HALIFAX

P.O. Box 1749
Halifax, Nova Scotia
B3J 3A5 Canada

Item No. 9.1.6
Halifax Regional Council
June 23, 2020

TO: Mayor Savage and Members of Halifax Regional Council

SUBMITTED BY: Original Signed by
Jacques Dubé, Chief Administrative Officer

DATE: May 4, 2020

SUBJECT: **HalifACT 2050: Acting on Climate Together**

ORIGIN

On October 30, 2018, the following motion of Regional Council was put and passed:

"That Halifax Regional Council request a staff report to investigate a Municipal Climate Change Directorate (MCCD) working under the direction of the Chief Administrative Officer (CAO), to outline what HRM must do to meet the outcomes of the Intergovernmental Panel on Climate Change (IPCC) Special Report 1.5C of 2018. The goals of the MCCD to be as follows:

1. *To provide HRM with an (sic) Climate Change Action Plan (CCAP) in the summer of 2019;*
2. *To provide HRM with, based on the best scientific evidence, a path to meet the first IPCC 1.5C target by cutting total CO2 emissions by 40% by 2030; and*
3. *To provide a Climate Change Action Plan to meet the IPCC targets of zero CO2 emissions by 2040."*

On January 29, 2019, the following motion of Regional Council was put and passed:

"THAT Halifax Regional Council request that staff prepare a report and recommendations and return to Council within one year with respect to:

1. *The recognition by HRM Council that the breakdown of the stable climate and sea levels under which human civilization developed constitutes an emergency for HRM.*
2. *That staff provide Regional Council with an update on current staff reports pertaining to climate change, including, but not limited to, the report for the creation of a Climate Directorate, reporting directly to the CAO, and the Green Network Plan.*
3. *The incorporation into the Municipality's climate targets and actions the need to achieve net-zero carbon emissions before 2050 and net negative carbon emissions in the second half of the century.*
4. *The establishment of a remaining carbon budget for corporate and community emissions commensurate with limiting warming to 1.5˚C and an annual reporting process with respect to the expenditure HRM's remaining carbon budget."*

RECOMMENDATIONS ON PAGE 2

5. The establishment of a "Climate and Equity" working group to provide guidance and support for the Municipality's efforts to transition off of fossil fuels in ways that prioritize those most vulnerable to climate impacts and most in need of support in transitioning to renewable energy.

LEGISLATIVE AUTHORITY

Halifax Regional Municipality Charter, Section 34(3): "The Council shall provide direction on the administration, plans, policies, and programs of the Municipality to the Chief Administrative Officer."

RECOMMENDATION

It is recommended that Halifax Regional Council:

1. Authorize the direction contained in the HalifACT 2050: Acting on Climate Together plan, as contained in Attachment A.

2. Direct the Chief Administrative Officer to carry out the actions contained in the HalifACT 2050: Acting on Climate Together plan as part of the multi-year budgeting and business planning process, including establishing a target of net-zero municipal operations by the year 2030.

3. Direct the Chief Administrative Officer to prioritize efforts in the following critical core areas:
   a) Create new energy retrofit and renewable energy programming;
   b) Develop a detailed and costed plan for retrofitting existing municipal buildings to be net-zero ready and climate resilient;
   c) Develop an electric vehicle strategy, increase charging infrastructure and replace fleet vehicles with electric vehicles;
   d) Explore opportunities to require net-zero standards for new buildings in the municipality;
   e) Develop a framework for assessing and protecting critical infrastructure;
   f) Support communities for climate adaptation and climate-related emergencies; and
   g) Develop a financing strategy to operationalize the HalifACT 2050 plan over 30 years.

4. Accept in principle the need to resource the plan and direct the Chief Administrative Officer to return to Council with a resource plan at the appropriate time, when the Municipality is in a more financially stable position.

5. Request that staff provide annual progress reports on the implementation of the HalifACT 2050: Acting on Climate Together plan, to Regional Council through the Environment and Sustainability Standing Committee.

CLIMATE ACTION DURING AND AFTER COVID-19

Responding to a changing climate is an urgent global crisis that requires immediate action with a steep decline in greenhouse gas emissions in the next ten years. We must prepare for the worst-case climate scenario and strive for accelerated emissions reductions across all sectors. Although this plan requires significant investment, the long-term financial return is larger than the upfront costs. In addition to the financial benefits, the implementation of this plan will lead to a healthier, more equitable and resilient community. As immediate action is critical to a successful outcome, acting initially on the following seven key areas is paramount.

1. Retrofit and renewable energy programming
2. Retrofit municipal buildings to be net-zero ready and climate resilient

3. Electrification of transportation
4. Net-zero standards for new buildings
5. Risk and vulnerability assessments
6. Capacity building for climate adaptation
7. Sustainable financing strategy

In order to succeed in these areas, and to achieve the targets set out in HalifACT 2050, the Municipality must prioritize climate action across all Business Units. A mainstreaming of climate thinking requires fundamental adjustments to operations, business plans and budgets. The Municipality will consider how best to structure climate efforts internally to ensure rapid implementation across all Business Units.

This plan was developed and drafted before COVID-19, a virus that has created a new reality for every person, business and government around the world. Staff recognizes the need for the Municipality to react and adjust to the new financial circumstances caused by this global pandemic, and therefore proposes to continue implementing HalifACT as best as possible with existing resources until the economy has begun to recover and additional resources can be supported. However, the likelihood of achieving the required climate targets will be jeopardized with current staff levels. To support the existing staff working on climate change, the administration will scan for staff abilities and capacities across the organization that can be redirected to climate action and will consider the effective organization of these resources. This may result in adjustments to other municipal operations. It is anticipated that much of the stimulus funding for economic recovery will be green in nature, focused on climate action and sustainability. With the adoption of HalifACT, the Municipality will be well-positioned to take advantage of opportunities as they arise. Staff is already involved in many green stimulus conversations with the provincial government and other key stakeholders.

Acting quickly and effectively to address the climate emergency is challenging and complex, requiring the community and all major stakeholders to come together for collaborative, inclusive, multi-disciplinary solutions to ensure an equitable transition to a low carbon economy. Transformational change is required, which is difficult and disruptive. However, should the Municipality and its partners effectively respond to the climate crisis, we will all benefit from improvements in social, environmental and economic factors critical for a safe and connected, vibrant and healthy community.

BACKGROUND

HalifACT 2050: Acting on Climate Together (plan found in Attachment A) is the Municipality's long-term climate action plan to reduce emissions and help communities adapt to a changing climate. This plan is an update and consolidation of two existing priority plans aimed at reducing greenhouse gas emissions (climate change mitigation); the Community Energy Plan (2007 and 2016) and the Corporate Plan to Reduce GHG Emissions 2012-2020 (2011). This plan also integrates climate adaptation, which is the preparation of communities and infrastructure against the current and future impacts of climate change. Climate adaptation has not been included in the two previous plans.

The plan is supported by Regional Plan[1] policies E-25 to E-34 which outline the Municipality's commitment to reducing emissions, conserving energy, increasing energy security, diversifying energy supply and demonstrating local government leadership. The plan aligns the Municipality's efforts to support international, national and provincial energy and climate change initiatives that seek to responsibly transition to a low-carbon economy by 2050. These initiatives include the 2015 Paris Agreement, the 2016 Pan-Canadian Framework on Clean Growth and Climate Change, and the objectives of Nova Scotia's *Sustainable Development Goals Act*, among others. HalifACT strengthens the Municipality's ongoing climate change mitigation and adaptation commitments under the Global Covenant of Mayors for Climate & Energy, and the Canadian Partners for Climate Protection program.

[1] Regional Municipal Planning Strategy - https://www.halifax.ca/sites/default/files/documents/about-the-city/regional-community-planning/RegionalMunicipalPlanningStrategy.pdf

In October 2018, the Intergovernmental Panel on Climate Change (IPCC) released a special report that stressed the need to limit global warming to 1.5°C above pre-industrial levels within the next 12 years to prevent irreversible economic, environmental and social impacts. On January 29, 2019, Regional Council unanimously declared a climate emergency, emphasizing that climate change and sea level rise are a serious and urgent threat.

To assist in the development of HalifACT, the Municipality contracted Sustainable Solutions Group (SSG), an environmental consulting cooperative specializing in climate change modelling. SSG performed the technical emissions modelling and New Leaf, a professional facilitator, supported the stakeholder engagement to assist in the development of HalifACT and supporting documents.

Technical Modelling Results

As outlined in Attachment B, a baseline community-wide greenhouse gas (GHG) emissions inventory for 2016, and a business-as-usual (BAU) case were developed to determine existing and projected GHG emissions out to 2050. The BAU scenario illustrates the anticipated emissions associated with projected population and employment growth, should no additional policies or actions to address energy and emissions be actioned by 2050, other than those currently underway or planned. Under the BAU scenario, emissions are expected to decrease from 5.8 $MtCO_2e$ (megatonnes of carbon dioxide equivalent) in 2016 to 3.9 $MtCO_2e$ in 2050 (a decrease of 33%). The majority of these reductions are expected as a result of the projected decarbonization of the provincial electricity grid, improved fuel efficiency in vehicles, marginal electrification of transportation, and decreased energy demand for space heating due to a warming climate.

In order to align with the IPCC recommendation to keep within 1.5°C of warming, a steep emissions reduction scenario (referred to as the low carbon scenario) was developed to demonstrate the scale and pace of emissions reduction action needed across a variety of sectors including buildings, energy supply, transportation, water, wastewater, and solid waste.

Results indicate that by implementing the low-carbon scenario, 95% of emissions can be reduced by 2050, and cumulative emissions limited to 45 $MtCO_2e$ between 2020 and 2050. While the scenario includes significant efforts to improve energy efficiency and a shift to renewable sources with current-day technology, 5% of emissions remain in 2050, and the 1.5°C carbon budget is exceeded by 8 $MtCO_2e$. The ability to address the remaining 5% will improve in the next 30 years as new technologies and fuel sources such as hydrogen are developed. Currently, 95% of commercially available hydrogen comes from non-renewable fossil fuels such as coal, oil, and natural gas. The feasibility of implementing a hydrogen economy using hydrogen from green sources is the subject of a separate report which is being developed for the Environment and Sustainability Standing Committee. That technology aside, deploying current-day technology on a bigger scale is needed as waiting to implement changes until new technologies are available will not reduce emissions enough to meet the 1.5°C carbon budget.

Carbon Budget

A carbon budget is the estimated total amount of carbon dioxide equivalent that can be emitted to the atmosphere while remaining within the advised global temperature threshold. Carbon budgets can be calculated at various scales, from global to local. The carbon budget for the municipality to meet the 1.5°C threshold is shown in Figure 1. The area under the curve represents the cumulative carbon emissions in the carbon budget. While the target of net-zero emissions is important, Halifax must commit to a steep reduction pathway so as to limit total carbon emissions over time and stay within the carbon budget.

Figure 1 shows that under a BAU scenario (in the absence of significant efforts to reduce emissions), the municipality will not follow the 1.5°C pathway and will only modestly reduce emissions by 2050, emitting a total of 121 Mt CO_2e between 2020 and 2050. To be consistent with a 1.5°C pathway, the municipality's carbon budget is 37 $MtCO_2e$. Under a BAU scenario, the municipality exceeds its carbon budget (the area under the 1.5°C curve) by 2028.

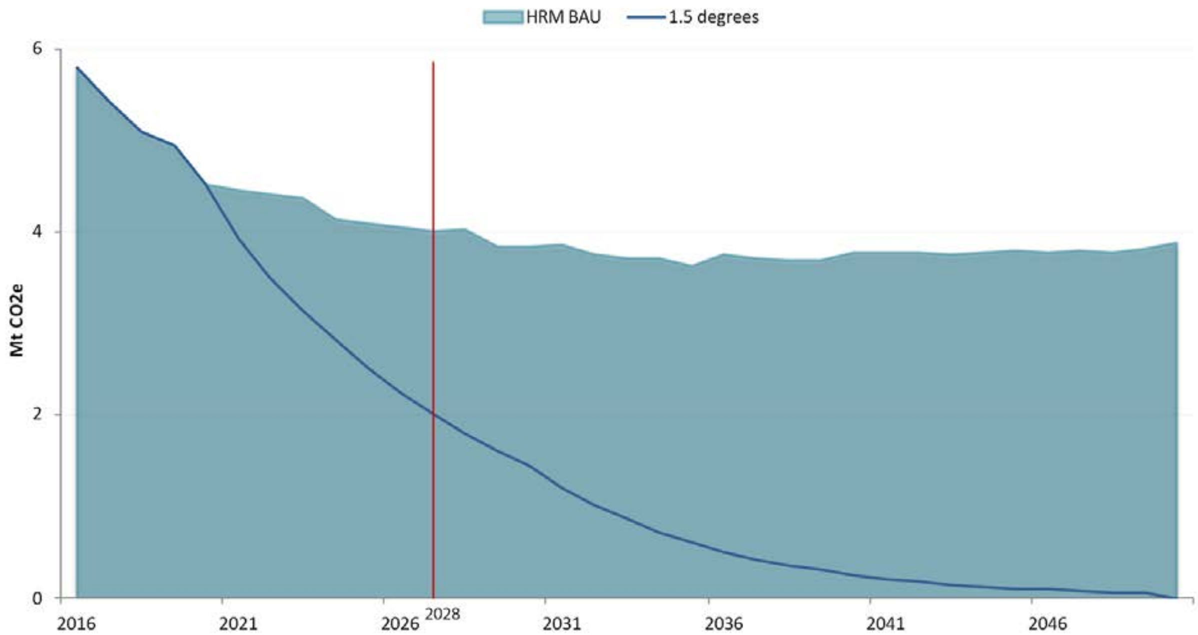

Figure 1: Halifax's emissions under the BAU scenario and following the1.5°C pathway, 2016-2050 (Mt CO2e)

The pathway to a low carbon economy is critically important because the sooner we reduce emissions, the more we reduce *cumulative* emissions over time. Aligning with the 1.5°C pathway requires a steep decline in emissions, especially in the next ten years. All cities, states, provinces and nations need to strive for ambitious climate action as a global collective in order to succeed in stabilizing the climate at a safe level.

Recognizing that not all cities are equal, C40 Cities[2] conducted an analysis for member cities to share the remaining carbon budget equitably[3]. A threshold GDP per capita value of $15,000 was used to categorize cities into either "Peaking" or "Declining" per capita emissions groups. Cities' current emissions per capita were then used to further subdivide cities into one of four categories:

1. "Steep Decline" – Cities with a GDP per capita over $15,000 and emissions above the average for C40 (emissions need to be immediately and rapidly reduced and the city is sufficiently developed to do so).
2. "Steady Decline" – Cities with a GDP per capita over $15,000 but emissions lower than the average for C40 (the city is sufficiently developed to immediately reduce emissions, but a less rapid rate of reduction is required than for the Steep Decline group).
3. "Early Peak" – Cities with GDP per capita below $15,000 and higher than average emissions per capita (an early emissions peak is required, although the city's development status means that decline cannot be immediate).
4. "Late Peak" – Cities with a GDP per capita below $15,000 and lower than average emissions per capita (a slightly later emissions peak is possible).

Combined with each city's projected population growth out to 2100, these trajectories create an overall C40 carbon pathway that member cities need to follow to secure their contribution to limiting global temperature rises to 1.5°C. A summary of this classification is shown in Table 1.

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[2] C40 Cities is an organization committed to delivering the goals of the Paris Agreement at a local level. C40 Cities consists of about 95 cities around the world, representing over 700 million citizens and one quarter of the global GDP – https://www.c40.org/about

[3] C40 Cities Classification – https://www.c40.org/researches/deadline-2020

SSG assessed Halifax inline with the C40 Cities methodology. As Halifax is a municipality with a high GDP (Gross Domestic Product) and a high GHG emissions intensity per capita, it is recommended that a steep decline be followed to fulfill an ethical obligation to cut emissions quickly and significantly as we are relatively well-positioned to do so. Governments with lower GDP and/or lower per capita emissions may move at a slightly slower pace and additional outside assistance may be required to resource the necessary actions.

Table 1: C40 Cities Classification

GHG/Capita	GDP/Capita	Pathway	Example Cities
High	High	Steep Decline	Toronto Melbourne New York City
	Low	Early Peak	Cape Town Durban
Low	High	Steady Decline	Stockholm Seoul London
	Low	Late Peak	Quito Caracas Amman

Adaptation

As outlined in the Adaptation Baseline Report (Attachment C), localized climate projections for the municipality indicate higher annual and seasonal average temperatures, more extreme peak temperatures, more frequent heat waves, increased annual precipitation, and increases in the intensity and frequency of extreme weather events like storms, flooding, and wildfires. With these risks in mind, communities need to begin preparing for these impacts through adaptation.

To minimize and reduce the damaging impacts of climate change, specifically designed adaptation actions and activities need to be undertaken. Adaptation responses can be planned in advance, to reduce long term costs and develop more effective strategies than unplanned, ad-hoc and reactive responses. A key component of adaptation planning is identifying and recognizing that vulnerabilities are variable between communities. These vulnerabilities can be reduced through adaptive management practices. As vulnerabilities can vary from community to community and HRM is geographically a large area, adaptation plans need to be developed at a local or neighbourhood scale.

Economic Development

The transition to a low carbon economy requires investments in building retrofits, renewable energy, energy storage, transit systems and active transportation infrastructure. In the modelling work done for HalifACT, these public and private investments, which are incremental to business as usual investments, total $22 billion over 30 years. To put this into perspective, this investment is an annual investment equivalent to 4% of Halifax's current annual GDP of approximately $17 billion[4].

As part of the technical emissions modeling, a high-level economic model was completed that identifies the costs, savings, net present value, and marginal abatement costs of the modelled actions.

[4] Statistics Canada reports that Metropolitan Halifax's GDP was $17.3 billion - https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610042301

SSG used a model that includes a high-level financial analysis of community-wide capital and operating costs for households, businesses, and the Municipality. The financial analysis is linked temporally and spatially to the actions in the model, allowing costs to be tracked as actions are implemented out to 2050. Figure 2 shows the annual costs and savings of the low carbon pathway relative to the BAU scenario.

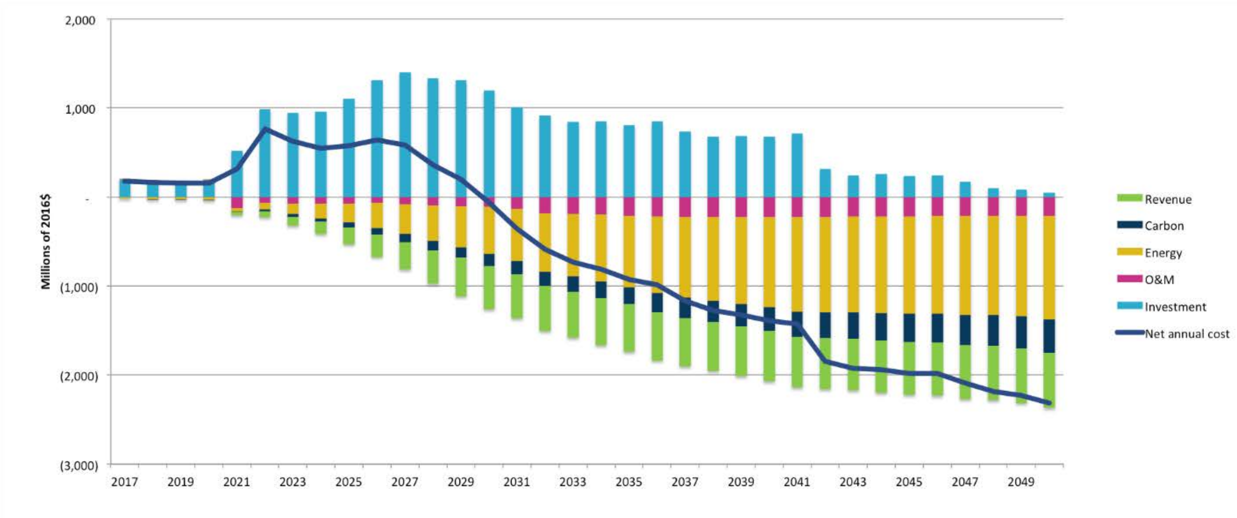

Figure 2: Summary of annual low carbon scenario costs (above x-axis) and savings (below x-axis) relative to the BAU scenario

In the low carbon scenario, energy costs decrease by 2030 as retrofits are undertaken, on-site renewables are more broadly deployed, transit is expanded, and the number of electric vehicles increases. Costs stabilize in the 2040s when most energy efficiency efforts have been achieved. Figure 2 demonstrates that although there is significant upfront investment needed to achieve the low-carbon pathway, there are substantial savings and a financial return beginning around 2030. In 2016, all community energy costs totaled $1.5 billion. In the BAU scenario, these are projected to increase to $1.73 billion per year by 2050. Should the steep emissions reduction scenario be achieved, energy costs per year are estimated to drop to $565 million in 2050, a 62% decrease from 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. Figure 3 provides greater detail of the investment by sector for the low carbon scenario to be implemented.

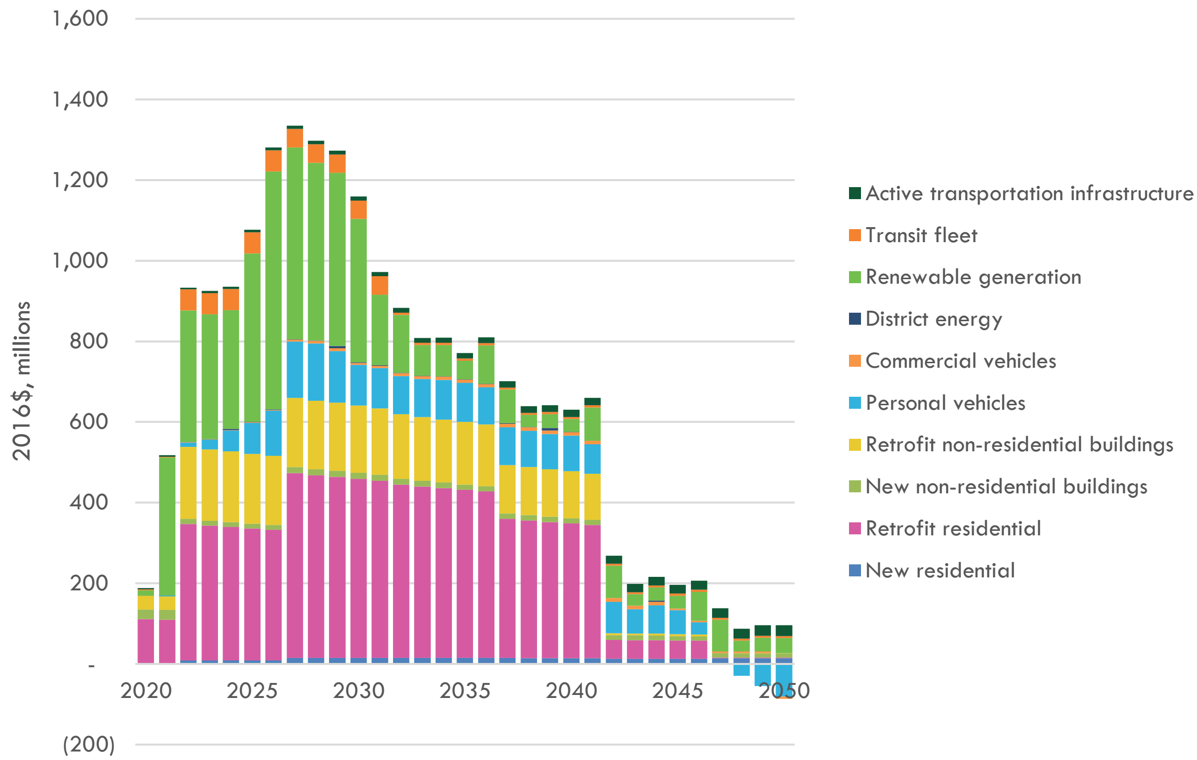

Figure 3: Low carbon investment by economic sector

Employment by occupation and location is tracked in the model, paired with population growth estimates. Employment related to the construction of new buildings, retrofit activities, and energy infrastructure is modelled based on the timing and implementation of the low carbon actions using sector-specific employment multipliers. The low carbon 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. The breakdown of jobs by sector for the next ten years can be found in Table 2, with the majority of new green jobs in the renewable energy and home contracting sectors. Further details on the financial modelling work can be found in Attachment D.

Table 2: Person years of employment resulting from the low carbon pathway over ten years

Sector	Person years of employment (2020-2030)
Active transportation	597
Local renewable generation	32,763
Commercial vehicles	86
District energy	95
Non-residential buildings -- New	962
Non-residential buildings -- Retrofit	14,578
Non-residential equipment	238
Personal vehicles	2,517
Residential buildings -- New	596
Residential buildings -- Retrofit	33,111
Residential equipment	844
Transit infrastructure	3,746

Wedge Diagram & Actions

The wedge diagram in Figure 4 illustrates the emissions reduction impacts of the low carbon scenario actions relative to the BAU scenario. The diagram shows the GHG emissions reductions that are projected from each of the actions. To find a detailed description of the actions, refer to the technical document (Attachment D). The modelling results indicate that the largest potential GHG reductions come from retrofits of existing residential and non-residential buildings, and the increased deployment of renewable energy. The relative size of the wedges has been used to guide the approach to implementation and the prioritization of the first series of critical actions.

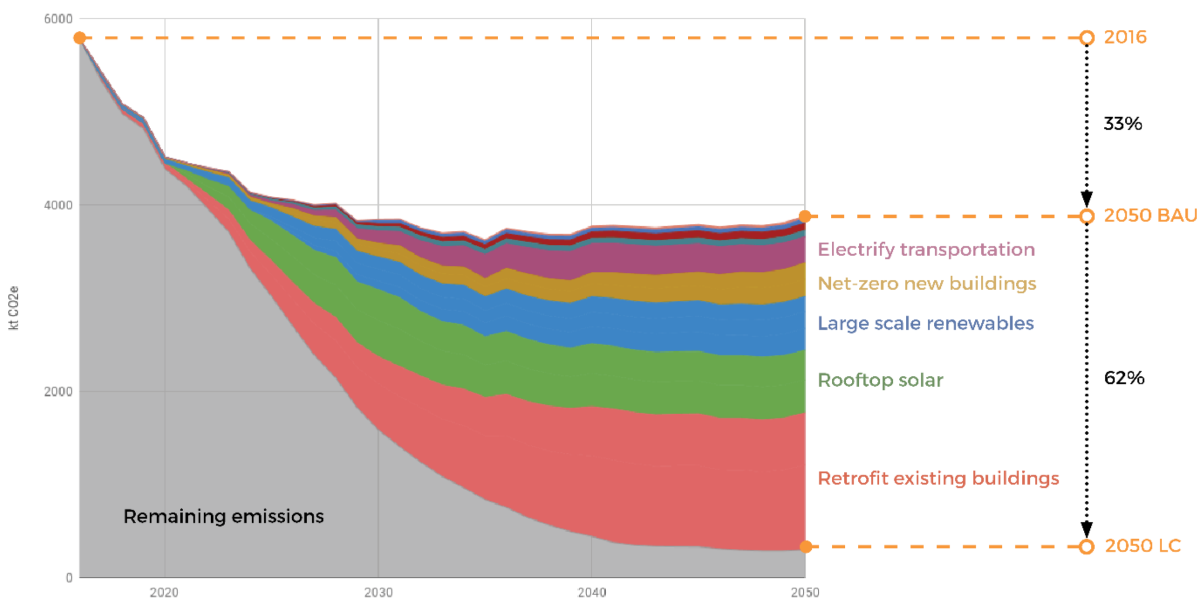

Figure 4: Wedge diagram of actions for the low carbon pathway

Stakeholder Engagement

As the success of HalifACT 2050 relies heavily on community action, stakeholder engagement and public consultation was critical for evaluating the complex issue of climate change and in finding solutions to existing barriers to mitigation and adaptation. To inform both the pathway to a low carbon economy and priority actions to achieve a 2050 target, the core HalifACT 2050 team held meetings with over 250 internal and external stakeholders including all levels of government, utilities, non-profits and advocacy groups, academics and educators, industry, Mi'kmaq peoples, African Nova Scotian communities, Acadian groups, youth and more. A summary of stakeholder meetings, public engagement and outreach can be found in the full Community Engagement Report in Attachment E.

DISCUSSION

HalifACT 2050: Acting on Climate Together, is intended to set the direction for climate change mitigation and adaptation programs, policies and investments across the municipality. While the plan gives several specific recommendations for municipal implementation, the vast majority of GHG reductions can only be achieved by joint implementation with external stakeholders and the broader community. It will be necessary to build on the strong stakeholder engagement that has taken place during the development of the plan to ensure that implementation is a joint and collaborative effort with all levels of government, utilities, private businesses, citizens and others.

Continued Collaboration

Given the importance of continued action on the global climate crisis, which affects every sector of society, public and stakeholder engagement will continue through the implementation of the plan. Maintaining strong partnerships with stakeholders is critical for success.

