Community Energy Investment Plan: The Way Forward

Part 2: Technical Backgrounder

This section of the CEIP provides a detailed overview of the technical analysis.

1. INTRODUCTION

The intent of the Bridgewater Community Energy Investment Plan (CEIP) is to accelerate the transition of the entire community and surrounding area into a sustainable energy future. "Energy sustainability" is defined, as a starting point for the BCEI, as: transitioning to a low carbon energy future, while enhancing quality of life and meeting the community's basic needs.

The CEIP engaged a broad cross-section of residents, businesses, and organizations to begin taking concrete action on innovative energy solutions, and developing a practical roadmap. The overall objectives of the CEIP are to:

- Put the community on a path toward deep energy reductions and infrastructure transformation, Re-imagine the community's relationship to "energy" in all its forms;
- Address critical concerns such as energy conservation, renewable energy generation, energy poverty and affordability, and the community's long-term energy security;
- Demonstrate economic development opportunities that will come from a transition to a sustainable energy future: and,
- Exercise community-wide leadership in energy sustainability.

2. THE PROCESS OF DEVELOPING THE PLAN

The development of the Community Energy and Investment Plan (CEIP) involved three main stages, depicted in Figure 8.

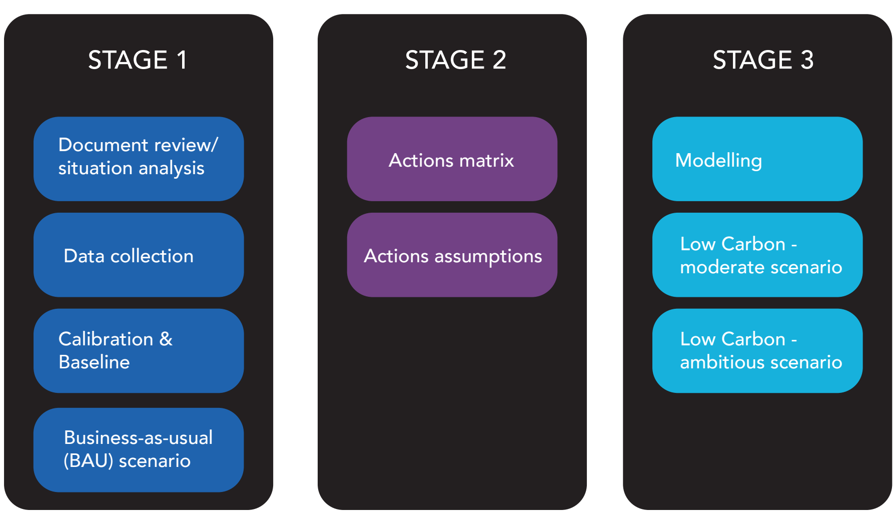

Figure 8. Process diagram.

Stage 1: Current Conditions

A document review/situational analysis was undertaken to understand the current context for energy and emissions in Bridgewater. The review included municipal, regional, provincial and federal policy on municipal energy and emissions; projected growth and demographic trends in various sectors, and all plans, policies, programs, targets, actions, and initiatives currently planned, approved, funded and/or underway at all levels of government.

After significant efforts in data collection, calibration and analysis, a baseline energy and emissions inventory for the Town of Bridgewater for the year 2011 was completed.

Informed by the review/situational analysis and the baseline inventory, a business-as-usual (BAU) scenario was developed for the period from 2012 to 2050 to illustrate energy use and greenhouse gas emissions for the Town of Bridgewater, if no additional policies, actions or strategies are implemented (beyond those assumed in the BAU).

Stage 2: Identifying Actions

The next stage involved the development of an actions matrix, a catalogue of actions based on research of best practices of municipal actions to reduce energy consumption and greenhouse gas emissions. The matrix was reviewed with Town staff and additional refinement and analysis was undertaken to develop a list of actions relevant to the context of Bridgewater. This process was informed by the results of the BAU analysis, which provided insight on the major drivers of emissions in the Town and therefore helped to identify areas with emissions reduction potential.

In total, 19 actions were identified and a list is provided in Table 4.

Modelling assumptions and parameters were developed for each action. These assumptions were derived from a detailed review of academic literature, and the application or modelling of the action in another municipality. Initially, assumptions for one low carbon scenario were developed- the moderate scenario (LC-mod), and after analysis of the initial results, a more ambitious low carbon scenario was developed. The ambitious low carbon scenario (LC-amb) was subsequently named the Energy Shift scenario. The assumptions underlying the actions are explained in more detail in subsequent sections.

Stage 3: Evaluating low carbon futures

Stage 3 involved the modelling and testing of the actions to develop an integrated scenario. In total, two scenarios were developed and modelled for the period of 2016[4] to 2050. The types of actions or descriptions of actions does not differ between the two scenarios; the only differences are in the assumptions associated with the rate of application or the level of ambition for certain actions.

Table 8 lists the actions modelled for the LC-mod and LC-amb (Energy Shift) scenarios.

Table 8. Actions matrix for LC-mod and LC-amb modelling.

BUILDINGS		**LC-mod**	**LC-amb (Energy Shift)**
New buildings - buildings codes & standards			
1	New dwellings are net zero energy	✓	✓
2	New commercial buildings are passive house	✓	✓
Existing buildings - retrofitting			
3	Retrofit old homes (prior to 1980)	✓	✓
4	Retrofit new homes (after 1980)	✓	✓
5	Retrofit commercial buildings	✓	✓
6	Increase the efficiency of industrial operations		✓
Renewable energy generation (on-site, building scale)			
7	Install heat pumps in homes	✓	✓
8	Install heat pumps in businesses	✓	✓
9	Install solar PV on homes and businesses	✓	✓
10	Solar hot water heating on homes and businesses	✓	✓
ENERGY GENERATION			
Low or zero carbon energy generation (community scale)			
11	Ground-mounted solar PV	✓	✓
12	Develop a district energy system in the downtown	✓	✓
13	Home or business-based energy storage	✓	✓
14	Run of river hydro system	✓	✓
15	Wind turbines		✓
TRANSPORT			
16	Expand and electrify transit	✓	✓
17	Increase/improve cycling & walking infrastructure	✓	✓
18	Electrify personal vehicles	✓	✓

4 The model is calibrated with a 2011 baseline year; the BAU scenario was developed for the period 2012-2050, using observed data to calibrate to the year 2015. The LC scenarios, which explore the impact on future unobserved years, start in 2016.

19	Electrify commercial vehicles	✓	✓

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

Engaging the community

An extensive community engagement process was undertaken during Stage 2 and 3, including the following:

- An interactive website and a social media presence.
- An energy narrative workshop that explored the current understanding and perception of energy in the Town.
- A crowd-sourcing activity that identified potential actions on a web-based platform.
- A wedges workshop that identified preferred actions in scenarios.
- A multi-criteria analysis workshop that evaluated actions against a range of social, environmental and economic criteria.
- Additional polls and surveys.

Additional to the CEIP engagement processes, activities such as the Energize Bridgewater Discovery Fair, the Community Energy Centre (a pop-up storefront), online polls, the Energy Partnership, the Living Energy Laboratory and other strategies also facilitated the participation of the community.

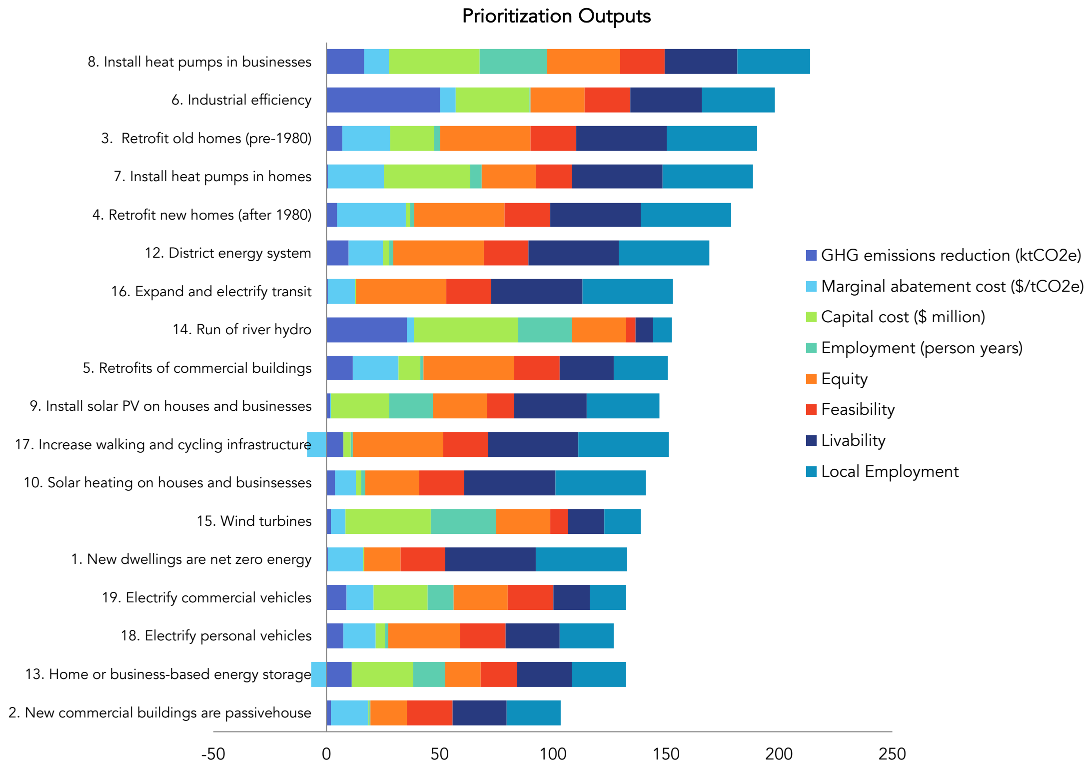

Figure 9. Example of prioritised output from the MCA analysis

3. MODELLING

The energy and emissions modelling was completed using CityInSight. CityInSight is a comprehensive energy, emissions and finance model developed by Sustainability Solutions Group (SSG) and whatIf? Technologies Inc. (whatIf?).

The emissions accounting framework used within CityInsight is based on the Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories (GPC) framework. The baseline and BAU scenario account for emissions associated with emissions generating activities, including buildings, transportation, energy production, and waste.

Table 9. Characteristics of CityInSight

CHARACTERISTIC	DESCRIPTION
INTEGRATED	Designed to account for and to model all sectors that relate to energy and emissions at a municipal scale while describing the relationships between sectors.
STOCKS AND FLOWS	For any given year various factors shape this picture of energy and emissions flows, including: the population and the energy services it requires; commercial floorspace; energy production and trade; the deployed technologies which deliver energy services (service technologies); and the deployed technologies which transform energy sources to currencies (harvesting technologies). The model makes an explicit mathematical relationship between these factors – some contextual and some part of the energy consuming or producing infrastructure – and the energy flow picture. Some factors are modelled as stocks – counts of similar things, classified by various properties. For example, population is modelled as a stock of people classified by age and gender. Population change over time is projected by accounting for: the natural aging process, inflows (births, immigration) and outflows (deaths, emigration). The fleet of personal use vehicles, an example of a service technology, is modelled as a stock of vehicles classified by size, engine type and model year with a similarly classified fuel consumption intensity. As with population, projecting change in the vehicle stock involves aging vehicles and accounting for major inflows (new vehicle sales) and major outflows (vehicle discards). This stock-turnover approach is applied to other service technologies (e.g. furnaces, water heaters) and also harvesting technologies (e.g. electricity generating capacity).
SCENARIO-BASED	Once calibrated, CityInSight enables the creation of scenarios to explore different possible futures. Each scenario can consist of either one or a combination of policies, actions and strategies.
SPATIAL	The configuration of the built environment determines the ability of people to walk and cycle, accessibility to transit, feasibility of district energy and other aspects. CityInSight therefore includes a full spatial dimension that can include as many zones as are deemed appropriate. The spatial component to the model can be integrated with Town GIS systems, land-use projections and transportation modelling.
ACCOUNTING FRAMEWORK	CityInSight is designed according to the accounting framework of the GHGProtocol for Cities, the international standard for emissions inventories for cities.
ECONOMIC IMPACTS	The model incorporates a full financial analysis of costs related to energy (expenditures on energy) and emissions (carbon pricing, social cost of carbon), as well as operating and capital costs for policies, strategies and actions. The model generates marginal abatement curves to illustrate the cost and/or savings of policies, strategies and actions. CityInSight also accounts for the impact of policies, strategies and actions on household incomes and public and business expenditures.
OPEN SOURCE	CityInSight is open source and can be used on an ongoing basis without additional costs such as licensing fees or otherwise.
VISUALIZATIONS	An interactive visualization platform can be used to enable staff and other stakeholders to explore the results of the scenarios.

3.1 Modelling actions: scenarios and sequencing

Scenarios

A scenario is an internally consistent view of what the future might turn out to be—not a forecast, but one possible future outcome. Scenarios are coherent in describing the relationships between different variables and reflecting an evolution of current physical stocks such as buildings and vehicles.

Modelling actions in CityInSight involve two distinct steps: first, assumptions for each of the actions are modelled to quantify the emissions reduction impact against the BAU scenario; and then secondly, an integrated scenario is developed, whereby all the actions are modelled together to capture feedback between and among the actions.

The feedback between the actions can significantly influence the emissions reductions associated with an action. For example, when modelled against the BAU scenario, a shift to increased walking mode share represents reduced gasoline if a vehicle trip is avoided. However, In the integrated scenario, because of the introduction of electric vehicles, the elimination of a vehicle trip results in reduced electricity consumption, which represents significantly less GHG emissions reductions.

Sequencing

Because of the feedback between the actions, the sequence in which the actions are implemented in the model influences the outcome associated with a particular action. In general, actions that reduce consumption and maximise efficiency are prioritized and deployed prior to actions related to fuel switching and local energy generation. Examples include prioritising mode share shifts to walking and cycling prior to electrification of the vehicle fleet, or prioritizing retrofits and improved building codes to buildings before switching to renewables. Figure 10 illustrates a schematic of the sequencing of actions, grouped into two general categories, as they were implemented in the model.

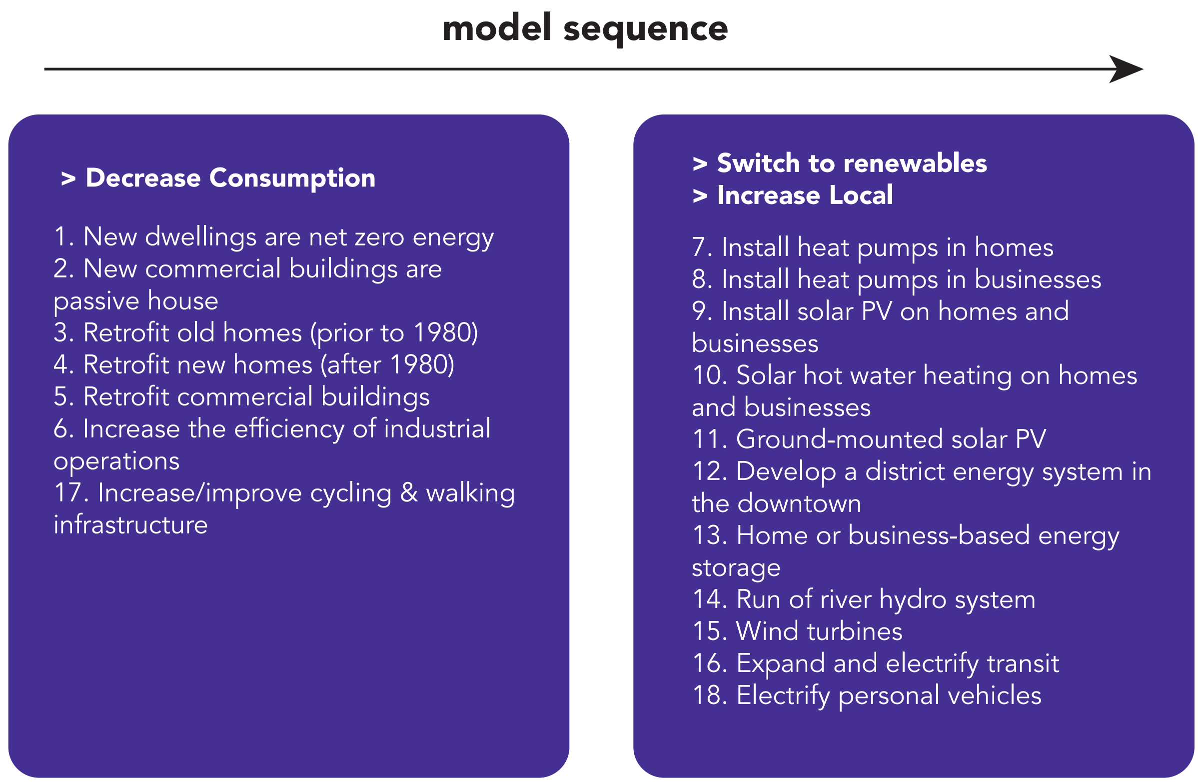

Figure 10. Sequencing schematic of actions in modelling.[5]

Land-use

A key aspect of the modelling method is to represent different aspects of Bridgewater in space. The Town was divided into zones, which allow for the exploration of what happens in a smaller unit of geography, as well as providing a structure to describe how people move from one location to another. Figure 11 illustrates the zones (pink lines) in relation to buildings and parcels in the Town.

5 Action numbers are according to Table 1 which categorizes actions by sector (not sequencing), and is shown in Figure 10 for reference only; sequencing of actions was deployed according to the two main groups shown in Figure 10.

Figure 11. Bridgewater zones, parcels and buildings

Each parcel was then classified according to the building type. Figure 12 illustrates different types of residential dwellings.

Figure 12. Residential parcels classified by type

Once buildings were classified by type, energy profiles were developed and calibrated against observed data provided by Nova Scotia Power and Efficiency NS. When a calibrated model is developed, spatial representations of energy consumption can then be generated, for example, energy density in Figure 13, which highlights concentrations of energy consumption over the area of the zone.

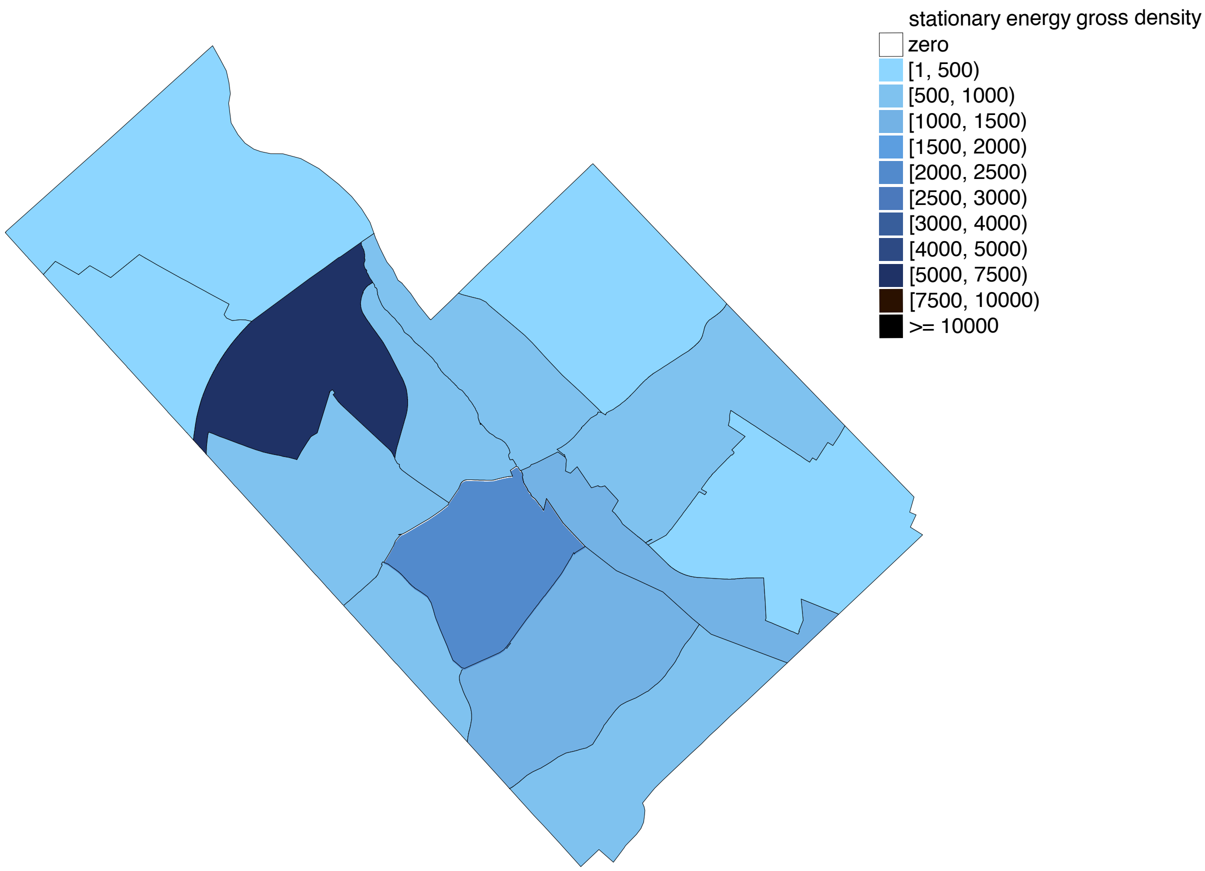

Figure 13. Stationary energy density (GJ/ha)

As future scenarios are developed, the spatial distribution of energy consumption changes as new buildings are added and fuel sources evolve. The model than represents trips from home to work, home to school, home to other and non-home based, using traffic counts and surveys as control totals. The resulting spatial representation of trips highlights different characteristics, in case of Figure 14 indicating that the highest percentage of walking trips are concentrated in the downtown zones.

