transportation emissions (tCO2e) by fuel	2016	share 2016	2050 (BAU)	share 2050	2050 (LC)	share 2050	% +/- 2016-2050 LC	% +/- 2050 BAU-2050 LC
Diesel	184,200	16.5%	169,300	22.3%	100	0.2%	-100.0%	-100.0%
Electricity	70	0.0%	111,900	14.7%	45,600	95.7%	67823.7%	-59.3%
Gasoline	930,200	83.5%	479,500	63.0%	2,000	4.1%	-99.8%	-99.6%
Total	1,114,500		760,800		47,600		-95.7%	-93.7%

Transportation emissions (tCO2e) by vehicle type	2016	share 2016	2050 (BAU)	share 2050	2050 (LC)	share 2050	% +/- 2016-2050 LC	% +/- 2050 BAU-2050 LC
Car	481,300	43.2%	240,100	31.6%	16,000	33.7%	-96.7%	-93.3%
Heavy truck	83,000	7.5%	71,000	9.3%	4,200	8.8%	-94.9%	-94.1%
Light truck	519,200	46.6%	407,400	53.6%	25,500	53.5%	-95.1%	-93.7%
Urban bus	31,000	2.8%	42,200	5.5%	1,900	4.0%	-93.9%	-95.5%
Total	1,114,500		760,800		47,600		-95.7%	-93.7%

Waste Sector Emissions

Waste emissions by type

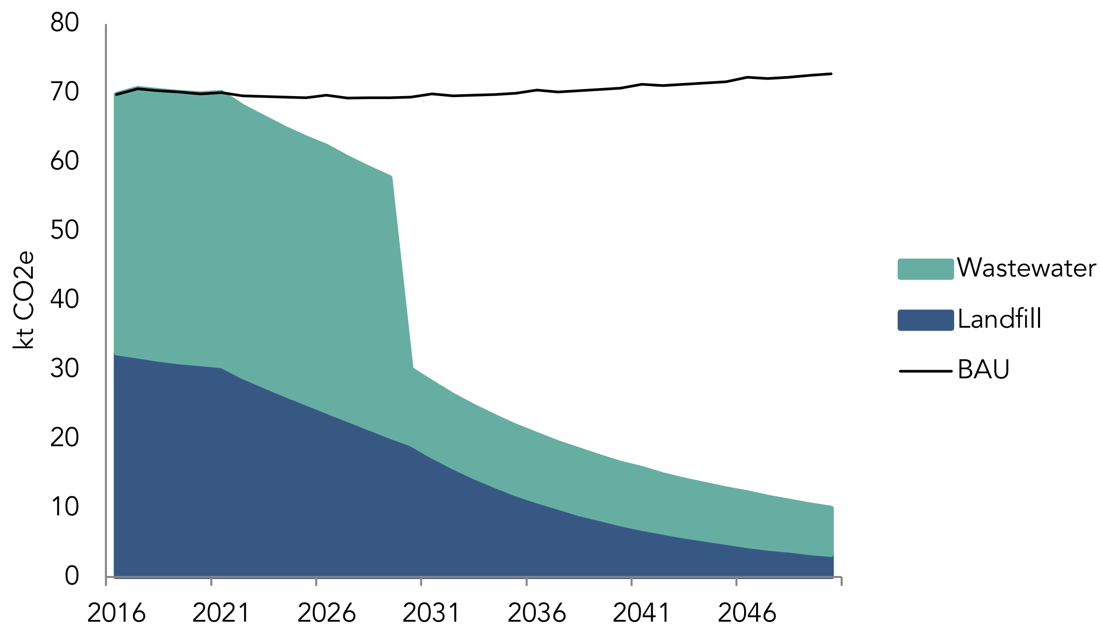


Figure A23. Projected LC3 waste emissions (ktCO2e), 2016-2050.