As the urgency for drastic climate action increases, so does the level of effort by many governments, industry, academia, businesses, innovators, etc. New programs, legislation, policies and technologies are being introduced, and can be expected to continue. The Municipality will leverage opportunities as they become available and can adjust plans and strategies as needed. **The success of HalifACT 2050 is dependent not only on actions taken by the Municipality, but of many critical stakeholders in our community as well.** The Municipality requested that external stakeholders submit letters of commitment as part of their participation in HalifACT. To date, 13 letters have been received (Attachment F) from many key stakeholders outlining support and commitments for collective climate action. Letters have been submitted by the following organizations:

- Building Owners and Managers Association (BOMA)
- Canadian Green Building Council (CaGBC)
- Clean Foundation
- COIN Atlantic - Coastal and Ocean Information Network
- Dalhousie University
- Ecology Action Centre
- Efficiency Nova Scotia
- Halifax Chamber of Commerce
- Halifax Water
- Heritage Gas
- Nova Scotia Department of Energy and Mines
- Nova Scotia Environment
- The Confederacy of Mainland Mi’kmaq

Province of Nova Scotia

The Province of Nova Scotia recently passed new legislation in October 2019 called the *Sustainable Development Goals Act*, which commits the provincial government to a target of net-zero emissions by

2050. This end target is identical to HalifACT 2050, but the pathway differs. The Province has set an interim goal to reduce its emissions by 53% from 2005 levels by 2030. The HalifACT low carbon scenario calls for a steeper decline in the short term in consideration of the municipality's overall carbon budget.

To achieve both the municipal and the provincial targets, the Province of Nova Scotia will need to create additional policies, programs and incentives that accelerate deep emissions reductions. As approximately half of Nova Scotia's emissions originate in the Halifax Regional Municipality, it is critical that we continue to be close partners throughout implementation. Consultation on regulation and policies to support the goals of the Act is planned and the Municipality, as a key stakeholder, will provide recommendations that can advance the implementation of HalifACT 2050.

The Municipality has the opportunity to show leadership in Atlantic Canada and influence all levels of government through impactful policies and programs. As the municipality consists of rural, suburban and urban communities, successful programs, policies and public education campaigns can be shared and replicated widely across the Atlantic region.

Nova Scotia Power Incorporated

As the largest energy provider in the province, effective collaboration with Nova Scotia Power (NSP) is critical to the success of HalifACT 2050. As such, NSP has been a key stakeholder in the development of HalifACT 2050 and the Municipality has been and continues to be an active stakeholder in NSP's Integrated Resource Plan (IRP). The IRP will develop a roadmap that guides NSP's long-term electricity supply and demand out to 2045. Through the IRP, various scenarios will be modelled and evaluated based on metrics such as cost, emissions reduction, grid reliability and flexibility to accommodate future unknowns and opportunities. Scenarios to be modeled range from an 80% emission reduction over 2005 levels to net-zero emissions by 2045. The IRP is expected to be finalized in September 2020 and presented to the Utility and Review Board for approval. Should NSP decarbonize their electricity production faster than anticipated, the emissions reductions from actions in HalifACT 2050 will be realized sooner. The Municipality will continue working with NSP throughout the implementation of the IRP and HalifACT 2050.

NSP's infrastructure is designed to convey electricity generated primarily by mechanical means in one direction from the provincial grid to the customer. Infrastructure changes will be needed to accommodate wide scale generation of solar electricity by customers to be sold to the grid. As a result, the pace and location of roof top solar programs and electrification of heating systems will need to be coordinated with NSP. This coordination, as well as the role of the NS Utility and Review Board is a key challenge as we move forward and may drive the pace of implementing some aspects of HalifACT 2050. Grid capacity and the intermittency of renewable energy sources are barriers that need to be addressed collaboratively.

HalifACT 2050 is intended to be a living document that will continue to be updated and supported with supplementary costing and technical plans during implementation out to 2050. Currently, HalifACT 2050 is intended to set up the framework for the scale and timeline of actions that are needed to lead us on the 1.5°C pathway to net-zero emissions by the year 2050. Significant, additional work is needed to get the municipality and wider community set up for success.

A complete list of actions is included in the plan in Attachment A. Given the magnitude of action required to address the climate challenge, staff have identified and prioritized the first critical areas of action, which include:

1. Retrofit and renewable energy programming;
2. Retrofit municipal buildings to be net-zero ready and climate resilient;
3. Electrification of transportation;
4. Net-zero standards for new buildings;
5. Risk and vulnerability assessments;
6. Capacity building for climate adaptation; and
7. Sustainable financing strategy.

Halifax Water

The Regional Halifax Water Commission (Halifax Water) is a separate corporate entity, wholly owned by the Municipality and regulated by the Nova Scotia Utility and Review Board. Water and waste water are included in the municipal operations target of net-zero by 2030. The Municipality will work closely with Halifax Water to ensure that, collectively, municipal operations achieve this target.

Halifax Water will be setting GHG reduction targets in 2020/21 and has stated that these targets will align with HalifACT 2050 as much as possible. Halifax Water has begun a Vulnerability to Climate Change Risk Assessment Pilot Project to understand risks and vulnerabilities of critical infrastructure. The Municipality will work with Halifax Water and other key stakeholders responsible for critical infrastructure to better understand these risks and to inform future investments and decisions. The Municipality recognizes that Halifax Water provides services to some but not all of the municipality, and that the protection of water supply and critical infrastructure is the responsibility of many.

Action Area 1: Retrofit and Renewable Energy Programming

The results of SSG's modelling (Table 3 of the Baseline Inventory and BAU Report (Attachment B), show that 70% of community-wide emissions come from existing commercial and residential buildings. This presents a significant opportunity for deep carbon reduction through building retrofits. As such, the Municipality must develop a deep energy retrofit program to achieve a 50% reduction overall energy demand from existing buildings by 2040 in partnership with other levels of government, utilities, and stakeholders.

Fundamentally, reducing emissions in existing building stock can be achieved through the following actions:

- Reduce energy consumption and demand;
- Improve efficiencies;
- Switch to lower carbon-intensive fuels, and
- Generate on-site renewable energy.

Property Assessed Clean Energy (PACE) programs have been a proven method for reducing emissions in buildings across the country. Through the Solar City Program, the Municipality has committed more than $12 million to the installation of solar energy systems, totaling 4.3 MW (Megawatts) of solar capacity. These systems are expected to save property owners a total of $820,000 each year in utility costs and reduce annual emissions by approximately 3,600 ktCO_2e (kilotonnes of carbon dioxide equivalent). Since the pilot program began in 2013, it has been effective in reducing many barriers to solar adoption and played a key role in incubating the Nova Scotia solar industry, which now has over 50 solar contractors actively participating across the province. While successful, a mere fraction (0.3%) of the 1,300 MW of rooftop solar needed to meet the targets of HalifACT 2050 have been realized. To meet these targets, the program needs to be scaled up significantly and expanded to include deep energy retrofits.

Deep energy retrofits are expensive. An incentive program that achieves the necessary size and scale of impact will require substantial capital investment that goes beyond what the Municipality can afford to lend. Other public and private capital is needed. The Municipality is currently working with the Federation of Canadian Municipalities as a key contributor to the development of the new Community Ecoefficiency Acceleration Fund. The fund is intended to assist in scaling up existing PACE programs and to offer a pathway to draw on private capital, which has been a proven catalyst for PACE programs in the United States. Research and stakeholder engagement continue on the potential for and structure of private lending partnerships. As these conversations continue, additional partnerships will be sought, taking advantage of any existing incentives and complementary programs.

Over the next year, there are several specific actions the Municipality can undertake to begin the development and deployment of a retrofit program. To accurately inform the most appropriate measures, a technical retrofit guide will need to be developed to support the various building archetypes. At this time, PACE financing can support private residences and non-profits. The Municipality does not have legislative authority to offer PACE financing to commercial or mixed-use buildings. As the existing commercial building stock contributes to over 30% of community-wide emissions, *HRM Charter* amendments to enable commercial PACE would be needed. PACE is also not the only financing mechanism that can be used; other partnerships and mechanisms will be explored during the design phase.

While PACE programs have been successful in alleviating the upfront cost of solar energy systems, barriers still exist for property owners who are experiencing energy poverty, which are those households who are spending greater than 10% of their income on home energy needs[5]. As such, any new program will be analyzed through a lens of social equity to explore ways in which to make the program more accessible to all property owners across the municipality. These modifications could include longer financing terms and/or a reduced interest rate that would result in a cash-flow positive situation earlier in the term, reducing the additional monthly burden and significantly increasing participation.

In addition to retrofit programs, the Municipality will explore forward-thinking policies such as building energy rating and equipment replacement standards. These policies help transform the market by holding owners and operators accountable for building energy performance. Energy ratings inform buyers and renters about the energy performance of buildings and provide insight to building owners and operators on how to become more energy efficient. Specifying equipment standards and energy auditing during renovations may be possible in building codes and will be investigated during the design and implementation of building the retrofit and renewable energy program.

Action Area 2: Retrofit Municipal Buildings to be Net-zero Ready and Climate Resilient

Currently, corporate operations result in approximately 1% of community-wide emissions. While this number may seem low, the Municipality has the responsibility to lead and demonstrate practices that will encourage broader emission reductions within the community to achieve climate targets and positively impact economic development. The latest inventory of corporate emissions indicates a substantial opportunity to achieve deep emission reductions by first focusing on the corporate building stock. Eighty-five percent (85%) of all corporate GHG emissions in 2016/17 were from municipally-owned buildings.

To accelerate emission reductions in existing corporate buildings, the Municipality has partnered with Efficiency Nova Scotia (ENS). Through this partnership, ENS provides the Municipality with an on-site energy manager tasked with identifying energy and emission reduction measures throughout the organization. To date, just over $2 million has been spent on efficiency measures with $400,000 covered through ENS incentives. These projects will realize annual energy and emission reductions of 10 GWhe (Gigawatt hours equivalent) and 6,500 $ktCO_2e$ respectively, saving the Municipality $1.3 million annually.

This work needs to be scaled up and sped up if the Municipality is to align with the technical analysis of HalifACT 2050, which recommends retrofitting and future-proofing all existing Municipal buildings to net-zero ready by 2030. To meet this target, a detailed infrastructure plan for both new and existing corporate buildings will be developed in consultation with other business units and presented to Regional Council, outlining both the capital costs and lifecycle savings. Priority actions of the plan will include energy efficiency measures and on-site renewables.

For new buildings, the Municipality can influence change by requiring all corporate buildings meet top-level energy performance standards. Once a community-wide standard is developed, an Administrative Order will be recommended to Regional Council that would require all new municipal buildings meet the most aggressive tier of the standard, which is expected to be net-zero ready and climate resilient. This Municipal leadership will be key in encouraging market and industry transition to more stringent energy standards. As the standard has yet to be developed, the Municipality will continue to include both high-efficient and renewable technologies in new builds in the interim.

[5] Energy Poverty & Equity Map - https://cuspnetwork.ca/energy-poverty-equity-mapping/

Historically, the Municipality has aimed to meet LEED certification for all new builds, but more recently the focus has switched to incorporating performance-based measures, such as percentage better than Code and energy consumption per floor area. For example, the Woodside Ferry Terminal renovation and the Mackintosh Depot Replacement will be built to exceed the 2015 National Energy Code of Canada for Buildings (NECB) by a minimum of 15%. In addition, Fire Station #62 in Williamswood will include a 50kW solar electric system, and other high efficiency measures which will bring it close net-zero ready construction. More recently, the new fire station in Hammonds Plains will aim for net-zero ready using existing tools and technologies and will serve as a template for future corporate buildings. Building to these standards today will reduce operating and maintenance costs and will protect against future climate impacts.

Action Area 3: Electrification of Transportation

In 2016, the transport sector contributed to 20% of overall community emissions. While this percentage is expected to decrease slightly by 2030 due to improved fuel efficiency standards, complete electrification of transportation is crucial to achieve a steep decline in emissions.

On September 17, 2019[6] Regional Council gave staff direction to develop a Municipal Electric Vehicle Strategy that is intended to address both short and long-term barriers to the community-wide adoption of electric vehicles (EV). In February 2020, the Municipality issued an RFP for evaluating possible policy levers, corporate and community infrastructure needs, and public education that would advance the municipality in becoming an EV-ready city. The strategy will also provide recommendations on the transition of light-duty municipal fleet vehicles. Aside from lifecycle savings and emission reduction potential, the resulting strategy will outline priority actions and associated capital investment required, to be presented to Regional Council for further direction.

As the strategy is being completed, the Municipality will begin looking at short-term fleet transition and workplace charging. As light-duty fleet vehicles are retired, they must be replaced with the best-suited and most cost-effective EV solution. While EVs are expected to reach cost parity by the late 2020s, there is currently an average premium of $10,000 to $20,000.[7] This premium could be reduced through the Federal Zero Emission Incentive Program[8], as municipalities are eligible for ten rebates of up to $5,000 on select EV purchases per year. Charging infrastructure is required to accommodate these EVs. This infrastructure would not only serve the fleet vehicles but also personal vehicles, an increasingly common request. Cost sharing through Natural Resources Canada's Zero Emission Vehicle Infrastructure Program could be leveraged for the installation of this charging infrastructure. After all available rebates, the additional premium required for the first set of EVs and associated infrastructure can be covered in 2020/21 with the new climate change capital account ($1 million). By focusing first on light-duty vehicles there is the opportunity to address general barriers to electrification of transportation. This will prove beneficial to the ongoing multi-stakeholder discussion on electrifying public transportation.

Research and discussions continue on the required electrification of Halifax Transit vehicles. On May 26, 2020, Regional Council approved an Electric Bus Proposal that would allow for 50% of the Halifax Transit fleet to be transitioned to Battery Electric Buses (BEB) by 2027/28. However, this transformative project requires significant funding, which has not yet been secured. Funding opportunities are being pursued to support the acquisition of a first set of EV buses along with required upgrades to the Ragged Lake Transit Facility. A new full-time staff position is included in Transit's 20/21 Operating Budget to hire a Fleet Transition Manager to support this work.

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[6] Initiatives to increase the number of electric vehicles and charging stations in the Municipality - https://www.halifax.ca/sites/default/files/documents/city-hall/regional-council/190917rc1532.pdf

[7] 2018 Nissan Altima MSRP $26,000; 2018 Nissan LEAF MSRP $36,000; 2018 Ford Focus MSRP $18,000; 2018 Ford Focus Electric MSRP $35,000 - https://www.autotrader.ca/

[8] Federal iZEV Program - http://www.tc.gc.ca/en/services/road/innovative-technologies/zero-emission-vehicles.html

<u>Action Area 4: Net-Zero Standards for New Buildings</u>

The municipality's population is expected to increase 30% by 2050, which will drive the demand for new residential and non-residential floor space. While new buildings will be more efficient than the current building stock, the modelling results for the low carbon pathway indicate that all new buildings, both residential and non-residential, must be built to a net-zero ready standard by 2030. Net-zero ready buildings incorporate existing tools and technologies to significantly reduce building energy demand and carbon intensity before adding onsite renewables or purchasing off-site renewables/carbon credits. In most cases, building to net-zero ready is financially feasible as a result of the lower operating and maintenance costs, protection against volatile energy costs and less costly future retrofits. [9]

All municipalities in Nova Scotia currently observe the 2017 National Energy Code of Canada for Buildings (NECB). Nationally, there is a movement towards the development of a tiered federal energy code, like that of the British Columbia (BC) Step Code[10]. The BC Step Code outlines a series of energy targets, with clear timelines on when these targets will be mandatory. Similar to the BC Step Code, the most aggressive tier of the new federal code is expected to be net-zero ready. In January 2020, the Municipality participated in a workshop hosted by the Department of Energy and Mines and Efficiency Canada to discuss and gather feedback on this new code. Public consultation for the code was completed in March and is expected to be introduced later this year for adoption by the provinces and territories. The Province of Nova Scotia has historically been progressive in adopting new versions of the NECB and based on recent discussions it is expected that they will do the same for this new code. The Province plans to conduct a market readiness assessment to determine which tier will be provincially mandated. The timing for provincial adoption is expected to be in 2022.

Once the new federal code is released later this year, it is recommended that the Municipally perform its own assessment to determine which tier best aligns with the recommendations of HalifACT. As the interim target of the SDGA differs from that of HalifACT, there is a chance that municipal and provincial priorities may not align. Should this be the case, staff will return to Council to request more stringent new construction standards than those required by the Province. Through S 4(2) of the *Building Code Act*, the Council of a municipality may recommend that the Minister prescribe additional standards applicable to the construction of buildings in that municipality, that are more stringent than the standards of the provincial code. This approach is similar to the direction of the BC Step Code where the province has granted all municipalities authority to prescribe any tier of the BC Step Code, providing they meet the minimum tier prescribed by the province. In Nova Scotia, regulating additional standards for local governments would empower those local governments that have the capacity and resources to champion the code and drive market transformation.

If the request to the Province is unsuccessful, the Municipality may consider incentives similar to that of the Toronto Green Standard (TGS)[11]. The TGS is a municipal version of the BC Step Code, as it outlines the most effective path to meeting the City of Toronto's GHG emission reduction targets through four progressive energy and resilience performance tiers. To encourage meeting these tiers, financial incentives are offered by the city in the form of waived permitting fees and refunds on development charges. Current tools available to the Municipality for incenting parties to build beyond the legislated NECB include density bonusing within the Regional Centre and refunding building permit fees.

<u>Action Area 5: Risk and Vulnerability Assessments for Critical Infrastructure</u>

Public Safety Canada defines critical infrastructure as processes, systems, facilities, technologies, networks, assets and services essential to the health, safety, security or economic well-being of Canadians and the effective functioning of government.

[9] Making the Case for Building to Zero Carbon - https://www.cagbc.org/cagbcdocs/advocacy/Making_the_Case_for_Building_to_Zero_Carbon_2019_EN.pdf
[10] BC Step Code - https://energystepcode.ca/
[11] Toronto Green Standard - https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/toronto-green-standard/

The Municipality has several ongoing efforts related to risk and vulnerability assessments of critical infrastructure. Climate considerations are embedded in many projects across the organization, such as bridge replacements, road design and ferry terminal renovations. The municipal Emergency Management Office (EMO) is currently working on itemizing and prioritizing critical infrastructure within the municipality in the context of hazards and risks from an emergency management perspective. Planning and Development has ongoing floodplain studies for the Sackville and Little Sackville Rivers and the Shubenacadie watershed. An implementation plan is currently in development for the top ten priority flood prone areas in the municipality identified in the National Disaster Mitigation Program: Flood Risk Assessment Study[12]. The implementation plan will consider mitigation strategies including traditional and green infrastructure options.

A consolidated effort to assess critical municipal infrastructure more holistically and comprehensively is required to understand what risks and vulnerabilities are associated with the infrastructure, what subsequent risks result from a failure of critical infrastructure (e.g. public safety and environmental health), and what mitigative actions can be considered by the Municipality to maintain the infrastructure over time. A framework for conducting detailed risk and vulnerability assessments of critical infrastructure across all asset classes should be included as an essential early action in the implementation of HalifACT. These assessments will then lead to more detailed maintenance plans for critical infrastructure. The Municipality will need to engage key stakeholders as they conduct similar work on their critical infrastructure. Lack of proactive action and investment will increase the risk to existing and planned critical infrastructure.

Action Area 6: Capacity Building for Climate Adaptation

Significant efforts to increase community resilience to climate impacts in the municipality continue across many Business Units. Key areas of focus for climate adaptation capacity building include emergency management, ecosystem protection and increasing food security.

Emergency Management
The EMO is in the process of purchasing new backup generators for potential comfort centres during emergencies, including its first propane generator (lower GHGs than diesel) for the Musquodoboit Fire Station. Public engagement and education efforts promoting the importance of emergency preparedness are ongoing.

Collaboration with EMO to conduct climate hazard mapping and promote emergency preparedness continues. Workshops took place in partnership with the Joint Emergency Management (JEM) teams in two rural areas and one urban area of the municipality, which included a presentation and a mapping exercise for community members to identify past hazards, vulnerabilities, and exposures to climate risks. The community feedback is being digitized to share online. These workshops provided a better understanding of some of the localized risks and identified many community strengths and innovative solutions to consider. This work should continue across all regions of the municipality and at an even smaller scale to better capture individual communities.

Stakeholder consultation with some faith-based organizations explored the idea that these organizations and their places of worship play a critical role in emergency management. These buildings can act as gathering places and shelters, and the faith leaders can assist in reaching their members to promote emergency preparedness and to support them in times of emergency. It is recommended that work continue with places of worship, similar to work that was done in three cities in Ontario, called the Lighthouse Program[13].

[12] National Disaster Mitigation Program – Flood Risk Assessment Study - https://www.halifax.ca/sites/default/files/documents/city-hall/regional-council/181016rc1421.pdf
[13] Vibrant Communities Case Study - ttps://www.tamarackcommunity.ca/hubfs/Resources/Case%20Studies/Case%20Study%20%7C%20Building%20a%20Neighbourhood-based%20Urban%20Climate%20Adaptation.pdf?hsCtaTracking=90acda0e-0187-4c5c-8314-daacf6d753cd%7C65bf4dac-a70a-40ef-907c-2b123338b8d8

Communicating climate risks and emergencies to newcomers and residents who speak other languages requires additional effort. The Municipality and its Office of Diversity & Inclusion collaborate with the Immigrant Services Association of Nova Scotia (ISANS), academic institutions and other stakeholders to continue to improve emergency management communications in multiple languages and build more resilient communities.

Ecosystem Protection

Natural areas and green infrastructure play a significant role in adaptation, specifically by reducing heat and flooding impacts, primarily through increasing infiltration and reducing the heat island effect, improving water quality, providing shading and areas of reprieve, as well as increasing carbon sequestration capacity. Natural areas and green infrastructure include all natural or human-made elements that can provide ecosystem services. Examples include parks, trees, shrubs, urban forests, green roofs and walls, gardens, bioswales, natural channels, watercourses, ponds, and constructed wetlands. In accordance with the 2016 direction from the Nova Scotia Utility and Review Board, the Municipality is working collaboratively with Halifax Water to develop stormwater management standards that will capture and treat stormwater on-site for high-density residential, institutional, commercial and industrial developments. Further work will include applying these new standards to the public right-of-way through the Municipal Design Guidelines.

The Municipality will protect, restore, maintain, and expand its natural areas. 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. Parkland acquisition, construction and repairs can all be done through a lens of climate resilience. Cooling centres, splash pads, drinking fountains and shaded areas will become more important as temperatures increase. The Green Network Plan and Urban Forest Master Plan include policies related to climate action. Continued support through budget and business planning is required to implement these two plans. This could include additional region-wide tree planting and re-greening programs. Regional Council provided direction to expand naturalization efforts in parks and rights-of-way areas in January 2019 to enhance biodiversity and improve ecosystem health and resilience in the urban environment.

As sea level rise, overland flooding, coastal flooding and coastal erosion continue and worsen, the Municipality will need to review and update flood models, land use bylaw regulations and consider the implications of the Coastal Protection Act and any associated regulations and policies that are passed. New LIDAR data has been recently acquired to create an updated and expanded Digital Elevation Model for the entire municipality, including the coastal zone and river watersheds. This model is nearing completion and will be used to conduct land use vulnerability assessments to inform future decisions for land use and infrastructure.

Food Security

Food security is of critical importance to residents, as indicated in the results of the Shape Your City survey. The Municipality is a member of the Halifax Food Policy Alliance and is co-leading the development of the Food Action Plan for our region. Actions to preserve food during power outages include community generators that can be shared, and community freezers in libraries with backup generators. During Hurricane Dorian in fall 2019, the food banks lost power. These types of risks can be mitigated with proper planning and collaboration among stakeholders. Ideas for adapting to changing agricultural conditions and potential crop losses from extreme weather need to continue to be researched and explored.

Action Area 7: Develop a Sustainable Financing Strategy

Decarbonizing and adapting to the impacts of climate change will require significant investment and mobilizing the required funds for the task ahead will be a challenge 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 governments to explore and establish new mechanisms for financing climate action, including private sources of finance.

A critical first step is to create a detailed financing strategy for the continuous implementation of HalifACT from now until 2050. Climate financing tools to explore include[14]:

- Green bonds, which are debentures, the proceeds of which are earmarked for projects with an environmental benefit;
- Environmental impact bonds, that 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,
- Broader use of revolving funds, which provide financing for climate-related projects that result in ongoing cost savings that replenish the fund.

It should be noted that at the current time municipalities in Nova Scotia do not have the legislated authority to provide, or access, such financing instruments. Currently, all municipalities must raise capital debt through the Nova Scotia Municipal Finance Corporation, this includes accessing the FCM Green Fund.

Additionally, it is worth exploring how these types of funding mechanisms, along with others such as the Task Force on Climate-Related Financial Disclosures (TCFD) and municipal investing, further influence costs of borrowing and insurance premiums for the Municipality and residents/businesses more broadly, attract private investment needed for climate action, and establish Halifax as a preferred location for climate-related investment and clean technology.

Climate considerations must also be further integrated into overall 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)[15] 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 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

[14] Mobilizing Finance for Sustainable Growth - http://publications.gc.ca/collections/collection_2019/eccc/En4-350-2-2019-eng.pdf
[15] Task Force on Climate-related Financial Disclosures - https://www.fsb-tcfd.org/

of environmental departments to the center of attention and mainstreamed it into daily operations and decision making.

Corporate Asset Management & Capital Planning

Apply a climate lens to capital planning to ensure financial decisions and asset management are climate-informed. Progress on municipal asset management goals has been moving steadily forward. Systems have been put in place - technology and business processes - to have a single source of infrastructure inventory, mapped and accompanied by key pieces of information. Systems have also been put in place to begin tracking maintenance costs by specific asset to gain a better understanding of individual performance and overall health. With more than two years of data now in the systems, staff are learning to leverage the information for improved decision making. The Asset Management team is working with groups across the organization to integrate the building blocks of asset management methodologies, reinforce a high degree of quality and compliance, and navigate evidence-based decision-making for infrastructure.

Over the latter half of 2019, the Asset Management team updated Regional Council and sought its approval to shift the annual Capital Budgeting process to a longer-term Strategic Capital Planning process. This included direction to develop a 3-year balanced capital budget and 10-year capital outlook as part of the 2020/21 budget process. Council approved project evaluation methodology, including alignment with Council's own priorities, risk assessment, impact on services, and determining appropriate timing. Council also endorsed direction for asset investment, instructing staff to structure the budget to focus 70-80% on asset recapitalization and 20-30% on service growth. The Municipality began including climate risk considerations in capital planning and budgeting in 2019 in preparation for the 2020/21 fiscal year. Efforts will continue to further refine the ways in which the Municipality considers climate change in its capital planning process. The intended outcome is to better understand and account for the emissions associated with municipal 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.

Two capital accounts for 2020/21 have been approved for climate change-specific work. The first is $2 million for energy efficiency initiatives (CB190008) in municipally-owned buildings. In the last two years, just over $2 million was spent on efficiency measures through this account, with $400,000 covered through rebates and incentives by Efficiency Nova Scotia. The measures implemented will realize an annual operational savings of $1.3 million, resulting in a payback period of just over one year. Typical energy efficiency measures include LED lighting retrofits, air sealing and recommissioning of building systems. Waste heat recovery opportunities will be a large focus in 2020/21. The second account is new for fiscal year 2020/21 and has $1 million for beginning the implementation of HalifACT (CB200012) to begin fleet conversion, install EV charging infrastructure, and install renewable energy systems in corporate buildings. Amounts in this new climate change account are currently forecasted to grow modestly to $5 million in 2029/30. However, these numbers will be revisited as part of the development of a detailed financing strategy.

Plan Implementation

While the implementation of HalifACT will require a significant financial contribution from all levels of government and the community, the cost of inaction will continue to grow. It has been estimated that every dollar invested proactively can save as much as four[16] to six[17] dollars on recovery. Table 3 provides a high-level financial analysis by SSG based on the technical modelling work, identifying estimated costs, savings,

[16] Godschalk, D. R., Rose, A., Mittler, E., Porter, K., & West, C. T. (2009). Estimating the value of foresight: aggregate analysis of natural hazard mitigation benefits and costs. Journal of Environmental Planning and Management, 52(6), 739-756.

[17] National Institute of Building Sciences (2017). Natural Hazard Mitigation Saves: 2017 Interim Report.

net present value, and marginal abatement of implementation. This shows that over the lifetime of the plan there is an overall financial gain if all recommended actions are taken.

Table 3: Summary of Low Carbon Scenario Financial Metrics (2016 $ Billions)

Metric	Cumulative Costs and Savings to 2050 (undiscounted)	Net Present Value (discount rate of 3%)
Cost	$(22.10B)	$(14.86B)
Operation and Maintenance	$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 Savings	**$22.31B**	**$8.67B**

Resourcing Climate Action

While it is imperative to begin work on all recommended actions in HalifACT in order to achieve the net-zero target by 2050, the Municipality is constrained financially as it responds to the economic disruption from COVID-19. There are currently six fulltime and two contract positions that deliver on Energy & Environment's mandate, which includes climate change, water resource management, environmental risk and compliance, clean energy, and other sustainability efforts. Currently, three employees are exclusively focused on climate-related work, with the rest of the team supporting as much as possible.