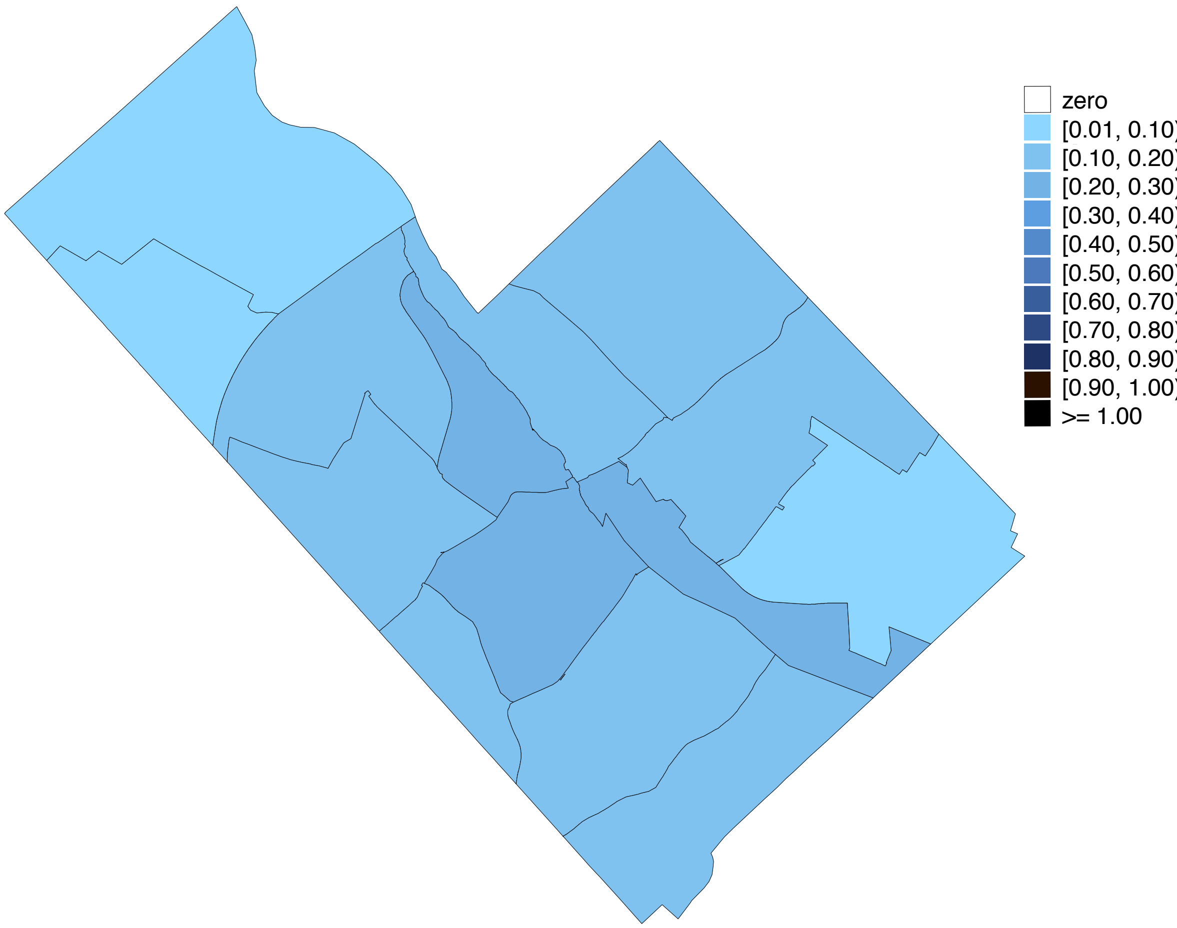

Figure 14. Walking mode share (%).

4. ENERGY AND EMISSIONS SCENARIOS

4.1 Business-as-usual (BAU) scenario

Prior to developing the two low carbon scenarios, a Business-as-usual (BAU) scenario was developed for the time period from 2012 to 2050 to illustrate energy use and GHG emissions for the Town of Bridgewater, if no additional policies, actions or strategies are implemented. The BAU reflects plans, policies, programs and/or projects at the municipal, provincial and federal levels that have been funded (i.e. provincial electric vehicle incentives) or are currently being implemented (i.e. federal fuel efficiency regulations).

While population continues to grow until 2031, the BAU projection indicates that emissions fluctuate over time ending with an overall decrease from 310 KT CO2e in 2016, to 240 KT CO2e in 2050 (Figure 5). The primary drivers for this reduction are:

A decreasing emissions factor for electricity in Nova Scotia as the share of renewable energy increases: The historical data for the electrical grid is obtained from a variety of sources including Statistics Canada's CANSIM tables for total capacity and generation, along with Environment Canada's National Inventory Report (NIR) specifically for the years from 2011 to 2014. For the BAU scenario, the electricity generation input variables were set on the basis of National Energy Board's Energy Future 2016, beginning in 2015, see Figure 5 below.[6]

Improving vehicle fuel efficiency standards: The BAU scenario incorporates the implementation of harmonised fuel efficiency standards that apply to Canada including the CAFE Standards for Light-Duty Vehicles, MYs 2022-2025[7] and Phase 1 (2014-2018) and 2 (2018-2027) of Fuel Efficiency and GHG Emission Program for Medium- and Heavy-Duty Trucks.[8]

Decrease in heating degree days due to a warming climate, a decrease that is partially offset by an increase in cooling degree days;[9]

Increase in energy retrofits of existing buildings (retrofitting 18 homes per year at an average of 20% energy savings), calculated;

Increasing numbers of electric vehicles in overall stock of vehicles, Figure 6.

As the BAU projects a fairly flat trajectory, significant effort beyond what is assumed in

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

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

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

9 For a description of the HDD/CDD projection used, see: Richards, W, and Daigle, R. (2011) Scenarios and guidance for adaptation to climate change and sea-level rise- NS and PEI municipalities.

the BAU is required to achieve a reduction of 80% by 2050.

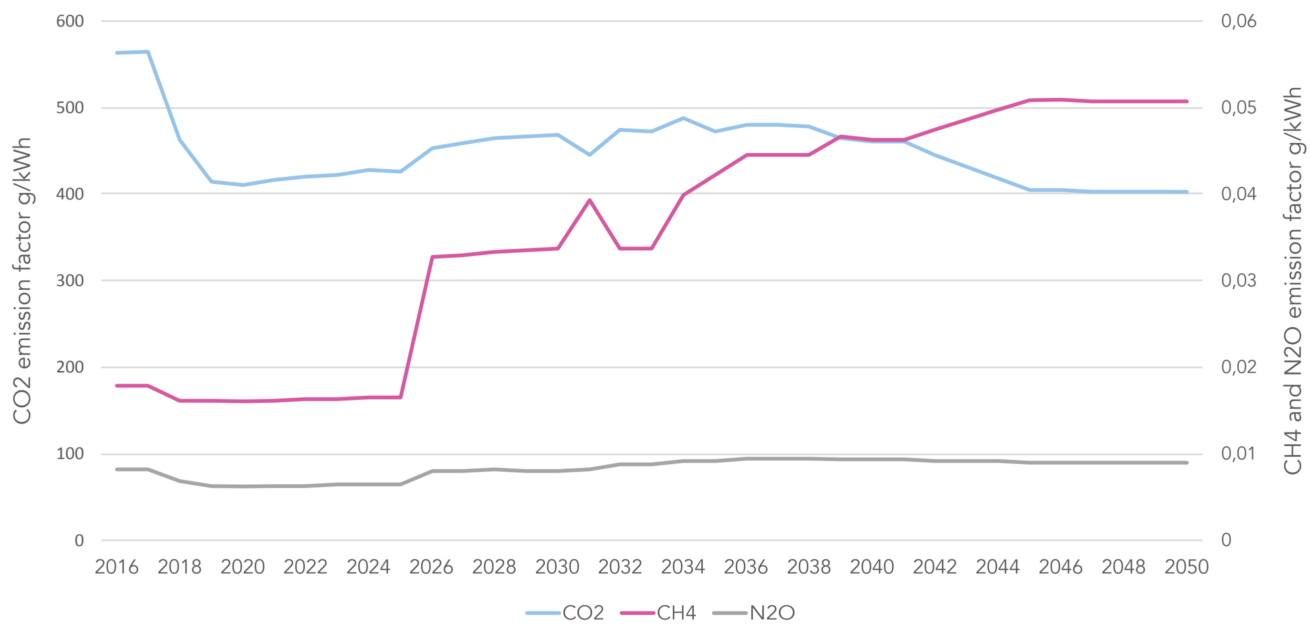
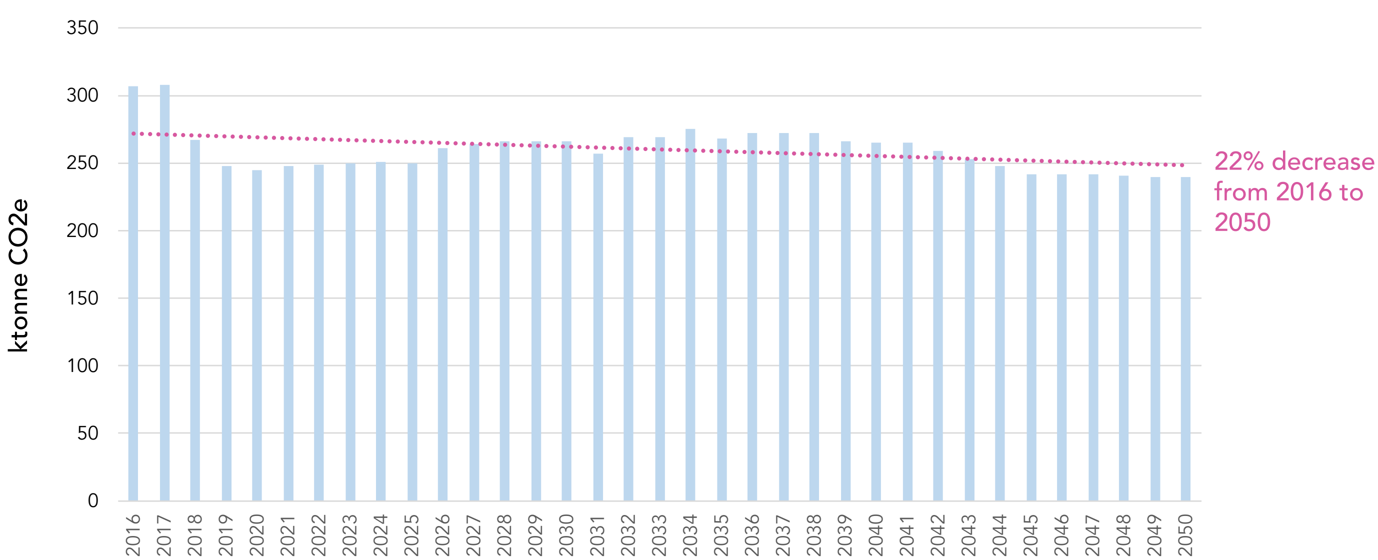


Figure 15. Nova Scotia generated electricity emissions factors, 2016-2050.

Figure 16. GHG emissions for Bridgewater, 2016-2050, BAU.



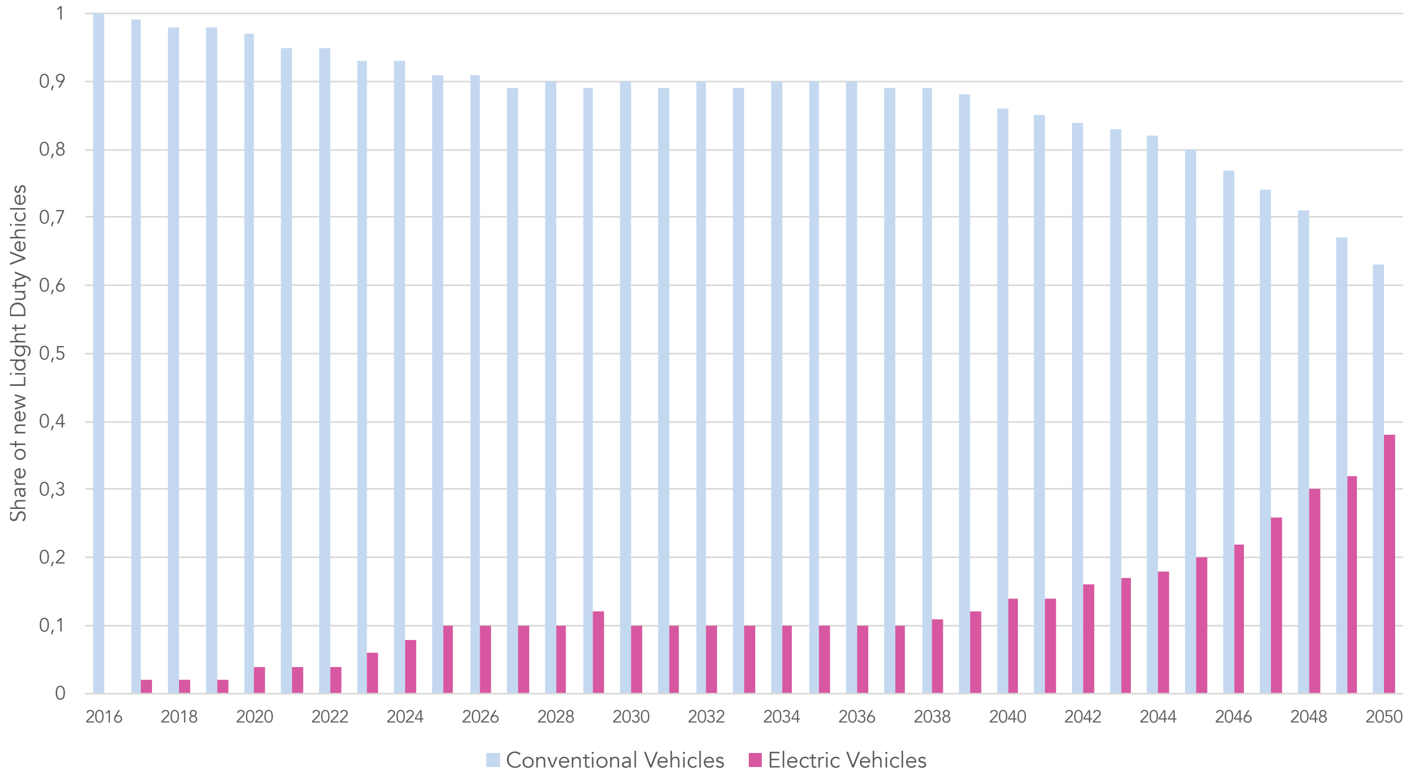


Figure 17. Share of new Light Duty Vehicles, 2016-2050, BAU.

4.2 Low Carbon scenarios overview

In 2050, the LC-mod scenario achieves an emissions reduction of 254 KT CO2e, representing a 66% reduction over the 2011 baseline of 385 KT CO2e, with 131 KT CO2e remaining. The majority of the emissions remaining in 2050 result from imported electricity consumption for industrial process emissions. To meet the 80% reduction objective, an additional reduction of 57 KT CO2e would be required, as illustrated in Figure 7.

The LC-amb scenario builds upon the moderate scenario with a set of more ambitious assumptions, which focus on increasing industrial efficiency (action 5C), increasing the deployment of ground mounted solar PV (action 11 Amb) and the introduction of wind turbines (action 13C). These changes achieve further emissions reductions of 57 KT CO2e in comparison with the LC-mod scenario.

The remaining emissions in the LC-amb scenario are 74 KT CO2e of which the majority is associated with imported electricity coming from the provincial grid used in the industrial sector. In total, the LC-amb scenario achieves a reduction of 311 KT CO2e, representing an 81% reduction over the 2011 baseline of 385 KT CO2e, with 74 KT CO2e remaining.

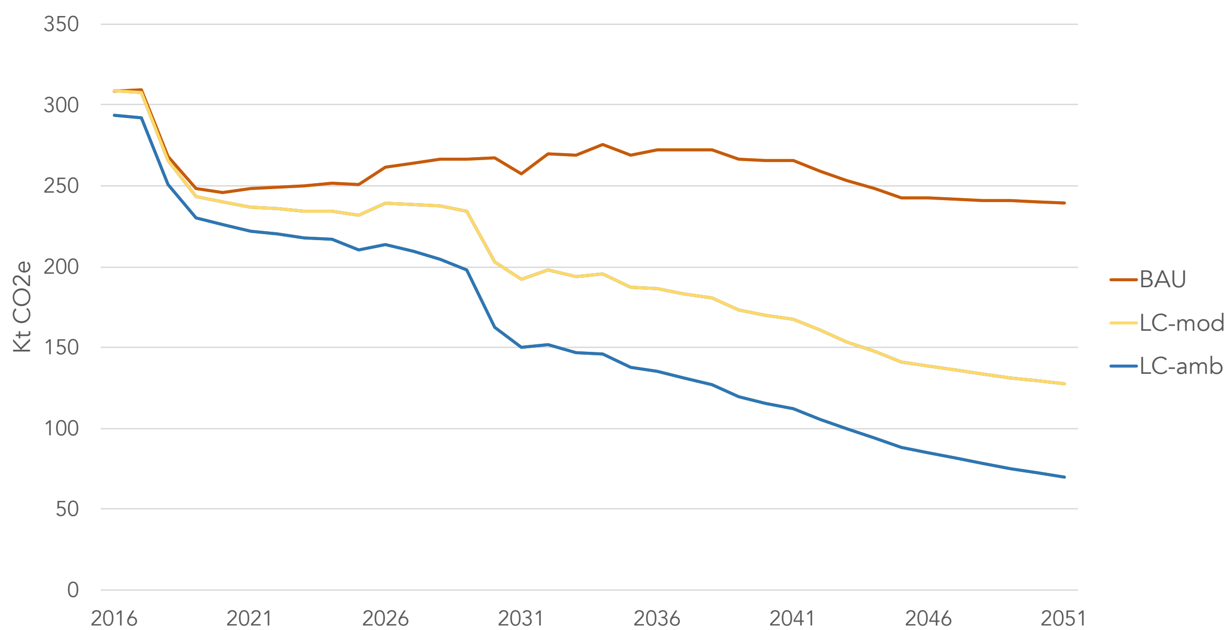


Figure 18. BAU, LC-mod and LC-amb projections, 2016-2050.

The subsections below describe the assumptions underlying each low carbon scenario. Details of the assumptions (eg. variables modelled) for each individual action by scenario are included in Appendix 1.

4.3 Low Carbon - Moderate (LC-mod)

The LC-mod scenario represents a significant level of effort to reduce emissions in the Town of Bridgewater. While referred to as "moderate" for the purposes of this report, the scenario is by no means moderate in terms of ambition; reducing emissions in this scenario relies on a major and sustained effort by the Town, the private sector, higher levels of government, and citizens. LC-mod requires significantly scaling up many activities that the Town already has underway, and introduces many new ones.

ASSUMPTIONS

BUILDINGS

Two distinct set of actions target the buildings sector; those for existing buildings and those for future buildings. Existing buildings are considered to be any buildings built before 2016.

- New construction

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

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

PassiveHouse levels of performance require energy consumption for space heating to be less than 15kWh/m2/yr, and total primary energy energy consumption to be less than 120 kWh/m2/yr; a significant improvement over current (2016) multi-residential buildings in Bridgewater, which have an average space heating consumption of 54 kWh/m2/yr, and total energy consumption of 75 kWh/m2/yr.

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

- Existing buildings

The primary focus for the existing building stock is to upgrade the energy efficiency of the buildings through retrofit programs, renovations and re-commissioning. All of the buildings constructed prior to 2016 are either retrofitted or renovated without overlap. Retrofits were applied to existing buildings according to their vintage and structure. Thermal energy savings of 50% and electrical savings of 50% were applied to single family homes, apartment, commercial buildings and town facilities.

- Building scale renewable energy

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

Air source heat pumps are incrementally introduced into 40% of residential buildings and 50% of commercial buildings by 2050. Separately, ground source heat pumps were installed in 20% of residential buildings and 35% of commercial buildings, again by 2050.

Solar photovoltaic systems were installed on 75% of the buildings by 2050, and using a net metering arrangement, the solar PV systems were sized to provide 30% of the electricity consumption for buildings of less than 5 storeys and 20% of the electrical load for apartments and commercial buildings. Solar hot water systems were installed on 40% of the residential buildings and 50% of the commercial buildings by 2050, supplying 50% of hot water requirements for both residential and non-residential buildings.

ENERGY GENERATION

- Ground mount solar PV

As electrification occurs in the transportation and building sectors, additional electricity capacity will be needed, and in the case of Bridgewater, there is a preference for local, renewable energy generation. This action models the addition of 8 MW per year of ground mounted solar PV between 2018 and 2050.

- District Energy

Energy systems planning is becoming critical to practical and responsible neighbourhood design or redesign.For Bridgewater this means the development of geothermal system in the downtown core. This actions models a district heating system which sources 50% sustainable biomass and 50% geothermal/river water heat pump for energy generation.

- Energy storage

Energy storage bridges the temporal gap between when renewable energy is generated and when there is a demand for the energy, increasing the percentage of energy that can be used, and decreasing the reliance on fossil fuel-based peaking plants. For this reason, in modelling, energy storage is assumed to increase the capacity factor for renewable energy. The action assumes a capacity factor of 36% for installed storage. For Bridgewater, a target of 12 MW was identified between 2018 and 2050.

- Run of River Hydro

To further supplement the additional electricity capacity required in this scenario this action models the installation of a 20MW run of river hydro system.

- Biogas

This action models the processing of excess biogas from the wastewater treatment facility to generate heat and power.

TRANSPORTATION

- Active transportation

Increased cycling mode share

The Town of Bridgewater is committed to implementing a community Active Transportation and Connectivity Plan (ATCP) to promotes better community health by providing new and improved recreational opportunities such as, walking, biking and rollerblading. As part of this initiative this action assumes that 50% of the cyclable trips (a trip that is 5 km or less) in Bridgewater will shift to cycling by 2050. It is important to note that trips which are classified as cyclable are a small portion of the overall trips.

Increased walking mode share

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

- Electrifying vehicles & transit

Vehicle technologies

The primary intervention in the transportation sector is to electrify the vehicle and transit fleet. Electrifying the transit fleet (action 15) includes incrementally transitioning buses in Bridgewater, starting in 2020, so that the fleet is fully electric by 2040.

For personal vehicles, the action assumes all new vehicles in Nova Scotia after 2030 will be electric, including personal light-duty vehicles; an action which is consistent with commitments announced by Germany[10] and Norway.[11]

For commercial vehicles, EV uptake is increased incrementally from 2020 to 2050, whereby 90% of commercial vehicle activity in Bridgewater will be electric in 2050.

Included in the electrifying of personal vehicles (action 22), is an assumption around the uptake and impact of autonomous vehicles (AV). Based on a scenario developed

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

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

by the Rocky Mountain Institute,[12] the action assumes that personal vehicle ownership declines by 50% by 2050 but personal vehicle kilometres travelled (VKT) increases by 20%.[13] The increase in VKT results as new cohorts of the population (young and elderly, for example) have access to vehicles, and the convenience of private vehicles increases, with the cost of travel decreasing.[14]

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

4.4 Low Carbon - Ambitious (LC-amb)

The LC-amb scenario represents an even more significant level of ambition compared with LC-mod. Firstly, emissions are further reduced as the efficiencies in industry are developed and implemented, ground mounted solar photovoltaics are scaled up and wind generation is added. LC-amb reduces emissions further compared with LC-mod meeting the 80% emissions reduction objective.

ASSUMPTIONS

BUILDINGS

- Industrial Efficiency

The LC-amb focuses on industrial use in the industrial sector increase industrial efficiency by 50% by 2050.

ENERGY GENERATION

- Ground mount solar PV

This action increases the generation of electricity in the LC-mod scenario from 8 MW per year of ground mounted solar PV between 2018 and 2050 to 12MW.

- Wind Generation

As further electricity generation is required to reach the objective of 80% emissions reductions 6 2MW wind turbines are installed in this action.

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

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

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

5. RESULTS & ANALYSIS

5.1 Pathways

As described in Section 2, for each scenario, the emissions reduction impact of the actions are quantified and evaluated against the BAU scenario; thereafter all the actions are modelled together in the form of an integrated scenario. Once the results of the integrated scenario are calculated, the proportionate reductions from each action are distributed on a year over year basis to generate a wedge diagram, illustrated in Figure 19 for the LC-mod scenario, and Figure 20 for the LC-amb scenario.