Appendix B:
List of Actions and Associated Assumptions for the LC3 Scenario

Appendix B: List of actions and associated assumptions for the LC3 scenario

Action theme	Assumption
BUILDINGS	
New construction - residential buildings	Net zero by 2030 By 2030, 100% of all new residential construction: > meets standards for thermal demand (TEDI) & total demand (EUI) [15 kwh/m2 thermal (TEDI) and 120 kwh/m2 total (EUI), consistent with Passive House & Toronto Green Standard] > install solar pv or other to get to net zero
New construction - non-residential buildings	Net zero by 2030 By 2030, 100% of all new non-residential construction: > meets standards for thermal demand (TEDI) & total demand (EUI) [15 kwh/m2 thermal (TEDI) and 120 kwh/m2 total (EUI), consistent with Passive House & Toronto Green Standard] > install solar pv or other to get to net zero
Retrofit existing residential buildings	Retrofit 100% by 2040 >Achieve 50% thermal savings and 50% electrical savings through deep retrofits in 100% of existing residential buildings by 2040. >Install heat pumps in residential buildings, so that by 2040, 100% of space heating demand in residential building stock is met with electric heat pumps >Install electric water heaters in residential buildings, so that by 2040, 100% of water heating demand is met with electric water heaters
Retrofit existing non-residential buildings	Retrofit 100% by 2040

	>Achieve 50% thermal savings and 50% electrical savings through deep retrofits in 100% of existing residential buildings by 2040. >Install heat pumps in residential buildings, so that by 2040, 75% of space heating demand in residential building stock is met with electric heat pumps >Install electric water heaters in residential buildings, so that by 2040, 100% of water heating demand is met with electric water heaters
Industrial efficiency	Improve industrial process efficiency by 75% by 2040.
ENERGY GENERATION	
Rooftop solar pv & storage - residential	>Scale up solar pv installations on residential buildings to reach 100% of the solar potential [800 MW] by 2030. Solar potential derived from estimating solar eligible rooftop space on residential buildings. >100% of installed solar PV on residential includes storage; 50% thermal storage + 50% batteries
Rooftop solar pv & storage - non-residential	>Scale up solar pv installations on non-residential buildings to reach 100% of the solar potential [500 MW] by 2030. Solar potential derived from estimating solar eligible rooftop space on non-residential buildings. >100% of installed solar PV on residential includes storage; 25% thermal storage + 75% batteries
Utility scale ground mount solar pv	> Scale up ground mount solar pv to 200 MW by 2030 + another 100MW between 2030-2050 with battery storage
Offshore wind	Scale up offshore wind installations to 80 MW by 2035
Onshore wind	Scale up onshore wind installations to 100 MW by 2035 + another 100MW between 2035-2050
District energy	Switch 100% of existing DE to renewable sources by 2050 Expand DE (100% renewable) in high energy densities areas
TRANSPORTATION	

Transit & active transportation	By 2030, mode share targets as identified in the Integrated Mobility Plan are achieved. Mode share targets are increased out to 2050.
Electrify transit & municipal fleet	100% electric by 2030, including ferries
Electrify personal & commercial vehicles	Scales up EVs so that by 2030, 100% of new vehicle sales are EVs
WATER & WASTEWATER	
Water & WW treatment & pumping energy	Energy used to treat and pump water and wastewater is reduced 50% by 2050 through water conservation, efficient water use, treatment and pumping efficiency, and reduction of stormwater entering the wastewater system.
Wastewater biogas recovery	80% wastewater through anaerobic digestion by 2030
SOLID WASTE	
Waste reduction	Reduce waste generation 30% by 2050
Waste diversion	100% diversion by 2050
Waste biogas recovery	100% organics to anaerobic digestion

Appendix C:
Financial Assumptions

Table 1: New Dwelling Building Construct

Average of values for Halifax ($/m2)	
Single	1,292
Double/Row	1,238
Apartment 1-4 store	1,238
Apartment 5-14 stor	2,359
Apartment > 15 stor	2,476

source: *Altus Group Cost Guide - 2018*

Table 2: Dwelling Operations & Maintenance Costs

Household spending intensity	
$/m2/yea	3.18

source: *Statistics Canada. Table 11-10-0222-01 Household spending, Canada, regions and provinces*

Repairs and maintenance for owned living quarters

Table 3: Commercial Vehicle Capital Costs, 4.5 tonnes and under

$/vehicle	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
gas	56,912	57,239	57,566	57,893	58,083	58,274	58,464	58,655	58,845	59,061	59,277	59,492	59,708	59,924	59,924	59,924	59,924
diesel	61,279	61,772	62,266	62,759	63,055	63,351	63,648	63,944	64,240	64,336	64,431	64,527	64,622	64,718	64,718	64,718	64,718
electric	93,410	93,383	93,355	93,328	88,101	82,875	77,648	72,422	70,058	67,695	65,331	62,967	60,604	58,240	58,240	58,240	58,240