The consultant's report recommends that thirty new positions are urgently needed to carry out the climate plan. The original intention was to create nine new positions in 2020/21. Three of these positions were approved in the recast Planning and Development operating budget for 2020/21. Three new climate change positions are needed for a total of four, with two focused on mitigation and two on adaptation. Three new clean energy positions are needed for a total of four focused on renewable energy, building energy performance, electrifying transportation and building energy retrofits. One climate financing specialist is needed along with two environmental technicians to provide broad technical and research support.

Ideally, resourcing, including additional consulting support, should be aligned to implement the plan at the scale and in the time that is required. While additional resources are necessary to implement the plan, they must be deferred at this time of financial uncertainty. A scan of the administration will be conducted to search for current employees with relevant skills and capacity to be redeployed to contribute to plan implementation. Implementing HalifACT 2050, including any redeployment, will require adjustments to existing municipal operations.

Efforts by each Business Unit are required for successful climate action. Additional staff and financial resources across the organization will be needed going forward as the plan is actioned over time and will be requested as part of the annual progress report for HalifACT and through the annual business plan and budgeting process. Funding opportunities that include staff support will continue to be explored.

Reporting and Monitoring

Staff will present an annual progress and update report to Regional Council outlining the impact our collective actions of HalifACT are having on emissions and risk reduction. The report will highlight the capacity of the Municipality as an organization to implement both corporate and community-wide action. Social, economic and environmental key performance indicators will be considered in reporting on climate change mitigation and adaptation progress; the most foundational indicator of impact being annual GHG emissions.

The progress report will include a combination of quantitative and qualitative indicators across three main areas, with the specific format to be decided during the first year of implementation. The high-level areas of indicators include:

- Climate and climate events indicators;
- Action implementation and effectiveness indicators; and
- Capacity and learning indicators.

CONCLUSION

Even though there are many challenges to effective climate action, the climate emergency also presents many opportunities. As much as climate change presents risks, the actions that reduce GHG emissions and increase resilience can save money, increase community wellbeing and improve environmental sustainability. Actioning the seven critical core areas outlined in this report will lead to a more equitable, prepared and sustainable community.

HalifACT is a pathway to a resilient and low carbon community. The ways in which we achieve the goals outlined in the plan may change as new technologies and policies emerge and opportunities arise. However, the time to act is now. Uncertainty is not a reason for delay. The Municipality must work with a focus on cooperation, adaptive management, urgency and equity to collectively and successfully tackle the climate crisis.

FINANCIAL IMPLICATIONS

The recommendations in this report are intended to enable HRM to provide broad community leadership on Climate Change. Close cooperation and partnership with multiple stakeholders are critical to success.

The recommendations are also intended to lead to the development of specific municipal initiatives (programs) and costing of the supporting operating and capital actions. Because these initiatives have not been fully developed, it is not yet possible to indicate the full breadth of their long-term financial implications. However, the scope of the recommendations suggests that the cost of the various actions is substantial and will likely impact the long-term capital plan, future operating budgets, and both debt and tax levels.

Proposals to electrify HRM's fleet, retrofit existing buildings or construct new net-zero buildings will require a substantial amount of capital budget. There are various approaches that might be followed such as the issuance of additional debt, cost-sharing through senior levels of government or delaying already approved projects. It is also worth noting that these initiatives will build upon rehabilitation and replacement projects that will likely occur regardless. The report identifies several financing alternatives that can be investigated further. Information on the partial electrification of Halifax Transit buses was reported to Regional Council on May 26, 2020 (Item 9.1.7 Strategic Transit Projects – Rapid Transit Strategy and Electric Buses). Estimated costs were included in that report, including upfront implementation costs and potential operating savings.

Regional Council could consider options for dedicated HRM funding. A dedicated Green Tax (possibly through a reserve or revolving fund) could be created. For example, 3 cents on all general tax rates would generate $15 million dollars a year. This could be invested in deep energy retrofits of HRM buildings and/or electrification of HRM's fleet. Or an equivalent amount of debt solely related to climate change could be accessed, i.e. a planned increase in HRM's debt level, which could be partially paid back through energy savings.

Note, however, the operating savings discussed in this report are based upon hypothetical modelling, based on Halifax's current energy use and infrastructure, applying costs and energy savings for known technological solutions. The savings stated are for the community at large. At this time, the extent of any operational savings to the Municipality are not known and cannot be relied upon as a funding source. Future policy decisions and project designs will inform HRM's potential savings, as will technological advances.

Significant federal funding is already tied to green outcomes and there are no indications this will change, as the government continues to state that climate action is urgent and necessary. There is also provincial funding to which the Municipality could apply. It is anticipated there may be significant additional funding focused on infrastructure and climate action, as part of the country's economic recovery strategy. Staff will actively monitor and collaborate on funding opportunities to ensure the Municipality is well-positioned to apply for new funding available to implement HalifACT 2050.

A PACE program for deep energy retrofits has not been fully designed. The financial implications to HRM are not immediately apparent but could include administrative costs, incentives and the costs of any financing or guarantees. At this time, HRM does not have the legislated authority to offer such a program. Further analysis of options and risks to HRM would have to be explored before a decision to request legislative amendments could be recommended.

Next Steps

Specific programs, required to carry out the core action areas described in the report to support HalifACT 2050, will be provided to Halifax Regional Council (via ESSC) for its review and approval, as they are developed. Development of these programs will require additional resources. No additional financial requests are being made for the 2020/21 fiscal year, beyond what has been approved in the recast COVID-19 budget on June 9, 2020. However, it is anticipated that six additional HalifACT staff and consulting work at a cost of approximately $850,000, annually, will be requested during the 2021/22 budget cycle or as soon as financially feasible. The annual capital budgeting plan will also include the objectives of HalifACT2050 in its evaluation framework. The longer-term goal is to present a 10-year capital plan that would clearly schedule projects that advance Council's strategic priorities.

Significant investments in climate action will be required to achieve the longer-term targets set out in HalifACT 2050. Required funding requests for its implementation will be addressed through future Council decisions related to the long-term capital outlook and annual capital and operating budgets.

RISK CONSIDERATION

The risks associated with climate change are complex and multifaceted. Regional Council has declared a climate emergency and by not reacting promptly and effectively, Halifax could be faced with a reputational risk with its citizens, stakeholders, and other cities and governments. Climate change poses an immediate and long-term risk to human health, the built environment, and the natural environment.

Failure to prepare for the hazards of climate change, will increase the severity of the impacts from both chronic and acute climate events. These impacts can include damage to infrastructure, a reduced ability to deliver essential services, impacts to human health and safety, and damage to essential ecosystem services.

If climate change is not considered in financial decision-making, there is the risk of investing poorly and maladapting, resulting in long-term costs that are exponentially higher. By not investing in and preparing for climate change, resiliency becomes more difficult, and the physical and economic impacts of climate change will have the greatest effect on the most vulnerable sectors of society.

COMMUNITY ENGAGEMENT

Extensive public and stakeholder engagement for the development of HalifACT is detailed in the Community Engagement Report (Attachment E). Implementation of the plan will require continued engagement of the public and key stakeholders.

ENVIRONMENTAL IMPLICATIONS

There are significant environmental, economic and social benefits associated with the implementation of HalifACT 2050. These positive implications are outlined within the body of this report and associated attachments.

ALTERNATIVES

1. Regional Council may reject the staff recommendations. This is not recommended for the reasons outlined in this report, including the fact that all levels of government around the world must act to limit warming to 1.5°C above pre-industrial levels within the next 10 years to prevent irreversible economic, environmental and societal impacts.

2. Regional Council may defer approval of the staff recommendations until such time that the plan can be financially supported. This is not recommended as staff can still progress critical core areas to a certain degree without additional resources.

3. Regional Council may choose to add additional core action areas for 2020/21. Any additional effort beyond what is outlined in this report will need to be resourced with additional staff and funding. This is not recommended for the reasons outlined in the report.

ATTACHMENTS

Attachment A: HalifACT 2050: Acting on Climate Together
Attachment B: Baseline and BAU Report
Attachment C: Adaptation Baseline Report
Attachment D: Technical Report
Attachment E: Community Engagement Report
Attachment F: Letters of Commitment from External Stakeholders

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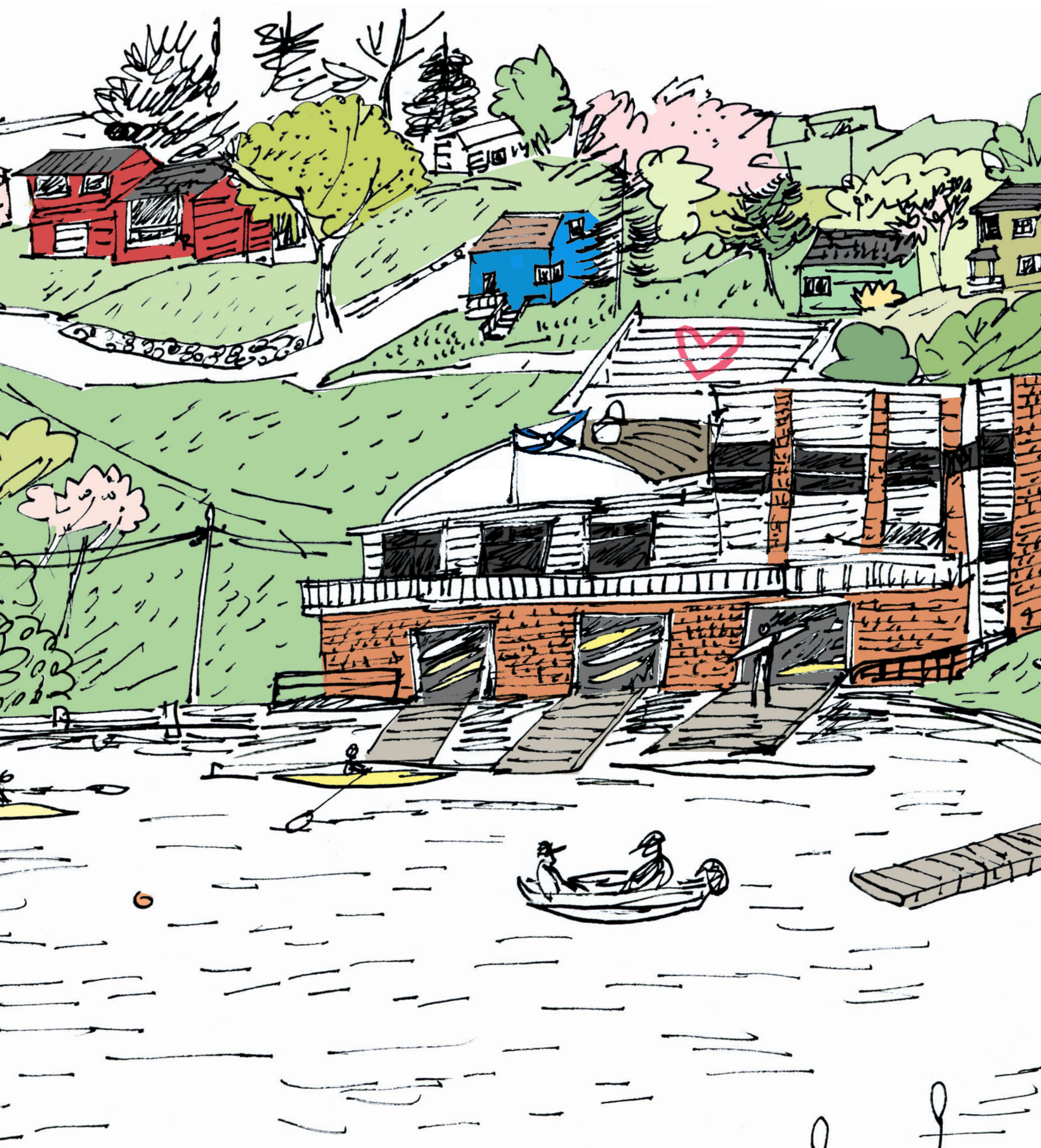
A copy of this report can be obtained online at halifax.ca or by contacting the Office of the Municipal Clerk at 902.490.4210.

Report Prepared by: Shannon Miedema, Manager, Energy & Environment, 902.209.6194
Taylor Owen, Climate Change Specialist, Energy & Environment, 902.266.2389
Kevin Boutilier, Clean Energy Specialist, Energy & Environment, 902.490.6821

Attachment A

HalifACT 2050

ACTING ON CLIMATE TOGETHER



Acknowledgments

Land Acknowledgement

We would like to acknowledge that we are on the traditional and ancestral territory of the Mi'kmaq people, who are the original peoples. The Peace and Friendship treaties were signed between the British Crown and the Mi’kmaq between 1725 and 1769.

Halifax Regional Council adopted a Statement of Reconciliation[1] in 2015. Reconciliation requires ReconciliAction. We recognize the importance of meaningful consultation with our Mi’kmaq community, who has an unwavering commitment to environmental stewardship and future generations. We are all Treaty beneficiaries as Mi'kmaq and settlers alike and have shared roles and responsibilities to protect our lands and communities from the impacts of climate change.

Acknowledgements

On January 29, 2019, Halifax Regional Council declared a climate emergency, emphasizing that climate change is a serious and urgent threat to our community. The level of ambition in our community’s new climate strategy, HalifACT 2050, was made possible by Council’s recognition of the urgent need for action in response to the existing and predicted future threats of climate change. This plan was developed in collaboration with Sustainability Solutions Group (SSG), a consultancy specializing in climate change mitigation and adaptation modelling and planning.

More than 250 internal and external stakeholders from all levels of government, utilities, nonprofits and advocacy groups, academics and educators, industry, the Mi’kmaq, African Nova Scotian communities, Acadian groups, youth and more helped develop the plan. Stakeholder meetings were supported and facilitated by a community engagement consultancy, New Leaf.

Key insights with respect to public opinion on climate change and community-level climate hazards and impacts were gained from in-person events and presentations throughout the municipality, as well as thousands of responses from online surveys and interactive mapping.

This work would not have been possible without the dedication and valued contributions of many municipal employees across the organization.

Thanks to all. May we approach the climate emergency with a hopeful, energetic and collaborative spirit, Acting on Climate Together.

[1] http://legacycontent.halifax.ca/council/agendasc/documents/151208ca1442.pdf

Foreword from Mayor

To be included upon approval from Halifax Regional Council.

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THE CHALLENGE

CHAPTER 1

E Fitzgerald.

THE CHALLENGE

1. Responding to the Climate Emergency

Climate change is an urgent, complex and global crisis. Its long timeline, globally dispersed impacts, and the level of societal and systems change required make it challenging to rapidly transition to a low carbon future.

We are at a pivotal moment in human history. The next ten years will determine whether or not society can successfully address climate change. This report is Halifax's response to address the climate crisis, stimulate the economy, create new jobs, and build a more resilient future.

In 2018, the world's leading scientific body on climate change released a report titled Global Warming of 1.5°C. The report indicated that the risks of climate change can be substantially reduced by limiting warming to 1.5 degrees Celsius (°C) above pre-industrial levels.[2] If the world continues to emit its current level of greenhouse gases (GHGs), we will breach the limit of 1.5°C of warming in just ten years.

In 2019, Halifax declared a climate emergency, joining countries and major cities around the world, as well as nearly 500 Canadian municipalities. This plan is Halifax's response to that declaration[3].

HalifACT 2050: Acting on Climate Together is the Municipality's long-term action plan to reduce emissions and help communities adapt to a changing climate.

1.1 Halifax's Climate is Changing

Climate change risks health, economic growth, safety, livelihoods and the natural world. These impacts are being felt here at home.

Projections[4] indicate that Halifax will experience higher temperatures, more heat waves, more rain and snow and an increasing number of more severe storms, flooding events and wildfires. Extreme weather drives other climate hazards such as sea level rise, decreased snowpack and

[2] The remaining global carbon budget for having a 66% chance of limiting warming to 1.5°C is 420 $GtCO_2e$. Global annual GHG emissions are approximately 42 MtC20e. (Intergovernmental Panel on Climate Change (IPCC), 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, Maycock, M. Tignor, and T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.)

[3] The full technical report and other supporting documents for HalifACT 2050 can be accessed by visiting http://www.halifax.ca/climate or by contacting the Municipality.

[4] Climate Atlas of Canada, version 2 (July 10, 2019), using BCCAQv2 climate model data. https://climateatlas.ca/.

unpredictable runoff, and increases in invasive species and vector-borne diseases[5]. Figure 1 shows some of the projected changes Halifax can expect to experience between 2051 and 2080.

Change	1976-2005 Mean	2051-2080 Low	2051-2080 Mean	2051-2080 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. Projected climate changes for Halifax

Climate hazards pose risks for people, the built environment, natural systems and resources, economies, livelihoods, and safety. Examples of increased risks for Halifax include:

- damage to physical infrastructure such as buildings, roads, communications equipment, water and wastewater treatment plants;
- reduced water quality and quantity;
- stresses on agriculture and food systems;
- threats to biodiversity and ecosystem resilience;

[5] Vector-borne diseases are infections that are transmitted by the bite of infected insects or other arthropods, including mosquitos, ticks, and flies. Examples include Lyme disease and West Nile virus. Climate change expands the range of the vectors of disease and increases the likelihood of vectors surviving the winter.

- uncertainty for fisheries and forestry;
- physical adversity and mental health impacts;
- increased demands on emergency services;
- financial impacts on businesses and economies; and,
- diminished capacity of government to effectively provide public services.

1.2 Time is of the Essence

A deep reduction in greenhouse gas emissions requires transitions in energy, land, urban and infrastructure systems (including transport and buildings), and industrial systems. This transition provides an opportunity to create new businesses and new jobs, improve the built environment, stimulate innovation, and improve health outcomes.

In 2016, Halifax emitted approximately 5.8 MtCO_2e (million tonnes of carbon dioxide equivalent).[6] Modelling results indicate that if no additional policies, actions or strategies to address energy and emissions are implemented other than those currently underway or planned, this total decreases to 3.9 MtCO_2e by 2050. The decrease results from fuel efficiency standards in vehicles, planned decarbonization[7] of the provincial electricity grid, and reduced heating needs as the climate warms.

Halifax needs to reduce emissions to 1.4 MtCO_2e by 2030 (75% by 2030 from 2016), and to net-zero MtCO_2e by 2050 (100% by 2050 from 2016) to align with a 1.5°C pathway. Figure 2 shows the difference between Halifax's Business As Usual (BAU) scenario and the 1.5°C pathway from 2016 to 2050.

To better understand the scale of this undertaking, 1 Mt CO_2e is equivalent to the emissions from 216,000 cars driven for an entire year, or the emissions from driving around the world 99,650 times![8]

[6] There are many different greenhouse gases. In order to measure total emissions, we convert each gas that is not carbon dioxide into a calculation of carbon dioxide equivalent (in order to compare apples to apples instead of apples to oranges).

[7] The process to achieve zero fossil fuel existence. Typically refers to a reduction of the carbon emissions associated with electricity, industry and transport.

[8] United States Environmental Protection Agency, 2020. Greenhouse Gas Equivalences Calculator. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

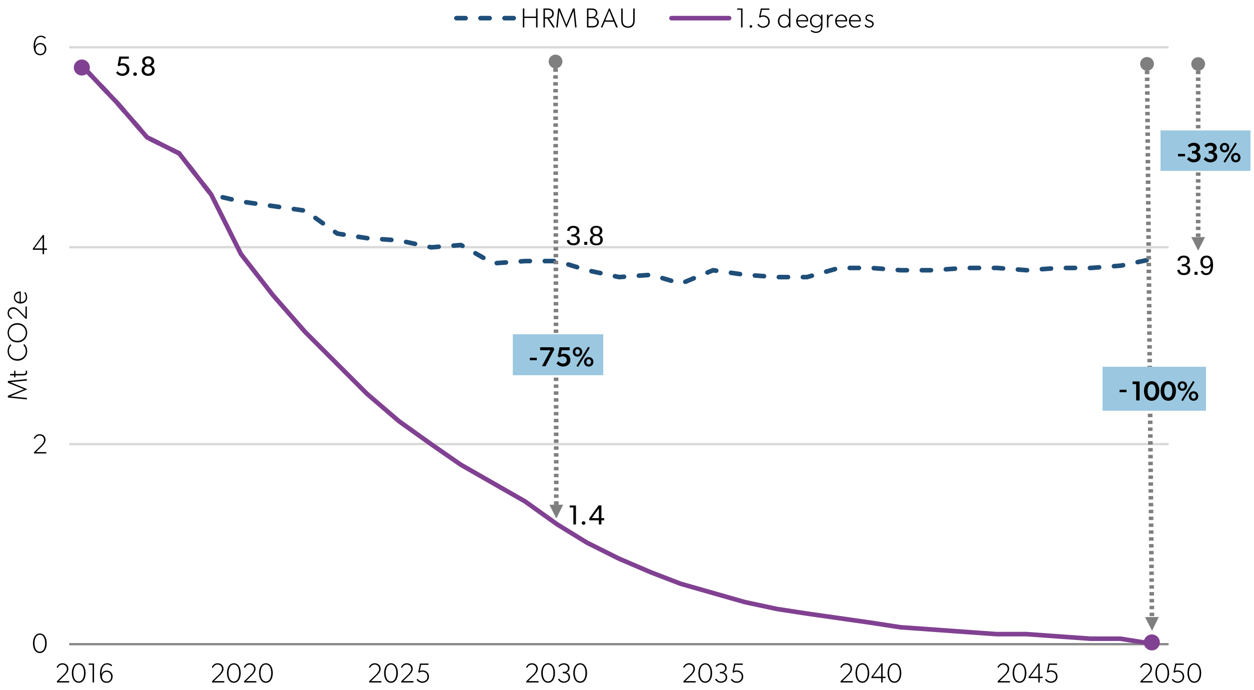


Figure 2. Halifax's 1.5°C pathway and carbon budget

1.3 The Carbon Budget - Every Tonne Counts

Every tonne of GHG emissions between now and 2050 counts. While GHG emission targets typically specify a level of annual emissions by some future target year (e.g. 30% below 2010 levels by 2030), it is the cumulative emissions over time that determine the degree of global warming that will take place. A carbon budget can be thought of like a bank account, with limited money that is spent over time. Using the carbon budget approach, it is the cumulative emissions between the present and the target year that are limited.

Carbon budgets can be calculated at various scales, from global to local. To be consistent with a 1.5°C pathway, the municipality's carbon budget is 37 $MtCO_2e$. The area under the purple curve represents the cumulative carbon emissions in the 1.5°C pathway. While the target of net-zero emissions[9] is important, Halifax must commit to a steep reduction pathway to limit total emissions over time and stay within the carbon budget. Under a BAU scenario, the municipality exceeds its carbon budget (the area under the 1.5°C curve) by 2028.

[9] Net-zero emissions refers to the end state where we reduce emissions as low as possible and then offset the remaining emissions using carbon capture techniques and purchased carbon offsets.

1.4 The Opportunity

1.4.1 HEALTHY VIBRANT COMMUNITIES

Responding to the climate emergency results in everyone benefiting from improvements in social, environmental, and economic factors critical for safe and connected, vibrant and healthy communities. Reducing GHG emissions and building resilience to climate impacts improves air quality, reduces noise pollution, provides space for recreation, physical activity and social interaction, and generally beautifies a city; the result is improved health and wellbeing of residents. Adapting to the changing climate will strengthen emergency preparedness and infrastructure resilience and enhance natural habitats and biodiversity. Many of these are no-regret measures that improve the quality of life in communities.

1.4.2 AN ECONOMIC OPPORTUNITY

HalifACT 2050 is as much an economic development plan as a climate action plan. Major investments will be required to decarbonize the building and transportation sectors and to generate clean electricity, amongst other actions. These investments will generate employment and stimulate new and existing businesses.

Based on the low carbon pathway modelled for Halifax, the first ten years of actions result in an annual average 9,000 person-years of employment. Table 1 shows the areas of this employment growth.

Table 1. Person-years of employment resulting from the low carbon pathway over ten years, 2020-2030

SECTOR	PERSON-YEARS OF EMPLOYMENT
Active transportation	597
Local renewable generation	32,763
Commercial vehicles	86
District energy	95
Non-residential buildings -- New	962
Non-residential buildings -- Retrofit	14,578
Non-residential equipment	238
Personal vehicles	2,517
Residential buildings -- New	596
Residential buildings -- Retrofit	33,111
Residential equipment	844
Transit infrastructure	3,746

1.4.3 A JUST TRANSITION

Deep emission reductions require innovation, rapid diffusion of new technologies, and the reshaping of markets and socioeconomic systems. Transitions are, by definition, disruptive.

A just transition is an approach that aims to minimize the impact on workers and communities, and to engage with the individuals and organizations who are impacted. [10]

In addition to a just transition, Halifax can preferentially deploy strategies or actions that simultaneously deliver other objectives related to health, equity, poverty alleviation, and reconciliation.

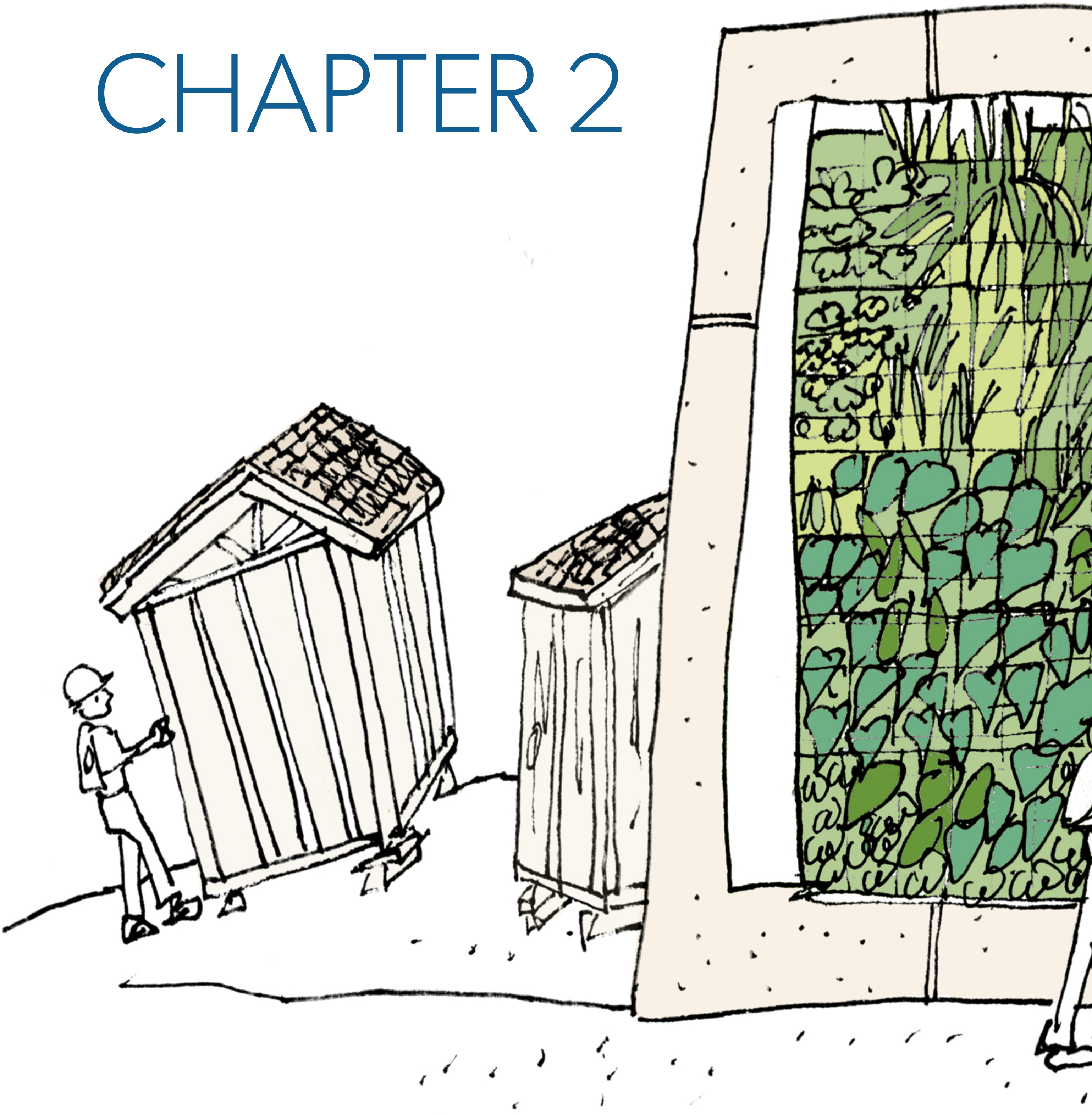
Not all people will be affected equally by climate change. Distinct groups, communities, and populations will be disproportionately affected by climate change due to one or more of the following factors: increased exposure to climate risks, increased sensitivity to climate risks, and limited adaptive capacity for coping with climate impacts. Similarly, not all will be able to equally contribute to the significant action and investment required to decarbonize.