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

The pathway of LC-mod descends to 131 KT CO2e by 2050, representing a 66% reduction over the 2011 baseline of 385 KT CO2e. Achieving an emissions reduction of 80% under the LC-mod scenario requires additional reductions of 57 KT CO2e.

The pathway of LC-amb descends to 74 KT CO2e by 2050, representing an 81% reduction over the 2011 baseline of 385 KT CO2e.

The emissions reduction contribution of each action under the LC-mod and LC-amb scenarios in the year 2050 is shown in Table 10.

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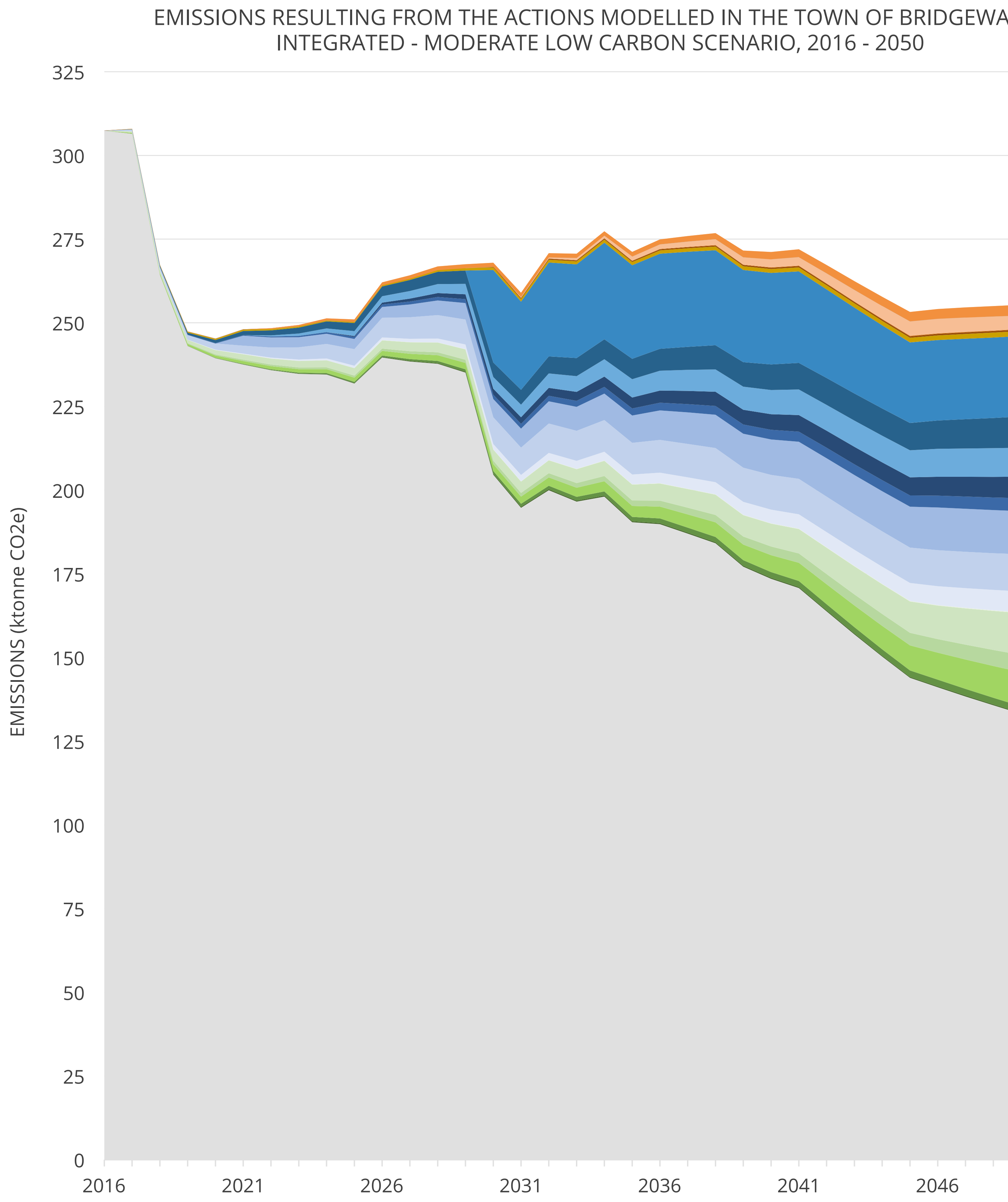
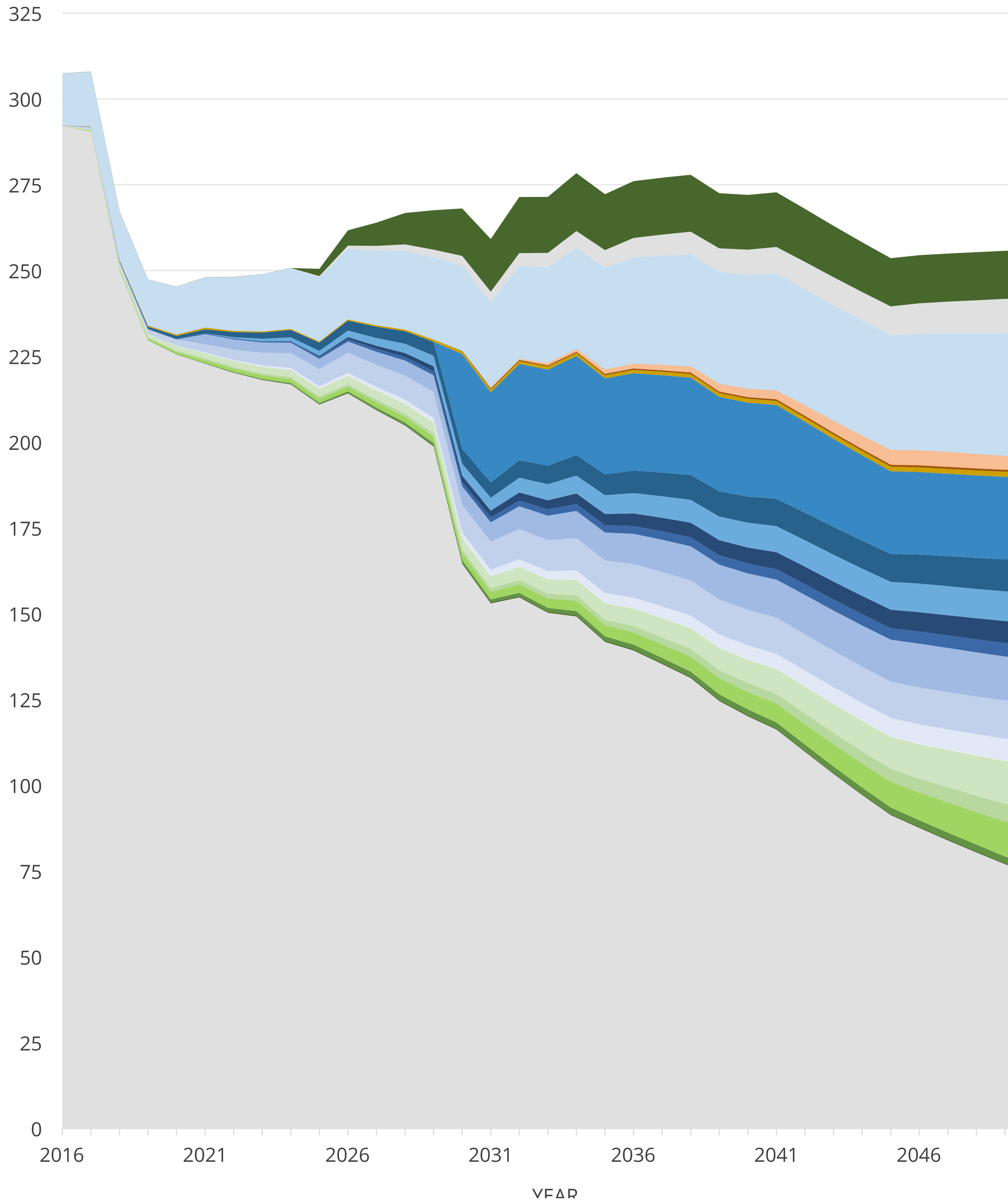

EMISSIONS RESULTING FROM THE ACTIONS MODELLED IN THE TOWN OF BRIDGEWA
INTEGRATED - MODERATE LOW CARBON SCENARIO, 2016 - 2050
EMISSIONS (ktonne CO2e)
325
300
275
250
225
200
175
150
125
100
75
50
25
0
2016
2021
2026
2031
2036
2041
2046

TOWN OF BRIDGEWATER EMISSIONS REDUCTION ACTIONS CHART LEGEND

- Introduce grid connected CHP to use surplus WWTP biogas
- Autonomous vehicles
- Electrify commercial vehicles
- Electrify personal vehicles
- Electrify municipal fleet
- Increase walking and cycling infrastructure
- Expand and electrify transit
- Run of river hydro
- Home or business-based energy storage
- District energy system
- Ground-mounted solar PV
- Solar heating on houses and businsesses
- Install solar PV on houses and businesses
- Install heat pumps in businesses
- Install heat pumps in homes
- Retrofit town facilities
- Retrofits of commercial buildings
- Retrofit new homes (after 1980)
- Retrofit old homes (pre-1980)
- New commercial buildings are passivehouse
- New dwellings are net zero energy
- Remaining Emissions - mod

Figure 19. LC-mod emissions reductions, 2016-2050.

EMISSIONS RESULTING FROM THE ACTIONS MODELLED IN THE TOWN OF BRIDGEWATER
INTEGRATED - AMBITIOUS LOW CARBON SCENARIO, 2016 - 2050



TOWN OF BRIDGEWATER EMISSIONS REDUCTION ACTIONS
CHART LEGEND

- Introduce grid connected CHP to use surplus WWTP biogas
- Wind turbines
- Ground-mounted solar PV
- Industrial efficiency
- Autonomous vehicles
- Electrify commercial vehicles
- Electrify personal vehicles
- Electrify municipal fleet
- Increase walking and cycling infrastructure
- Expand and electrify transit
- Run of river hydro
- Home or business-based energy storage
- District energy system
- Ground-mounted solar PV
- Solar heating on houses and businsesses
- Install solar PV on houses and businesses
- Install heat pumps in businesses
- Install heat pumps in homes
- Retrofit town facilities
- Retrofits of commercial buildings
- Retrofit new homes (after 1980)
- Retrofit old homes (pre-1980)
- New commercial buildings are passivehouse
- New dwellings are net zero energy
- Remaining Emissions - amb

Figure 20. LC-amb emissions reductions, 2016-2050.

Table 10. Emissions reduction results of actions for LC-mod and LC-amb, kt CO2e in 2050.

		kt CO2e (2050)	
BUILDINGS		LC-mod	LC-amb
New buildings - buildings codes & standards			
1	New dwellings are net zero energy	0.24	0.25
2	New commercial buildings are passivehouse	1.78	1.87
Existing buildings - retrofitting			
3	Retrofit old homes (prior to 1980)	9.81	10.31
4	Retrofit new homes (after 1980)	4.98	5.23
5	Retrofit commercial buildings	11.99	12.6
6	Increase the efficiency of industrial operations		34.39
Renewable energy generation (on-site, building scale)			
7	Install heat pumps in homes	5.87	6.17
8	Install heat pumps in businesses	10.1	10.61
9	Install solar PV on homes and businesses	11.59	12.17
10	Solar hot water heating on homes and businesses	3.63	3.82
ENERGY GENERATION			
Low or zero carbon energy generation (community scale)			
11	Ground-mounted solar PV	5.78	9.49
12	Develop a district energy system in the downtown	7.91	8.31
13	Home or business-based energy storage	8.67	9.11
14	Run of river hydro system	21.68	22.77
15	Wind turbines		13.29
TRANSPORT			
16	Expand and electrify transit	1.37	1.44
17	Increase/improve cycling & walking infrastructure	0.42	0.44
18	Electrify personal vehicles	5.08	5.33
19	Electrify commercial vehicles	1.26	1.33
20	Autonomous vehicles	-3.57	-3.75
	Total	**108.59**	**165.18**

5.2 Energy

The sankey diagrams (Figures 21, 22 and 23) depict the energy flow by fuel and sector through Bridgewater in 2050, in the BAU, LC-mod, and LC-amb scenarios respectively.

Overall, energy decreases significantly in the LC-mod and LC-amb scenarios. Additionally, and more significant perhaps, is the reduction in conversion losses; the ratio of useful energy to conversion losses in BAU 2050 is 1.8:1, compared with 2.1:1 in LC-mod and 2.3:1 in LC-amb. The LC-mod and LC-amb represent a more efficient energy system, in which less energy is “wasted”.

Energy consumption in all of the sectors decline significantly, primarily due to the increased efficiencies introduced into the building stocks and the introduction of electric vehicles.

Both the LC-mod (Figure 22) and LC-amb (Figure 23) sankey diagrams indicate that overall consumption of electricity decreases compared with BAU (Figure 21) despite major emphasis on fuel switching to electricity, particularly in the transport sector. This reduction is a result of the increased efficiencies in the building stock, which exceeds the addition of new electricity consumption. These diagrams also show a decreased reliance on outside sources of energy production, both fossil fuels and electricity, as a larger portion of Bridgewater's energy is generated locally as indicated by the Elec Gen node.

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

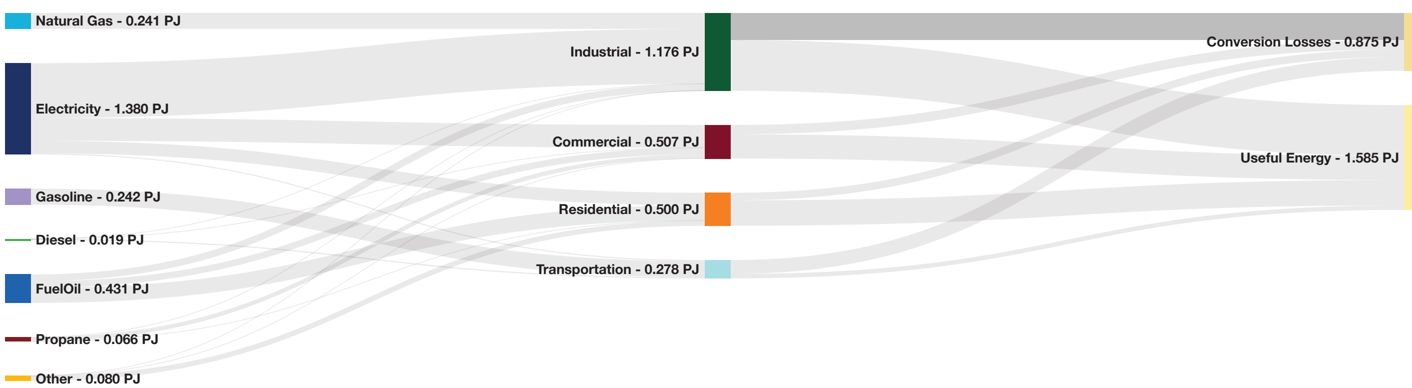


Figure 21. Energy flow sankey diagram, BAU 2050.

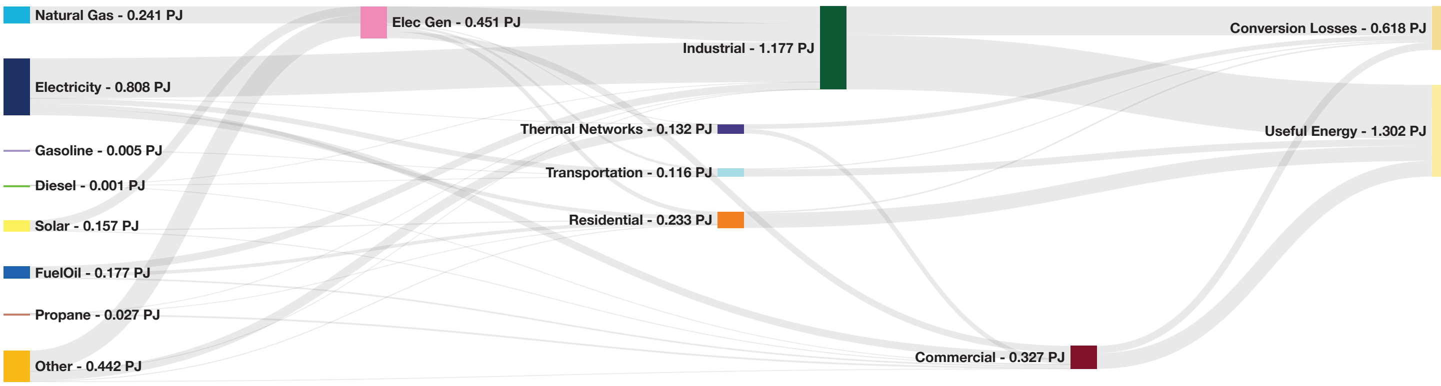


Figure 22. Energy flow sankey diagram, LC-mod 2050.

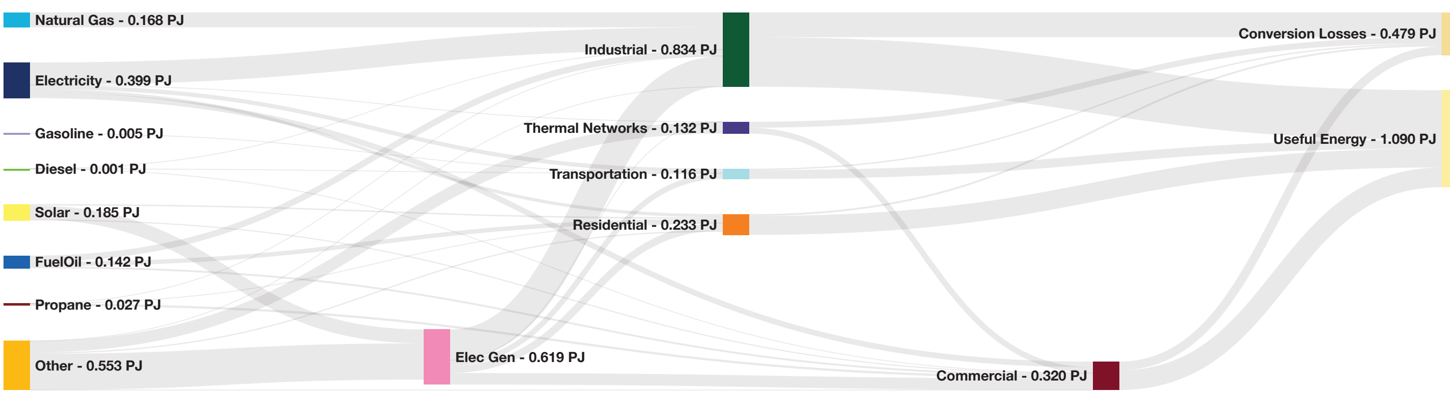


Figure 23. Energy flow sankey diagram, LC-amb 2050.

LC-MOD

The LC-mod scenario sees a gradual decrease in overall energy consumption to 2050, with a significant decrease in the industrial sector (Figure 14) as decentralized energy generation is brought online in 2030. Increases in electricity and renewable sources, are evident as fuel shifting in the buildings and transport sectors increases to 2050 (Figure 15).

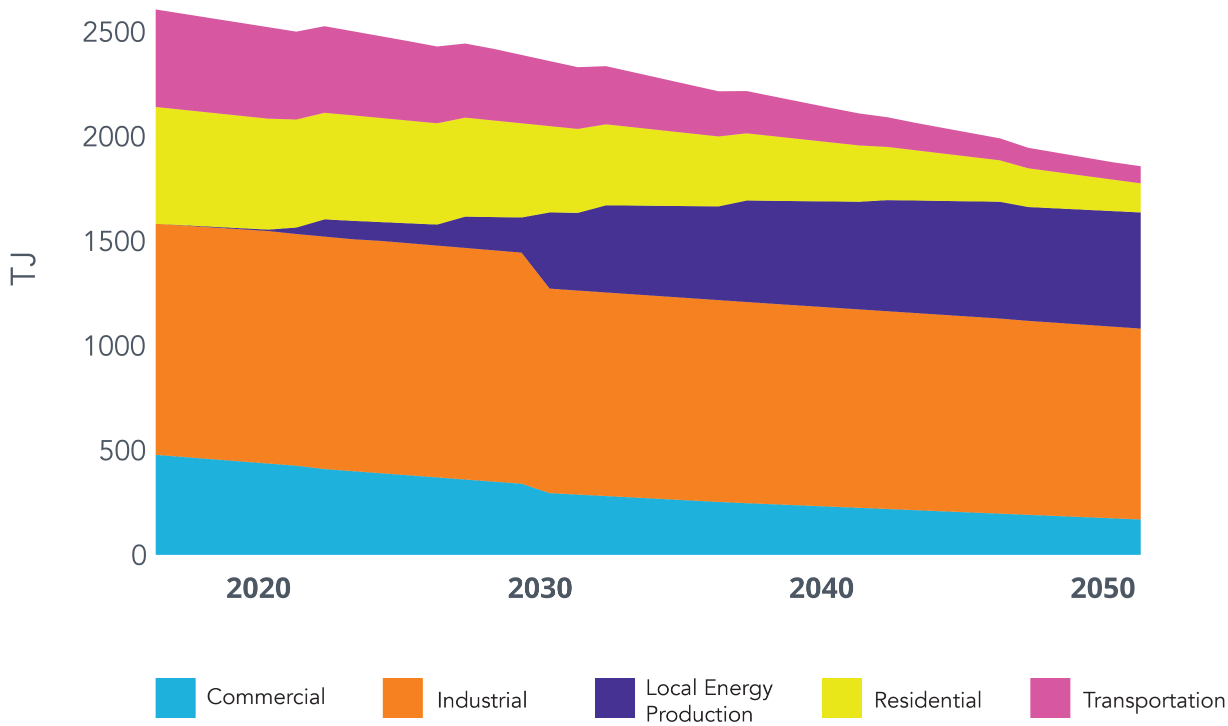


Figure 24. Energy by sector, LC-mod, 2016-2050.