$/vehicle	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
gas	59,924	59,924	59,924	59,924	59,924	59,924	59,924	59,753	59,582	59,412	59,241	59,070	59,775	60,480	61,185	61,890	62,595
diesel	64,718	64,718	64,718	64,718	64,718	64,718	64,718	64,407	64,097	63,786	63,476	63,165	63,640	64,115	64,590	65,065	65,540
electric	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240

ource for gas and diesel: *https://about.bnef.com/blog/battery-pack-prices-fall-as-market-ramps-up-with-market-average-at-156-kwh-in-2019/*

source for electric: same as personal use vehicles assuming light trucks

with these factor applied: - car to light truck factor: 1.75 - manufacturing to retail cost factor: 1.5 - USD to CAD exchange rate: 1.3

Table 4: Commercial Vehicle Capital Costs, 4.5- 14.9 tonne tonne

$/vehicle	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
gas	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500
diesel	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500
electric	132,762	125,840	118,917	111,994	108,517	105,040	101,564	98,087	94,610	95,174	95,738	96,303	96,867	97,431	97,431	97,431	97,431

$/vehicle	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
gas	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500
diesel	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500
electric	97,431	97,431	97,431	97,431	97,431	97,431	97,431	94,845	92,259	89,672	87,086	84,500	84,500	84,500	84,500	84,500	84,500

source: *Zhu, Lin & F Burke, Andrew. (2014). Analysis of Medium Duty Hybrid-Electric Truck Technologies using Electricity, Diesel, and CNG/LNG as the Fuel for Port and Delivery Applications.*

Table 5: Commercial Vehicle Operations & Maintenance Costs, 4.5 tonnes and under

$/vehicle/year	2017	2021	2026	2031	2036	2041	2046	2051
gas/diesel	4,462	4,462	4,462	4,462	4,462	4,462	4,462	4,462
electric	2,974	2,974	2,974	2,974	2,974	2,974	2,974	2,974

source: *Zhu, Lin & F Burke, Andrew. (2014). Analysis of Medium Duty Hybrid-Electric Truck Technologies using Electricity, Diesel, and CNG/LNG as the Fuel for Port and Delivery Applications.*

Table 6: Commercial Vehicle Operations & Maintenance Costs, 4.5 -14.9 tonnes

$/vehicle/year	2017	2021	2026	2031	2036	2041	2046	2051
gas/diesel	8,321	8,321	8,321	8,321	8,321	8,321	8,321	8,321
electric	5,547	5,547	5,547	5,547	5,547	5,547	5,547	5,547

source: *Zhu, Lin & F Burke, Andrew. (2014). Analysis of Medium Duty Hybrid-Electric Truck Technologies using Electricity, Diesel, and CNG/LNG as the Fuel for Port and Delivery Applications.*

Table 7a: Transit Bus Capital Costs

$/vehicle	2021	2026	2031	2036	2041	2046	2051
dieselBioDieselMix	700,000	700,000	700,000	700,000	700,000	700,000	700,000
electricity	1,035,168	983,409	934,239	887,527	843,150	800,993	760,943

source: *Calcuation for capital costs from internal sources; electric includes charging station and building infrastructure costs*

Assumes 50% of cost of EV bus is related to batteries and cost declines from 161 $/kWh in 2020 to 100 in 2026 to 61 in 2031 as per BNEF projections

Table 7b: Ferry Capital Costs

$/vehicle	2021	2026	2031	2036	2041	2046	2051
dieselBioDieselMix	9,000,000	9,000,000	9,000,000	9,000,000	9,000,000	9,000,000	9,000,000
electricity	11,000,000	11,000,000	11,000,000	11,000,000	11,000,000	11,000,000	11,000,000

source: *Transit Master Info - September 4, 2019.xlsx from HFX*

https://assets.new.siemens.com/siemens/assets/api/uuid:01a7cbed-c7fc-4884-a591-bc5c5fed2f0e/study-electrification-e.pdf

Table 8: Transit Bus Maintenance Costs

$/vehicle/5-year	2021	2026	2031	2036	2041	2046	2051
diesel	$ 23,702	$ 23,702	$ 23,702	$ 23,702	$ 23,702	$ 23,702	$ 23,702
electricity	$ 16,591	$ 16,591	$ 16,591	$ 16,591	$ 16,591	$ 16,591	$ 16,591

source: *Calcuation for bus maintenance from internal sources*

Table 9: Transit Infrastructure Costs

$/year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Total expenditures	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

source: *no data provided by Hfx*

Table 10: Active Mode Infrastructure Costs

$/year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Total expenditures	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

source: *no data provided by Hfx*

Table 11: Road Infrastructure Cost Savings

$/year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Total expenditures	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