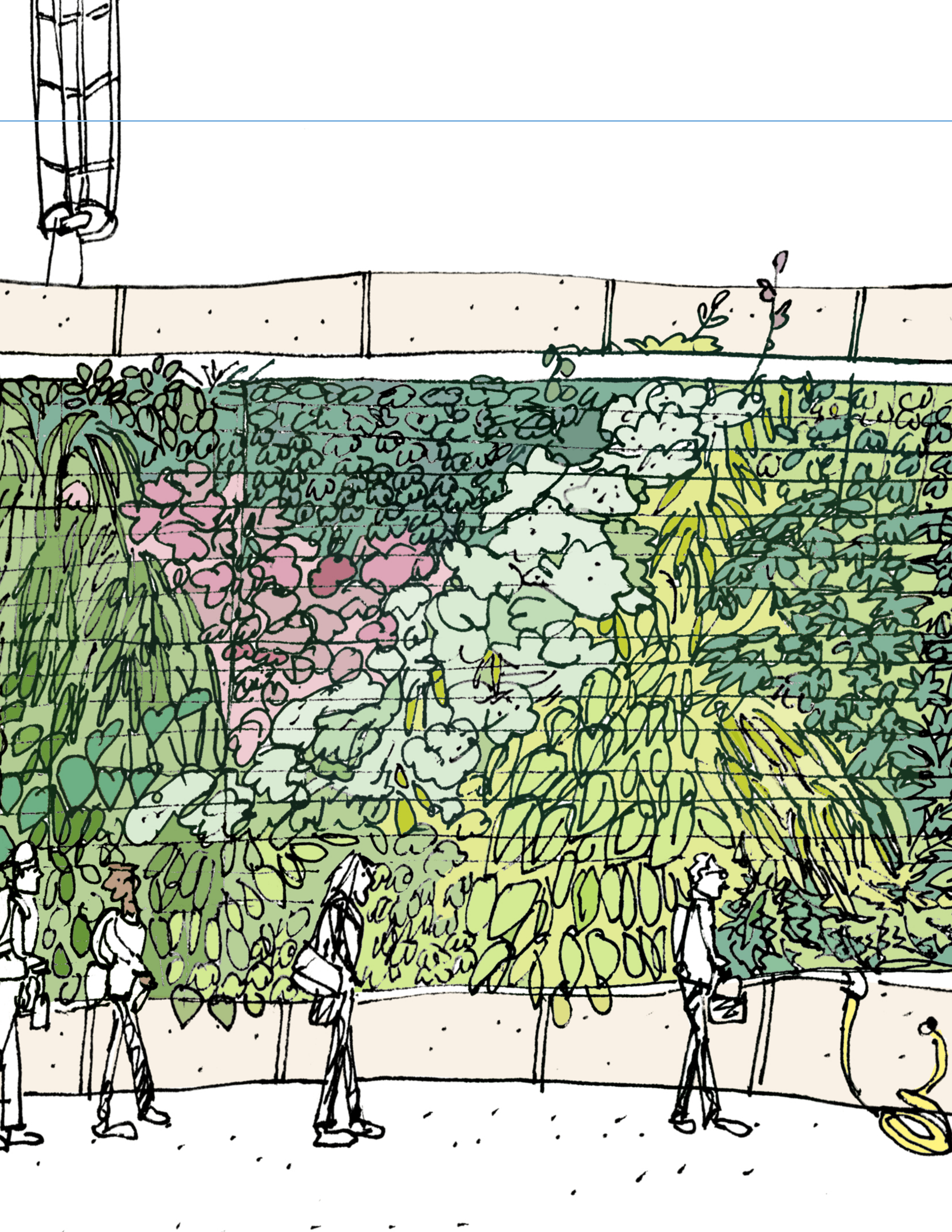
The success or failure in moving towards a decarbonized and climate resilient future will be measured both by how quickly society is able to reduce emissions and adapt to the impacts of climate change, and by how equitable and sustainable the transition is. With the constraint of limited resources, it is essential to prioritize the most vulnerable and affected members of the community, many of whom are already confronting other social and economic challenges. We must consider social equity at all levels of decision-making, program design, and implementation.

[10] Task Force on Just Transition for Canadian Coal Power Workers and Communities, Canada, & Environment and Climate Change Canada. (2019). A just and fair transition for Canadian coal power workers and communities. http://epe.lac-bac.gc.ca/100/201/301/weekly_acquisitions_list-ef/2019/19-11/publications.gc.ca/collections/collection_2019/eccc/En4-361-2019-eng.pdf

A COMMUNITY VISION

CHAPTER 2





2. A Community Vision

2.1 Broad Engagement

The development of HalifACT 2050 included advisory groups of municipal employees and community members, technical modelling and broader public engagement.

Over the past year, the HalifACT 2050 project team engaged hundreds of internal and external stakeholders and community members across the municipality. The engagement process increased awareness, facilitated discussions about strategies, tools and barriers to action, strengthened existing networks, and built new networks and partnerships to support implementation.

The project team hosted five stakeholder workshops and more than 35 pop-up sessions, presented to more than 25 groups or organizations and met with three Joint Emergency Management volunteer teams. HalifACT 2050's online presence through Shape Your City saw more than 2,800 visitors, 1,300 survey respondents, and 23,000 votes cast for priority actions. Social media channels were used to raise awareness and spark conversation.

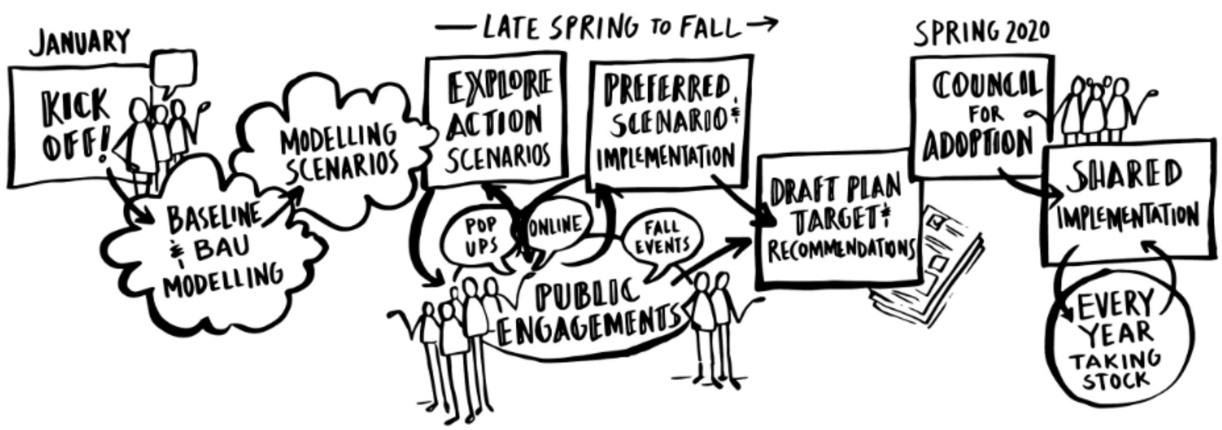


Figure 3. Process for developing HalifACT 2050

2.2 Insights

The project team received extensive information from each workshop, engagement session, and from social media platforms. The final plan and summary of actions reflects the ideas shared by stakeholders and residents. Key insights from the engagement are listed below.

- New and revised policies, regulations, standards and codes are needed to reach Halifax's targets.
- Equity needs to be considered in program development and delivery. The combination of an unequal distribution of wealth and an uneven distribution of impacts needs to inform action on climate change.
- Land-use, transportation, food and infrastructure planning policies either help or hinder efforts to address climate change.
- New funding mechanisms are needed to enable the required investments.
- Government leadership will include convening partners, developing policies, leveraging government assets and supporting research.
- Knowledge gaps within and across communities, sectors, and governments need to be addressed.
- Investment in monitoring, data collection and research will support an understanding of the current situation, risks, hazards and opportunities and will support monitoring and evaluation.

2.3 The Voice of the People

The success of HalifACT 2050 is tied to community action and stakeholder participation. HalifACT 2050 is a community-wide plan and requires collaborative solutions that overcome barriers to both mitigating and adapting to climate change. The project team engaged with more than 250 internal and external stakeholders including all levels of government, utilities, nonprofits and advocacy groups, academics and educators, industry, Mi'kmaq peoples, African Nova Scotian Communities, Acadian groups, youth and more. Participants indicated an urgency to address the climate emergency and to work together to safeguard our future.

"Now is the time for action, we've been talking a long time - time to move and make decisions. Time is getting shorter and we can't wait."

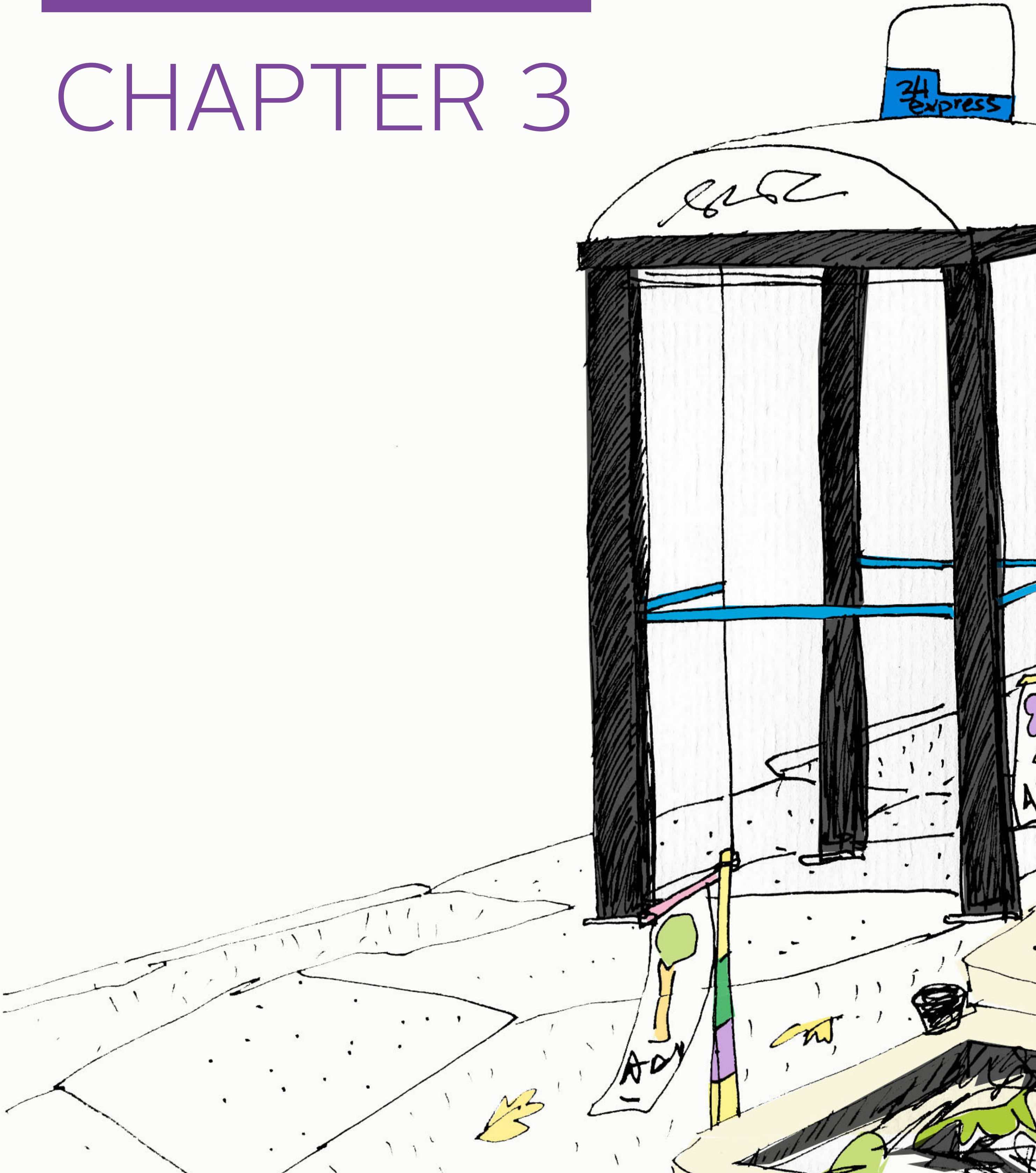
"Congratulations for being brave and bringing a diverse group of people together for next steps."

"This is really important, we can't fail, we have to do it."

"Halifax can be a test bed, we can share that knowledge with areas that have less resources."

GUIDING PRINCIPLES

CHAPTER 3



3. Guiding Principles

The creation and implementation of HalifACT 2050 is guided by the following common principles of climate action planning.[11]

Leadership: Innovation in community energy and emissions planning in Canadian municipalities has been defined by leadership as opposed to regulation. Climate action planning requires changes to established frameworks and practices, and these in turn are most likely to succeed when they are inspired by an understanding of how they will benefit the community and are encouraged and supported by both the leadership of elected officials and senior managers in the municipality.

Alignment: Climate change targets and actions are more likely to succeed where they align with community goals, aspirations and policies for public health, fiscal efficiency, self-reliance, economic prosperity, resilience, inclusiveness, full employment and community planning and development.

Leverage: The key to local government success in lowering community emissions is in its ability to leverage its control and influence over decisions, investments and behaviours in the community that determine emissions levels.

Engagement and Empowerment: Successful low carbon community transition requires grassroots citizen involvement and financial investment (municipality + private sector). Active citizen, household, business and investor engagement is the best route to successful energy and emissions action.

Implementation: Climate literacy for municipal leadership and staff, and community stakeholder relations that are mutually empowering are key to achieving the multiple benefits of the transition to low carbon communities.

Integration: The transition to a low carbon future requires embedding the low carbon objective in all aspects of community planning, policy, and infrastructure investments.

Opportunities: Taking advantage of opportunities can play a key role in developing momentum in the transition to a low carbon community. Such opportunities may be direct—such as financial support available from federal and provincial governments—or indirect—such as a proposal to redevelop a brownfield site or social housing, public health or youth employment initiatives.

Inclusivity: Energy and emissions plans need to involve multiple city government departments, stakeholders and communities, with attention to marginalized groups, in all phases of planning and implementation.

[11] SSG (2018) Community Emissions Reduction Planning: A Guide for Municipalities. Prepared for the Government of Ontario. Available at: https://prod-environmental-registry.s3.amazonaws.com/2018-04/Community%20Emissions%20Reduction%20Planning%20Guide.pdf

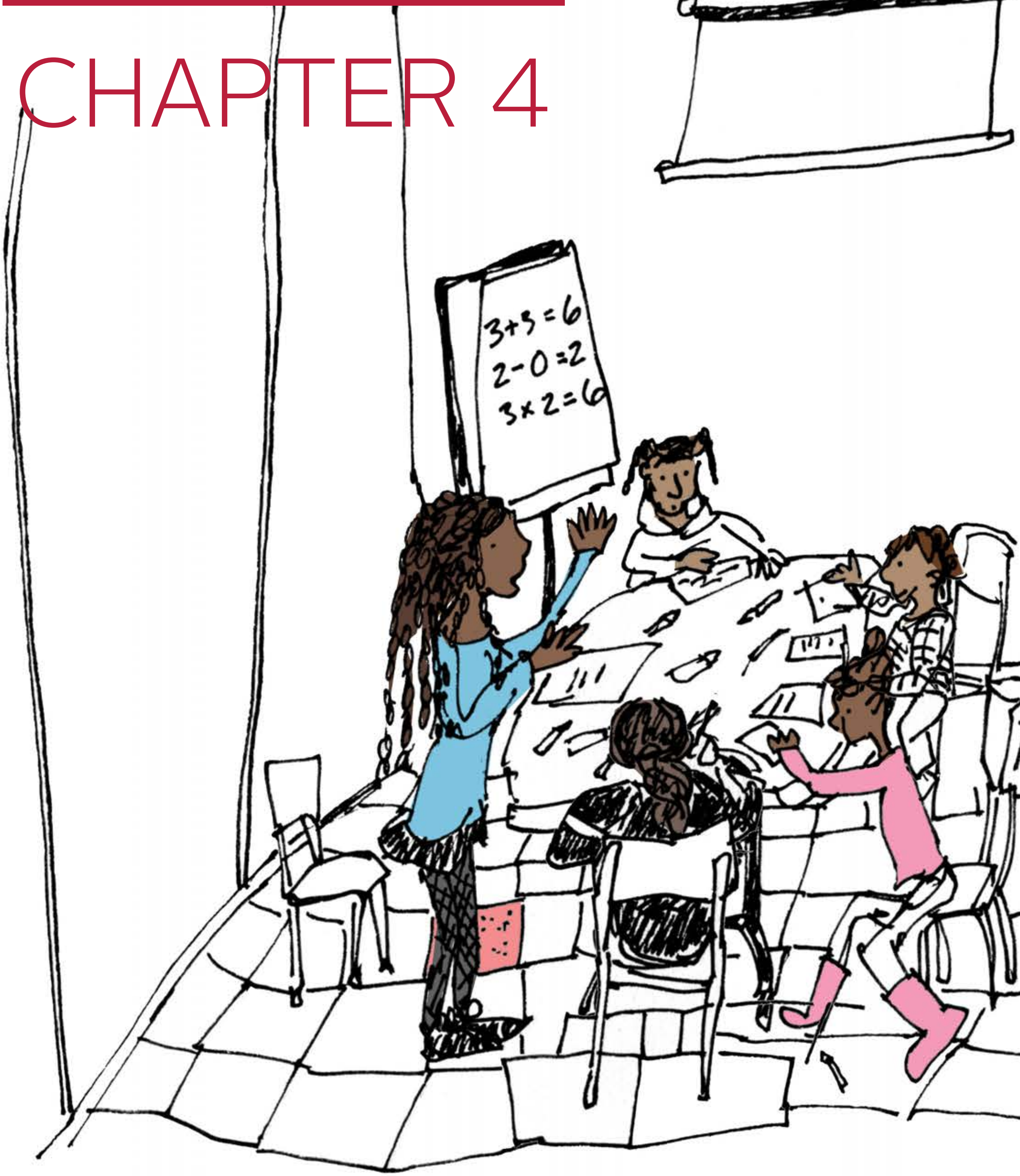
Equity: The climate action plan needs to ensure that its activities equitably address the risks of climate change and share the costs and benefits of action across the municipality. Considerations include impact on access to services, household incomes, economic opportunities, investment in infrastructure and others.

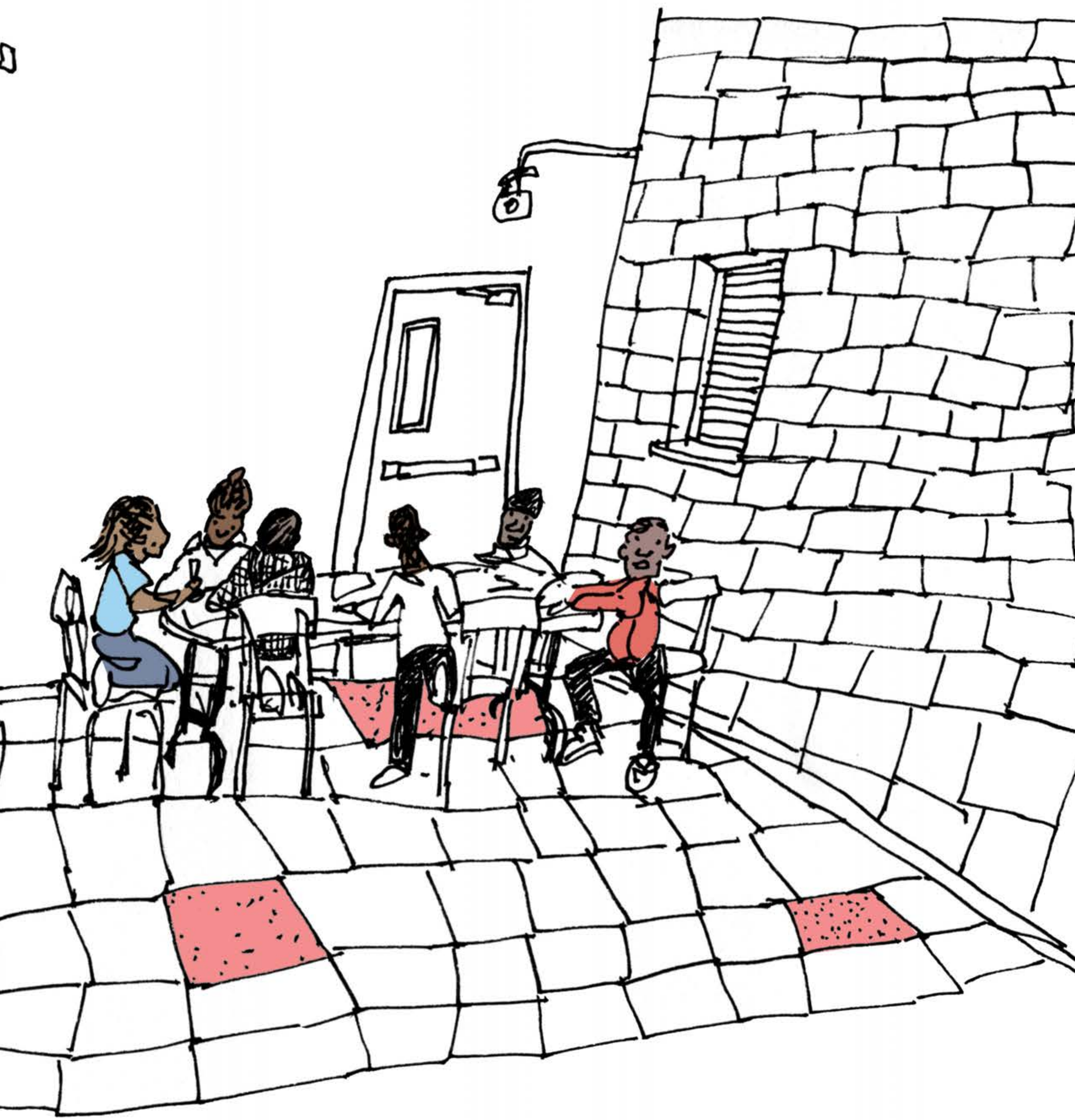
Innovation: Energy and emissions planning is an evolving field and the need for innovation is urgent in order to develop and secure pathways to deep GHG emissions reductions. Innovation requires a willingness to take risks, to fail, and to learn.

Accountability: Transparency is key to ensuring that energy and emissions plans are accountable. Transparency includes following an open decision-making process, and setting goals that can be measured, reported, independently verified, and evaluated. Using transparent modelling and assumptions instills trust in the justification for actions and policy changes.

DECARBONIZING HALIFAX

CHAPTER 4





4. Decarbonizing Halifax

4.1 The Pathway

A low carbon pathway was constructed with actions that align with the 1.5°C pathway. Actions from multiple sectors were modelled, including buildings, energy supply, transportation, water, wastewater and solid waste. The pathway consists of four aspects:

Baseline year: The year 2016 was used as the baseline, aligning with the census. Bottom-up data for buildings (size, shape) and transportation (driving distances) was calibrated with observed energy consumption data from utilities and other sources for this year to ensure that the model meaningfully portrays the energy system in Halifax.

Business As Usual (BAU) scenario: A BAU scenario was developed that accounts for changes in Halifax out until 2050 including an increasing population, new dwellings and workplaces, evolving transportation patterns, decreased GHG emissions from the electricity grid, federal fuel efficiency standards, the impact of climate change on heating and cooling requirements in buildings, and other factors.

Actions: Actions represent physical changes to the energy system or to activities that reduce GHG emissions. Each action is represented as a wedge.

Remaining emissions: The remaining GHG emissions constitute the pathway for a decarbonized Halifax after the actions have been implemented.

Modelling for the HalifACT 2050 plan was completed using demographic, building, transportation, and energy use data, analyzed in the CityInSight model. This model is an integrated energy, emissions, and finance model that allows for a deeper understanding of the relationships between energy use, emissions, and population behaviour. CityInSight allows for detailed analysis of the impacts of actions to reduce energy use and GHG emissions in both time and space and allows for complex interactions between actions to more accurately reflect the impact of potential actions on the future.


QUEEN
PAVIA

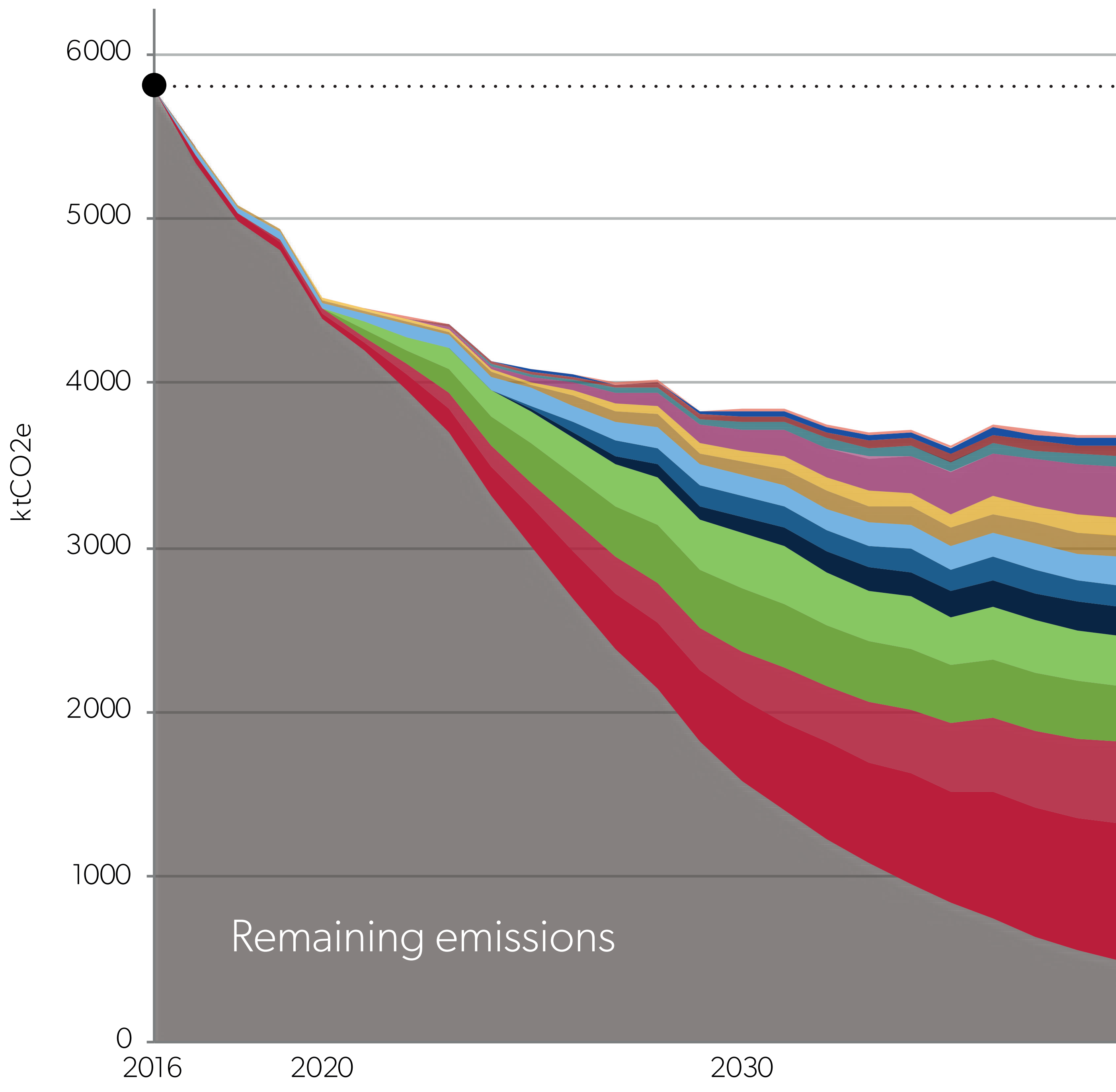
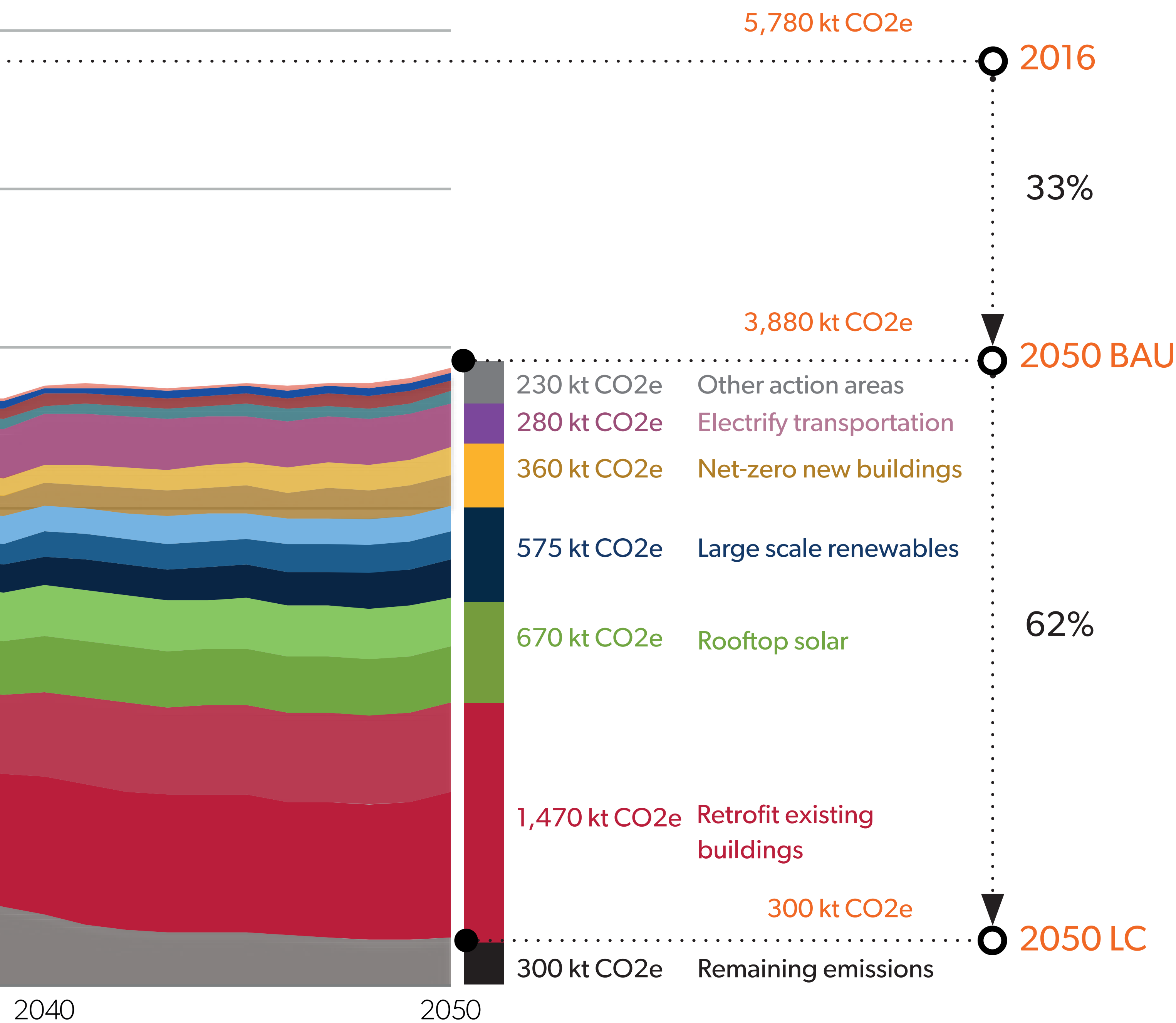


Figure 4. Pathway to reduce GHG emissions aligned with 1.5°C



5,780 kt CO2e
2016
33%
3,880 kt CO2e
2050 BAU
230 kt CO2e
Other action areas
280 kt CO2e
Electrify transportation
360 kt CO2e
Net-zero new buildings
575 kt CO2e
Large scale renewables
670 kt CO2e
Rooftop solar
62%
1,470 kt CO2e
Retrofit existing buildings
300 kt CO2e
2050 LC
300 kt CO2e
Remaining emissions
2040
2050

In 2016, fuel and electricity consumption in residential, commercial and industrial buildings accounted for 70% of all energy use in Halifax and 77% of total GHG emissions. Actions in the building sector include deep energy retrofits, fuel switching heating and water systems to electricity, implementing green building standards to reduce the GHG intensity of new buildings, and improving industrial process energy use. These actions collectively achieve a reduction of 1,830 kilotonnes of carbon dioxide equivalent (ktCO_2e) by 2050 ("Net-zero new construction" and "Retrofit existing buildings" wedges in Figure 4).