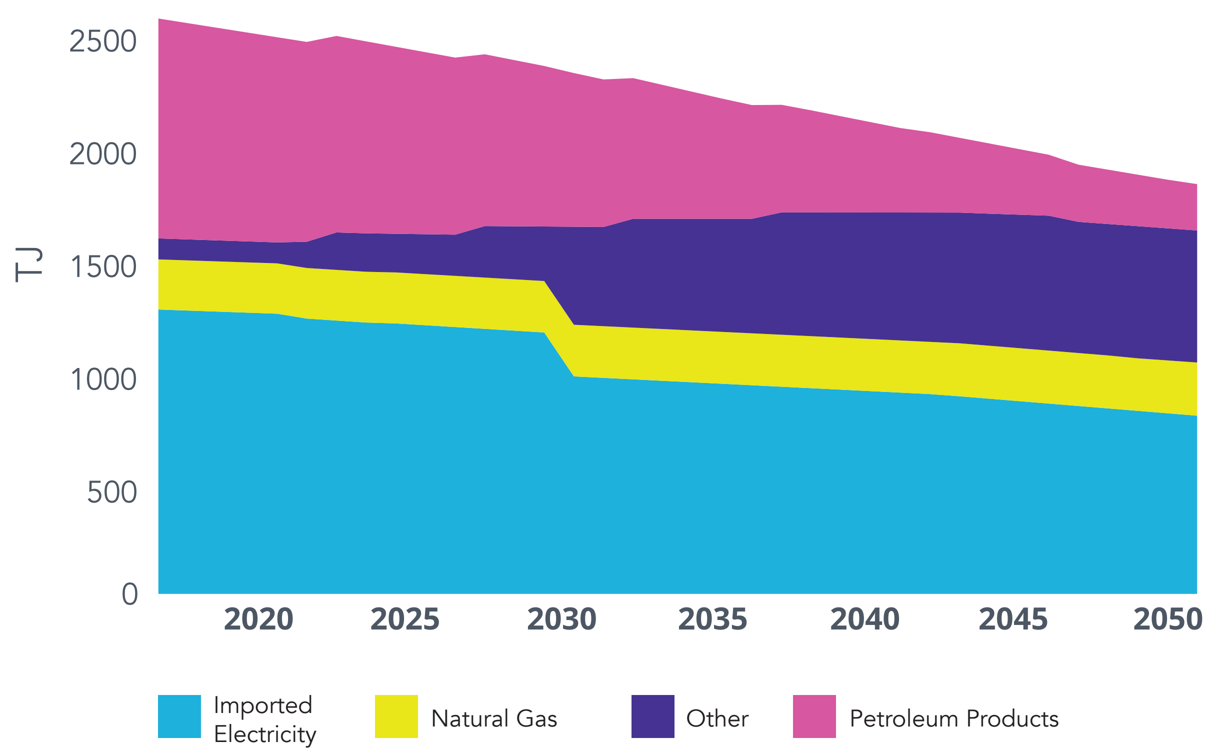


Figure 25. Energy by fuel, LC-mod, 2016-2050.

LC-AMB

The LC-amb scenario also sees a gradual decrease in overall energy consumption to 2050, to a slightly greater extent than LC-mod. Aggressive changes are evident in the industrial sector and local energy production (Figure 26). Electricity, solar and renewable natural gas (biogas) become the main sources of energy by 2050 (Figure 27).

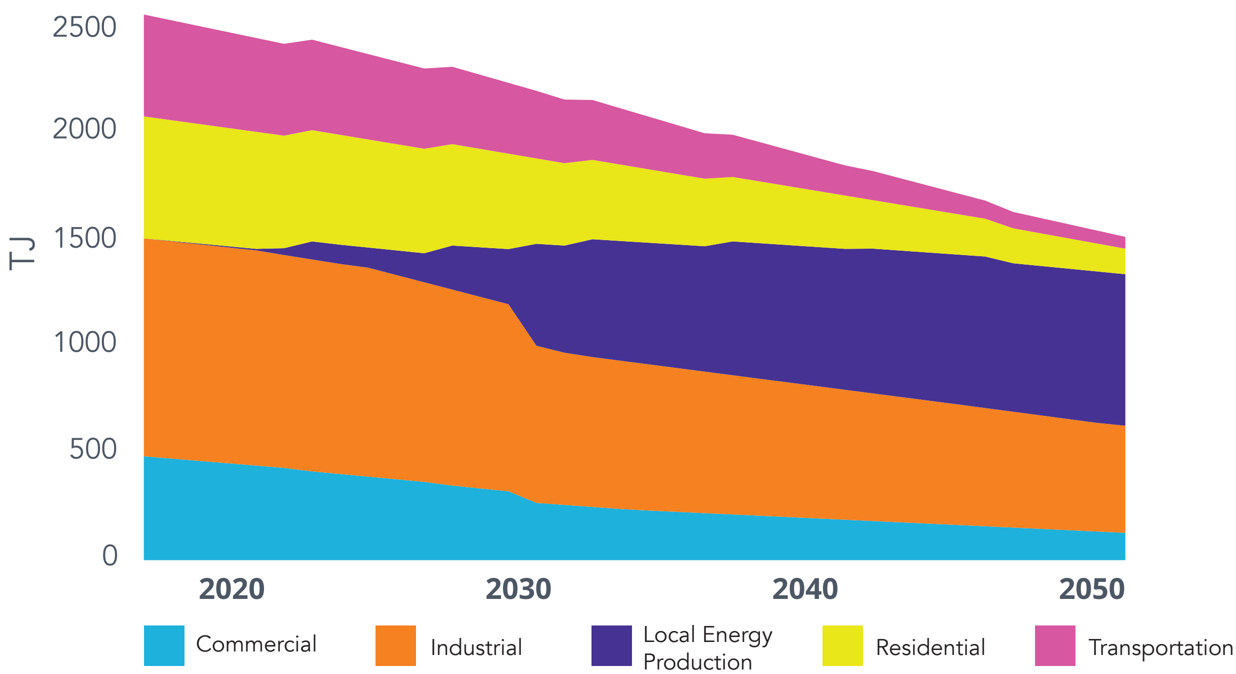


Figure 26. Energy by sector, LC-amb, 2016-2050.

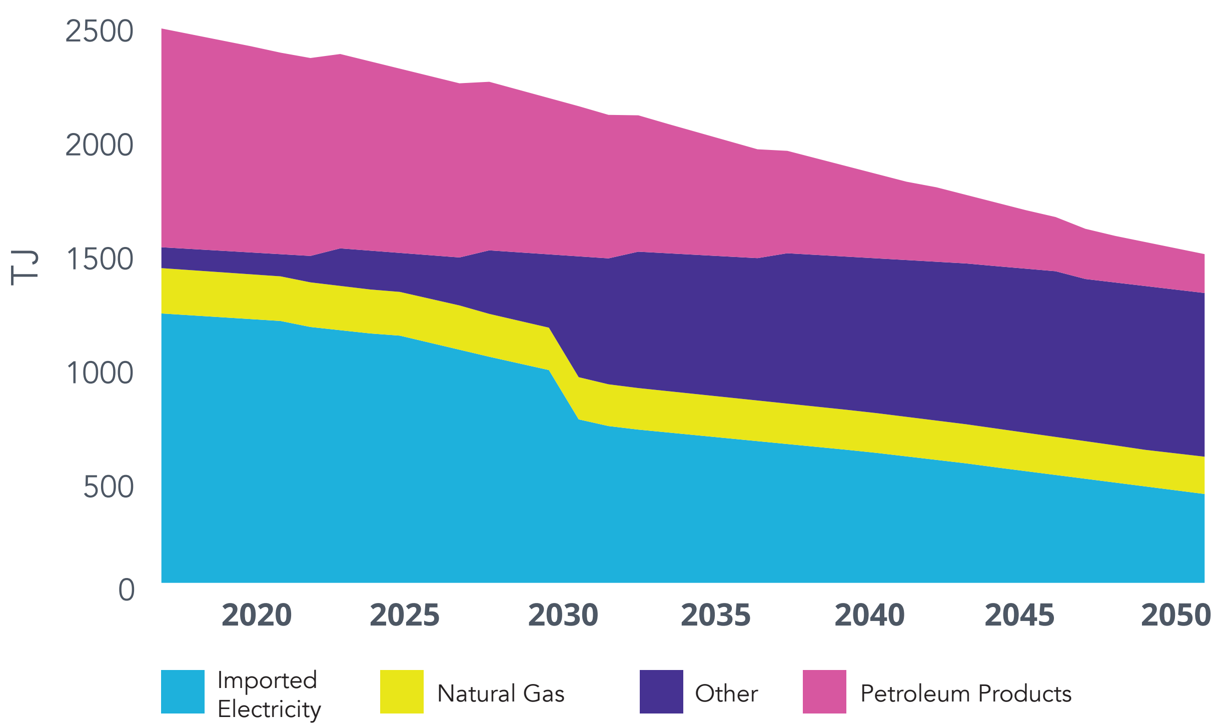


Figure 27. Energy by fuel, LC-amb, 2016-2050.

5.3 Emissions

LC-MOD

Emissions decline sharply from 2018 to 2020 as hydro electricity from Muskrat falls or other renewable energy sources becomes available. The bumpiness from 2025 to 2035 comes from the changing sources of imported electricity generation. During this time Nova Scotia is phasing out coal generated electricity and replacing it with natural gas and heavy oil based generating capacity, while also reducing hydro imports. While this transition is occurring renewable local energy production is brought online in Bridgewater showing a overall steady decline in emission through to 2050 (Figure 28).

A significant contributor of the emissions in Bridgewater remains imported electricity. Although reduced significantly imported electricity still makes up a large portion of emission sources (Figure 29).

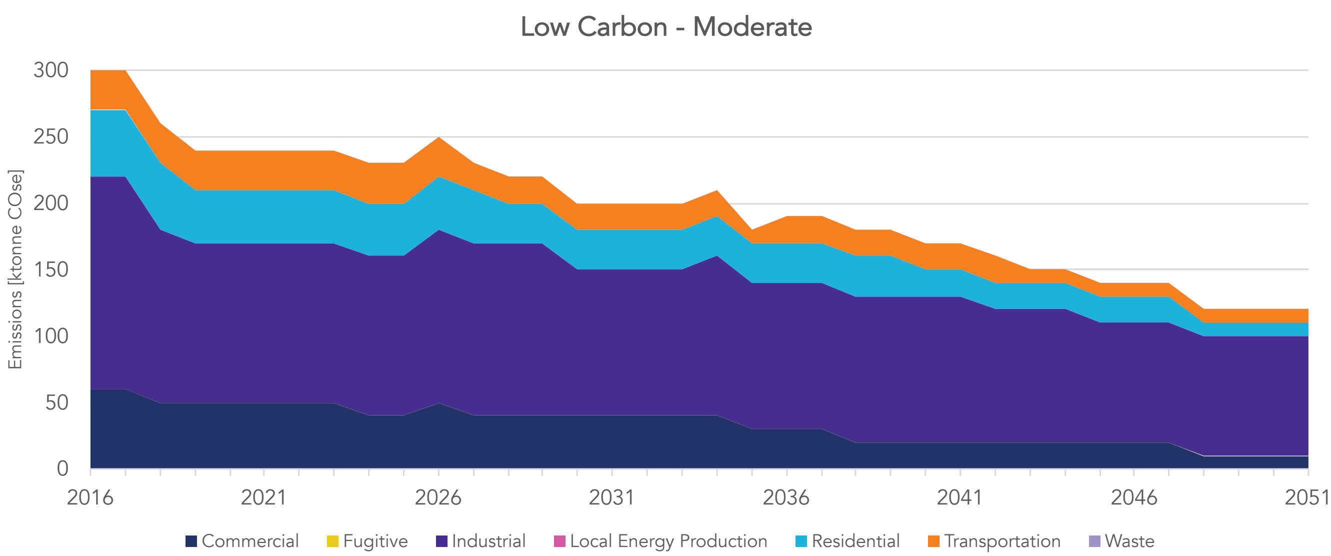


Figure 28. Emissions by sector, LC-mod, 2016-2050.

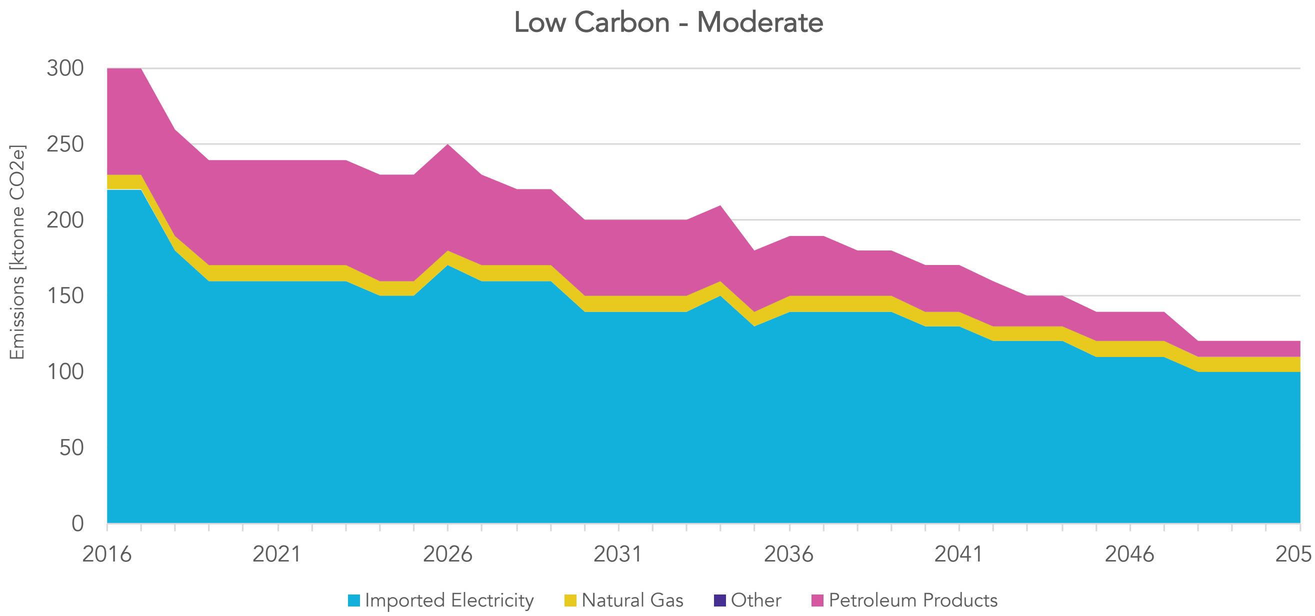


Figure 29. Emissions by fuel, LC-mod, 2016-2050.

LC-AMB

Emissions decline more rapidly to 2050 compared with LC-mod (Figure 30). Similar to LC-mod, significant reductions are attributed to the decrease in energy use in the industrial, residential and transportation sectors. In LC-amb, a significant decrease in emissions results from the reduction of imported electricity which still accounts for a majority of the emissions in Bridgewater (Figure 31).

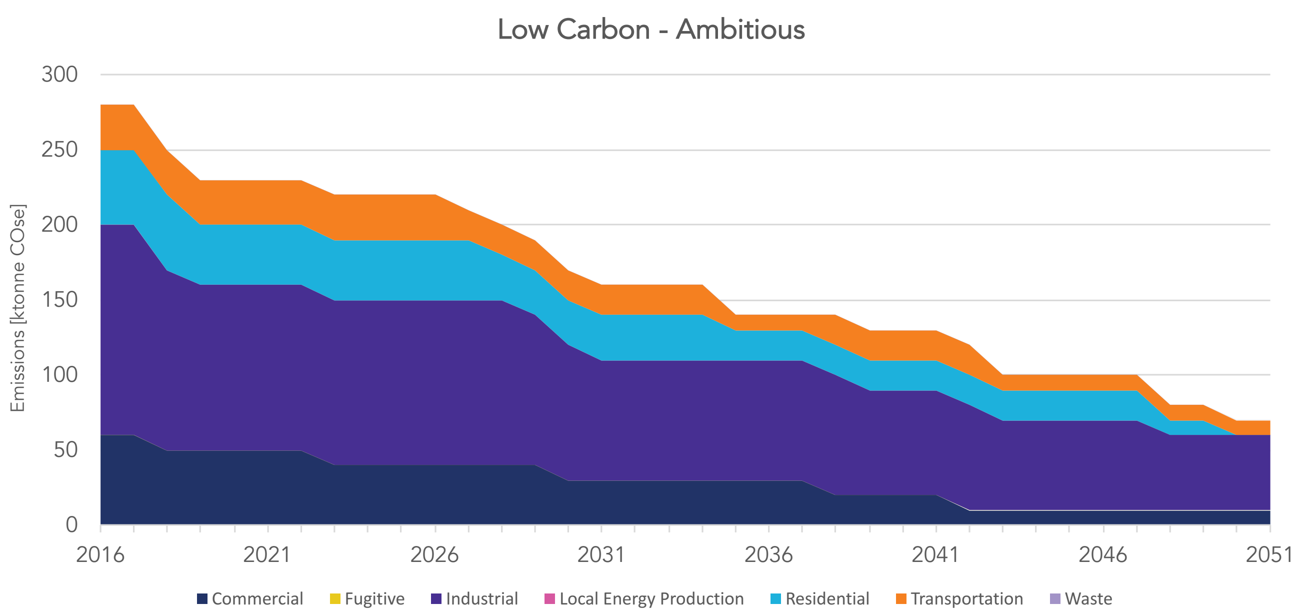


Figure 30. Emissions by sector, LC-amb, 2016-2050.

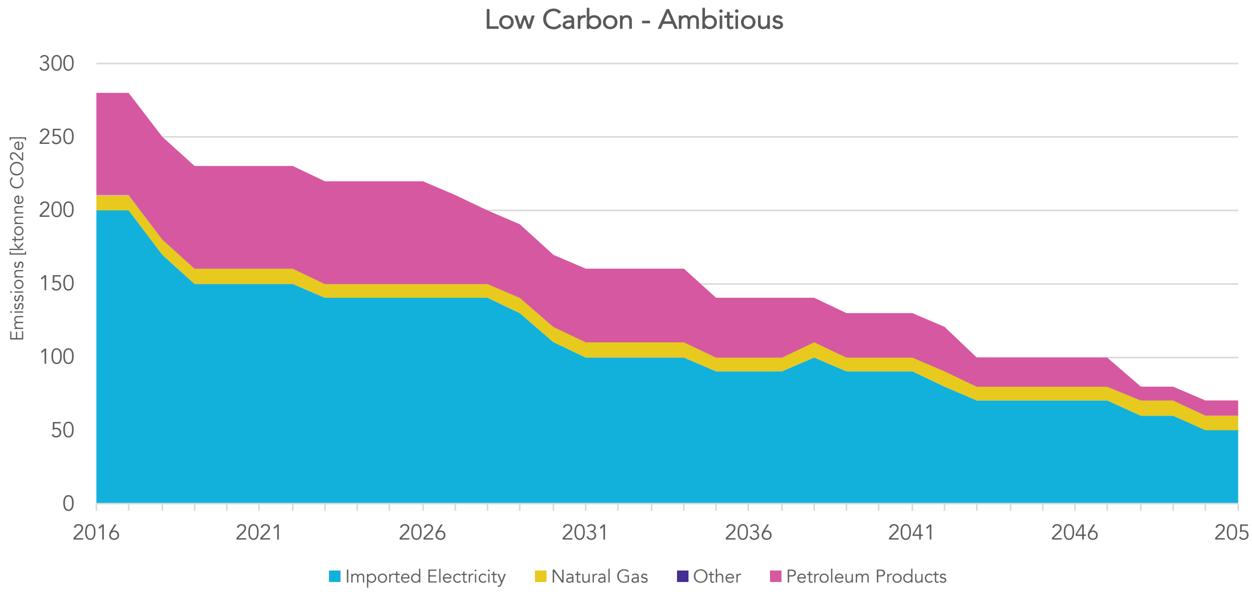


Figure 31. Emissions by fuel, LC-amb, 2016-2050.

5.4 Buildings

Energy consumption in buildings decreases significantly by 2050 in both low carbon scenarios, with residential buildings consuming approximately 73% (LC-mod) and 77% (LC-amb) less energy compared with 2016 (Figure 23). Commercial buildings use 66% (LC-mod) and 76% (LC-amb) less energy compared with 2016.

Emissions reductions in residential buildings in both the LC-mod and LC-amb result predominantly from decreases in consumption and generation of local electricity from renewables. Residential emissions decrease by 78% in LC-mod, and 83% in LC-amb, compared with 2016.

Similarly, emissions reductions in commercial buildings result predominantly from decreases in consumption and generation of local electricity from renewables in both LC-mod and LC-amb. Commercial emissions decrease by 74% in LC-mod, and 82% in LC-amb, compared with 2016.

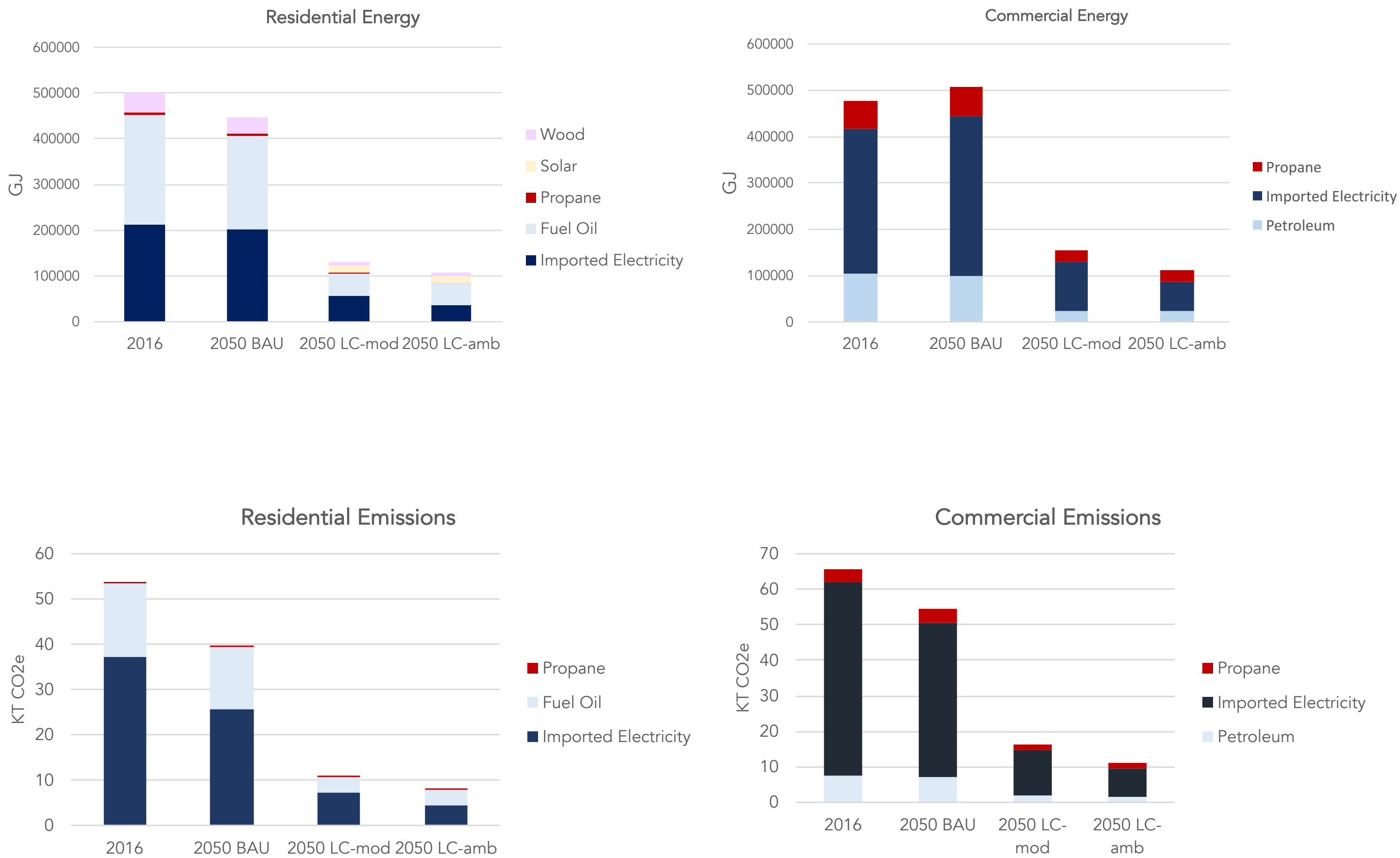


Figure 32. Residential and commercial buildings energy and emissions by fuel.