$/year	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Total expenditures	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

source: *no data provided by Hfx*

Table 12: Residential Heat Pump Capital Costs, Installed

$/heat pump	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Air source	5,850	5,850	5,850	5,850	5,883	5,915	5,948	5,980	6,013	6,045	6077.8	6110.2	6142.6	6175	6194.6	6214.2	6233.8
Geothermal	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000

$/heat pump	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Air source	6253.4	6273	6292.4	6311.8	6331.2	6350.6	6370	6389.6	6409.2	6428.8	6448.4	6468	6487.4	6506.8	6526.2	6545.6	6565
Geothermal	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000

source: *US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018*

assume USD to CAD exchange rate of 1.3

Table 13: Residential Heat Pump Operations & Maintenance Costs

$/heat pump/year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Air source	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5
Geothermal	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5

$/heat pump/year	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Air source	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5
Geothermal	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5

source: *US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018*

assume USD to CAD exchange rate of 1.3

Table 14: Residential Water Heater Capital Costs, Installed

$ / unit	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
30 Gallon natural ga	510	510	510	510	510	510	510	510	510	510	510	510	510	510	510	510	510
40 Gallon	1482	1478	1474	1470	1456.4	1442.8	1429.2	1415.6	1402	1387.6	1373.2	1358.8	1344.4	1330	1326.6	1323.2	1319.8
Solar 40 Gallon	3080.4	3053.6	3026.8	3000	2959.8	2919.6	2879.4	2839.2	2799	2759.2	2719.4	2679.6	2639.8	2600	2572.8	2545.6	2518.4
On Demand Electric	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
Heat Pump	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
District energy	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900

$ / unit	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
30 Gallon natural gas	510	510	510	510	510	510	510	510	510	510	510	510	510	510	510	510	510
40 Gallon	1316.4	1313	1306.4	1299.8	1293.2	1286.6	1280	1269	1258	1247	1236	1225	1216	1207	1198	1189	1180
Solar 40 Gallon	2491.2	2464	2430.6	2397.2	2363.8	2330.4	2297	2263.6	2230.2	2196.8	2163.4	2130	2096.4	2062.8	2029.2	1995.6	1962
On Demand Electric	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
Heat Pump	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
District energy	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900

source: *US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018*

Table 15: Residential Water Heater Maintenance Costs

$/unit/year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
30 Gallon natural gas	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
40 Gallon	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Solar 40 Gallon	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
On Demand Electric	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85
Heat Pump	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
District energy	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85

$/unit/year	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
30 Gallon natural ga	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
40 Gallon	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Solar 40 Gallon	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
On Demand Electric	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85
Heat Pump	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
District energy	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85

source: *US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018*

Table 16: Non Residential Heat Pump Capital Costs

$ / heat pump		
Air source (90 kbtu/hour)	10,075	Typical Capacity (90 kBtu/h)
Ground source (48 kbut/hour)	21,710	Typical Capacity (48 kBtu/h)

source: *US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018*

assume USD to CAD exchange rate of 1.3

Table 17: Non Residential Heat Pump O&M Costs

$/heat pump/year		
Air source	403	Typical Capacity (90 kBtu/h)
Ground source	195	Typical Capacity (48 kBtu/h)

source: *US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018*

assume USD to CAD exchange rate of 1.3

Table 18: Non Residential Water Heater Capital Costs

$/water heater		
Electric	5,135	Commercial Electric Resistance Water Heaters, Input Capacity 18 kW
Natural gas	7,085	Commercial Gas Storage Water Heaters, Input Capacity 200 kBtu/h

source: *US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018*

assume USD to CAD exchange rate of 1.3

Table 19: Non Residential Water Heater O&M Costs

$/water heater/year	
electric	65
natural gas	351

source: *US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018*

assume USD to CAD exchange rate of 1.3

Table 20: Commercial Energy Savings Capital Costs

$/GJ of energy save	2015	2020	2025	2030	2035	2040	2045	2050
Space heating	33	32	30	29	27	26	25	23
Water cooling	29	27	26	25	23	22	21	20
Water heating	25	24	23	22	20	19	18	18
Auxiliary equipment	34	32	31	29	28	26	25	24
Auxilary motors	33	31	30	28	27	26	24	23
Lighting	131	124	118	112	106	101	96	91

source: Achievable Potential: Estimated Range of Electricity Savings from Energy Efficiency and Energy Management, Ontario Power Authority (OPA), March 2014
Lighting values are based on COS cost estimates of 3.3 $/ft2 for EPC lighting projects
These represent the capital costs associated with 1 GJ of savings in year 1. There will be no further capital costs for that investment in the remaining years of the project