The expansion of transit and the switch to electric vehicles provides an additional 280 ktCO_2e of emissions reductions by 2050 ("Electrify transportation" wedge in Figure 4).

The total impact of new renewable electricity generation reaches 1,255 ktCO_2e by 2050. This new carbon-free generation consists of rooftop solar photovoltaics (PV)[12], larger-scale solar and wind installations, and the expansion and decarbonization of district energy systems.[13] Remaining GHG emissions in 2050 are reduced by 95% over 2016.

4.2 Alignment with 1.5°C

While the steep decline scenario includes major efforts to improve energy efficiency and to shift to renewable sources with current-day technology, 5% of emissions still remain in 2050, and the 1.5°C carbon budget is exceeded by 8 MtCO_2e. This gap indicates that Halifax will need to do more than what is in the pathway. Delay has the effect of increasing the gap and decreasing the likelihood of achieving Halifax's 1.5°C carbon budget.

Three strategies are possible to address the 8 MtCO_2e gap, which will be addressed in subsequent updates of HalifACT 2050. First, electricity for the community can be decarbonized more quickly. Second, new and emerging technologies can be deployed, such as green hydrogen.[14] Third, negative emissions actions that absorb and store carbon dioxide can be used to help close the gap (e.g. increasing tree canopy, restoring ecosystems and injecting carbon dioxide into concrete).

4.3 An Economic Stimulus

4.3.1 BUSINESS OPPORTUNITIES

The transition to a low carbon world involves investments across the economy in building retrofits, renewable energy, energy storage, transit systems and active transportation infrastructure. These investments, which are incremental to business as usual investments, total $22 billion over 30 years and will stimulate economic activity for existing and new businesses. To put this in perspective, this investment is an annual stimulus equivalent to 4% of Halifax's annual GDP of approximately $17 billion.[15] Much of the investment, for example in building retrofits, would be directed to local businesses and suppliers. Figure 5 shows these investments by economic sector.

[12] A technology that produces electricity from solar radiation.

[13] District energy systems use a central energy plant to provide efficient heating, cooling, and hot water to a group of buildings.

[14] Hydrogen fuel that is produced through renewable electricity.

[15] Statistics Canada reports that Metropolitan Halifax's GDP was $17.3 billion. See: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610042301

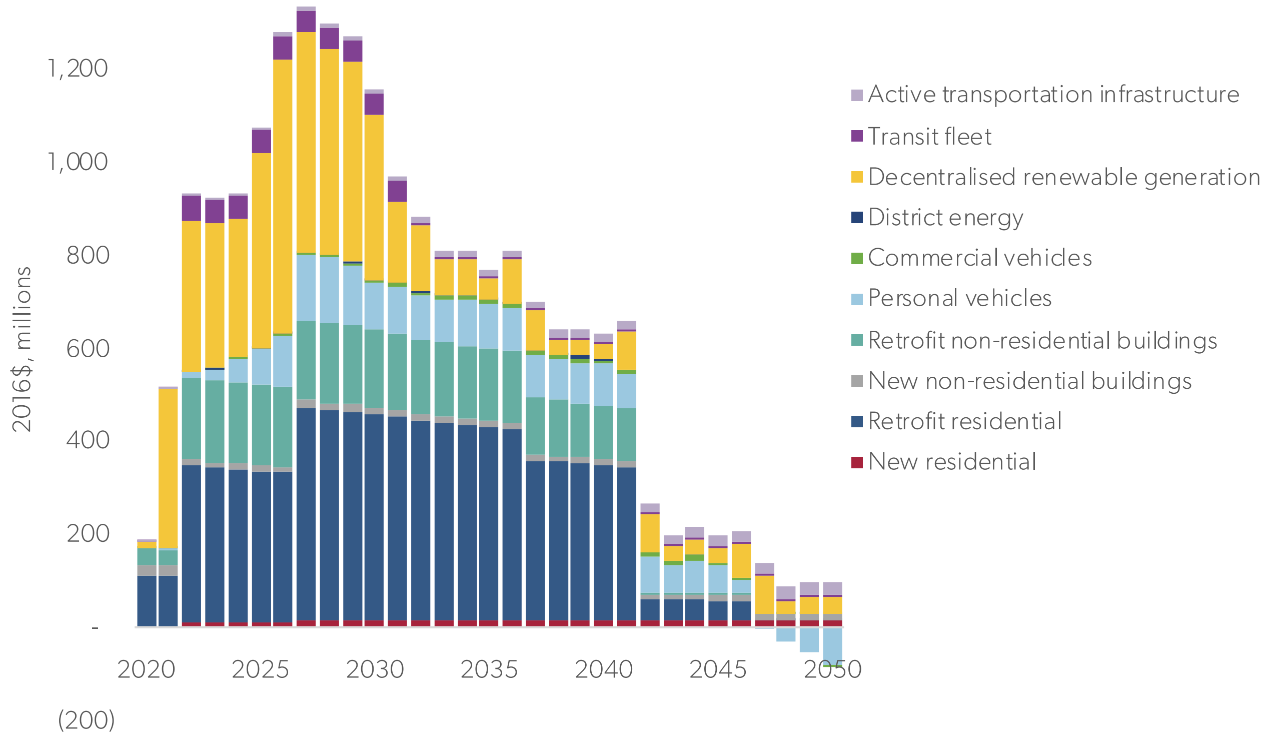


Figure 5. Low carbon investments by economic sector

4.3.2 REDUCING COSTS

A low carbon future is a lower cost future.

Low carbon investments generate financial returns. As a package, the investment is more than offset by cost savings, resulting in a net benefit of $22 billion, or $8.7 billion using a social discount rate of 3%.[16] The savings result from avoided energy costs, avoided operations and maintenance costs, avoided carbon pricing costs, and increased energy generation revenues. Each investment has a different financial return profile, depending on the savings or revenue generated, and future projections of avoided costs.

One of the largest savings occurs from avoided fuel and electricity costs. In 2016, total energy costs paid by the residents, businesses, and all other organizations in Halifax totalled $1.5 billion. Under a Business As Usual scenario, these are projected to increase to $1.73 billion by 2050. Through full implementation of the low carbon scenario, energy costs are reduced by $1.2 billion in 2050, most of which result from reduced consumption of gasoline and fuel oil. Figure 6 shows these energy savings over time.

[16] Discounting reflects the idea that people would rather have $100 now than $100 in ten years. The Government of Canada recommends 3% in circumstances where environmental and human health impacts are involved. Environment and Climate Change Canada. (2016).

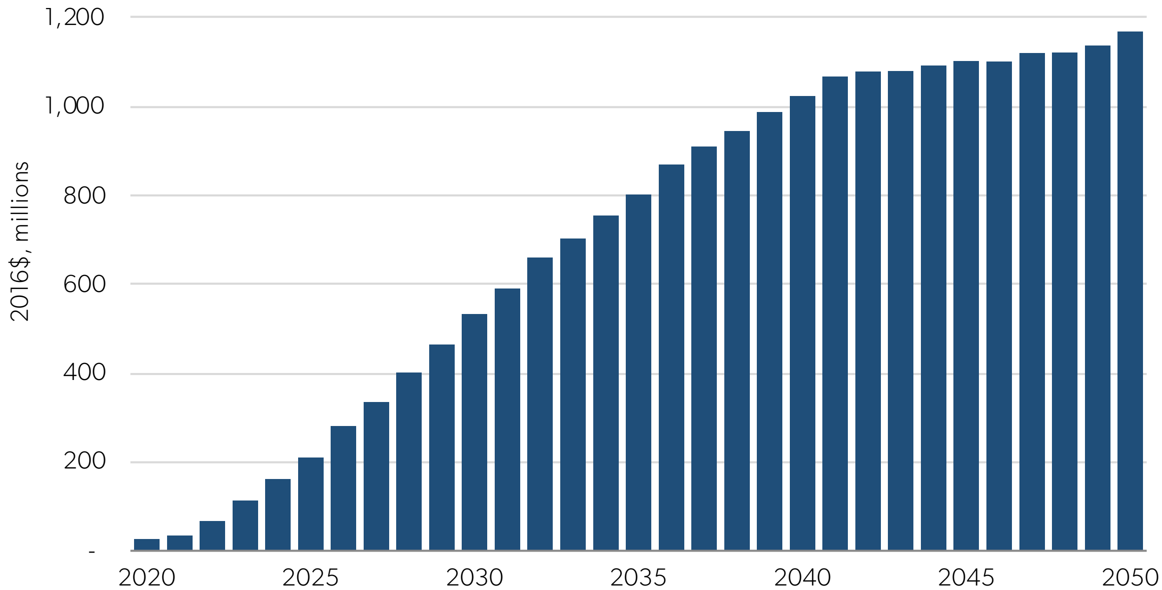


Figure 6. Annual savings in energy expenditures in Halifax from the low carbon pathway

Table 2 shows a breakdown of energy costs between 2020 and 2050 if the low carbon pathway is followed. These significant savings will improve the lives of residents and the strength of the economy by providing opportunities to use these savings to innovate, reinvest, save and enjoy.

Table 2. Impact of the low carbon pathway on energy costs

ENTITY	2020	2050
Energy costs per household	$5,220	$1,458
Businesses	M$315	M$117
Industries	M$55	M$45
Institutions	M$175	M$82

4.3.3 JOB CREATION

The transition requires many people to be engaged in work with new and existing jobs. New employment will result from the implementation of HalifACT 2050, with approximately 170,000 person years of employment generated between 2020 and 2050, an average of 5,500 annually, compared to the Business As Usual scenario. Figure 7 shows this additional employment by job category.

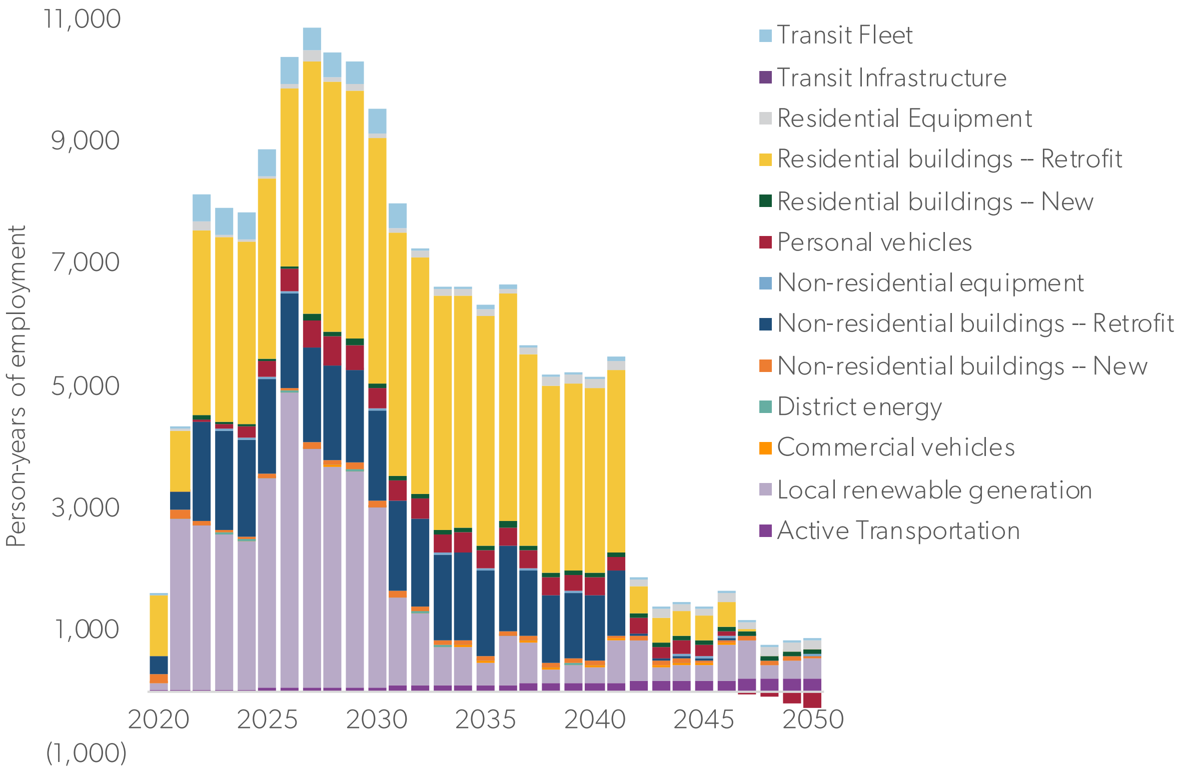
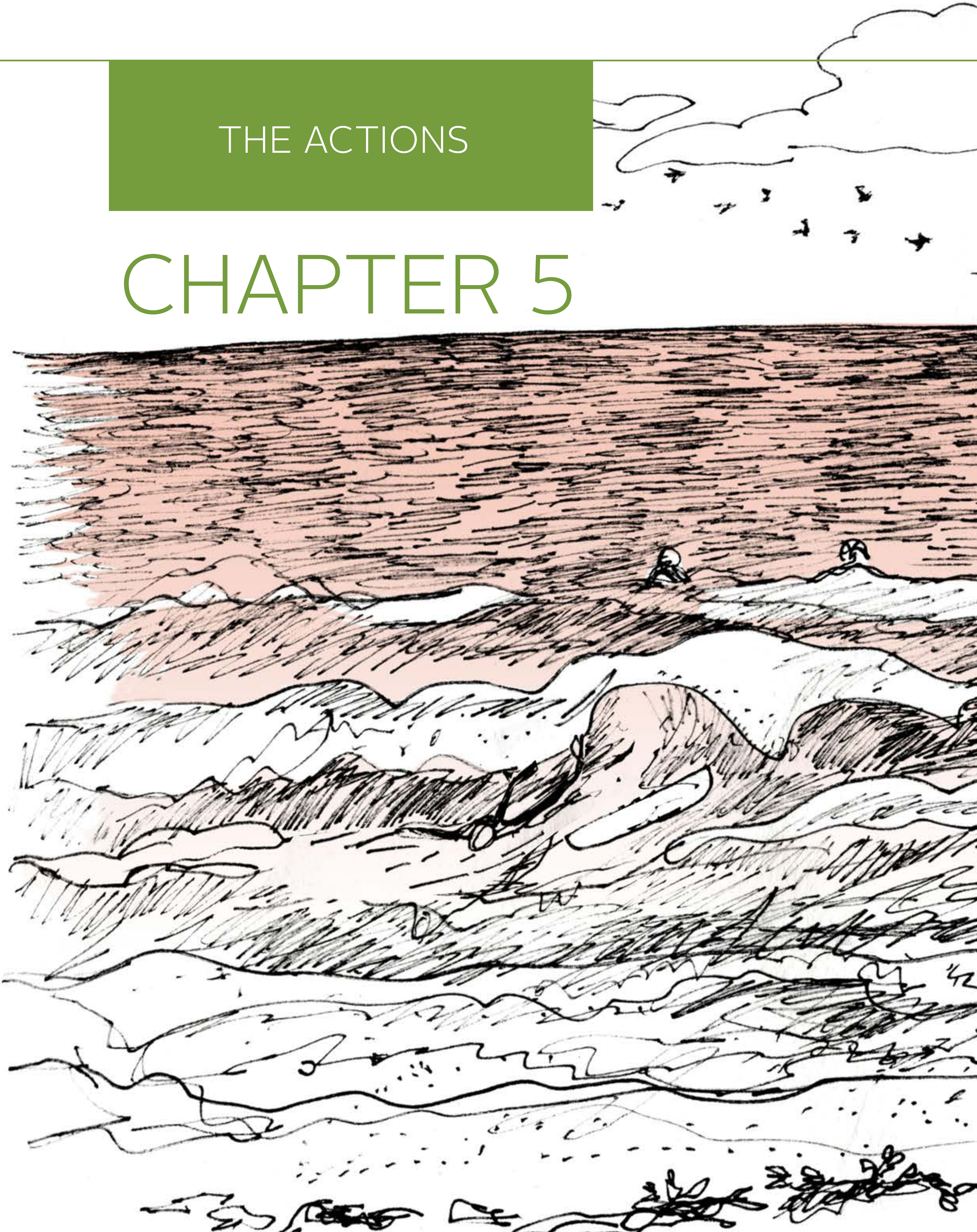
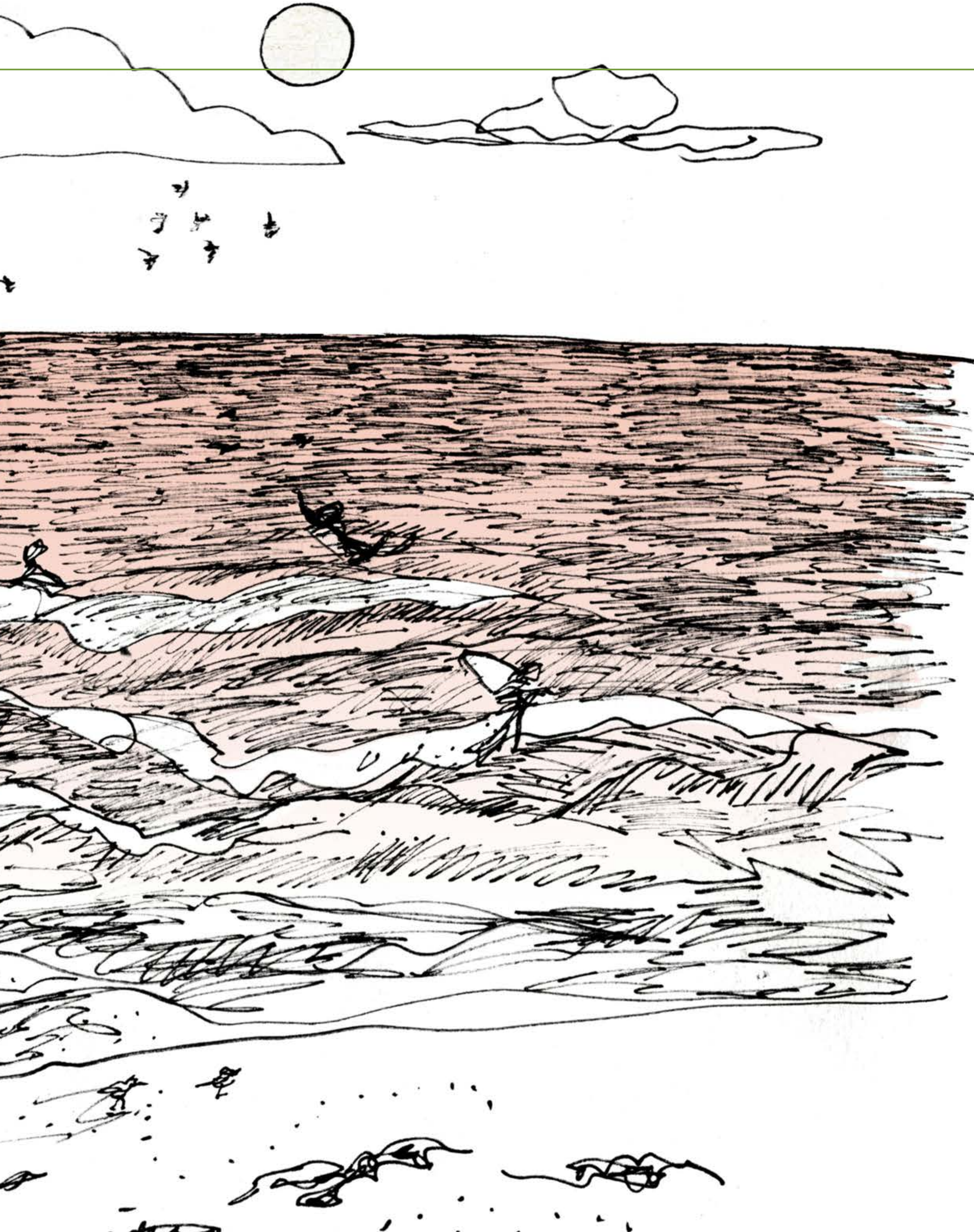


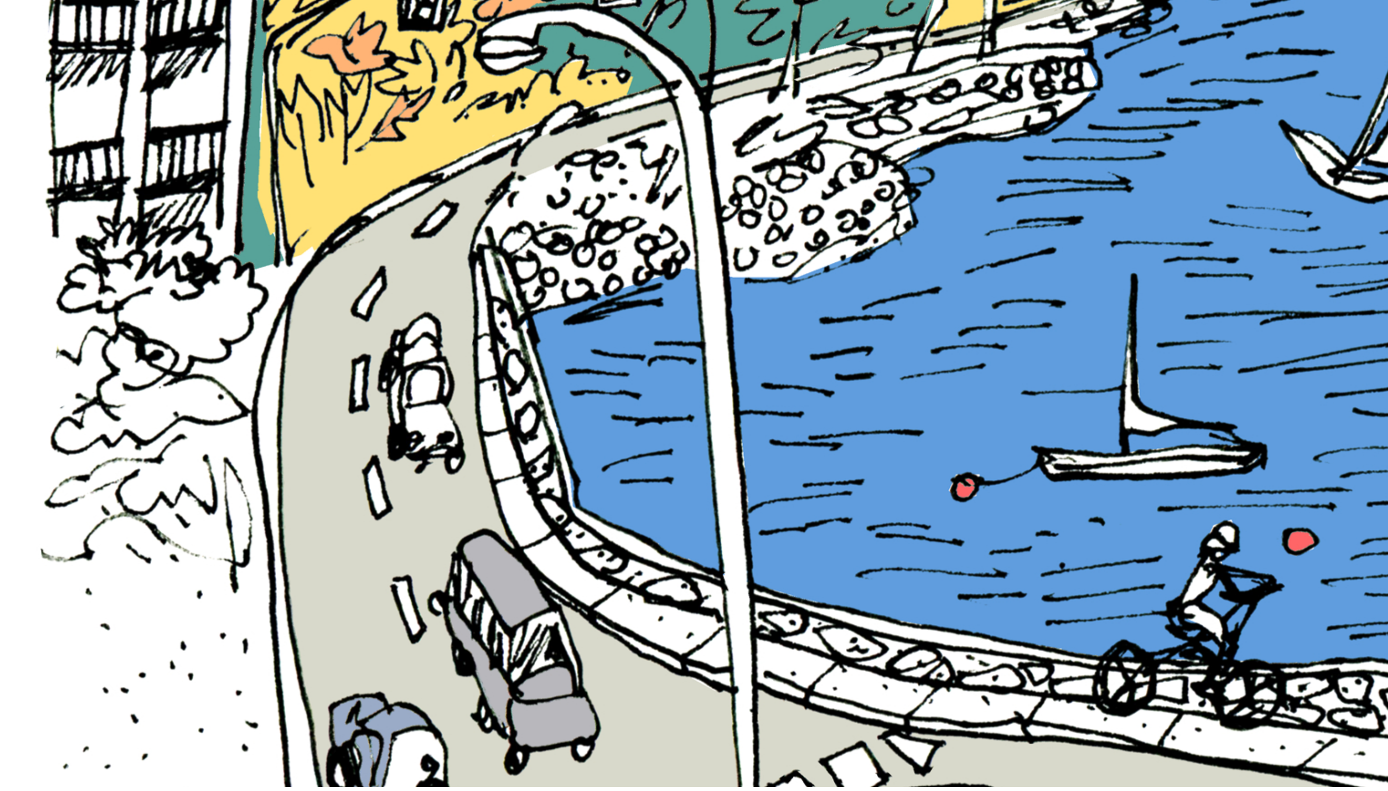
Figure 6. Person-years of employment by sector resulting from the low carbon pathway

THE ACTIONS

CHAPTER 5







5. The Actions

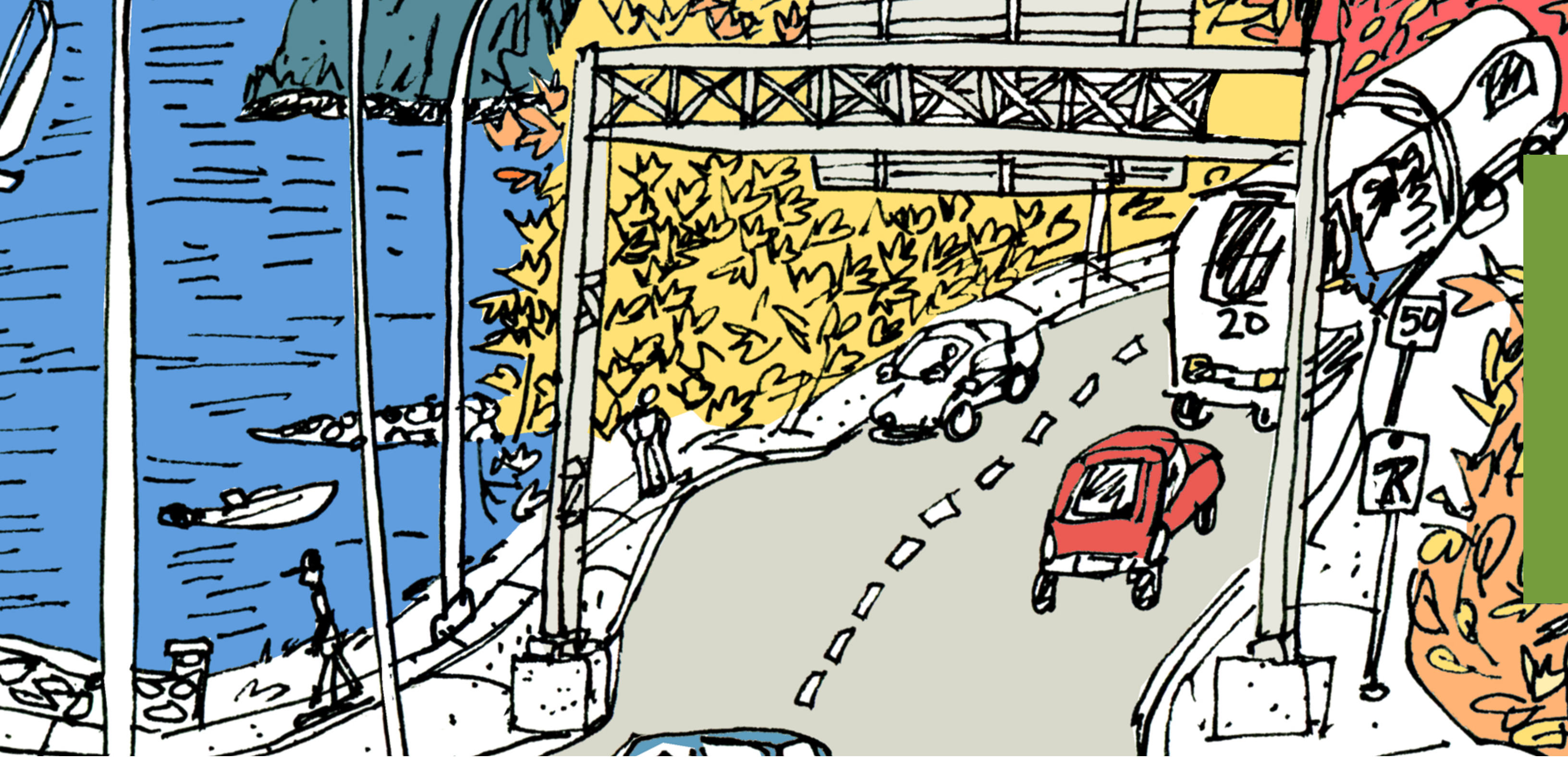
And now for the exciting part – the actions we can take collectively as a community to achieve our climate action goals from now until 2050. Actions are grouped by three main themes: decarbonized and resilient infrastructure, prepared and connected communities, and governance and leadership.