Building Archetypes

A set of 34 building Archetypes was developed to understand the building envelope changes required to retrofit Bridgewater's existing buildings. Small is defined as 0-999 ft2, medium is 1,000 to 1,999 ft2 and large is 2,000 ft2 or larger. Old is defined as constructed prior to 1960, contemporary as constructed between 1961 and 1995 and new as constructed in 1996 or later.

Type	Characteristic
Single Detached	small low old
	small low contemporary
	small low new
	small high old
	small high contemporary
	small high new
	medium low old
	medium low contemporary
	medium low new
	medium high old
	medium high contemporary
	medium high new
	large low old
	large low contemporary
	large low new
	large high old
	large high contemporary
	large high new
Semi Detached	small old
	small contemporary
	small new
	medium old
	medium contemporary
	medium new
	large old
	large contemporary
	large new
Mini Home	mini home

Type	Characteristic
Multi Unit	converted old
	converted contemporary
	converted new
	purposebuilt old
	purposebuilt contemporary
	purposebuilt new

The largest category is single detached, 1 story, medium accounting for 28% of the total buildings, followed by 2 storey small and medium, each with approximately 20%.

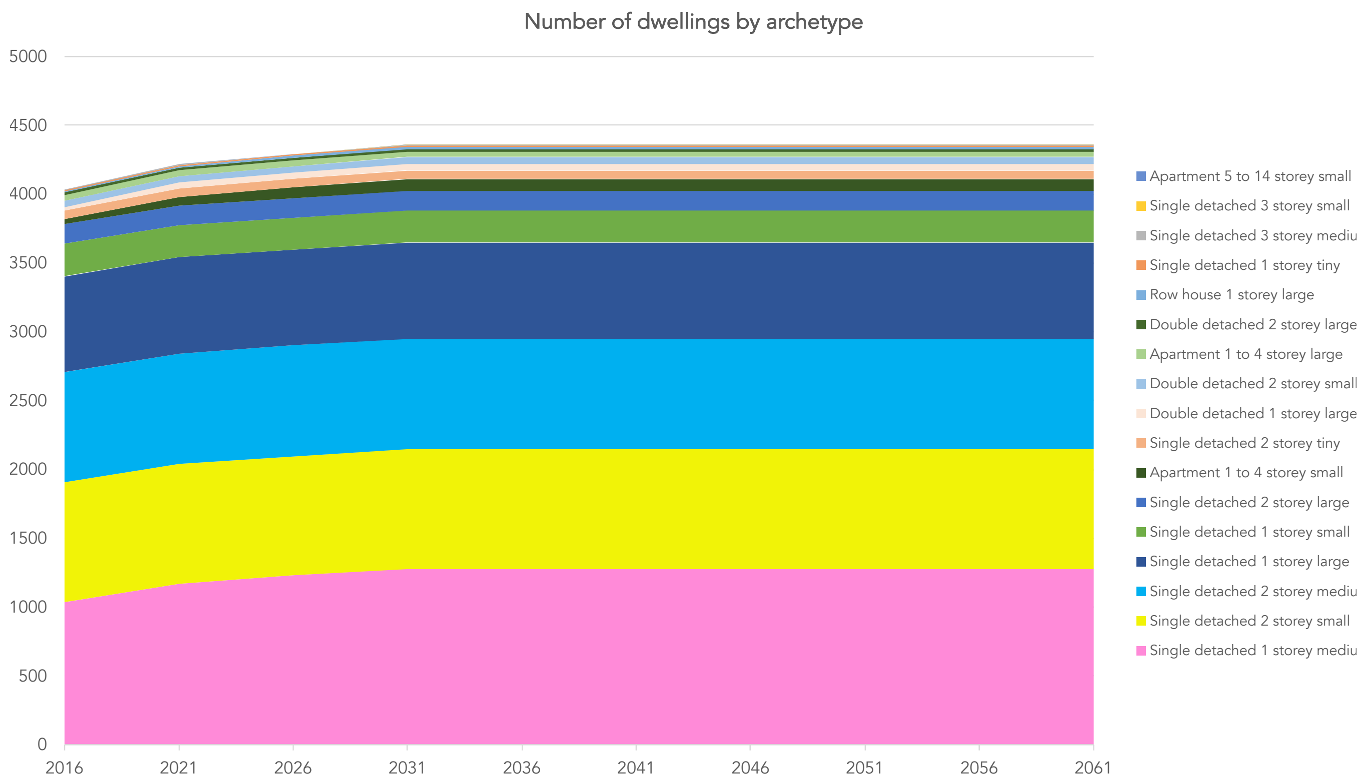


Figure 33. Number of dwellings by archetype

The scenario includes projections of approximately 15-40 new dwellings constructed each year. Figure 34 illustrates the number of new dwellings classified by archetype in five year steps.

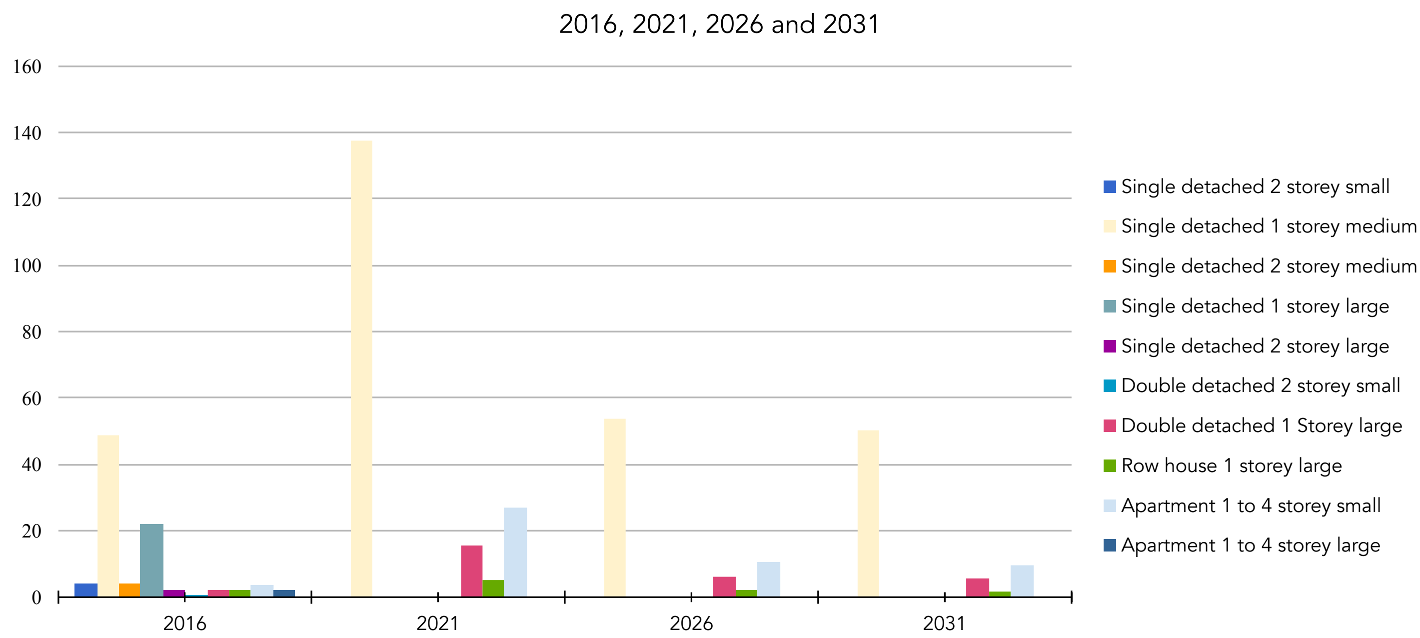


Figure 34. New dwellings by archetype in five year steps

A combination of fuel-switching and renovations was applied to existing buildings and new buildings were designed to be net zero energy and emissions. Figure 35 illustrates the energy use intensity of the building stock in 2011 and in 2050, highlighting the significant reductions in energy consumption in every archetype.

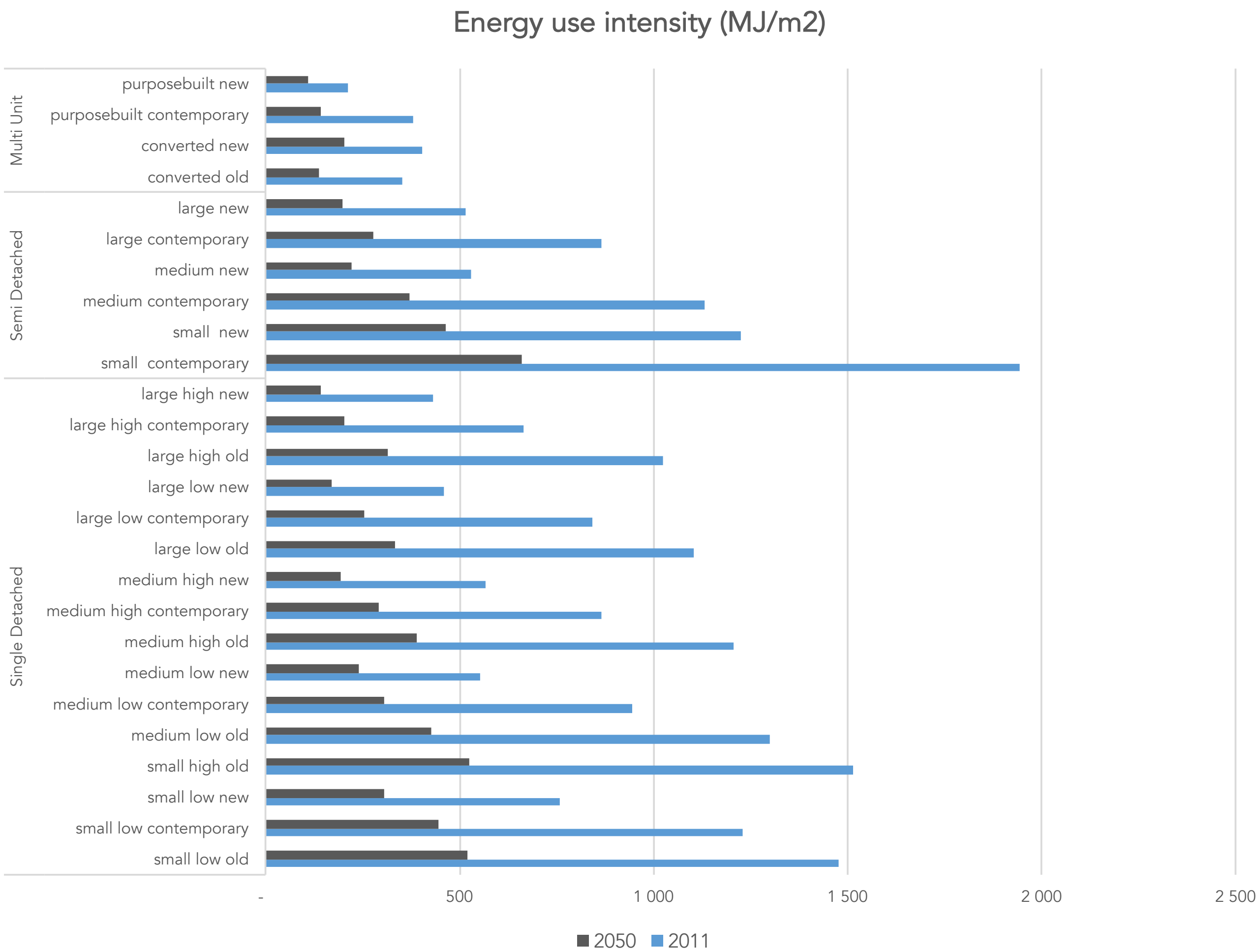


Figure 35. Comparison of average energy use intensity of the archetypes in 2011 and 2050

In order to evaluate renovation pathways, SketchUp Pro was used to construct 3D representations of two sample archetypes: Single Detached - medium low contemporary and Single Detached - medium high old. The 3D models were fed into Sefaira's Architecture SketchUp Pro extension. Using the buildings' geometry, properties, orientation and location, Sefaira simulated the building's energy requirements.

The geometry of the building is the first piece of information required to process an energy simulation. The geometry for this analysis included surfaces separating environments of significantly different temperatures. The building envelope consisted of the parts of the building that separate the internal (conditioned) space from the outside air or ground, including exterior walls, windows, doors, roofs, and the ground floor. The second piece of information required is building location, which enables Sefaira to apply location-specific climatic data. The climatic data originates from the US Department of Energy's EnergyPlus Weather information and contains data for 8760 hours of a 365-day year for location information, temperature, humidity and enthalpy, wind; and solar radiation. Halifax was the location used in the model.

Building properties were calibrated to 2011 energy consumption data by adjusting the model's window, walls, floor and roof heat transfer coefficients and building infiltration rates until the building's total energy consumption and energy use intensity (EUI) matched observed data. This calibration process ensured that the model is internally consistent with observed data and the projected data is comparable over time. Note that this process involved assumptions related to the performance of building components. The current building designs were then compared with building properties representing PassiveHouse levels of performance in order to understand the magnitude of changes required to retrofit these buildings.

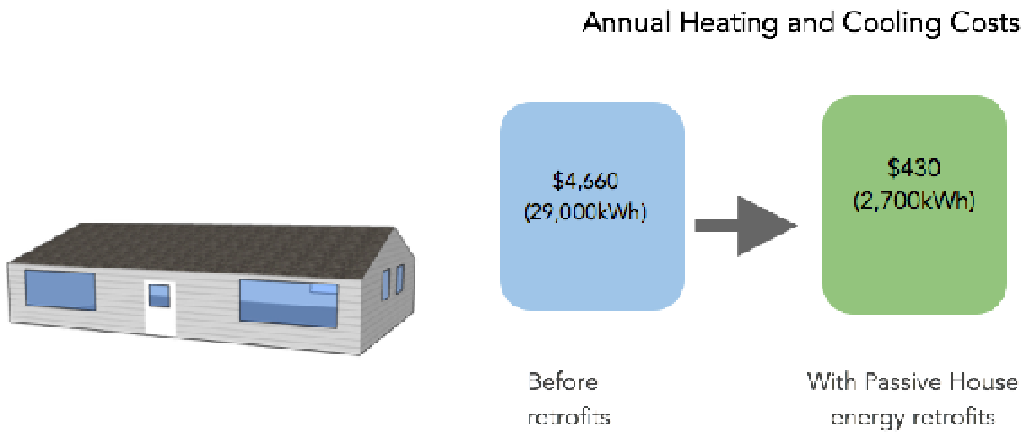


Figure 36. Single Detached - medium low contemporary 3D SketchUp Model.

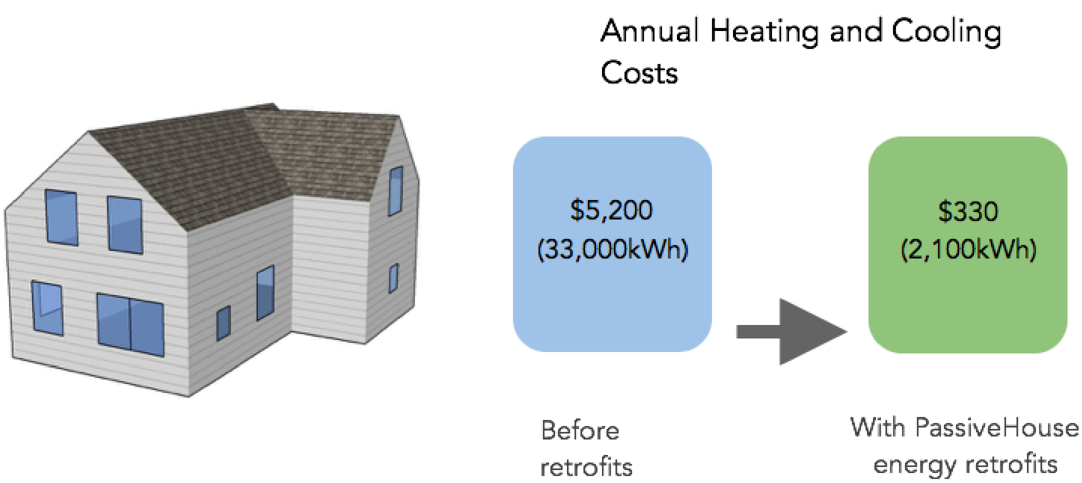


Figure 37. Single Detached - medium high old 3D SketchUp Model.

6. TRANSPORT

Person Trips

The majority of trips within the Town of Bridgewater are less than 5 km in length, creating a significant opportunity for mode shifting to walking and cycling.

Figures 38 and 39 illustrate the number of trips in the Town by mode and by trip length. Each coloured bar represents the number of trips. The LC-mod scenario (Figure 39) shows a significant increase in short trips by active transportation (pink bar) compared with the BAU (Figure 38). The decline in vehicle trips, particular for shorter trips, is apparent in the decreased blue bar, particularly for those of a distance of 5km or less.

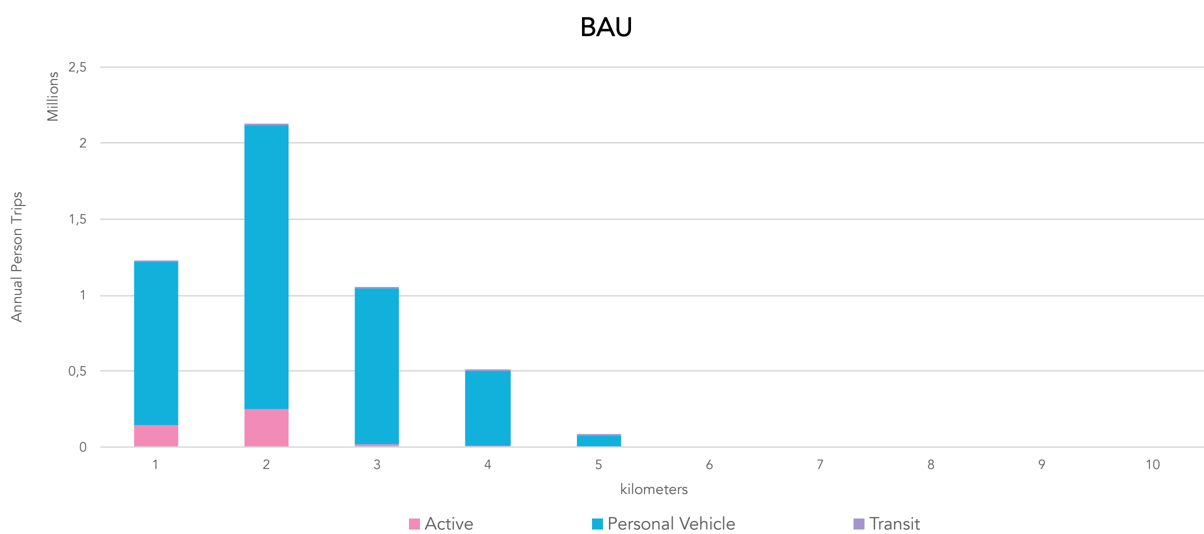


Figure 38. Person trips by mode and distance, BAU 2050.

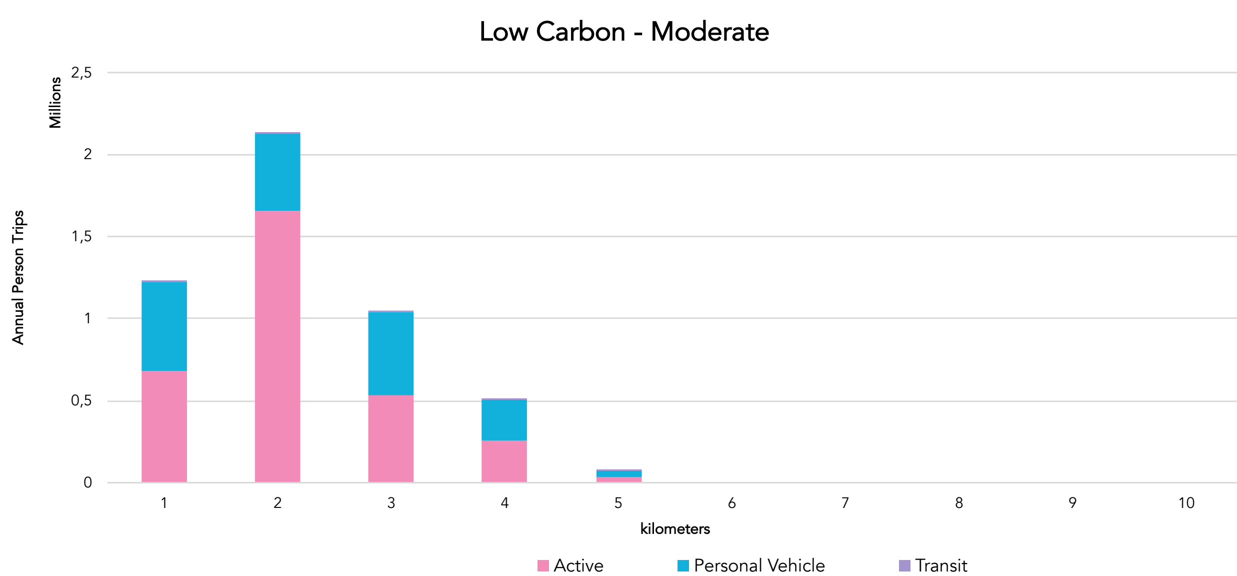


Figure 39. Person trips by mode and distance, LC-mod 2050.

Person kilometres travelled

Figures 40 and 41 illustrate the total person kilometres associated with each mode, according to the colour of shading for mode, and by trip length, for the BAU and LC-mod scenarios respectively.[15] The x-axis illustrates how distance travelled is distributed by trip length.

In LC-mod (Figure 41), there is a sharp increase in trips of less than 5 km that are travelled by active transportation, as highlighted by the pink bars, and a corresponding decrease in kilometres travelled by vehicle for the same trip length categories as represented by the blue bars.