Table 21: Residential Energy Savings Capital Costs

$/GJ of energy save	2015	2020	2025	2030	2035	2040	2045	2050
Space heating	124	118	112	106	101	96	91	87
Lighting	33	31	30	28	27	25	24	23
Major appliances	142	135	128	122	116	110	104	99
Water heater	81	77	74	70	66	63	60	57
Plug load	48	46	44	41	39	37	36	34

source: Achievable Potential: Estimated Range of Electricity Savings from Energy Efficiency and Energy Management, Ontario Power Authority (OPA), March 2014
space heating values are based on Home Energy Loan Program (HELP) in Toronto
These represent the capital costs associated with 1 GJ of savings in year 1. There will be no further capital costs for that investment in the remaining years of the project

Table 22: Electricity Production Capacity Capital Costs

$/kW	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Rooftop solar PV	3,587	3,368	3,149	2,930	2,795	2,661	2,526	2,392	2,257	2,192	2,127	2,063	1,998	1,933	1,904	1,875	1,847
Groundmount solar	2,217	2,091	1,966	1,841	1,753	1,666	1,578	1,491	1,403	1,387	1,371	1,354	1,338	1,322	1,309	1,296	1,283
Wind	4,776	4,662	4,547	4,433	4,376	4,319	4,261	4,204	4,147	4,090	4,033	3,975	3,918	3,861	3,832	3,804	3,775
Electricity storage	2,418	2,392	2,366	2,340	2,314	2,288	2,262	2,236	2,210	2,184	2,158	2,132	2,106	2,080	2,054	2,028	2,002
Hydropower	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575
Digester ICE	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698
Biogas CHP	1,061	1,056	1,050	1,044	1,040	1,035	1,031	1,026	1,022	1,018	1,014	1,009	1,005	1,001	1,000	998	997

$/kW	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Rooftop solar PV	1,818	1,789	1,760	1,731	1,701	1,672	1,643	1,634	1,625	1,616	1,607	1,598	1,589	1,580	1,570	1,561	1,552
Groundmount solar	1,270	1,257	1,244	1,231	1,218	1,205	1,192	1,181	1,170	1,158	1,147	1,136	1,125	1,114	1,104	1,093	1,082
Wind	3,747	3,718	3,689	3,661	3,632	3,604	3,575	3,546	3,518	3,489	3,461	3,432	3,403	3,375	3,346	3,318	3,289
Electricity storage	1,976	1,950	1,924	1,898	1,872	1,846	1,820	1,794	1,768	1,742	1,716	1,690	1,664	1,638	1,612	1,586	1,560
Hydropower	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575	3,575
Digester ICE	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698	2,698
Biogas CHP	995	994	993	991	990	988	987	986	984	983	981	980	978	977	975	974	972

source: 2019 NREL Annual Technology Baseline, assumes commercial solar rate for rooftop and utility for groundmount, Chicago location, mid range price, TRG 7 for wind, NPD 4 for hydro
Digester Danish Technology Catalogue
Biogas CHP Danish Technology Catalogue
assume USD to CAD exchange rate of 1.3
assume Euro to CAD exchange rate of 1.45

Table 23: Electricity Production Operations & Maintenance Costs

$/kW/year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Rooftop solar PV	22	21	21	20	19	17	16	14	13	13	13	13	13	13	13	13	13
Groundmount solar	19	18	17	16	15	14	12	11	10	10	10	10	10	10	10	10	10
Wind	100	97	95	93	92	90	89	87	86	85	83	82	80	79	78	78	77
Electricity storage	242	239	237	234	231	229	226	224	221	218	216	213	211	208	205	203	200
Hydropower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Digester ICE	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5
Biogas CHP	29	28	28	28	28	28	27	27	27	27	27	27	27	27	27	27	26