5.1 Actions Summary

DECARBONIZED AND RESILIENT INFRASTRUCTURE			
Efficient Buildings	Renewable Energy	Decarbonizing Transportation	Greening Government Operations
Water	Planning	Critical Infrastructure and Services	Coastal Preparedness
Natural Areas and Green Infrastructure Assets			

PREPARED AND CONNECTED COMMUNITIES			
Food	Community Capacity	Emergency Management	Business Economy

GOVERNANCE AND LEADERSHIP			
Monitoring and Reporting	Carbon Accounting	Mainstreaming Climate into Municipal Operations	Governance and Capacity for Action



Timelines for Action

In a perfect world we would get started on all 46 actions immediately, but we need to be realistic and consider resource constraints and other barriers to implementation. The timing and length of actions can be adapted to respond to changes in policy, technology and funding. We have assigned start times to each action as defined here:

Immediate: action to begin right away
Short: action should be initiated within 2-3 years
Medium: action should be initiated in the next 4-5 years
Long: action should be initiated in the next 6-10 years
Ongoing: action has been initiated and will continue throughout the life of the plan

5.2 Decarbonized and Resilience Infrastructure

5.2.1 EFFICIENT BUILDINGS

ACTION		TARGET OR OBJECTIVE	TIMING
1	Develop, adopt and apply a standard for net-zero and climate resilient new construction	Net-zero new construction by 2030	
2	Develop a retrofit program to enable and fast-track deep energy and climate resilience retrofits in residential and non-residential buildings	Retrofit all existing buildings by 2040	
3	Develop an industrial coalition and support program for improving industrial process efficiency	Improve industrial process efficiency 75% by 2040	

Buildings accounted for approximately 70% of total energy use in Halifax in 2016, and 77% of total emissions. Retrofitting residential and non-residential buildings, ensuring that new buildings are more efficient, and working to improve industrial processes are all necessary components of a successful energy transition for Halifax.

Enhanced performance of new buildings and the improvements made to existing buildings will also make buildings more resilient to future climate impacts such as severe storms, flooding and heat. To maximize the benefit, the retrofit program will prioritize members of the community who are considered most vulnerable to climate impacts.

These programs will be delivered in collaboration with the Municipality, private homeowners, businesses, other levels of government, and industrial partners. By working together to achieve the targets described above, building energy demand can be decreased by 60%, and GHG emissions by 92%.

Making New Buildings as Efficient as Possible

The design of new buildings can maximize energy performance by considering solar orientation, building shape, energy performance of the envelope and roof, and high-efficiency equipment.

In contrast, a retrofit is constrained by design decisions made in the past, especially orientation and building type. Retrofit programs also need to consider factors such as disrupting households or employees and working with and around existing components of a building or home.

As a result, there are physical limitations on the level of energy performance that can be achieved through deep retrofits and the avoided costs of building better now result in an imperative to maximize energy performance in new construction.

5.2.2 RENEWABLE ENERGY

ACTION		TARGET OR OBJECTIVE	TIMING
4	Expand programming for rooftop solar systems and energy storage	Install 1,300 MW of rooftop solar PV with storage by 2030	
5	Develop partnerships for large-scale solar 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	Develop a district energy initiative to decarbonize and expand district energy		
7	Actively support, advocate and partner with Nova Scotia Power, the Province, and others to decarbonize the provincial electricity grid		

Many of the actions and recommendations to reduce GHG emissions across Halifax require switching from higher-carbon fuels, like fuel oil and gasoline, to zero carbon electricity. Halifax already has a residential rooftop solar program, Solar City, which will be adapted and expanded to include deep energy retrofits and climate resilience measures. In addition, community-scale solar and wind generation will increase the supply of local renewable energy, while also stimulating the local economy and building on local business expertise. Halifax has existing district energy networks that will need to be transitioned to 100% renewable energy sources by 2050.

District Energy: A Path to Renewable Heat

District energy systems are mature technology that use centralized heating plants to heat or cool multiple buildings connected to a distribution network. The distribution system enables a plug and play approach to adopting new renewable sources of heat as technology evolves. Potential sources include waste heat from industrial processes, ground source heat pumps and deep water cooling.[17]

District energy systems are most effective when they serve energy-dense areas. A preliminary rule is that areas with an energy density of greater than 150 megajoules per square metre (MJ/m^2) are viable sites for district energy.[18] Typically this defines an area that includes large buildings with multiple uses, high residential density and compact neighbourhoods.

By including energy storage with renewable generation, communities will be more resilient to power outages from extreme weather events, and will be better able to supply essential services to the community.

[17] Hast, A., Syri, S., Lekavicius, V., Galinis, A. (2018). District heating in cities as a part of a low-carbon energy system. Energy, 152, 627–639, https://doi.org/10.1016/j.energy.2018.03.156.

[18] Moller, B., & Werner, S. (2016). Quantifying the potential for district heating and cooling in EU member states. http://www.heatroadmap.eu/resources/STRATEGO%20WP2%20-%20Background%20Report%206%20-%20Mapping%20Potential%20for%20DHC.pdf.

5.2.3 DECARBONIZING TRANSPORTATION

	ACTION	TARGET OR OBJECTIVE	TIMING
8	Expand 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	Collaborate with local organizations and businesses to develop a community-wide EV strategy	By 2030, 100% of new vehicle sales are electric	
10	Prepare for and catalyze electric vehicle uptake through planning and policy		

Halifax covers a large geographic area and as a result, communities and citizens are heavily reliant on public and private transportation for daily life. Switching to electric vehicles for private, public, and commercial transportation will reduce fuel costs, improve air quality, and reduce maintenance requirements. Wide-spread adoption of electric vehicles will require planning for and building charging infrastructure throughout Halifax, and coordination with local partners and industry specialists to prepare for a shift from gasoline to electricity.

By expanding transit and active transportation networks, more community members will be able to choose lower-carbon transportation methods, reducing congestion, improving air quality, and improving the physical and mental health of residents.

5.2.4 GREENING GOVERNMENT OPERATIONS

	ACTION	TARGET OR OBJECTIVE	TIMING
11	Adopt a commitment, develop a detailed and costed infrastructure plan, and finance implementation to achieve net-zero municipal operations by 2030	Achieve net-zero municipal operations by 2030	

Municipalities are on the frontline of climate action, as the infrastructure and services they operate are directly exposed to the impacts of climate change. As a result, municipalities around the world are taking leadership on reducing GHG emissions and adapting their operations.

Halifax's leadership role will include retrofitting and future-proofing existing municipally-owned buildings and requiring that new municipal buildings achieve net-zero emissions, beginning in 2020. Targets include electrifying the municipal fleet, including ferries, by 2030, developing a waste strategy to reduce residential waste and increase waste diversion, to generate renewable electricity in municipally-owned projects, and to purchase local zero-carbon electricity. These actions combine to achieve net-zero municipal operations by 2030.

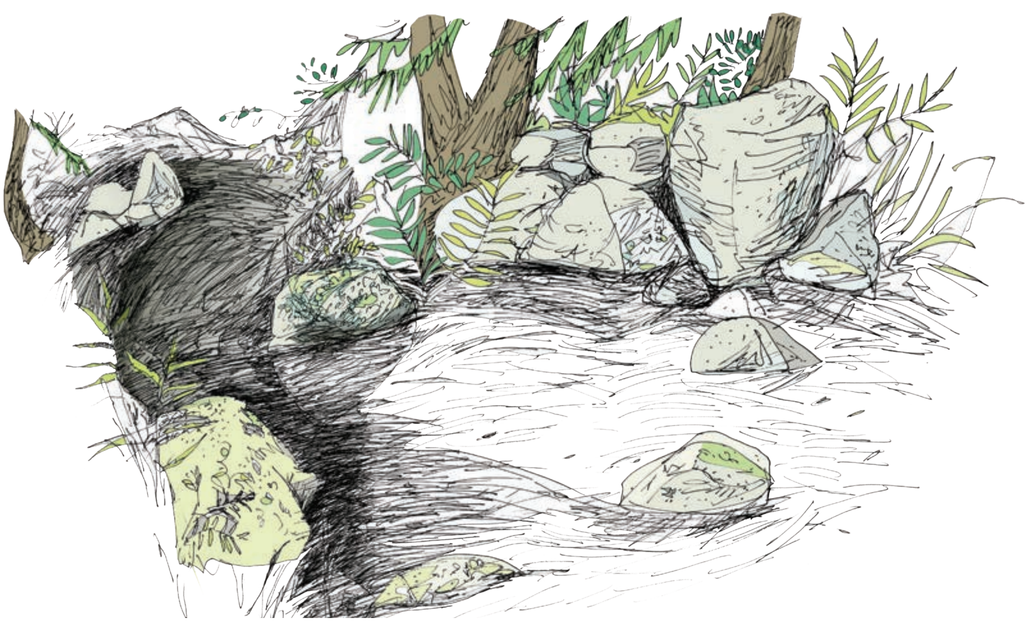
5.2.5 WATER

ACTION		TARGET OR OBJECTIVE	TIMING
12	Adopt a commitment and develop a detailed plan to achieve net-zero water and wastewater operations by 2030	Achieve net-zero water and wastewater operations by 2030	
13	Develop a holistic, integrated, and climate-informed water supply strategy	Future proof water systems and supply	
14	Develop a holistic, integrated, and climate-informed stormwater management plan and program		

Water and wastewater management in the future will require the management of energy and emissions, as well as future-proofing to ensure water supplies and infrastructure are adapted to future climate conditions and risks. Community-wide water conservation measures will include infrastructure improvements and water use behavioural changes, as well as reducing the amount of stormwater entering the wastewater system through sewer separation and promoting on-site infiltration and water retention.

Biogas recovery from wastewater will need to be used to generate electricity to replace other fuel sources, while also reducing the amount of GHG emissions released from wastewater.

Water resources require future-proofing to ensure a reliable supply of fresh water during emergencies, and as a result of changes in precipitation patterns and temperature. Management of water supplies, including stormwater, wastewater, and freshwater, will incorporate climate considerations. Green infrastructure is a core component of effective stormwater management. An integrated approach to water management will involve close coordination between the Municipality, the Halifax Regional Water Commission and the public.



5.2.6 CRITICAL INFRASTRUCTURE AND SERVICES

ACTION		TARGET OR OBJECTIVE	TIMING
15	Conduct a high-level risk assessment (HLRA) with internal and external stakeholders for utilities, transportation, water, health facilities and telecoms		
16	Conduct a detailed spatially-based risk and vulnerability analysis of municipally-owned and -operated critical infrastructure at the asset class and system level		
17	Install zero-emissions back-up power in critical infrastructure	Reduce risk to critical infrastructure	
18	Develop inspection procedures for high-risk infrastructure to identify resulting damage from extreme events		
19	Develop or update codes and design standards for new municipal and private infrastructure that reflect future climate impacts		

Halifax depends upon a complex network of infrastructure. These systems function to produce and deliver a reliable flow of services that are critical to support economic prosperity and social wellbeing. These systems include energy, telecommunications, transportation, water supply, wastewater treatment, solid waste management, buildings and food systems.

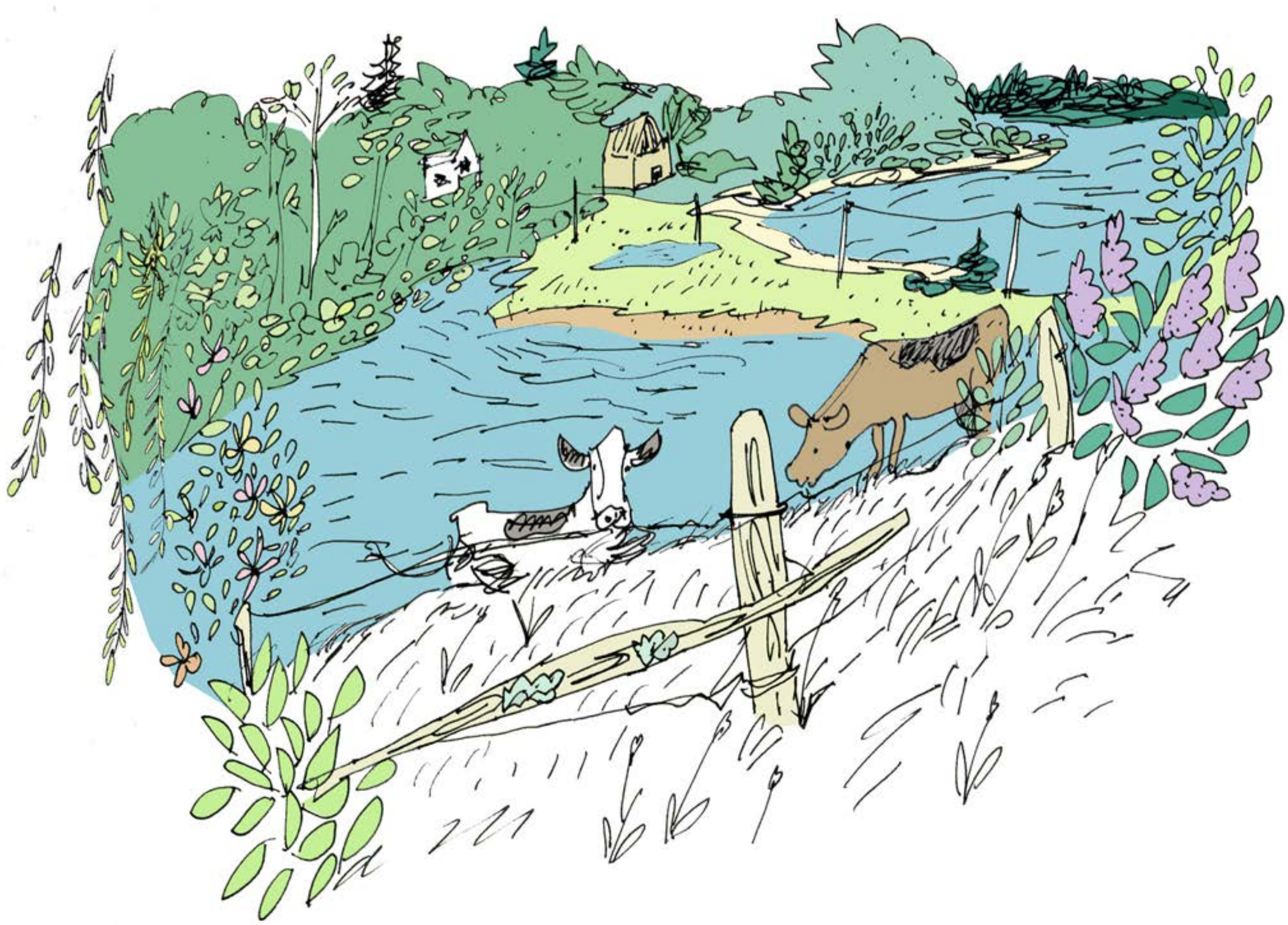
Critical infrastructure needs to withstand the impacts of climate change, both in the near and long term. This objective requires proactively protecting and strengthening infrastructure to ensure it can withstand increasingly extreme storms and climbing average temperatures amongst other impacts that come with climate change. By improving the resilience of infrastructure now, the reactive resources needed for emergency response or to repair or rebuild from future impacts are reduced.

5.2.7 NATURAL AREAS AND GREEN INFRASTRUCTURE

ACTION		TARGET OR OBJECTIVE	TIMING
20	Fund and implement the Green Network Plan and Urban Forest Master Plan		
21	Continue the naturalization program through pilot projects, public education and awareness to support the development of a region-wide naturalization program	Protect, restore, maintain and expand natural areas and green infrastructure assets	
22	Develop and implement a region-wide tree planting and re-greening program		

Natural areas and green infrastructure increase water infiltration and reduce runoff, reduce the heat island effect,[19] improve water quality, provide shade and areas for reprieve, and sequester carbon. Examples of natural areas and green infrastructure include parks, trees, shrubs, urban forests, green roofs and walls, gardens, bioswales,[20] natural channels, watercourses, ponds, and constructed wetlands.

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. Halifax 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.



[19] The heat island effect occurs when closely-packed buildings and paved surfaces amplify and trap heat in dense urban areas. These surfaces trap heat more effectively than natural ecosystems. Urban areas also generate heat through furnaces, air conditioners and vehicles, contributing to the problem.

[20] Bioswales are engineered channels designed to gather stormwater runoff. They typically are covered in plants and vegetation and allow runoff to enter back into the groundwater supply while also reducing overland flow.

Green Infrastructure

Stormwater best management practices (BMPs), such as green infrastructure, mimic natural processes to manage stormwater water at the source and create healthier urban environments. Recognizing this, the Municipality is working collaboratively with Halifax Water to develop stormwater management standards that will capture and treat stormwater on-site for high-density residential, institutional, commercial and industrial developments. Further work will include applying these new standards to the public right-of-way through the Municipal Design Guidelines. The reimagining of Spring Garden Road in downtown Halifax offers the opportunity to integrate ecological processes into an urban setting in a way that has not yet been tested in the municipality.

5.2.8 PLANNING

ACTION		TARGET OR OBJECTIVE	TIMING
23	Integrate climate into land use planning policies and processes	Plan and build a low-carbon resilient region	
24	Plan for the deployment of carbon-neutral district energy and microgrid systems		
25	Increase land protection and conservation on private lands through partnerships, collaboration and municipal planning requirements		
26	Acquire more land to preserve natural areas and ecosystem health in alignment with the Green Network Plan		

Land use planning plays a critical role in designing and building communities that are prepared and adapted to climate change, while also maintaining the physical and mental wellbeing of residents. Planning policies through the Regional Plan and municipal planning strategies can provide direction to reduce sprawl and allow for the efficient use of land, energy, and transportation systems. These strategies should also emphasize green spaces, urban forests, and community spaces that further reduce urban heat island effects and improve the environmental health of communities.

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.

Additionally, land use planning can help avoid development in hazard-prone or high-risk areas to reduce exposure to climate hazards through land-use bylaw setbacks, buffers and coastal elevations, and ensure that new development is climate-ready.

Conservation and Climate Action – A Perfect Pairing

We will not succeed in addressing climate change if we do not protect and enhance the natural environment we depend on for survival. Natural areas like forests and wetlands produce oxygen, filter the air we breathe, clean our drinking water, hold flood waters, regulate climate and absorb carbon dioxide, a greenhouse gas. Valuing these important functions economically is critical to their consideration in decision-making. Natural capital allows for this analysis, defined as "the stock of natural resources (finite or renewable) and ecosystems that provide direct or indirect benefits to the economy, our society, and the world around us."[21] By assigning value to things like flood control and climate regulation, these natural assets can be considered more meaningfully in cost benefit analyses and decision-making.

5.2.9 COASTAL PREPAREDNESS

	ACTION	TARGET OR OBJECTIVE	TIMING
27	Conduct a detailed spatially-based risk and vulnerability analysis of Halifax's coastal, waterfront, and shoreline area	Better prepare for climate related coastal changes and impacts	
28	Develop a coastal-specific adaptation strategy with coastal communities		

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.

Current policy requires a vertical setback from the coast for ground floor residential properties in the municipality for safety purposes. The Province of Nova Scotia recently enacted a new piece of legislation, the Coastal Protection Act, which will further protect coastal properties. The Municipality has procured a new Digital Elevation Model to allow for detailed flood risk modelling and land use vulnerability assessments.

In order to protect assets, manage coastal environments, and reduce exposure to climate risks, a detailed risk and vulnerability analysis of coastal, waterfront and shoreline areas will be completed, and a coastal-specific adaptation strategy will be implemented to protect and manage at-risk natural and infrastructure assets.

[21] TD Economics. 2014. Valuing the world around us: an introduction to natural capital. Special Report. November 20, 2015. Retrieved from https://www.td.com/document/PDF/economics/special/NaturalCapital.pdf

Cumulative Impact of Small Measures

One green roof, or one tree, while providing co-benefits[22] and reducing flooding and heat impacts, will only do so on a small scale. When deployed at a large scale, for example 10,000 green roofs or 100,000 trees, the cumulative impact to reduce risk more broadly and provide benefits become much more significant, specifically if they are deployed in areas prone to flooding and the heat island effect. For green infrastructure, the whole is truly more than the sum of its parts.

5.3 Prepared and Connected Communities

5.3.1 EMERGENCY MANAGEMENT

ACTION		TARGET OR OBJECTIVE	TIMING
29	Develop climate event evacuation plans: flooding, wildfire and coastal storm surge	Better prepare for increased climate-related emergencies	
30	Improve emergency management communication and coordination across EMO agencies and organizations		

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 organizations. Demands are likely to increase from both chronic stresses, such as higher average temperatures, and acute shocks, specifically extreme events such as heat waves and flooding, as a result of the growing impacts on human health.

Climate impacts are expected to be greater for vulnerable people and populations, including seniors, children, those experiencing social isolation, individuals with chronic conditions and disabilities, and socially or economically marginalized individuals.

In addition to preparing for an increase in extreme climate events, ongoing investment to increase the resilience of infrastructure and to provide supportive service to emergency management will alleviate the pressures on emergency management staff and infrastructure.

[22] Benefits that are additional to the primary objective (e.g. to energy efficiency and emissions reductions).

5.3.2 COMMUNITY CAPACITY

	ACTION	TARGET OR OBJECTIVE	TIMING
31	Create Disaster Support/Community Resilience Hubs for community self-sufficiency	Enhance the capacity of neighbourhoods to prepare for and recover from climate events	
32	Make emergency management training widely available to residents and businesses		
33	Undertake climate planning sessions with neighbourhood organizations to develop local climate plans and coordinate mitigation and adaptation efforts		
34	Work purposefully, meaningfully, and collaboratively, with the Mi'kmaq and other groups seeking reconciliation, including African Nova Scotian communities	Engage deeply and collaboratively	

More resilient neighbourhoods make a more resilient city. While comfort centres exist across the municipality and are critically important for emergency management, neighbourhoods that invest in connections, capacity building, and resources on a sustained basis are better able to withstand crises and address many of the chronic socioeconomic stresses that increase climate vulnerability. Increasing the built and social capacity of neighbourhoods not only empowers them to be more independently resilient, but contributes to the resilience of the region as a whole.

Each community will identify priorities and leaders to build capacity and connections with other communities to share resources, training, knowledge and solutions. The Municipality will help support capacity building and foster engagement and connectivity across communities.

5.3.3 FOOD

	ACTION	TARGET OR OBJECTIVE	TIMING
35	Improve food security and food systems resilience	Create and implement a Food Action Plan, and include climate change as a core component	

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 to GHG emissions, for example 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.

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. A focus of this plan is to address climate change, and funding its implementation will improve food systems resilience, reduce emissions from food, and build food security for those most vulnerable to the impacts of climate change.

5.3.4 BUSINESS AND ECONOMY

ACTION		TARGET OR OBJECTIVE	TIMING
36	Expand workforce and technology development programs and funding to grow skills and trades for decarbonization and resilience	Prepare and leverage business for the transition	
37	Develop a resilient decarbonized businesses program to support businesses to reduce emissions and prepare for climate impacts		

The transition to a low carbon and climate resilient future will generate professional and skilled labour positions and stimulate local economies. The Municipality will prepare for and catalyze this workforce by engaging with key stakeholders.

Incremental Capital Costs

Investments in existing and new infrastructure are made on an ongoing basis. Vehicles are replaced at the end of life, roofs are replaced on buildings, boilers are replaced, and so on. The low carbon pathway identifies when that infrastructure component will be replaced and substitutes a low carbon option. For example, when a vehicle is being replaced at the end of its life, an electric vehicle is purchased instead of a gasoline vehicle. The financial implication is that the upfront cost is the difference on the price tag between a gasoline vehicle and an electric vehicle, which is called an incremental cost. There are two trends that influence the financial implications of incremental investments:

- Low carbon investments generally result in cost savings over the lifetime of the investment. This leads to a net benefit, even with a higher upfront cost.
- The incremental costs of the low carbon investment are declining over time. For example, some analysts indicate that electric cars will be at price parity with conventional vehicles by 2026.

A Climate Ready Halifax

The technical pathways (combined set of policies and actions) for reducing GHG emissions are readily available today. But there is great uncertainty about how best to prepare for climate change, including the scale and location of the impacts. A climate ready organization is able to proactively adapt to rapidly and drastically changing conditions and provide stability and security in tumultuous times.

5.4 Coordinated Governance & Leadership

5.4.1 MAINSTREAMING CLIMATE INTO MUNICIPAL OPERATIONS

ACTION		TARGET OR OBJECTIVE	TIMING
38	Integrate climate into financial decision-making by incorporating climate-related financial disclosure; a cost of carbon and a social cost of carbon[23]; a municipal carbon budget; a climate lens to capital and business planning and asset management	Integrate climate thinking into municipal decision-making and governance	
39	Explore and establish new mechanisms for financing climate action		
40	Incorporate Environmental, Social, Governance (ESG) principles into the management of municipal funds		

Climate change is having, and will continue to have, a negative financial impact on Halifax. Decarbonizing and adapting to the impacts of climate change will require major investments, and mobilizing funding commensurate with the challenge will be difficult at many levels. However, the cost of inaction will only grow over time. Every dollar invested proactively can save as much as four[24] to six[25] dollars on recovery. Many decision-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.

Halifax will establish new mechanisms for financing climate action, while simultaneously rethinking its own municipal fund investment strategies. Embedding climate resilience considerations into financial decision-making will ensure that these investments contribute to reducing emissions and reducing risk throughout the region.

5.4.2 GOVERNANCE AND CAPACITY FOR ACTION

ACTION		TARGET OR OBJECTIVE	TIMING
41	Establish a central Climate Change Office in the Municipality	Integrate climate thinking into municipal decision-making and governance	
42	Significantly increase staff capacity for implementation		

[23] An estimate, in dollars, of the economic damages that would result from emitting one additional unit of greenhouse gases into the atmosphere. The social cost of carbon puts the effects of climate change into economic terms to help decisionmakers understand the economic impacts of decisions that increase or decrease emissions.

[24] Godschalk, D. R., Rose, A., Mittler, E., Porter, K., & West, C. T. (2009). Estimating the value of foresight: aggregate analysis of natural hazard mitigation benefits and costs. Journal of Environmental Planning and Management, 52(6), 739-756.

[25] National Institute of Building Sciences (2017). Natural Hazard Mitigation Saves: 2017 Interim Report.

Halifax can lead on climate change. This will require institutionalizing climate thinking throughout the organization to build the human and technical resource capacity needed to implement climate action both within the organization, and across the municipality.

In order to lead and implement climate action, Halifax will increase staffing throughout the organization, and work closely with key partners across the region. Staff members can be distributed throughout the organization, reporting back to a centralized climate entity with a mandate to unify and streamline the climate response.

Adaptive management: A safe space for innovation, risk and failure

Adaptive management is a style akin to an explorer who has a sense of direction but no clear route. It requires searching and exploring, watching out for possibilities and interrelationships, however unlikely they may seem. Tackling the climate crisis requires an adaptive management style.[26]

5.4.3 MONITORING AND REPORTING

ACTION		TARGET OR OBJECTIVE	TIMING
43	Develop an Annual Indicators Report and report annually on progress	Monitor and report on climate action and impact	

In order to track progress, measure success, evaluate programs and activities, and plan effectively, Halifax will need to monitor and report on:

- Climate and climate events;
- Implementation of actions, and the effectiveness of these actions; and
- Capacity and learning within the Municipality's staff and operations.

By reporting regularly on appropriate measures and indicators, Halifax will be able to understand and report on progress, and apply the approach of adaptive management to evolving climate impacts and risks. Halifax will take advantage of new opportunities, technologies and innovations and will help direct capacity building into appropriate actions and areas.