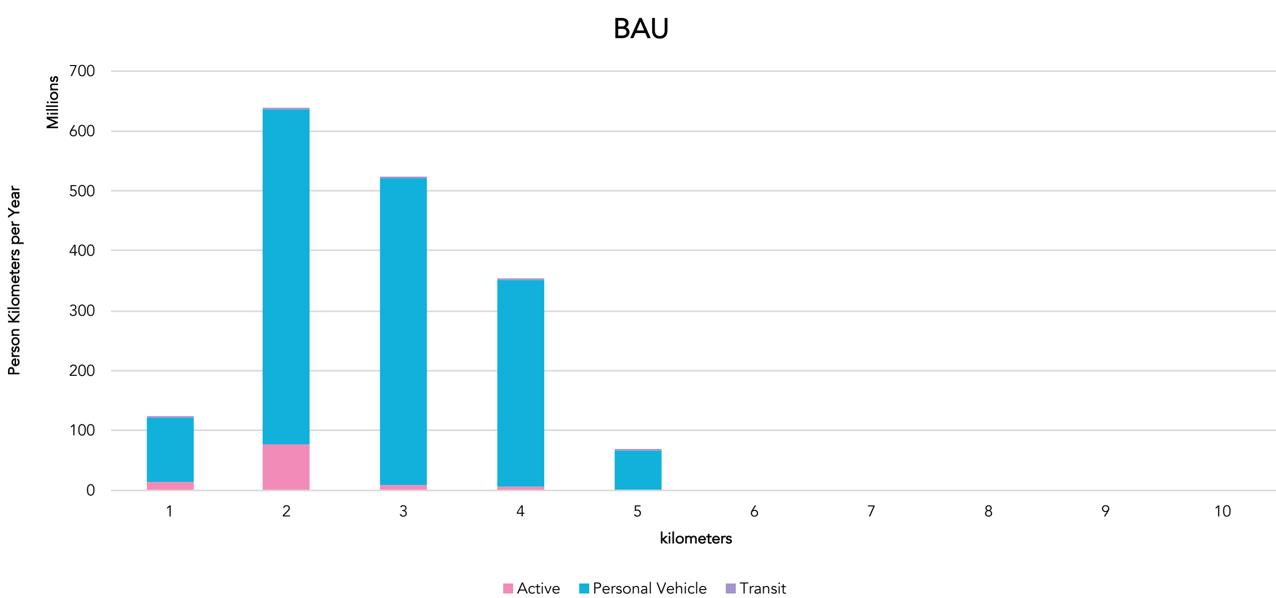


Figure 40. Distance travelled by mode and trip distance, BAU 2050.

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

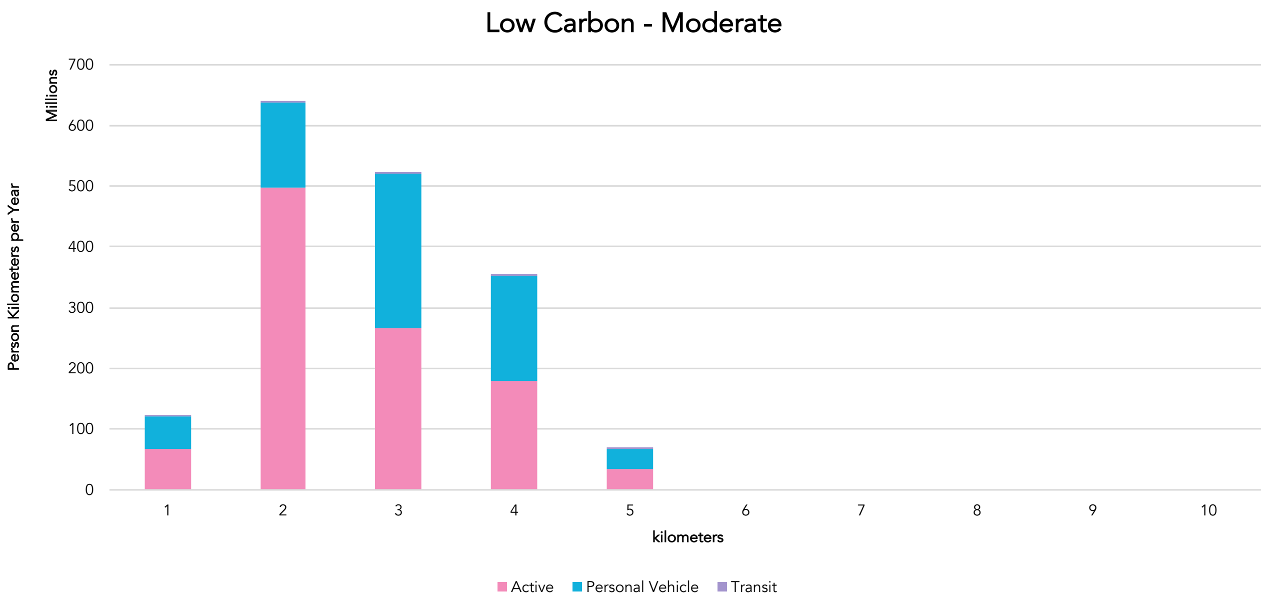


Figure 41. Distance travelled by mode and trip distance, LC-mod 2050.

Mode share

Active transportation modes experience gains in LC-mod over the BAU, particularly for shorter trips. Figures 42 and 43 illustrate mode share by trip length as a percentage of the total for BAU and LC-mod respectively. In BAU (Figure 42), active trips decline to near 0% when the trip length reaches 3 km, compared with LC-mod (Figure 43), where the share of active transportation trips for short trips increases significantly for trips less than 5km; personal vehicle trips also decrease for shorter trips.

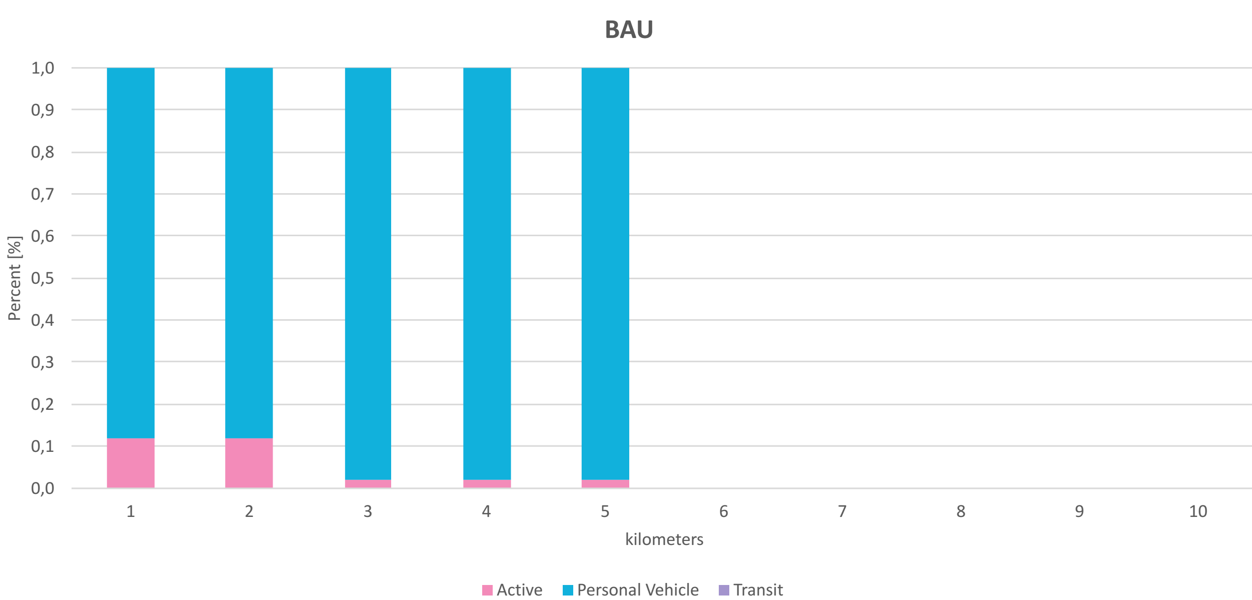


Figure 42. Person trip mode share by distance, BAU 2050.

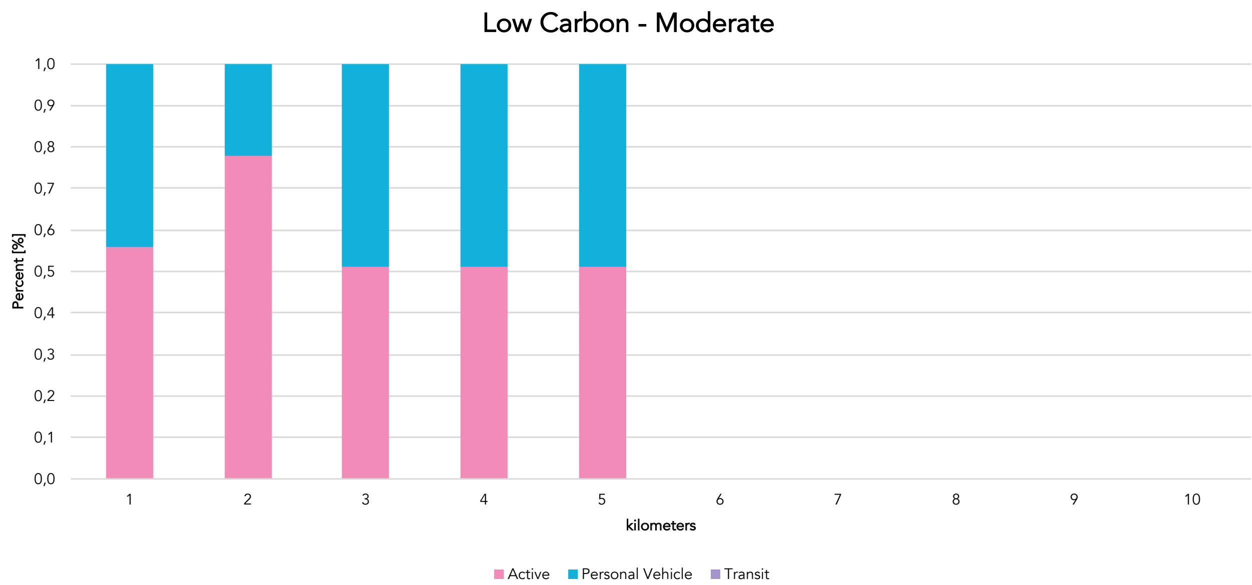


Figure 43. Person trip mode share by distance, LC-mod 2050.

Personal use Vehicle Kilometers Traveled (VKT) and average vehicle trip length

For internal trips, personal use VKT decreases slightly in LC-mod compared with BAU (Figure 44) as a result of mode shifting shorter trips to active modes. As described above in the LC-mod, there is a significant shift to active modes for internal trips between 0-5km.

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

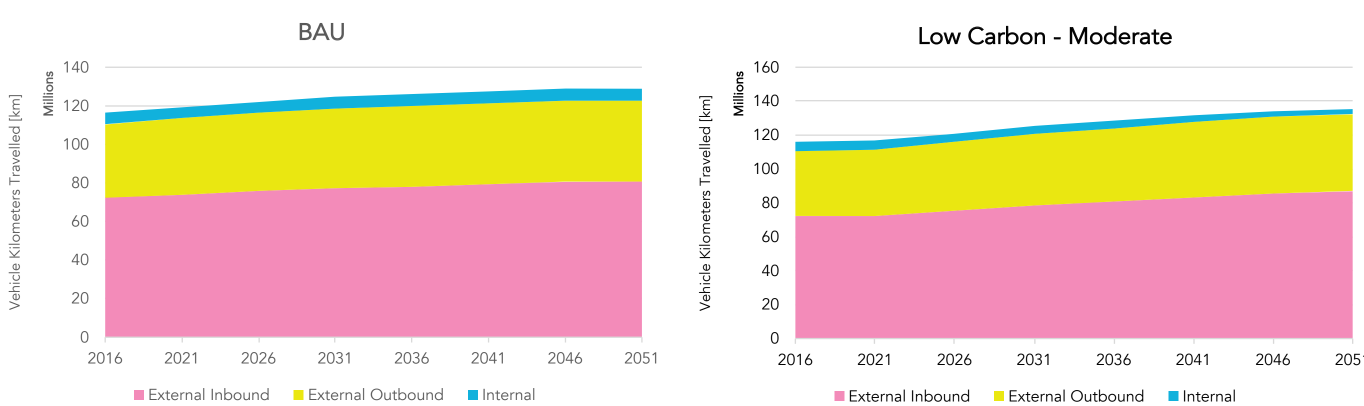


Figure 44. Personal use VKT.

Autonomous vehicles and electric vehicles

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

6. The Energy Shift

LC-amb was selected as the preferred scenario due to the alignment of its target with global ambition on GHG emissions reductions. The process of achieving the GHG reduction trajectory as described by LC-amb was defined as the Town of Bridgewater's Energy Shift. The Energy Shift is captured in Figure 45 both a reduction in total energy use by 2050 and a shift to local renewable energy.

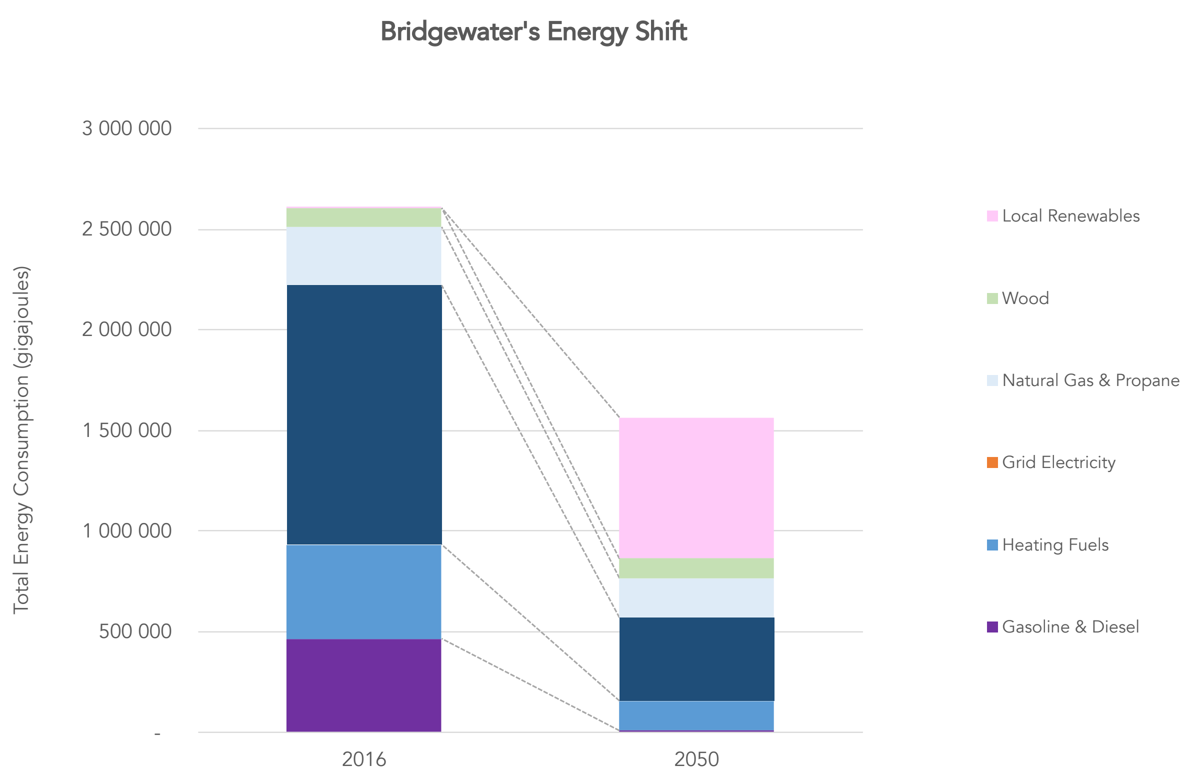


Figure 45. Total Energy Consumption 2016 vs 2050

7. FINANCIAL ANALYSIS

Detailed financial modelling of the actions and the three scenarios was completed, but this section focuses on the implications of the Energy Shift (LC-Amb). The financial analysis involved identifying projections of capital, operating and maintenance costs of vehicles, buildings, infrastructure and energy systems. A comprehensive financial data library is used for assumptions, drawing from sources including the National Energy Board, US Energy Information Agency, several specific data sources for particular stocks, and in some cases expert opinion.

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

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

Current dollars are calculated by translating the value of future dollars into present (2017) value, using discounting. Present value was calculated by applying a discounting rate of 3% to outflows and inflows beyond 2017. The discounting rate of 3% is recommended by the Government of Canada in circumstances where environmental and human health impacts are involved.[16]

Many of the actions save money

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

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

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

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

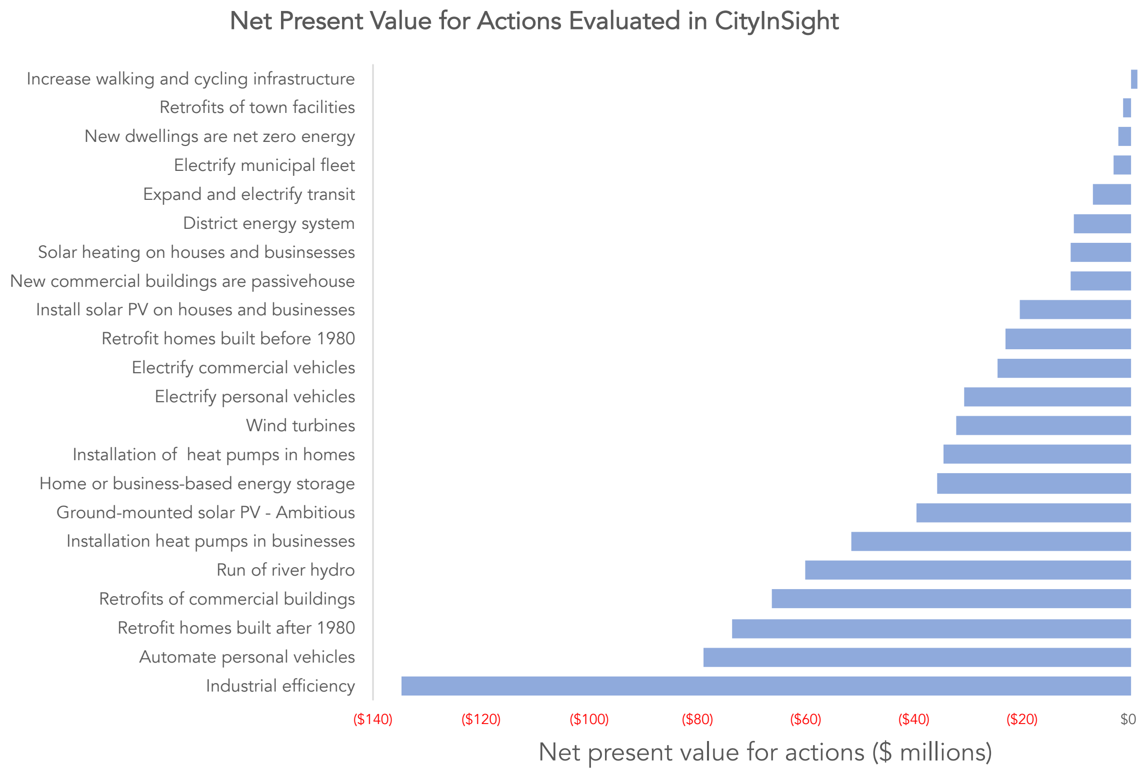


Figure 46. Net present value for each of the actions in LC-amb (Energy Shift)

The most notable financial savings result from retrofitting industrial buildings. Industry is a large consumer of natural gas in Bridgewater and fuel use makes up a significant portion of industrial operating costs. By reducing the amount of fuel consumed to perform the same operations, significant savings in the fuel purchased can be realized.

Only the increased walking and cycling infrastructure action has net costs over the period considered and therefore can be targeted for subsidies or grants and/or bundled with more lucrative actions, such as expanding and electrifying transit. It important to note that this action has additional benefits related to lowering health costs related to the overuse of sedentary forms of transportation that are not included in this analysis.

Reducing GHG emissions also saves money

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

There is a general perception that reducing GHG emissions costs money, and this is true in many sectors of the economy. In the context of Bridgewater, however, all but two of the actions analysed result in financial savings, up to $6,000 per tonne of GHG emissions reduced. Actions which generate both financial savings and GHG emissions reductions are no-loss opportunities. The implementation of these actions is likely currently constrained by legal, logistical or other barriers. A key focus on the CEIP is unlocking those opportunities so that the Town and its residents can both save money and reduce GHG emissions. Note that the marginal abatement cost for autonomous vehicles is positive in this chart. In fact, autonomous vehicles save money, because fewer vehicles need to be purchased, but they also increase GHG emissions, because they are driven further than non-autonomous vehicles- if autonomous vehicles are electric, they reduce GHG emissions and result in a significant marginal abatement savings. Note that in the modelling, autonomous vehicles and electric vehicles were modelled separately on an identical adoption curve in order to understand their respective impacts. In the integrated scenario when all of the actions are combined, autonomous vehicles are electric.

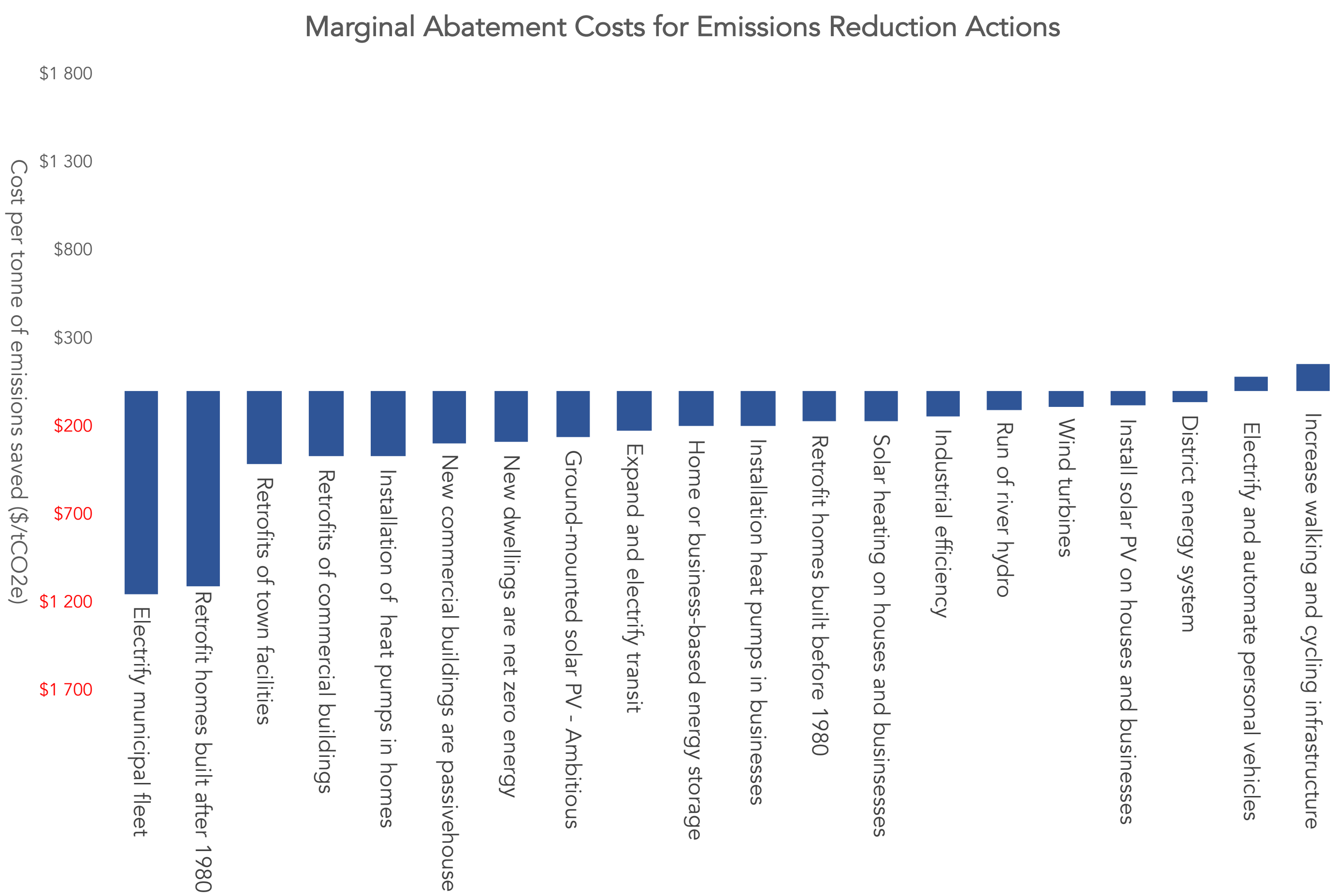


Figure 47. Marginal abatement costs

Capital requirements

The actions were bundled into three strategies: 1. Energy efficient buildings; 2. New community scale energy systems; and 3. Clean and active transportation systems.