$/kW/year	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Rooftop solar PV	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Groundmount solar	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Wind	77	76	75	75	74	74	73	73	72	72	71	71	70	70	69	69	68
Electricity storage	198	195	192	190	187	185	182	179	177	174	172	169	166	164	161	159	156
Hydropower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Digester ICE	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5
Biogas CHP	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26

source: *2019 NREL Annual Technology Baseline, assumes commercial solar rate for rooftop and utility for groundmount, Chicago location, mid range price, TRG 7 for wind, NPD 4 for hydro*

Digester *Danish Technology Catalogue*

Biogas CHP *Danish Technology Catalogue*

assume USD to CAD exchange rate of 1.3

assume Euro to CAD exchange rate of 1.45

Table 24: Personal Use Vehicles Capital Costs

$/vehicle	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Car - gas	32,522	32,708	32,895	33,082	33,191	33,300	33,408	33,517	33,626	33,749	33,872	33,996	34,119	34,242	34,242	34,242	34,242
Car - gas hybrid	37,074	37,125	37,177	37,229	37,174	37,119	37,064	37,009	36,954	36,925	36,896	36,866	36,837	36,808	36,808	36,808	36,808
Car - diesel	35,017	35,298	35,580	35,862	36,031	36,201	36,370	36,540	36,709	36,764	36,818	36,873	36,927	36,982	36,982	36,982	36,982
Car - plug-in electric	41,207	40,608	40,009	39,410	39,366	39,322	39,277	39,233	39,189	39,427	39,665	39,903	40,141	40,379	40,379	40,379	40,379
Car - electric	53,378	53,362	53,347	53,330	50,344	47,357	44,371	41,384	40,033	38,683	37,332	35,981	34,631	33,280	33,280	33,280	33,280
Light truck - gas	56,912	57,239	57,566	57,893	58,083	58,274	58,464	58,655	58,845	59,061	59,277	59,492	59,708	59,924	59,924	59,924	59,924
Light truck - gas hyb	64,879	64,970	65,060	65,151	65,055	64,959	64,862	64,766	64,670	64,619	64,568	64,516	64,465	64,414	64,414	64,414	64,414
Light truck - diesel	61,279	61,772	62,266	62,759	63,055	63,351	63,648	63,944	64,240	64,336	64,431	64,527	64,622	64,718	64,718	64,718	64,718
Light truck - plug-in	72,112	71,063	70,015	68,967	68,890	68,813	68,735	68,658	68,581	68,997	69,414	69,830	70,247	70,663	70,663	70,663	70,663
Light truck - electric	93,410	93,383	93,355	93,328	88,101	82,875	77,648	72,422	70,058	67,695	65,331	62,967	60,604	58,240	58,240	58,240	58,240

$/vehicle	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Car - gas	34,242	34,242	34,242	34,242	34,242	34,242	34,242	34,145	34,047	33,950	33,852	33,755	34,158	34,561	34,963	35,366	35,769
Car - gas hybrid	36,808	36,808	36,808	36,808	36,808	36,808	36,808	36,637	36,466	36,296	36,125	35,954	36,048	36,143	36,237	36,332	36,426
Car - diesel	36,982	36,982	36,982	36,982	36,982	36,982	36,982	36,805	36,627	36,450	36,272	36,095	36,366	36,638	36,909	37,181	37,452
Car - plug-in electric	40,379	40,379	40,379	40,379	40,379	40,379	40,379	40,081	39,782	39,484	39,185	38,887	38,264	37,642	37,019	36,397	35,774
Car - electric	33,280	33,280	33,280	33,280	33,280	33,280	33,280	33,280	33,280	33,280	33,280	33,280	33,280	33,280	33,280	33,280	33,280
Light truck - gas	59,924	59,924	59,924	59,924	59,924	59,924	59,924	59,753	59,582	59,412	59,241	59,070	59,775	60,480	61,185	61,890	62,595
Light truck - gas hyb	64,414	64,414	64,414	64,414	64,414	64,414	64,414	64,115	63,816	63,518	63,219	62,920	63,085	63,250	63,416	63,581	63,746
Light truck - diesel	64,718	64,718	64,718	64,718	64,718	64,718	64,718	64,407	64,097	63,786	63,476	63,165	63,640	64,115	64,590	65,065	65,540
Light truck - plug-in	70,663	70,663	70,663	70,663	70,663	70,663	70,663	70,141	69,619	69,096	68,574	68,052	66,963	65,873	64,784	63,694	62,605
Light truck - electric	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240	58,240

source: *Assessment of Vehicle Sizing, Energy Consumption, and Cost Through Large-scale Simulation of Advanced Vehicle Technologies, Argonne National Laboratory, March 2016*