[26] M. Clarke, M. Stewart, J. (1997). Handling the Wicked Issues—A Challenge for Government, p. 15.

5.4.4 CARBON ACCOUNTING

ACTION		TARGET OR OBJECTIVE	TIMING
44	Develop a values-based framework for carbon offsets	Get ready for neutrality and step up the carbon scope	
45	Develop a consumption-based emissions inventory		
46	Include embodied carbon in new construction standards for buildings		

The implementation of broad-sweeping emissions reductions and efficiency programs and policies will nearly eliminate Halifax's GHG emissions by 2050. Halifax's ability to address its remaining emissions will likely improve in the next 30 years, but negative emissions and offsets will likely need to be considered. The Municipality will consider the development of a values-based framework for carbon offsets that includes guidelines for future policies and programs, and a mandate to explore emerging opportunities.

Current GHG emissions inventories, including the one used as the basis for this plan, are limited to energy use and emissions produced within the geographical boundary of Halifax. The expansion of the emissions framework to include emissions associated with goods and services generated and produced outside of Halifax, and the carbon emissions embodied within new construction, will identify additional opportunities for GHG emissions reductions.

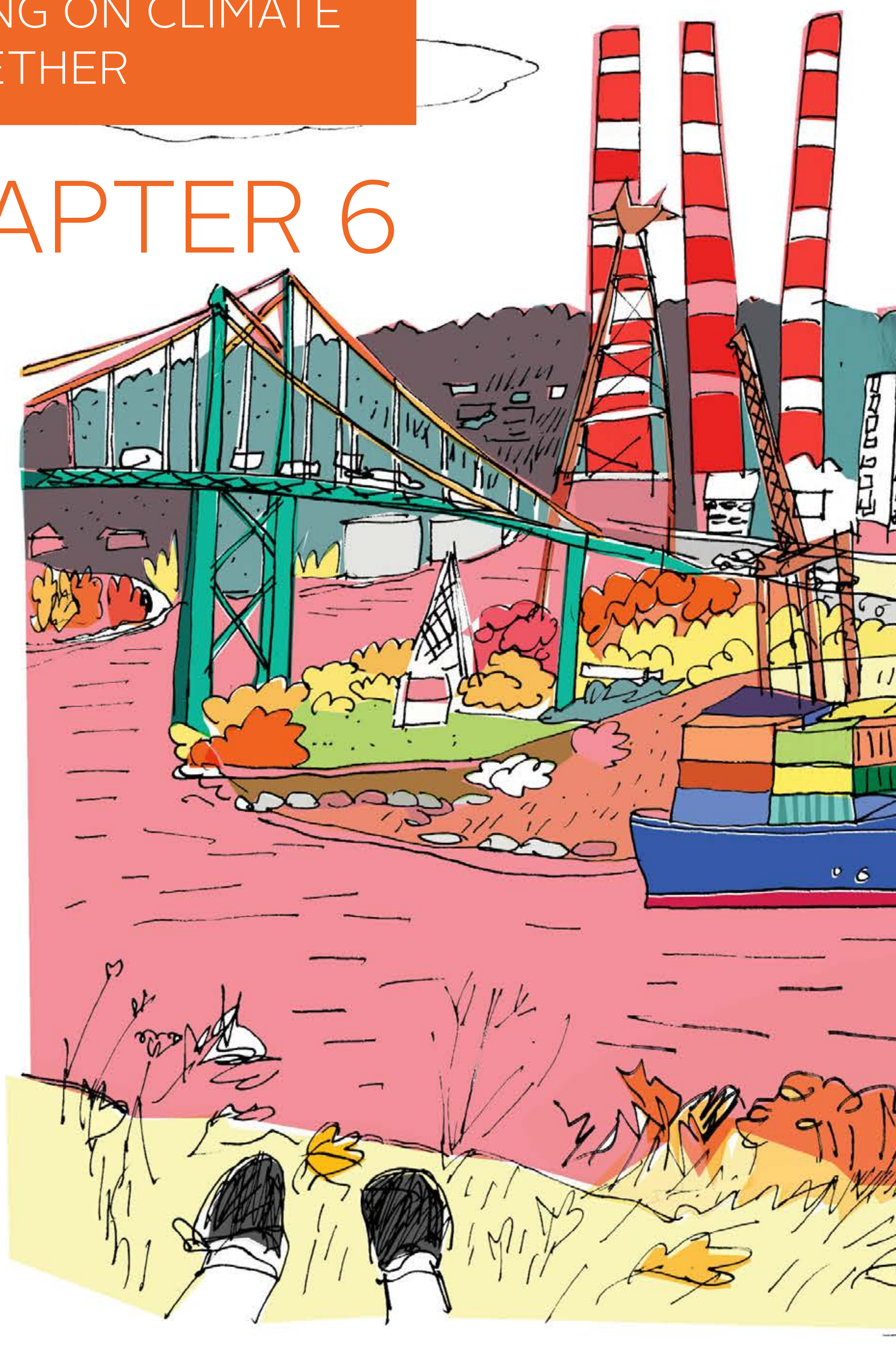
Municipal Carbon Budget

The City of Oslo in Norway has adopted a Climate Budget as an efficient governance system in order to achieve its GHG mitigation targets.[27] The main goals of the Climate Budget are to evaluate the impact of actions, and to require all municipal bodies to submit regular status reports on the actions under their responsibility. The Budget requires collaboration between departments in order to achieve the annual targets. The reporting process is aligned with the standard financial budget reporting cycle. Fourteen indicators are published three times each year on the city's Climate Barometer, which provides an early indication of progress.

[27] City of Oslo, 2019. City of Oslo Climate strategy and climate budget. https://www.oslo.kommune.no/politics-and-administration/green-oslo/best-practices/oslo-s-climate-strategy-and-climate-budget/#gref

ACTING ON CLIMATE TOGETHER

CHAPTER 6




ACL
EMF

6. Acting on Climate Together

The level of effort and timelines of this plan are ambitious and unprecedented. Halifax will mobilize its resources to support the implementation of the actions in HalifACT 2050, allocating responsibilities across the organization, and in many cases coordinating with partner organizations and other levels of government. In the next five years, Halifax will focus on seven priority actions that enable Halifax to remain within the low carbon pathway. These actions are as follows:

1. Retrofit and renewable energy programming
2. Retrofit municipal buildings to be net-zero ready and climate resilient
3. Electrification of transportation
4. Net-zero standards for new buildings
5. Framework for assessing and protecting critical infrastructure
6. Capacity building for climate adaptation; and,
7. Financing strategy to operationalize the HalifACT 2050 plan over 30 years.

Given the urgency of the issue and the scope of the solutions, multiple partners, both internal and external to the Municipality, are needed to effectively implement the actions outlined in this plan. New ways of working are required that allow us to work collaboratively, test and refine ideas with nimbleness, and easily track progress in addressing this complex problem. We will continue to test and explore different approaches to enable collaboration with community partners.

Reporting, measurement, and evaluation processes will increase the understanding of impacts of climate change and the scope and effectiveness of interventions. The project team will track climate and climate events, action implementation and effectiveness, and capacity and learning indicators and report on progress on a yearly basis. This process enables a safe space for trying new approaches and taking risks and ensures transparency for the broader community and stakeholders.

Every great challenge presents great opportunities. As much as climate change presents risks, the actions that reduce GHG emissions and increase resilience can save money, increase community wellbeing and improve environmental sustainability. Imagine the future of Halifax, should this plan be implemented - a more equitable, vibrant and cohesive city.

This plan is a pathway to a resilient and low carbon community, and there will be many twists and turns and decision points along the way as new technologies emerge, economies transform, science progresses, and society evolves. However, the time to act is now. Halifax will work in the spirit of cooperation, adaptive management, urgency, equity and hope to collectively and meaningfully tackle the climate crisis. Join us.

Attachment B

Halifax Regional Municipality

Energy Use and Greenhouse Gas Emissions

Baseline Inventory, 2016 &

Business-As-Usual Scenario to 2050

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

Completed by:

Sustainability Solutions Group

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Context

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

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

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

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

This report is divided into two parts:

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

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

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

Executive Summary

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

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

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

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

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

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

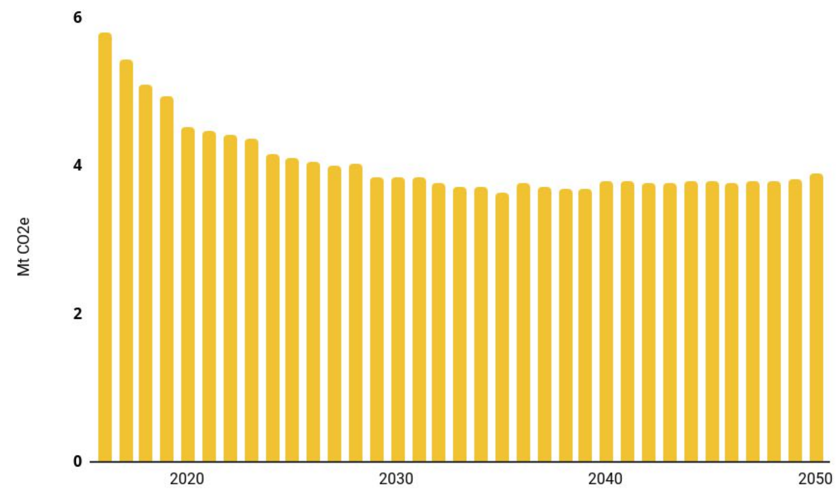


Figure 1. Projected BAU emissions for HRM (tCO2e), 2016-2050.

Part 1:

Energy & Emissions, 2016-2050

Demographics

Population

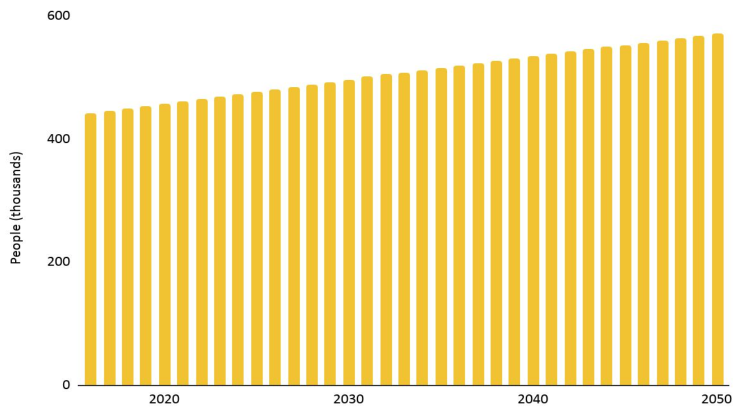


Figure 2. Projected population, 2016-2050.

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

Employment

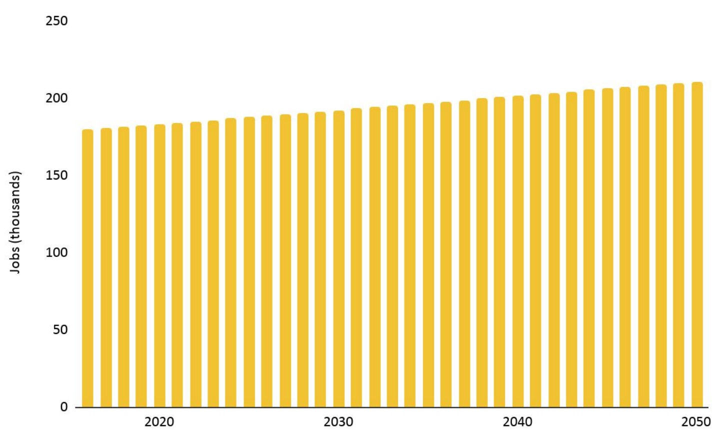


Figure 3. Projected employment, 2016-2050.

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

Households

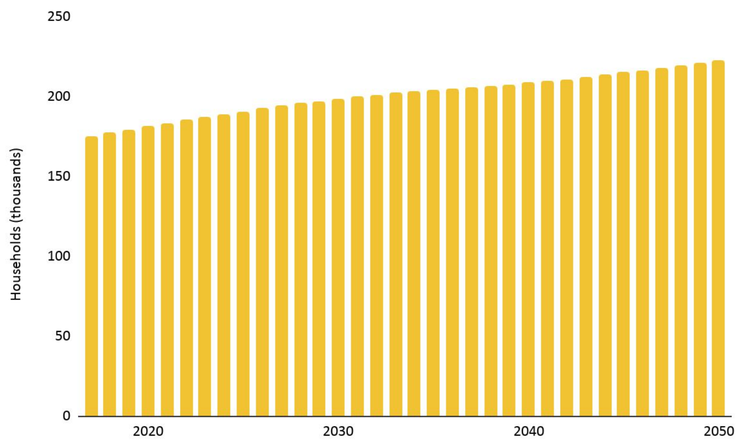


Figure 4. Projected households, 2016-2050.

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

Community Energy

Energy by sector

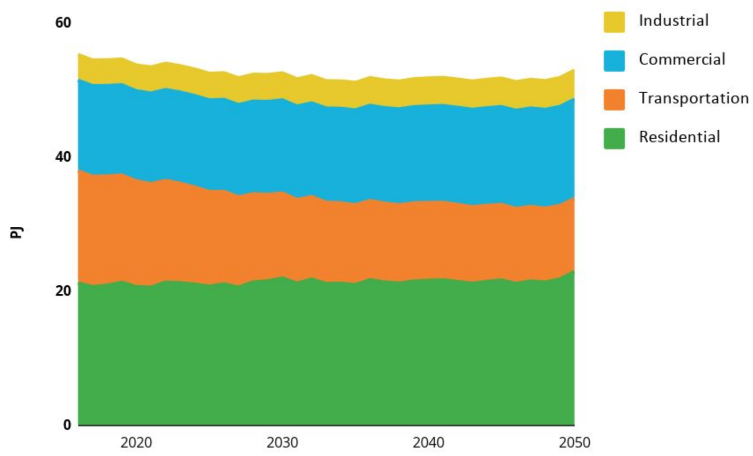


Figure 5. Projected BAU energy consumption (PJ) by sector, 2016-2050.

Energy by fuel

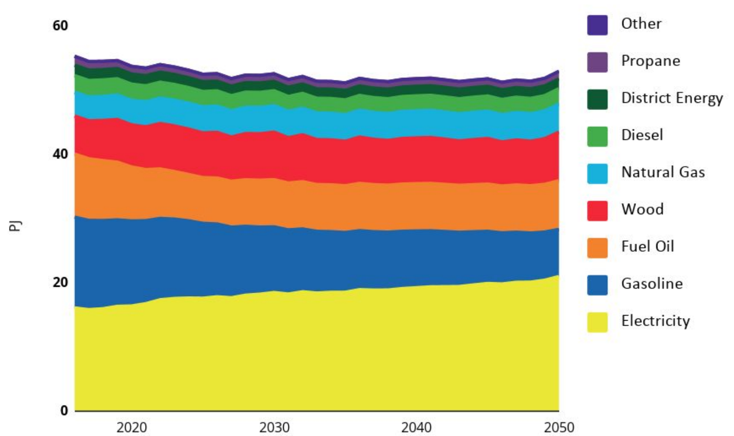


Figure 6. Projected BAU energy consumption (PJ) by fuel, 2016-2050.

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

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

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

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

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

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

Local Energy Production

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

Per Capita Energy

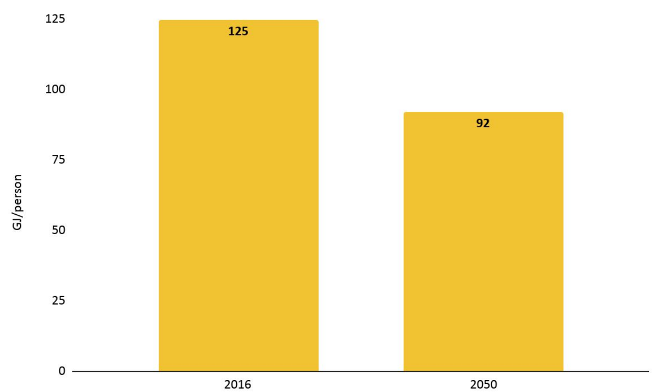


Figure 7. Projected BAU energy per capita (GJ/person), 2016 & 2050.

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

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

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

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

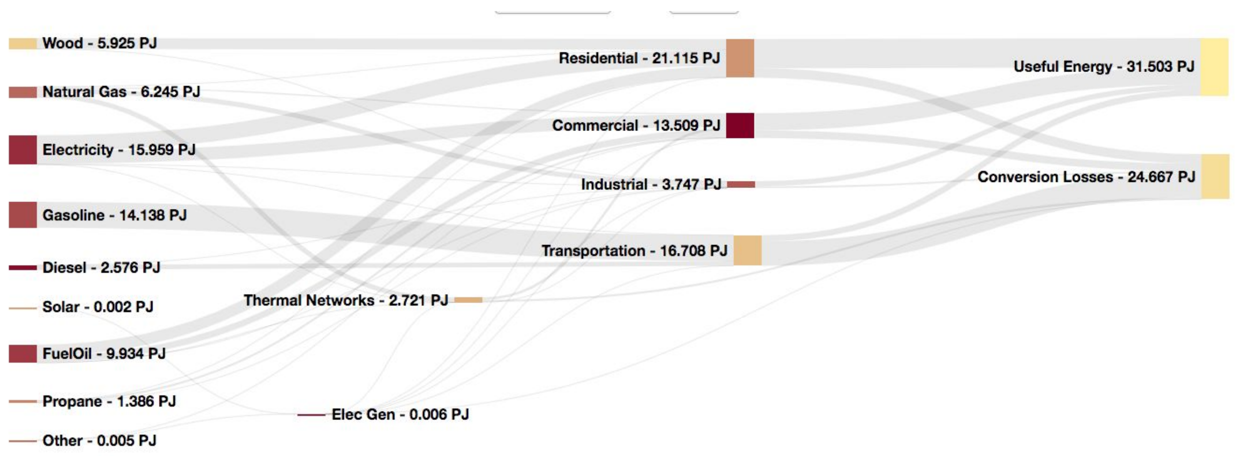


Figure 8. Energy flow, 2016.

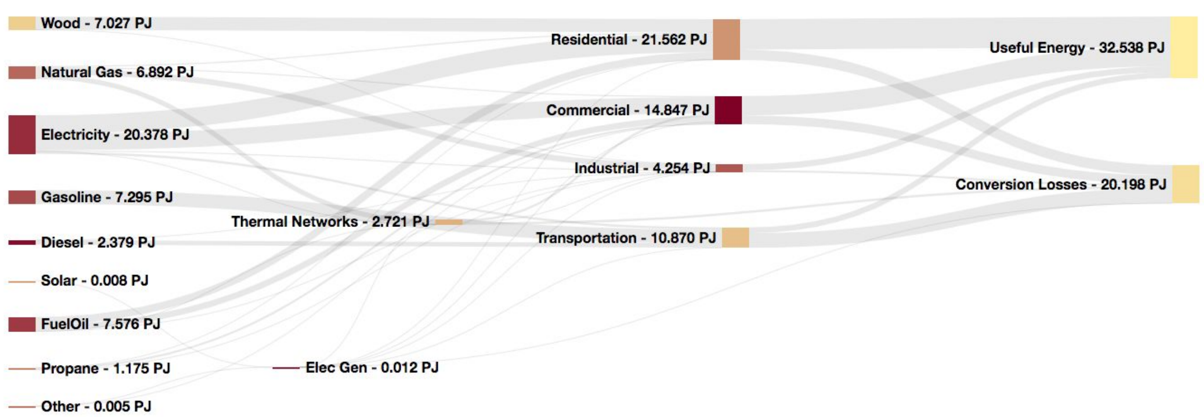


Figure 9. Energy flow, 2050 (BAU).

Energy flow and conversion

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

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

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

Community Emissions

Emissions by sector

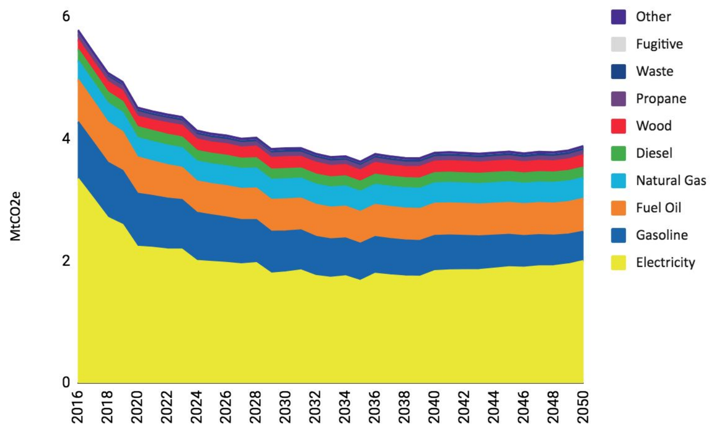


Figure 10. Projected BAU emissions (MtCO2e) by sector, 2016-2050.

Emissions by source

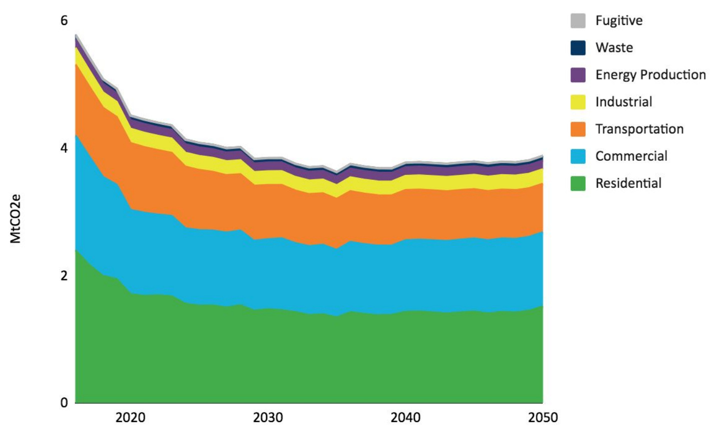


Figure 11. Projected BAU emissions (MtCO2e) by source, 2016-2050.

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

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

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

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

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

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

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

Per Capita Emissions

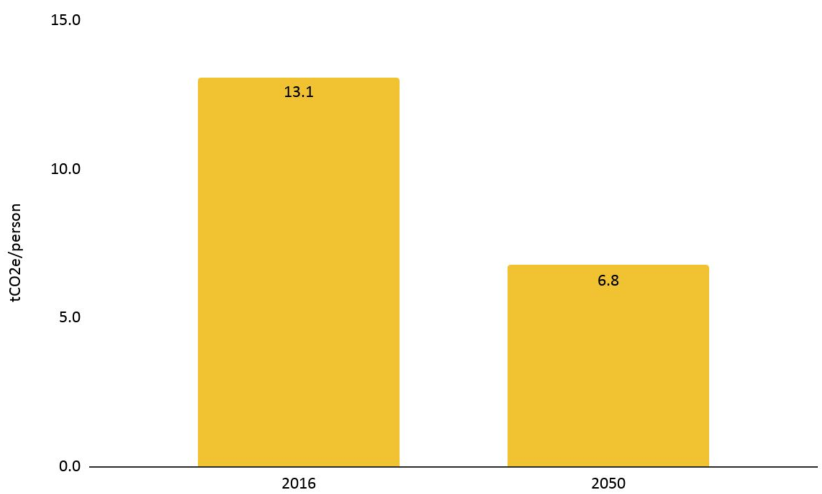


Figure 12. Projected BAU emissions per capita (tCO2e/person), 2016 & 2050.

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

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

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

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

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

[3] Fugitive emissions account for unintentional emissions associated with the transportation and distribution of natural gas within the city (through equipment leaks, accidental releases etc.) that is used within the buildings sector.

Buildings Sector Energy

Buildings energy by fuel

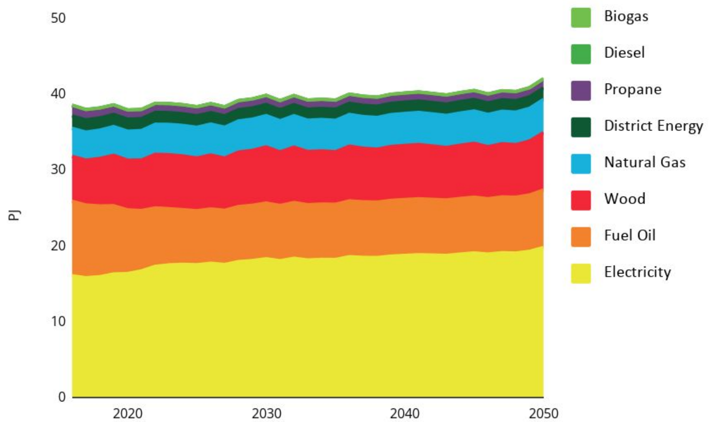


Figure 13. Projected BAU buildings energy use (GJ) by fuel, 2016-2050.

Buildings energy by end use

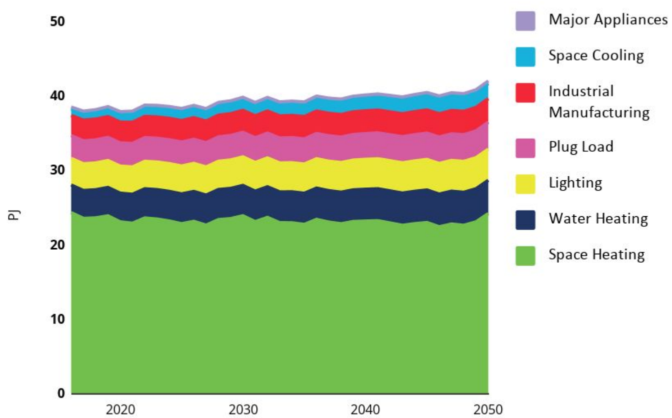


Figure 14. Projected BAU buildings energy use (GJ) by end use, 2016-2050.

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

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

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

Buildings energy by building type & fuel

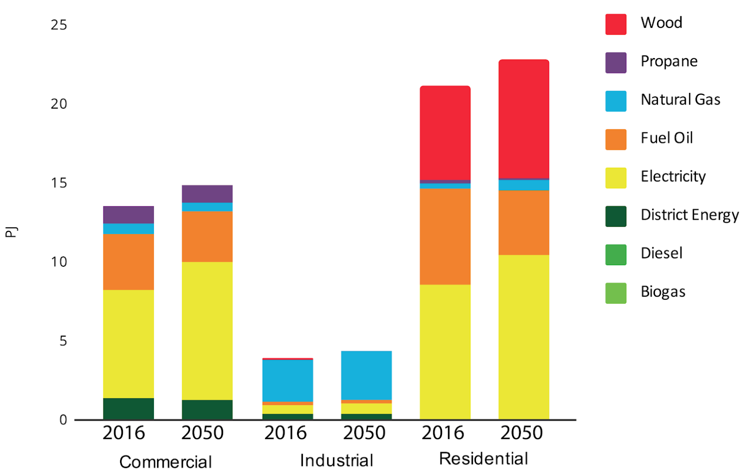


Figure 15. Projected BAU buildings energy use (GJ) by building type and fuel, 2016 & 2050.

Buildings energy by building type & end use

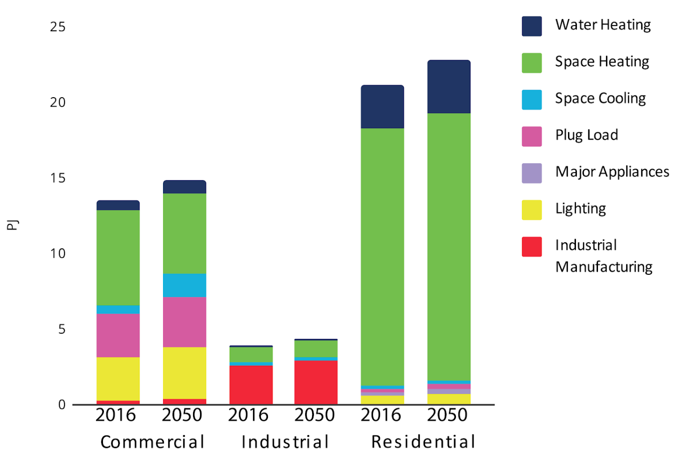


Figure 16. Projected BAU buildings energy use (GJ) by building type and end use, 2016 & 2050.

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

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

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

Per household energy

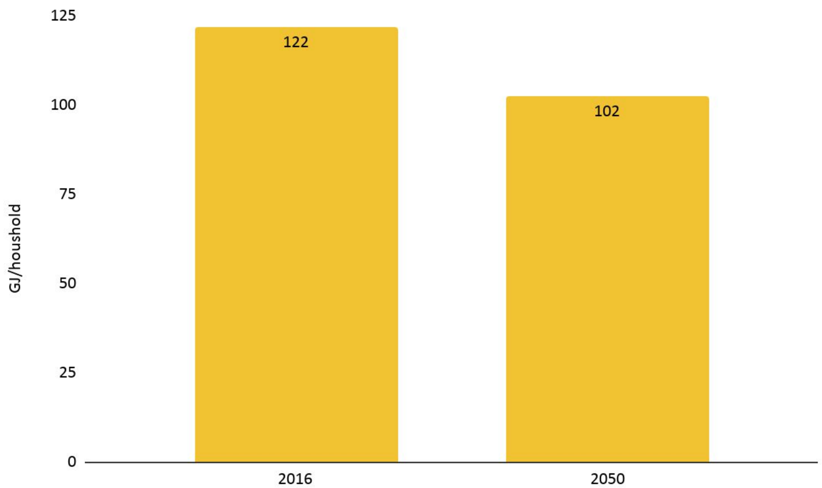


Figure 17. Projected BAU residential energy per household (GJ/household), 2016 & 2050.