Achieving the energy and emissions reductions described in the three technical strategies below requires an investment in local infrastructure and equipment, unprecedented in scale for the community, as highlighted in Figure 48. Peaks in Strategy 2 are associated with the construction of major energy infrastructure, including district energy, wind and hydro. The decreasing capital investment in Strategy 3 is mainly due to reduced vehicle purchases as vehicle ownership rates decline with the advent of autonomous (self-driving) vehicles.The impact of lower investments on vehicles will primarily translate into savings for households in Bridgewater, with areas where vehicles are manufactured bearing the brunt of the economic impacts of this transition.

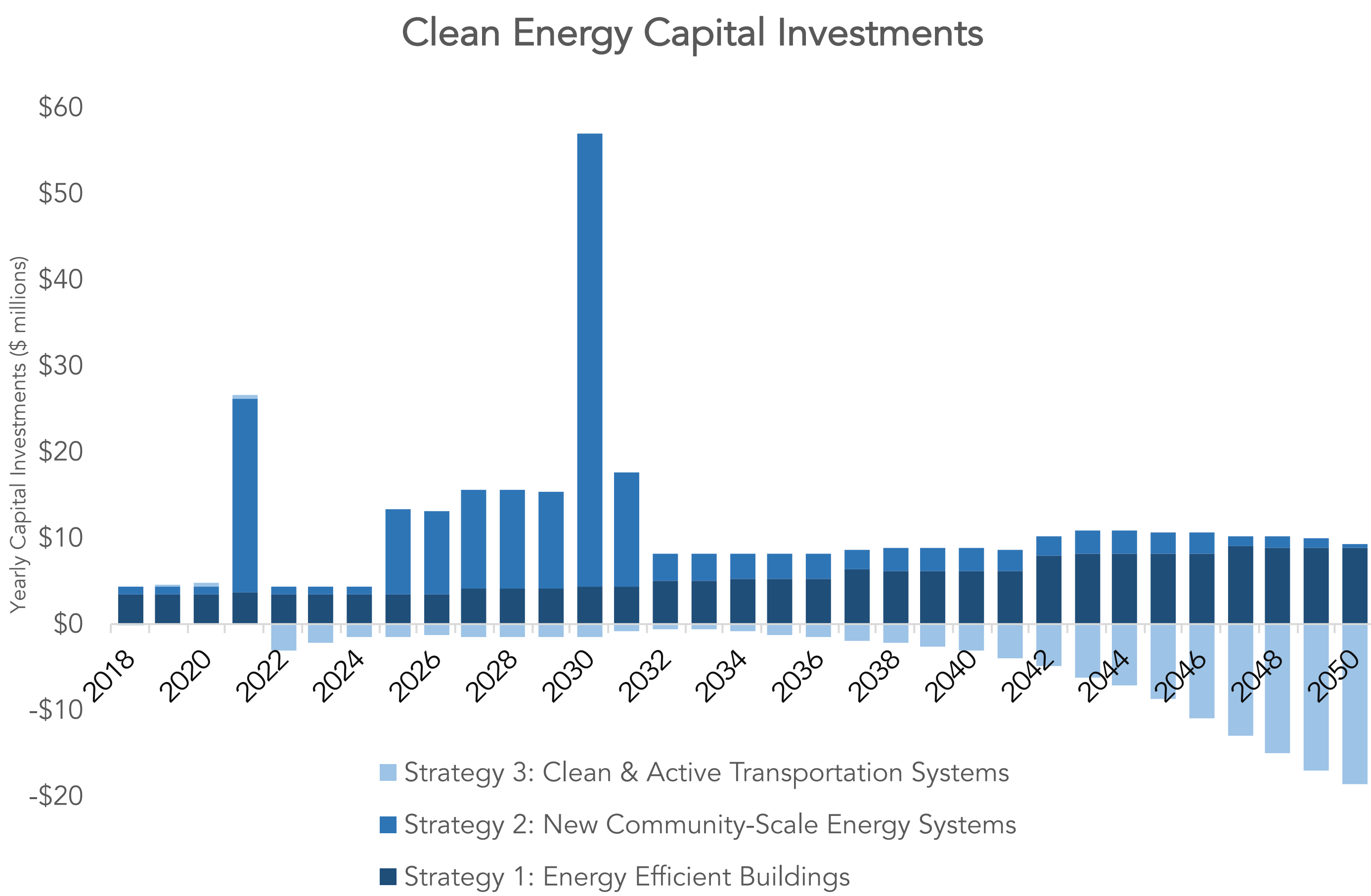


Figure 48. Capital investments by strategy, Energy Shift (LC-Amb)

Figure 49 illustrates the cumulative investment associated with the LC-amb in constant dollars; essentially the sum of the prior years' investments. For example, cumulative investment in year 12 would be the investments in year 11 + year 10 + year 9 and so on. For the later part of the time period LC-amb and LC-mod result in a negative investment – in other words the LC-amb requires less capital than the BAU scenario, in part because the costs of solar PV and electric vehicles decline below their fossil fuel alternatives, but primarily because of the decreased capital costs of shared autonomous vehicles. Increased investments in heat pumps in LC-amb offset some of the capital reductions associated with shared autonomous vehicles. The total additional investment over BAU is $240 million dollars between 2016 and 2050 for LC-amb. Note that the investment is over $300 million if each of the actions is implemented individually as opposed to using an integrated approach.

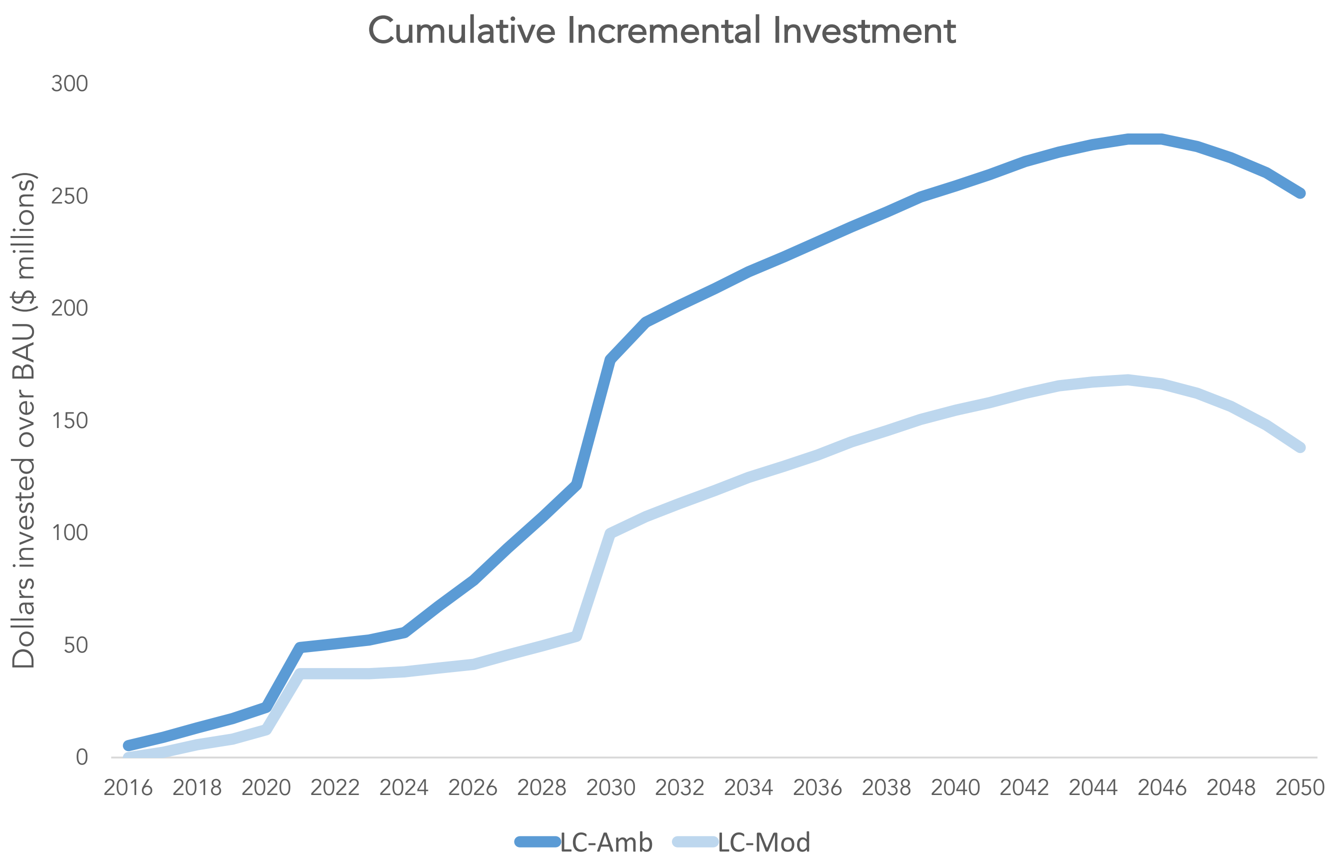


Figure 49. Total cumulative investment for the two low carbon scenarios

The clean energy investments described above are intended to ramp up over time, with Strategies 1 and 2 adding an average of $11 million worth of capital investments per year to the economy (before inflation). Many, though not all, of the dollars invested in clean energy infrastructure and equipment will land in and around the Bridgewater area, representing a large new economic driver for the community

Investment opportunities

The table below details investment opportunities for each action modelled over the lifetime of that action in current dollars. Within each strategy area, investment opportunities are listed in order from greatest relative energy / GHG benefit to the lowest benefit.

The return on investment illustrates the financial return associated with the actions. For example, if an action costs $100 to implement and generates $100 in savings, the return would be 0%. If that action generates $150, than the return is $150-$100, or

$50. The return on investment is then $50/$100 or 50%. The following tables provide a summary of the investment and savings from the period of 2018 to 2050, as well as the GHG emissions reduction.

Strategy 1: Energy efficient buildings: total $153 Million

Investment opportunity	Economic benefit	Energy benefit
	Total cost and return by 2050	Total greenhouse gas emissions reduced by 2050
Net zero and passivehouse performance standards: by 2030, all newly constructed buildings meet the highest energy performance standards	$1.7 million -> $15 million (805% return)	45 kilotonnes
Retrofit existing buildings: by 2050, the envelope efficiency of all homes and apartments, and all commercial facilities is improved by 50% and industrial facilities operate 50% more efficiently	$84 million -> $382 million (353% return)	1,290 kilotonnes
Heat pumps: by 2050, 60% of all residential buildings and 85% of all commercial buildings have heat pumps installed	$19 million -> $105 million (451% return)	354 kilotonnes
Solar PV and hot water: by 2050, 80% of all buildings have solar PV systems, and 50% of buildings have solar hot water systems installed	$48 million -> $80 million (65% return)	308 kilotnnes

Strategy 2: New community-scale energy systems : total $157 Million

Investment opportunity	Economic benefit	Energy benefit
	Total cost and return by 2050	Total greenhouse gas emissions reduced by 2050
Community-scale solar PV farm: by 2050, install 12MW of ground-mounted solar PV systems, and install 5kW battery banks in 50% of homes	$24 million -> $100 million (812% return)	329 kilotonnes
District energy system: by 2050, supply the downtown commercial buildings with district heating and cooling, generated through sustainably harvested local wood heat and geothermal heat exchange	$53 million -> $64 million (20% return)	156 kilotonnes
Community-scale wind and hydro power: by 2050, 60% of all residential buildings and 85% of all commercial buildings have heat pumps installed	$19 million -> $105 million (451% return)	354 kilotonnes

Strategy 3: Clean active transportation systems: Total- $66 million

Investment opportunity	Economic benefit	Energy benefit
	Total cost and return by 2050	Total greenhouse gas emissions reduced by 2050
Electric vehicles: by 2050, all vehicles in Bridgewater are electric, allowing vehicle batteries to add to the community's total energy storage	$24 million -> $80 million (226% return)	98 kilotonnes
Autonomous (self-driving) vehicles: by 2050, the majority of vehicles in Bridgewater operate autonomously, allowing households to own 50% fewer vehicles. However, increased access results in higher overall transportation energy consumption	$36 million -> $114 million (222% return)	-52 kilotonnes (increase)
Public transit and active transportation: by 2050, Bridgewater public transportation system is expanded and fully electric. Investments in walking and cycling infrastructure allow 50% of short distance trips to be done on foot or by bike	$4 million -> $10 million (139% return)	41 kilotonnes

Employment impacts

Job growth for skilled tradespeople and related industries

Dollars invested in energy projects mostly go toward tradespeople, equipment suppliers, contractors, and associated services such as engineering, legal and financial. However, some sectors, such as the automotive trades, may see a net decline in jobs due to the arrival of autonomous vehicles.

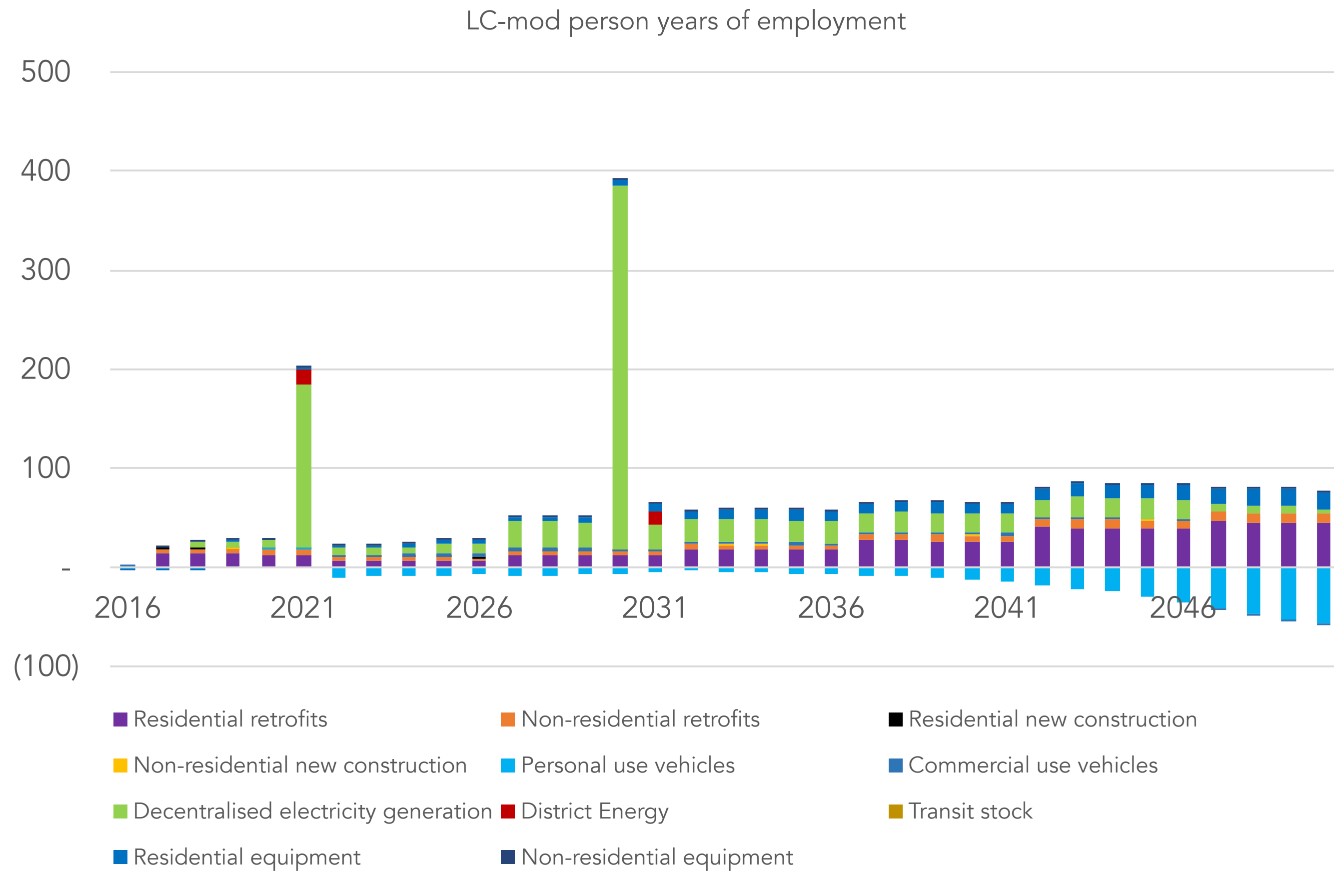


Figure 50. Employment resulting from the Energy Shift, person-years

Energy costs

If business continues as usual, Bridgewater's energy consumption will remains steady as the community grows while efficiencies gradually increase. That energy currently costs the community $89 million per year (2016 data).

The community is vulnerable to carbon pricing as much of our energy is supplied from carbon-heavy fossil fuel sources. If nothing changes, by 2050 energy costs are projected to rise to $206 million per year for the community (including minimal carbon pricing and 2% inflation per year). By making the investments described above, the community will have access to cleaner, more efficient, more secure and more affordable energy. Total savings are projected to be over $2 billion in energy costs over 33 years.

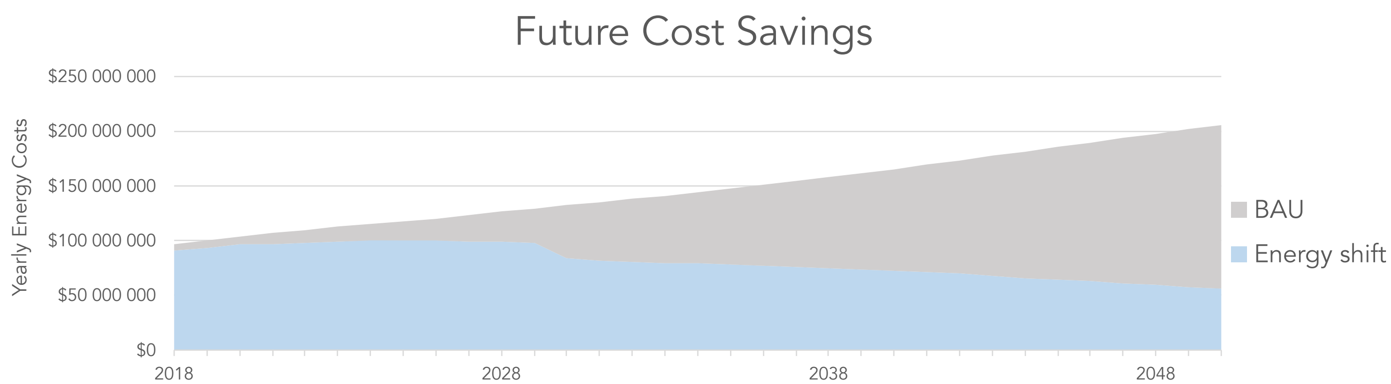


Figure 51. Total energy expenditures, BAU and Energy Shift (LC-Amb)

Households in Bridgewater spent $20 million per year on home energy costs in 2012, an average of between $4,100-$5,600 per household per year. On top of this, households spend an additional $1.600 on fuel for their personal transportation. In total, the average Bridgewater household spends about $6,500 per year on energy costs alone.

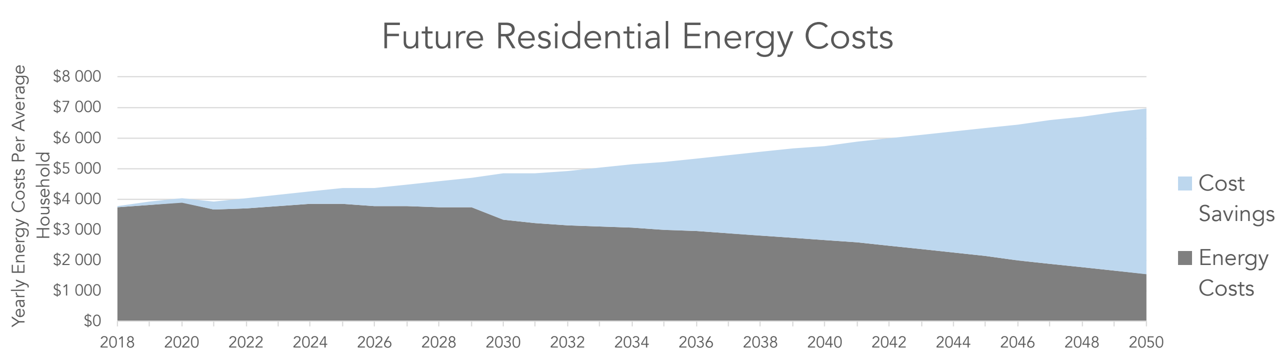


Figure 52. Future residential energy costs, BAU and Energy Shift (LC-Amb)

Bridgewater's commercial, institutional and industrial sectors spent $49 million per year on energy for their facilities in 2012, approximately $54 per m2 of conditioned floor space. By 2050, the BAU cost is projected to clear $130/m2, whereas LC amb is a $29/m2, a savings of $105/m2.