BNEF Battery Projections

with these factor applied: - manufacturing to retail cost factor: 1.5 - USD to CAD exchange rate: 1.3

Table 25: Personal Use Vehicles Maintenance Costs

$/vehicle/km	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Car - gas	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Car - gas hybrid	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Car - diesel	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Car - plug-in electric	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Car - electric	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Light truck - gas	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Light truck - gas hyb	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Light truck - diesel	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Light truck - plug-in	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Light truck - electric	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

$/vehicle/km	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Car - gas	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Car - gas hybrid	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Car - diesel	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Car - plug-in electric	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Car - electric	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Light truck - gas	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Light truck - gas hyb	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Light truck - diesel	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Light truck - plug-in	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Light truck - electric	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

source: [Comparing costs of electric and gas powered vehicles in Canada: Vincentric]

Table 26: District Energy Capital Costs

$/MW	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
District energy syste	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296

2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296	5,546,296

source: *Capital cost for geothermal district energy system for PPB internal costs*

Table 27: District Energy Operations & Maintenance Costs

$ / MW / year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
biogas boiler	2,832	2,817	2,803	2,789	2,782	2,775	2,767	2,760	2,753	2,746	2,739	2,731	2,724	2,717	2,703	2,689	2,674
biomass boiler	2,832	2,817	2,803	2,789	2,782	2,775	2,767	2,760	2,753	2,746	2,739	2,731	2,724	2,717	2,703	2,689	2,674
Geothermal heat exchanger	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000

$ / MW / year	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
biogas boiler	2,660	2,646	2,632	2,617	2,603	2,588	2,574	2,560	2,546	2,531	2,517	2,503	2,489	2,474	2,460	2,445	2,431
biomass boiler	2,660	2,646	2,632	2,617	2,603	2,588	2,574	2,560	2,546	2,531	2,517	2,503	2,489	2,474	2,460	2,445	2,431
Geothermal heat exchanger	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000

source: *Danish Energy Agency Technology catalogue: District heating boiler, natural gas fired, Electrical compression heat pumps - district heating, Absorption heat pumps - district heating*

Assume exchange rate of 1.45 Euros to$Can

Fuel Cost Intensities

For projections to 2040, percent changes in 2019 NEB Futures Report projections for end use prices were applied to 2019 data

Linear extrapolation applied after 2040

Table 28: Transportation Fuels

$/GJ	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Gasoline	28.23	29.22	29.97	30.29	30.91	31.51	31.95	32.34	32.69	33.06	33.44	33.83	34.23	34.65	35.08	35.27	35.47
Diesel	35.11	36.43	37.45	37.9	38.74	39.54	40.15	40.69	41.17	41.67	42.19	42.73	43.27	43.84	44.41	44.68	44.97

2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
35.68	35.89	36.11	36.32	36.54	36.77	36.99	37.23	38.52	38.89	39.27	39.65	40.02	40.4	40.77	41.14	41.52	41.89
45.25	45.54	45.84	46.14	46.45	46.76	47.07	47.39	49.13	49.64	50.15	50.67	51.18	51.69	52.2	52.71	53.22	53.73

source: *NEB Canada's Energy Future 2019, End - Use Prices, Reference Case*
Average retail price 2016 from Table: 18-10-0001-01 (formerly CANSIM 326-0009), combined with NEB trend

Table 29: Electricity

$/GJ	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Residential	41.54	41.54	41.58	41.63	41.67	41.71	41.75	41.79	41.84	41.87	41.92	41.96	42.00	42.04	42.09	42.13	42.17
Commercial	37.81	37.85	37.89	37.93	37.96	38.00	38.05	38.08	38.12	38.15	38.20	38.23	38.27	38.30	38.35	38.39	38.42
Industrial	22.41	22.43	22.46	22.48	22.51	22.53	22.54	22.57	22.59	22.62	22.64	22.66	22.68	22.71	22.73	22.75	22.78

2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
42.22	42.25	42.30	42.34	42.38	42.42	42.47	42.50	42.5	42.6	42.6	42.7	42.7	42.8	42.8	42.8	42.9	42.9
38.46	38.50	38.54	38.57	38.61	38.66	38.69	38.73	38.8	38.8	38.8	38.9	38.9	39.0	39.0	39.0	39.1	39.1
22.79	22.82	22.84	22.87	22.89	22.91	22.93	22.95	23.0	23.0	23.0	23.0	23.1	23.1	23.1	23.1	23.2	23.2

source: *NEB Canada's Energy Future 2019, End - Use Prices, Reference Case*
NSP starting price 2016 and NEB trend

Table 30: Natural Gas

$/GJ	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Residential	23.58	19.43	19.54	19.63	19.70	19.77	19.82	19.87	19.89	19.92	19.95	19.97	20.00	20.02	20.05	20.08	20.11
Commercial	15.04	12.58	12.67	12.74	12.80	12.86	12.90	12.94	12.96	12.99	13.01	13.03	13.05	13.08	13.10	13.13	13.15
Industrial	12.44	9.98	10.16	10.31	10.43	10.55	10.65	10.73	10.77	10.82	10.86	10.91	10.95	11.00	11.04	11.09	11.13

2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
20.13	20.16	20.18	20.22	20.24	20.27	20.29	20.32	20.5	20.5	20.6	20.6	20.7	20.7	20.7	20.8	20.8	20.9
13.17	13.19	13.22	13.24	13.26	13.28	13.31	13.33	13.4	13.5	13.5	13.5	13.6	13.6	13.6	13.6	13.7	13.7
11.18	11.23	11.27	11.32	11.36	11.41	11.45	11.50	11.7	11.8	11.8	11.9	11.9	12.0	12.1	12.1	12.2	12.3

source: *NEB Canada's Energy Future 2019, End - Use Prices, Reference Case*
Heritage gas rates 2016 and NEB trend

Table 31: Fuel Oil

$/GJ	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Residential	25.89	26.6	27.17	27.44	27.92	28.38	28.74	29.06	29.35	29.65	29.95	30.25	30.56	30.87	31.19	31.36	31.54
Commercial	22.51	23.13	23.62	23.86	24.28	24.68	24.99	25.27	25.53	25.78	26.04	26.31	26.57	26.85	27.12	27.27	27.42
Industrial	13.81	14.43	14.92	15.16	15.58	15.98	16.29	16.57	16.82	17.08	17.34	17.6	17.87	18.14	18.42	18.57	18.72

2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
31.71	31.89	32.07	32.26	32.44	32.63	32.81	33	33.8	34.1	34.4	34.7	35.0	35.2	35.5	35.8	36.1	36.4
27.58	27.73	27.89	28.05	28.21	28.37	28.53	28.7	$29.41	$29.65	$29.89	$30.14	$30.38	$30.62	$30.87	$31.11	$31.35	$31.59
18.87	19.03	19.19	19.35	19.51	19.67	19.83	19.99	$20.71	$20.95	$21.19	$21.43	$21.68	$21.92	$22.16	$22.40	$22.65	$22.89

source: *NEB Canada's Energy Future 2019, End - Use Prices, Reference Case*
Linear extrapolation applied after 2040

Table 31: Biogas

$/GJ	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
	$18.80	$13.10	$12.70	$12.30	$12.20	$12.20	$12.20	$12.20	$12.20	$12.20	$12.20	$12.20	$12.20	$12.10	$12.10	$12.10	$12.10
$/m3	*$0.71*	*$0.50*	*$0.48*	*$0.47*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.46*

2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
$12.10	$12.10	$12.10	$12.08	$12.07	$12.06	$12.05	$12.04	$11.42	$11.34	$11.26	$11.18	$11.10	$11.01	$10.93	$10.85	$10.77	$10.69
$0.46	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.43*	*$0.43*	*$0.43*	*$0.42*	*$0.42*	*$0.42*	*$0.41*	*$0.41*	*$0.41*	*$0.41*

source: *Fuels Technical Report Module 4: Fuels system Cost Outlook, Ontario Environment and Energy*

Table 32: Carbon Price

$/tonne CO2eq	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
reference	20	30	40	50	52	53	55	56	58	60	61	63	65	67	69	71	73

$/tonne CO2eq	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
reference	76	78	80	83	85	88	90	93	96	99	102	105	108	111	114

source: *Calculated internally post 2022*

Table 33: Electricity Revenue Rate

$/MWh	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
all technologies	150	152	154	156	158	161	163	165	167	169	172	174	176	178	179	179	179

$/MWh	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
all technologies	180	180	181	181	181	182	182	182	182	183	183	183	184	184	184	185	185

source: *Assumes net metering for rooftop solar and groundmount solar (industrial rate)*

IESO 2017 FIT Price Schedule, assumes differentiated revenues by technology