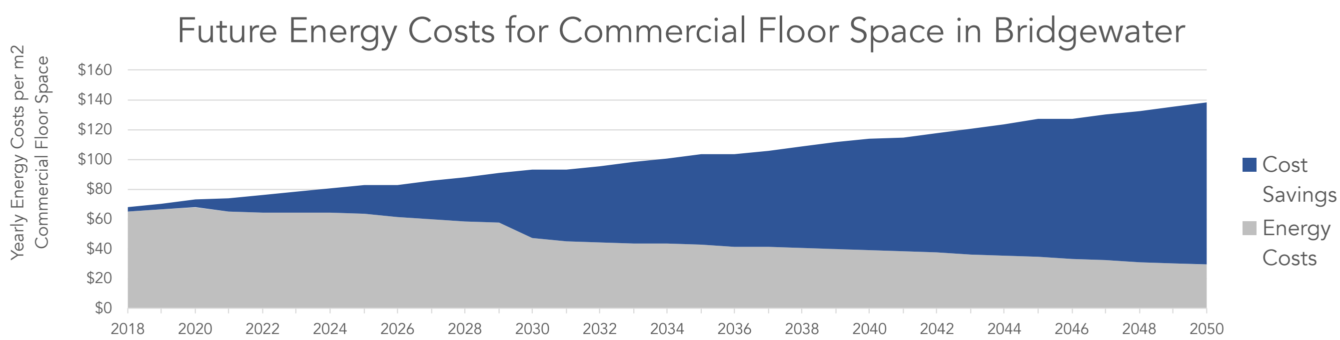


Figure 53. Future energy costs per unit floor space, BAU and Energy Shift (LC-Amb)

7. Implementation Mechanisms

As part of the Energy Shift analysis, a preliminary mapping of policies, mechanisms and strategies was completed to support the implementation of the actions that were modelled as part of the Energy Shift (LC-Amb).

Table 11. Mapping actions to mechanisms

Energy Shift actions		Impact	Modelling assumptions	Policy/mechanisms/ strategies
BUILDINGS				
New buildings - buildings codes & standards				
1	Residential - New residential housing development targets net zero	Avoided thermal and electric energy	Scales up to 100% of new homes by 2030: this will apply to all new dwellings in zone 6 between 2018 and 2050	Two key strategies; 1. Develop an incentive program (expedited building permits, cash incentives, reduced taxes) as well as technical capacity (free access to consultants and engineers) to support high performance buildings. 2. Lobby the province for the ability to introduce a stretch code.
2	Multi-res & Commercial - Passivehouse standard applied to multi-unit residential and commercial buildings	Avoided thermal and electric energy	Scales up to 100% of new multi res & commercial by 2030: Space Heat Demand <15 kWh/m2/yr Primary energy demand < 120 kWh/m2/yr this will apply to all new buildings in zone 6 between 2018 and 2050.	

Energy Shift actions		Impact	Modelling assumptions	Policy/mechanisms/ strategies
Existing buildings - retrofitting				
3	Retrofit homes prior to 1980	Avoided thermal and electric energy	Achieve thermal savings of 50%; electrical savings of 50%: scale up rate of retrofits exponentially beginning in 2020 so that all building stock pre 2016 is retrofit by 2050	An enhanced PACE program will be developed (mix of financing and grants) in order to achieve deeper GHG reductions. Possibility of selling the carbon reductions as offsets to help with the financing.
4	Retrofit homes after 1980	Avoided thermal and electric energy	Achieve thermal savings of 50%; electrical savings of 50%: scale up rate of retrofits exponentially beginning in 2020 so that all building stock pre 2016 is retrofit by 2050	
5	Retrofits of commercial and industrial	Avoided thermal and electric energy	Achieve thermal savings of 50%; electrical savings of 50%: scale up rate of retrofits exponentially beginning in 2020 so that all building stock pre 2016 is retrofit by 2050	
6	Retrofits of multi-residential	Avoided thermal and electric energy	Retrofit all buildings of 3 storeys or more built between 1945 and 1984. Number of retrofits increases exponentially between 2020 and 2050; Achieve 50% savings of thermal energy; 50% of electricity. Fuel switch to geothermal.	An enhanced PACE program will be developed (mix of financing and grants) in order to achieve deeper GHG reductions. Possibility of selling the carbon reductions as offsets to help with the financing.
5B	Retrofit town facilities	Avoided thermal and electric energy	Achieve 50% savings of thermal energy and 50% savings of electricity	Develop a revolving loan fund which uses savings from projects to finance reductions.
5C	Industrial efficiency		increase industrial efficiency by 50% by 2050	The Town can sign an MOU with major industrial partners committing to specific energy and GHG emissions reductions milestones, as well as responsibilities.
Renewable energy generation (on-site, building scale)				
7	Installation of heat pumps air and ground source residential	Fuel-shifting	Residential: Air source: scale up to 40% of the residential building stock by 2050: Ground source: scale up to 20% of the residential building stock by 2050:	Partner with utilities to provide incentives and financing for the install of heat pumps.
8	Installation of heat pumps air and ground source commercial	Fuel-shifting	Commercial: Air source scale up to 50% of the building stock by 2050; Ground source: scale up to 35% of the building stock by 2050	

Energy Shift actions		Impact	Modelling assumptions	Policy/mechanisms/ strategies
9	Solar PV- net metering all existing buildings	Local energy generation	30% of consumption for building electrical load for less than 5 storeys; 20% for multi-unit and commercial, adoption rate- scale up to 80% of buildings by 2050.	A renewable energy co-operative can coordinate bulk purchases, contractors and maintenance. The Town can coordinate with the cooperative to provide subsidised systems for low income dwellings, selling the carbon credits.
10	Solar heating/hot water	Fuel-shifting	Residential: scale up to 40% of the building stock by 2050: Commercial: scale up to 50% of the building stock by 2050	
ENERGY GENERATION				
Low or zero carbon energy generation (community scale)				
11	Solar PV - ground mount	Local energy generation	Install a total of 8 MW between 2018 and 2050 (put in zone 8 with industrial park).	A municipally-owned or cooperative energy utility will either directly develop projects or purchase energy from projects.
12	Develop a district energy system in the downtown	Local energy generation	Use 50% sustainable biomass as per the MTRI assessment and 50% geothermal/river water heat pump.	
13	Energy storage	Fuel-shifting	Install 5 kw battery banks incrementally until 50% of dwellings have them by 2050.	
13B	Run of river hydro system		Install a 20 mw system (similar to Sissiboo falls).	
13C	Wind		Install up to 6 2 MW wind turbines	
TRANSPORT				
Transit				
15	Expanded transit- combine with action 16.	Avoided transportation energy	Target 2% of inbound and outbound external trips for transit service by 2020, scaling to 10% by 2050.	The municipality will build on its experience with transit to explore a cooperative regional transit system, testing autonomous vehicles.
16	Electrify transit system	Fuel-shifting	Replace diesel bus with an electric bus	Financed by federal infrastructure funding.
Active				
17	Increase/improve cycling & walking infrastructure	Avoided transportation energy	Mode shift to 50% of the walking and cycling potential away from vehicles and driving. Use 2km for walking and 5km for cycling.	Introduce a bike share program
Private/personal use				

Energy Shift actions		Impact	Modelling assumptions	Policy/mechanisms/ strategies
19	Electrify municipal fleet	Fuel-shifting	Fleet is 100% electric by 2030; starting in 2020 and exponentially increasing the number of vehicles to 2030	An electric car share cooperative will be developed anchored by municipal use of small cars to introduce electric vehicles. EV infrastructure will be installed in appropriate locations with free charging incrementally over time. The municipality will use federal funding to electrify its fleet over five years setting an example.
20	Electrify personal vehicles	Fuel-shifting	Only EVs sold after 2030.	
21	Electrify commercial vehicles	Fuel-shifting	Projection for low carbon vehicles and for trucks: same as Toronto	
22	Autonomous vehicles	Avoided transportation energy	Household vehicle ownership rate declines by 50% by 2050 EV life expectancy declines by 50% due to higher duty cycle VKT per capita increases 20% to reflect increased vehicle travel demand, "deadhead" trips (without passengers) [VKT increases between 5-20%- see page 11]	No action.
LAND USE				
Transport Oriented Development				
23	Land-use change	Avoided transportation energy	Target future development (commercial and residential) downtown.	Provide incentives for new development to locate downtown

8. SENSITIVITY ANALYSIS

The Energy Shift scenario illustrates the emissions reductions of a potential pathway for Bridgewater and is developed based on a number of assumptions as described in this report. In that light, they reflect one possible interpretation of an uncertain future that is based on a particular trajectory of population growth, land-use planning, energy costs, adn equipment costs, amongst other components.

In order to test the impact of variation within the assumptions, a sensitivity analysis was undertaken. Sensitivity analysis involves the process of adjusting certain selected variables within the model in order to identify variables that have the most significant impact on the model outcomes of a scenario. The approach employed in this case was to adjust those variables that were identified as having a higher potential to "move the curve", (ie. the factors that appear to be contributing significantly to the low carbon scenarios). The results provide insight on which components need to monitoring more carefully to ensure the Town's Energy Shift is on track.

Adjusting key assumptions

Sensitivity analysis was applied to the LC-amb scenario; the assumptions and results of each are described in Table 12, and depicted in Figure 54. The impact (expressed in kT CO2e) shows the absolute emissions difference relative to the LC-amb in 2050.

Table 12. Sensitivity analysis variables and results.

Category	Variable adjustment	ENERGY Impact: relative to LC-amb (1,564,563 GJ)		EMISSIONS Impact: relative to LC-amb (77 kT CO2e)	
		+/- GJ	+/- %	+/- kt CO2e	+/- %
Built form					
Decrease population & employment	-10% dwelling units with reduced population -10% NR floorspace with reduced employment	-98,911	-11%	-10.30	-6.2%
Increase population & employment	plus 10% dwelling units with increased population +10% NR floorspace with increased employment	99,159	11%	10.30	6.2%
Heating degree days (HDD)					
Hold HDD fixed	Keep number of heating degree days fixed at baseline value.	39,437	4.4%	3.70	2.2%
Decrease HDD	Decrease number of heating degree days for 2040 and later by 10%. Linearly interpolate for 2012-2039.	-16,307	-1.8%	-1.50	-1.0%
Retrofits					
Decrease residential retrofits (Actions 3 & 4)	LC scenario with -25% residential retrofits (# units retrofitted to 2050 in actions 3 and 4).	133,050	14.75%	9.3	5.6%

Category	Variable adjustment	ENERGY Impact: relative to LC-amb (1,564,563 GJ)		EMISSIONS Impact: relative to LC-amb (77 kT CO2e)	
		+/- GJ	+/- %	+/- kt CO2e	+/- %
Electric Vehicle (EV) adoption					
Decrease in EV uptake in all vehicle stocks	Reduce 2050 EV share of light-duty vehicle stocks by 72%, compared to LC (100%) and BAU (22%). For 2050 non-stock vehicle activity reduce EV share to 45% compared to LC (90%) and BAU (~0%).	62,853	6.97%	4.9	3.0%
Vehicle kilometres travelled (VKT)					
Increase VKT	Gradual increase in passenger vehicle VKT by 20% in 2050.	-18,618	-2.1%	-1.0	-0.6%
Decrease VKT	Gradual decrease in passenger vehicle VKT by 20% in 2050.	18,618	2.1%	1.0	0.6%

The most significant variables tested were a change in population growth, which resulted in a proportionate change in GHG emissions. The sensitivity analysis highlighted the importance of retrofits; if 25% less dwellings are retrofit by 2050, total GHG emissions will be nearly 6% higher. If the impact of climate change is held constant a current levels, GHG emissions will be just over 2% higher. If the uptake of electric vehicles is slower than modelled, the impact is relatively small because the electric grid in Nova Scotia is still GHG intensive relative to other electric grids in Canada.

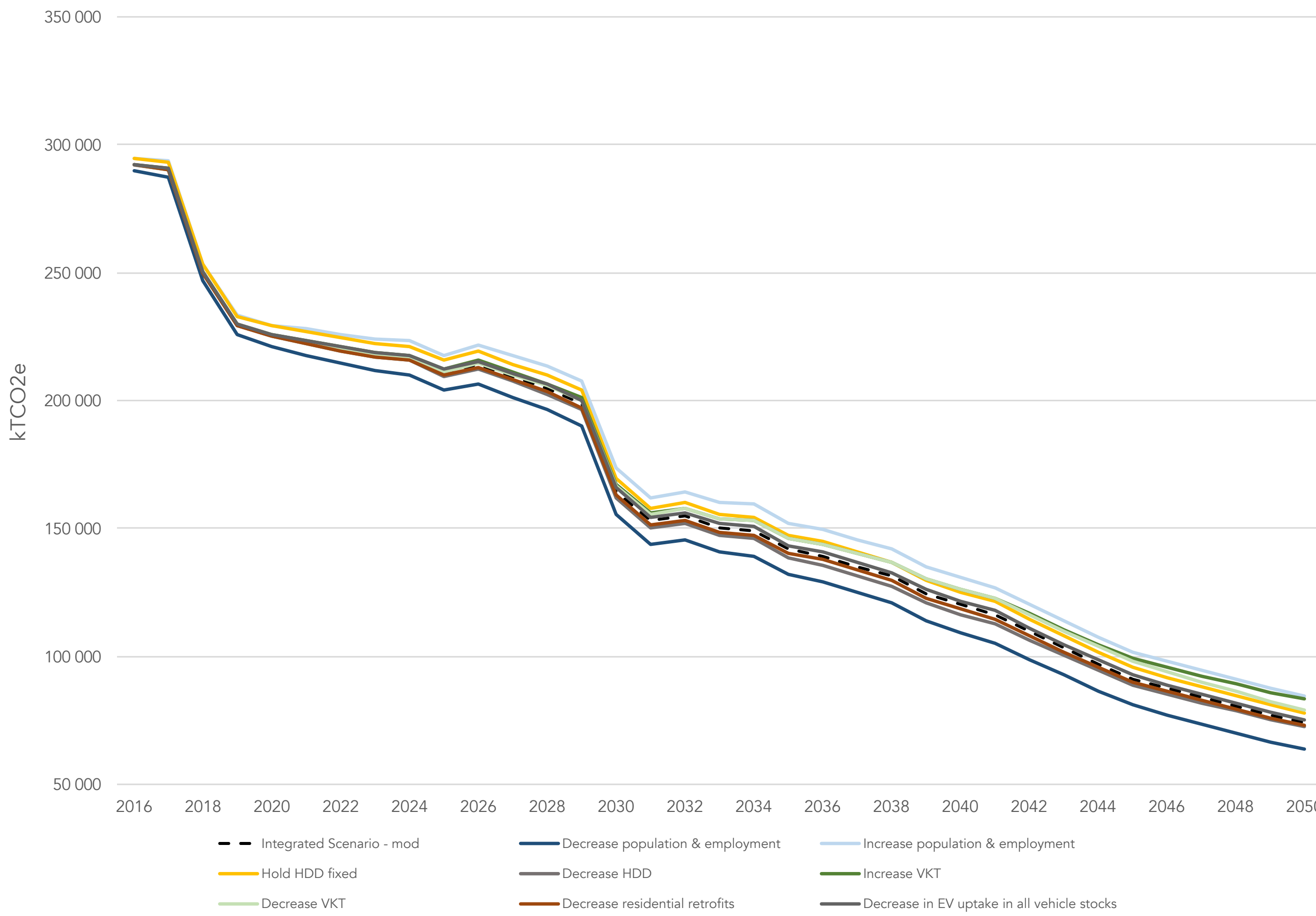


Figure 54. Change in LC-amb projection for modelled variables.

Economic development scenarios

In addition to evaluating the sensitivity to trends within the scenarios, the sensitivity of the scenarios themselves to different land-use and population trajectories was evaluated for both LC-mod and LC-amb. The Town of Bridgewater developed two different land-use scenarios.

1. Large-scale regional decline: All of the South Shore, including Bridgewater, rapidly lose population and development opportunities are significantly stunted by the middle of the century. Population experiences -10% population growth (decline) over 20 years, and no net non-residential growth by 2050. The implications are as follows:

- Overall resource environment and available capital is more constrained due to a weakened economy, and government investment in general is lower than in the BAU future.
- Much less new construction, smaller turnover in building stock, and smaller shift in relative floor areas between residential and non-residential building types.
- Loss of significant industries.
- Lower employment opportunities across the board.

- Transportation patterns remain proportionally the same, perhaps with reduced commercial traffic.

2. Regional retreat into small urban centres: in this scenario, Bridgewater's growth is actually significantly accelerated not due to its business success, but to the loss of viability in living and doing business in the surrounding rural areas. Rural residents, unable to keep up with rapidly rising cost of living, energy, and transportation, and the continued erosion of rural services and infrastructure, retreat into the nearest available town, which sees a spike in population growth. Increased business activity follows suit. The Town experiences 30% population growth (mostly older populations) by 2050, and 25% non-residential growth by 2050. The implications are as follows:

- Overall resource environment and available capital is more constrained due to high cost of doing business, but public need is able to drive continued investment into the Town's infrastructure.

- Much more construction, especially infill development as affordable housing becomes a significant development driver. Higher turnover in building stock, and greater shift in relative floor areas between residential and non-residential building types.

- Increase in business activity.

- Higher employment opportunities across the board, but is counterbalanced by a relatively older population that requires more support services.

- Transportation in and out of town is significantly reduced as the cost of transportation becomes unaffordable for routine use. Significant uptake of active modes of transportation. Public transit becomes an undeniable necessity.

The results of the analysis indicate that Bridgewater's GHG emissions profile is sensitive to population growth and highly sensitive to population decline. A significant increase in population downtown results in a small increase in GHG emissions, while a less significant decline in population results in a proportionately larger decrease, in one case nearing zero GHG emissions. The implication is that the Town can absorb additional population without altering its GHG emissions pathway, assuming the growth is concentrated downtown. If on the other hand, the population decreases, the Town's GHG emissions will fall more precipitous, because the modelled local renewable generation becomes closer and closer to providing 100% of the Town's energy requirements.

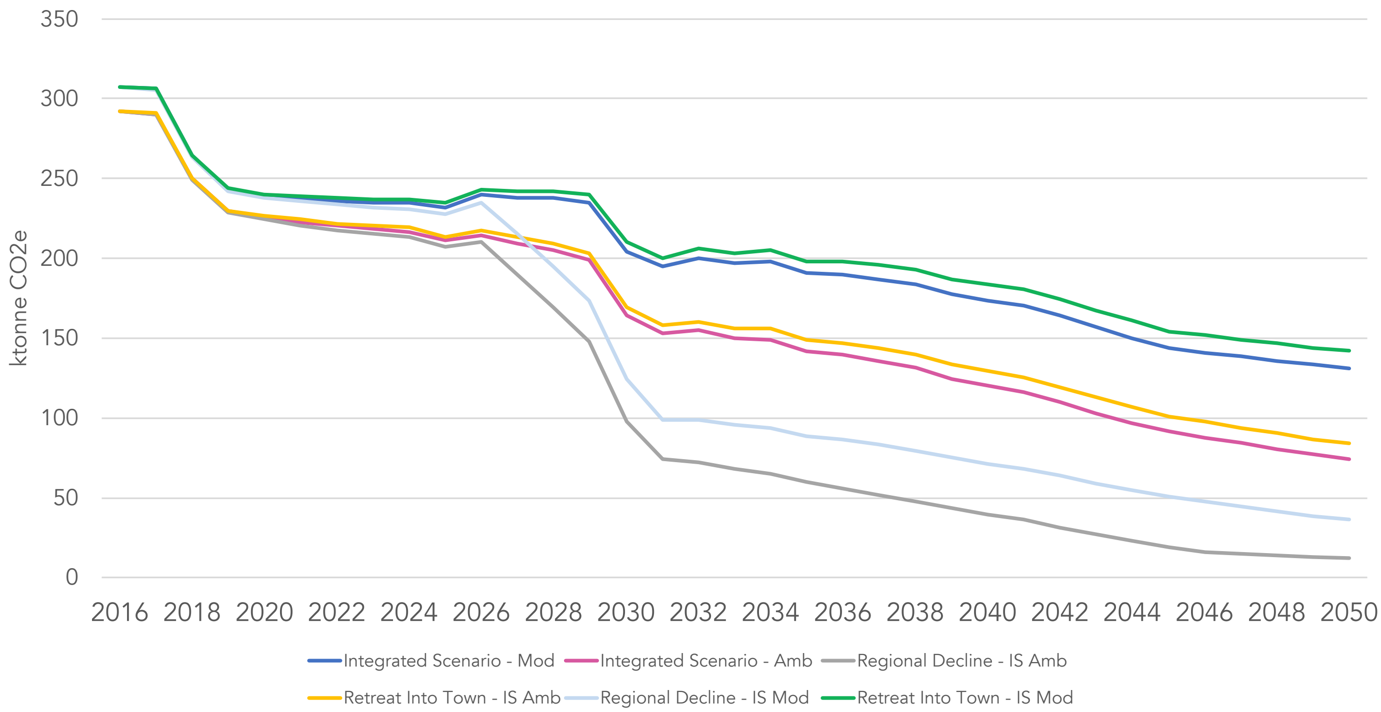


Figure 55. Sensitivity of the scenarios to population change.

9. FINDINGS AND OBSERVATIONS

The GHG emissions reduction target of 80% reduction of emissions for the Town of Bridgewater focuses on three main aspects: the efficiency of buildings; electrification of transportation; and, generation and/or purchase of renewable electricity. Actions which reduce demand for energy, such as increased walking and cycling and building retrofits, reduce the cost of achieving the target, but are not fundamental to reaching the target.

After land-use, which determines the configuration of the community, the design of buildings has the second longest implications, as buildings last forty or more years prior to replacement. Bridgewater's 2050 energy and GHG footprint consumption is a function of the currently existing building stock as opposed to the relatively small number of dwellings and buildings that will be added between now and 2050. Nevertheless the cost of future retrofits can be avoided by making an upfront investment in energy efficiency when those buildings are constructed.

Decarbonisation of the grid is critical to maximising the benefit of electrification of vehicles. While there is benefit from the efficiency of electric vehicles over the internal combustion engine, the significant GHG benefits occur when electricity generation does not result in GHG emissions. For this reason, Bridgewater's efforts to generate renewable electricity from wind, water, waste and solar are instrumental to ensuring both heat pumps and electric vehicles deliver the maximum GHG reductions.

Building retrofits also support the electrification of vehicles. Without the retrofits, there would likely be additional capacity pressures on the electrical system. By retrofitting dwellings and non-residential buildings, space is being created on the grid for new loads- electric vehicles. A district energy that focuses on biomass creates an efficient, low carbon system for heating the downtown, taking further pressure off the electrical grid, as well as creating the potential for storage and electrical generation. Storage is also an important part of the picture, as energy demand can be shifted off peak periods to times which low or zero carbon energy is being generated.

There are many reason to implement Bridgewater's Energy Shift. A summary is as follows:

- Reduces the exposure to energy cost escalation
- Reduces household and business energy costs
- Reduces air pollution from fossil fuel consumption both in Bridgewater and elsewhere.
- Generates new employment opportunities
- Enhances the profile of the community
- Increases the quality of the house and building stock
- Increases the health of the population

- Creates new revenue sources for businesses and other organisations
- Reduces the extent of energy poverty in the community

Such an effort is a relatively new endeavour for municipalities in Canada and there will be much to learn and mistakes made. This analysis, however, has demonstrated that the Energy Shift benefits the Town and the community financially, environmentally and socially.