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

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

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

Buildings energy (GJ) by fuel	2016	share 2016	2050 (BAU)	share 2050	% +/- (2016-2050)
Biogas	1,600	0.0%	1,700	0.0%	3.5%
Diesel	27,500	0.1%	28,400	0.1%	3.3%
District Energy	1,629,400	4.2%	1,517,800	3.6%	-6.9%
Electricity	15,969,200	41.5%	19,695,100	47.0%	23.3%
Fuel Oil	9,818,700	25.5%	7,578,400	18.1%	-22.8%
Natural Gas	3,692,900	9.6%	4,378,500	10.4%	18.6%
Propane	1,386,200	3.6%	1,178,000	2.8%	-15.0%
Wood	5,925,300	15.4%	7,566,900	18.0%	27.7%
Total	**38,450,800**		**41,944,900**		**9.1%**
Buildings energy (GJ) by end use	**2016**	**share 2016**	**2050 (BAU)**	share 2050	**% +/- (2016-2050)**
Industrial Manufacturing	2,695,500	7.0%	3,165,000	7.5%	17.4%
Lighting	3,570,200	9.3%	4,184,900	10.0%	17.2%
Major Appliances	253,400	0.7%	349,700	0.8%	38.0%
Plug Load	3,074,300	8.0%	3,617,400	8.6%	17.7%
Space Cooling	881,700	2.3%	2,017,400	4.8%	128.8%
Space Heating	24,264,600	63.1%	24,141,200	57.6%	-0.5%
Water Heating	3,711,000	9.7%	4,469,200	10.7%	20.4%
Total	**38,450,800**		**41,944,900**		**9.1%**

Buildings Sector Emissions

Buildings emissions by source

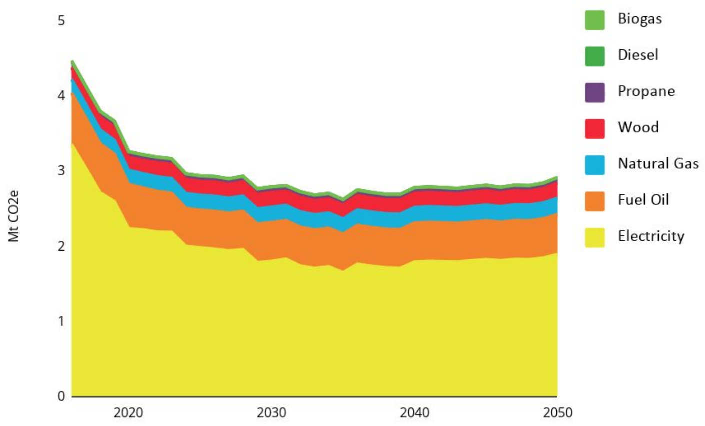


Figure 18. Projected BAU buildings emissions (kt CO2e) by source, 2016-2050.

Buildings emissions by end use

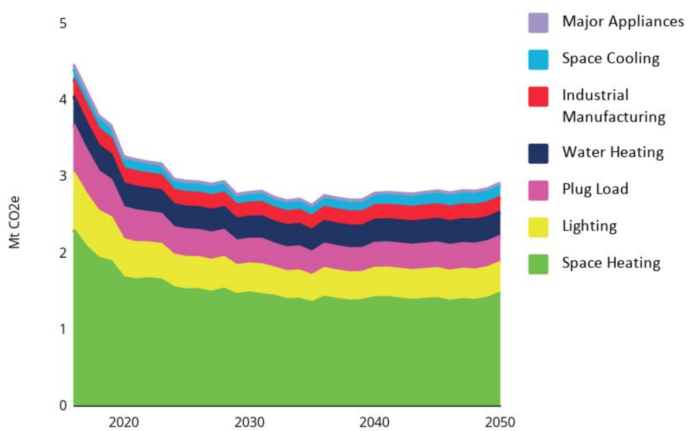


Figure 19. Projected BAU buildings emissions (kt CO2e) by end use, 2016-2050.

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

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

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

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

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

Buildings emissions by building type & source

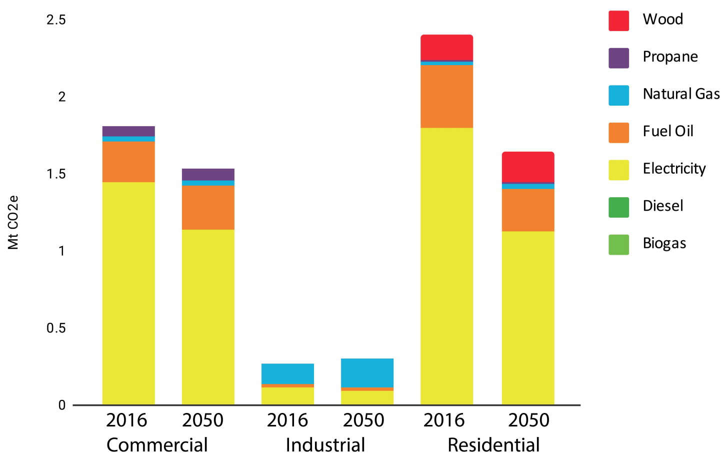


Figure 20. Projected BAU buildings emissions (kt CO2e) by building type and source, 2016 & 2050.

Buildings emissions by building type & end use

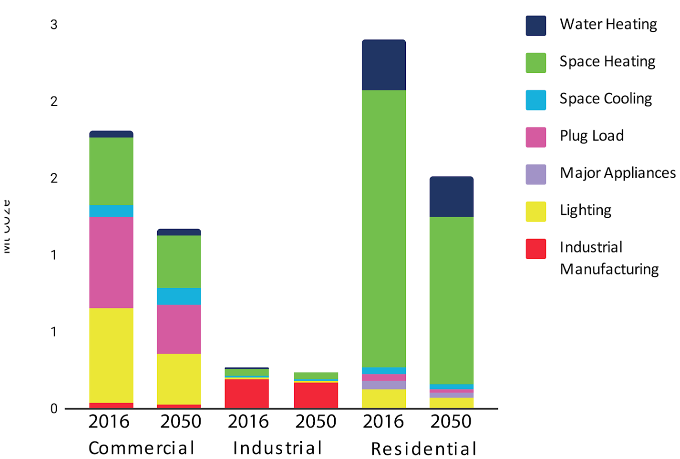


Figure 21. Projected BAU buildings emissions (kt CO2e) by building type and end use, 2016 & 2050.

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

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

Per household emissions

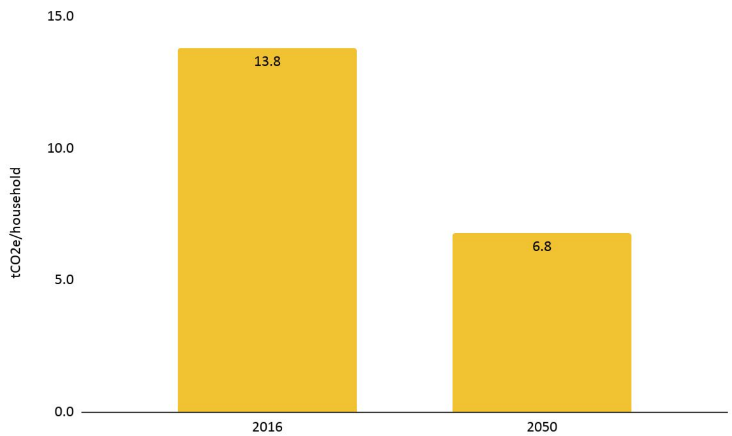


Figure 22. Projected BAU residential emissions per household (tCO2e/household), 2016 & 2050.

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

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

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

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

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

Transportation Sector Energy

Transportation energy by fuel

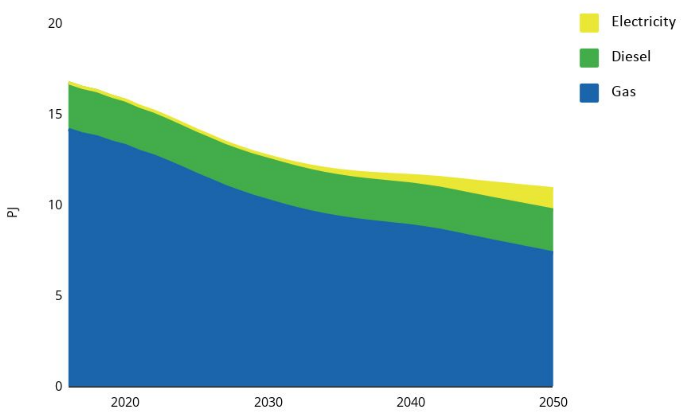


Figure 23. Projected BAU transportation energy use (PJ) by fuel, 2016-2050.

Transportation energy by vehicle type

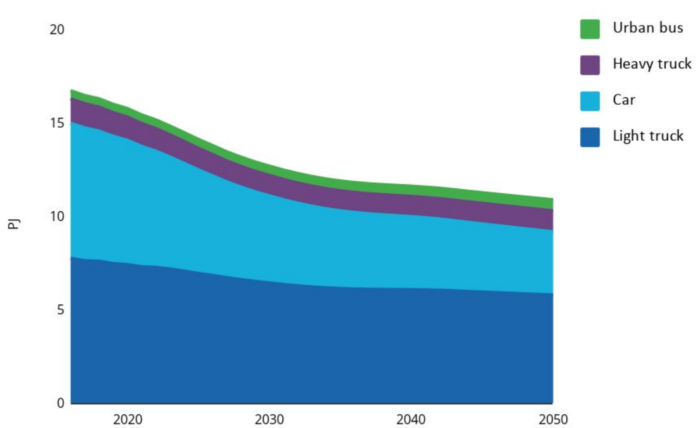


Figure 24. Projected BAU transportation energy use (GJ) by vehicle type, 2016-2050.

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

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

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

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

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

Transportation energy by vehicle type & fuel

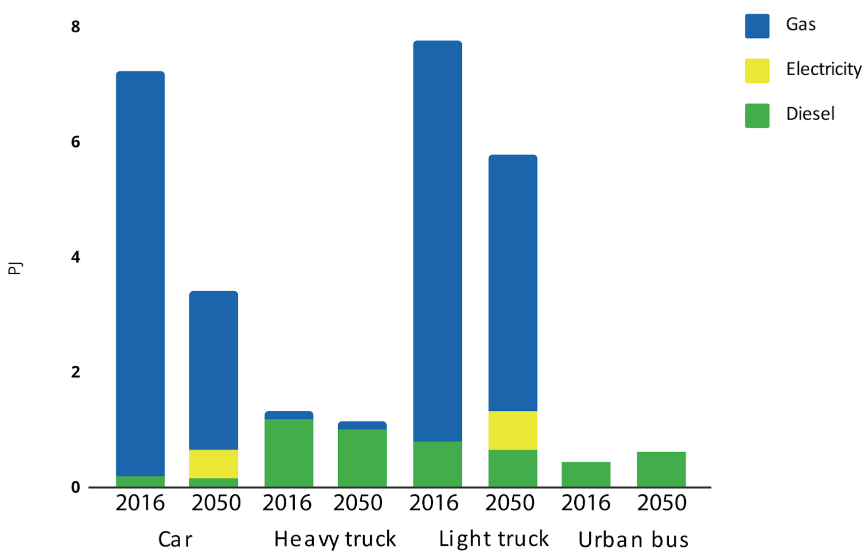


Figure 25. Projected BAU transportation energy use (GJ) by vehicle type and fuel, 2016-2050.

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

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

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

Transportation Sector Emissions

Transportation emissions by source

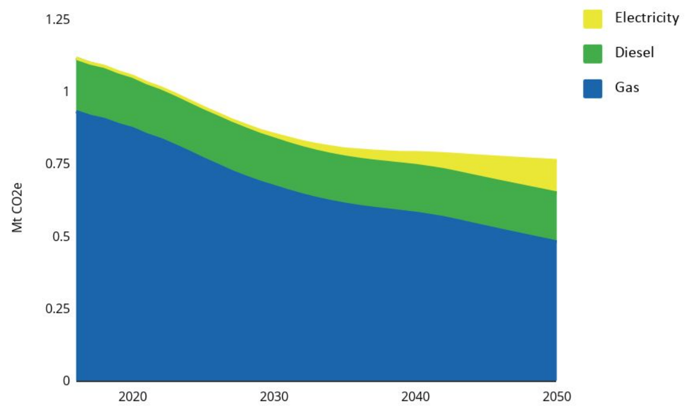


Figure 26. Projected BAU transportation emissions (kt CO2e) by source, 2016-2050.

Transportation emissions by vehicle type

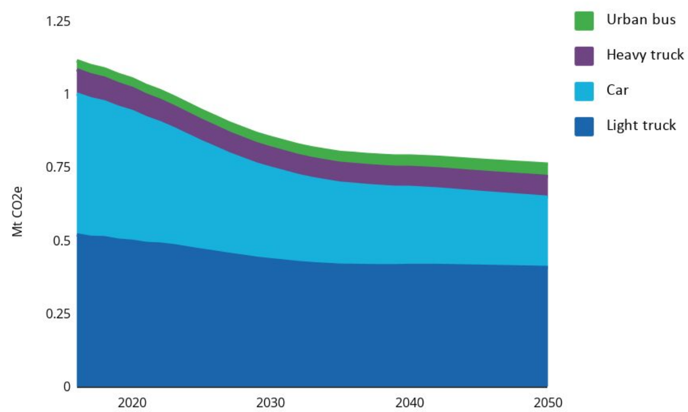


Figure 27. Projected BAU transportation emissions (kt CO2e) by vehicle type, 2016-2050.

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

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

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

Transportation emissions by source & vehicle type

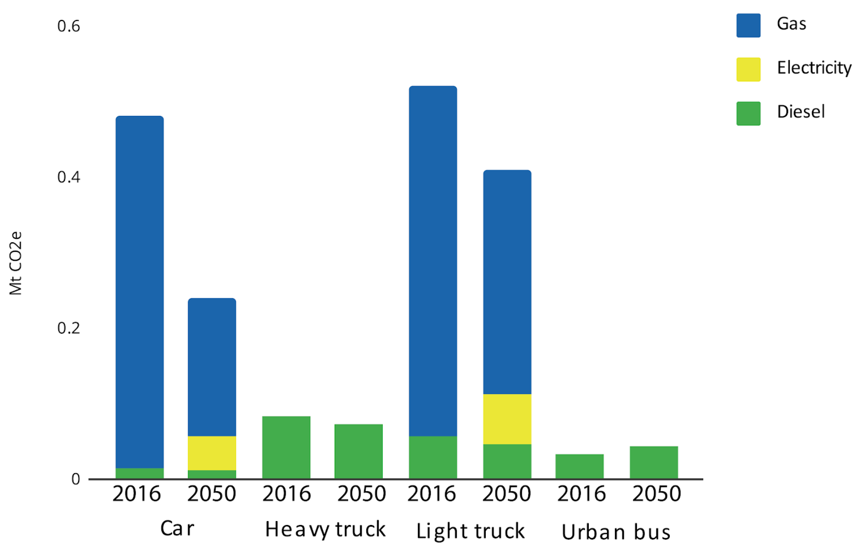


Figure 28. Projected BAU transportation emissions (ktCO2e) by source and vehicle type, 2016-2050.

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

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

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

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

Waste Sector Emissions

Waste emissions by type

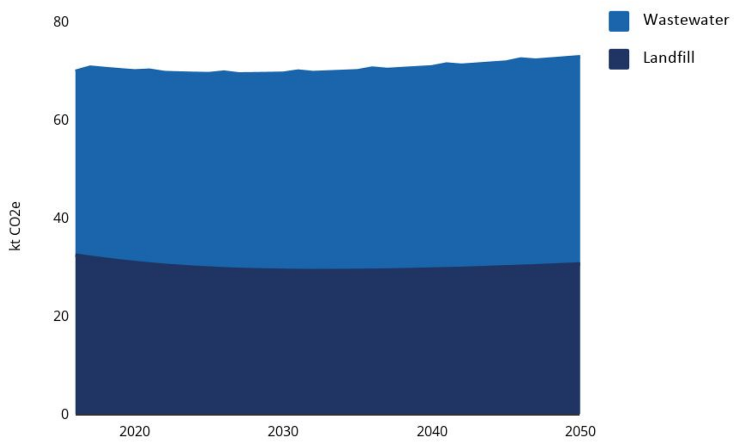


Figure 29. Projected BAU waste emissions (tCO2e), 2016-2050.

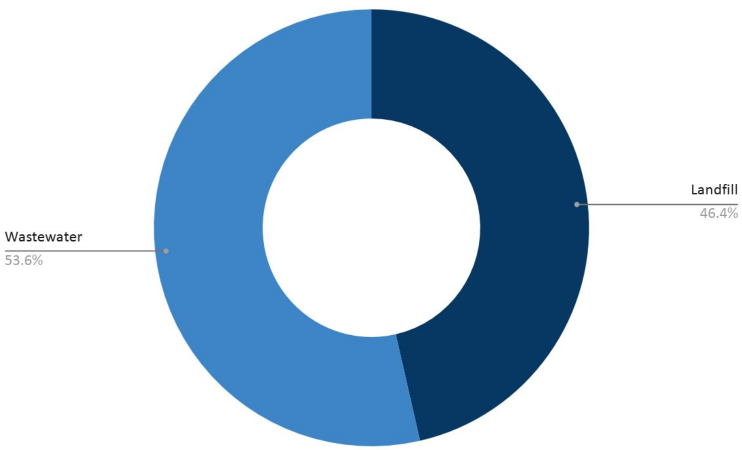


Figure 30. Waste emissions by type, 2016.

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

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

Summary Analysis

General

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

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

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

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

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

[4] Fugitive emissions account for unintentional emissions associated with the transportation and distribution of natural gas within the city (through equipment leaks, accidental releases etc.) that is used within the buildings sector.

Buildings

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

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

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

- **Heating and cooling degree days:** The BAU accounts for the influence of projected climate change by including an assumption for heating degree days (HDD) and cooling degree days(CDD).[5] The projection indicates a decrease in heating degree days (HDD), and an increase in cooling degree days (CDD) as the climate continues to warm towards 2050. A decrease in the number of heating degree days (the number of degrees that a day's average temperature is below 18° Celsius, at which buildings need to be heated) results in a reduction in the amount of energy required for space heating. This increase is partially offset by an increase in the number of cooling days (the temperature at which buildings start to use air conditioning for cooling), which results in an increase in energy usage. The overall impact is a net decrease in energy demand for buildings over time as a result of a warming climate; as building energy demand is significantly dominated by space heating, this outweighs any increases in cooling demand.

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

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

Transport

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

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

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

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

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

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

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

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

Waste

Waste emissions increase by 4.3% from 70.0 ktCO2e in 2016 to 73 ktCO2e by 2050. Emissions in this sector include those produced from solid waste and wastewater treatment, and are primarily driven by an increase in population. This result is not unexpected, as the BAU assumes no further reduction in the rates of per capita waste production, waste diversion, or improvement in treatment facilities.

Observations and insights for low carbon modelling

Switching to electricity provides a significant emissions reduction opportunity.

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

New electricity generation capacity from renewables will be needed.

- Significant efforts to fuel switch to electricity will require new generation capacity with renewables to ensure that the emissions factor for electricity continues to decline, as well as ensuring sufficient electrical capacity is available.

Retrofitting the existing building stock will be critical.

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

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

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

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

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

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

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

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

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

Part 2:

Data, Methods & Assumptions

Part 2: Emissions Framework, Scope, and Factors

Emissions Accounting Framework & Scope

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

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

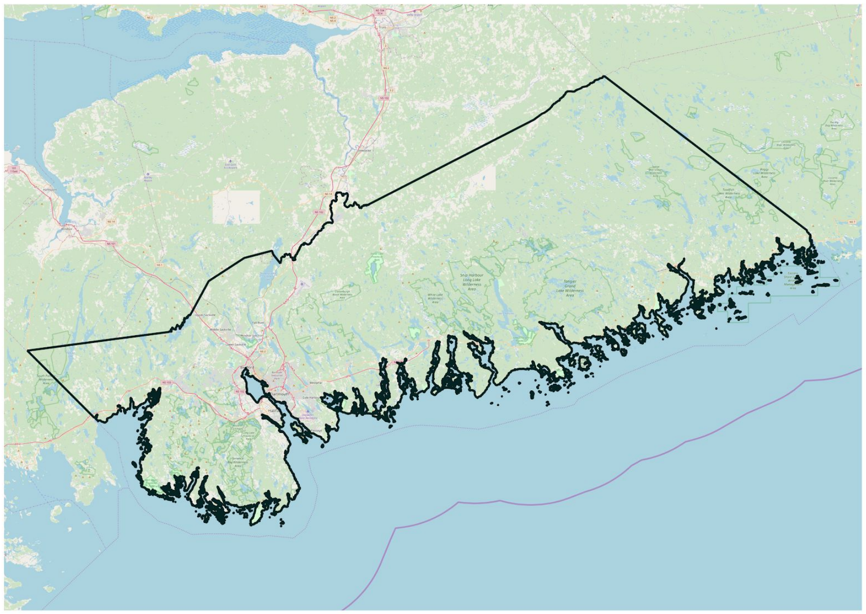


Figure 35. Municipal Boundary of Halifax.

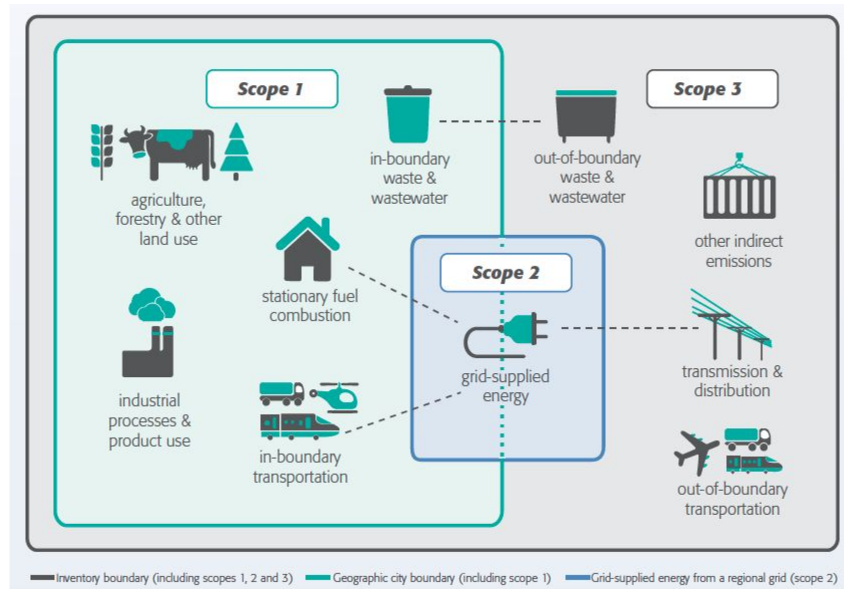


Figure 36. GPC scope boundaries.

Emissions Factors

Category	Description	Comment
Natural gas	49 kg CO2e/GJ	Environment and Climate Change Canada. *National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada*. Part 2. Tables A6-1 and A6-2, Emission Factors for Natural Gas.
Electricity	2016: CO2: 700.0 g/kWh CH4: 0.03 g/kWh N2O: 0.01 g/kWh 2050: CO2: 363.9 g/kWh CH4: 0.03 g/kWh N2O: 0.01 g/kWh	National Energy Board. (2016). *Canada's Energy Future 2018.* Government of Canada. Retrieved from https://www.cer-rec.gc.ca/nrg/ntgrtd/ftr/2018/pblctn-eng.html
Gasoline	g/L CO2: 2316 CH4: 0.14 N2O: 0.022	Environment and Climate Change Canada. *National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada.* Part 2. Table A6–12 Emission Factors for Energy Mobile Combustion Sources (Tier 2)
Diesel	g/L CO2: 2690.00 CH4: 0.051 N2O: 0.22	Environment and Climate Change Canada. *National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada.* Part 2. Table A6–12 Emission Factors for Energy Mobile Combustion Sources (Advanced Control)
Fuel oil	Residential g/L CO2: 2560 CH4: 0.026 N2O: 0.006 Commercial g/L CO2: 2753 CH4: 0.026 N2O: 0.031 Industrial g/L CO2: 2753 CH4: 0.006 N2O: 0.031	Environment and Climate Change Canada. *National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada.* Part 2. Table A6–4 Emission Factors for Refined Petroleum Products

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

Modelling

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

About CityInSight

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

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

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

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

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

Model Structure

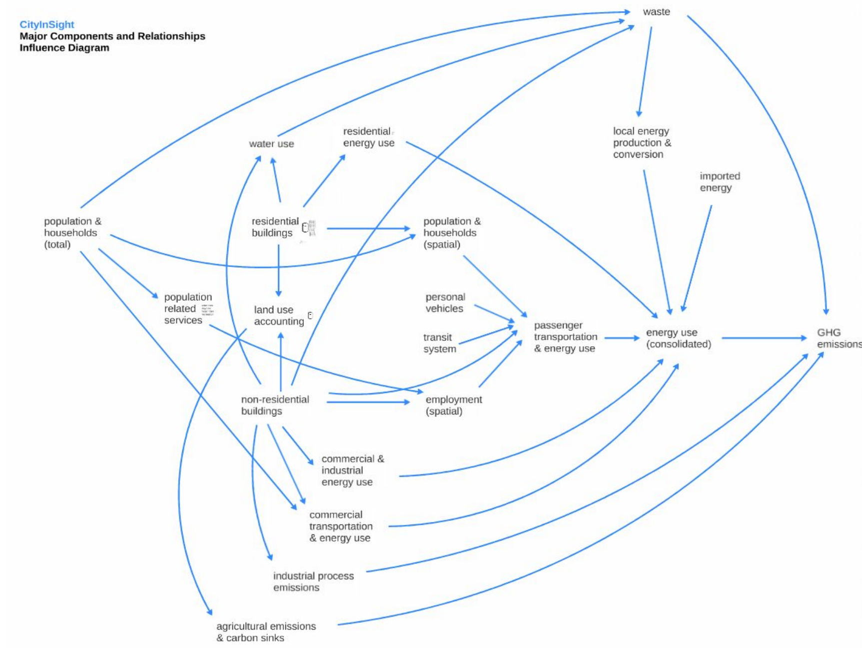
The major components of the model, and the first level of modelled relationships (influences), are represented by the blue arrows in Figure 2. Additional relationships may be modelled by modifying inputs and assumptions - specified directly by users, or in an automated fashion by code or scripts running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

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

Stocks and flows

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

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



Representation of CityInSight's structure.

Sub-models

Population and demographics

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

Residential buildings

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

Non-residential buildings

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

Spatial population and employment

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

Passenger Transportation

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

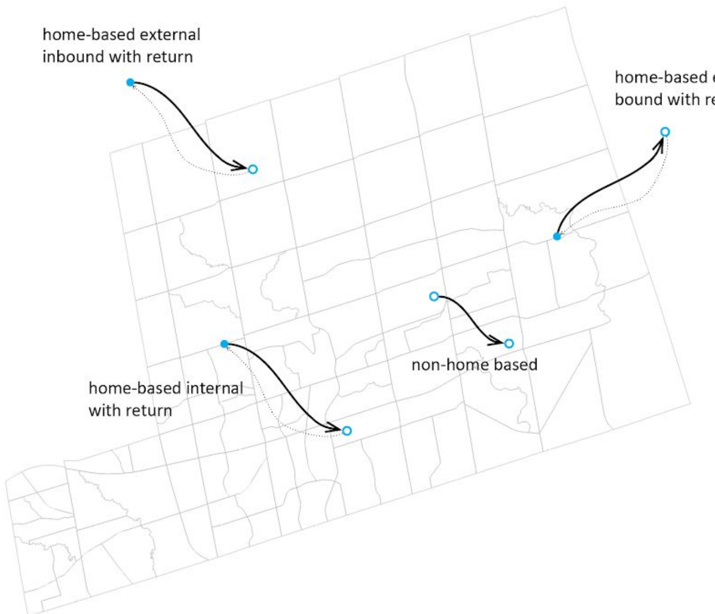


Figure 38. Conceptual diagram of trip categories.

Waste

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

Energy flow and local energy production

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

Finance and employment

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

Scenario Development

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

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

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

Business-As-Usual Scenario

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

Methodology:

1. Calibrate model and develop 2016 baseline using observed data and filling in gaps with assumptions where necessary;
2. Input existing projected quantitative data to 2050 where available:
    - Population, employment & households projections from Municipality by transport zone;
    - Build out (buildings) projections from Municipality by transport zone (if available);
    - Transport modelling from Municipality;
3. Where quantitative projections are not carried through to 2050 (eg. completed to 2041), extrapolate the projected trend to 2050;
4. Where specific quantitative projections are not available, develop projections through:
    - Analysing current on the ground action in the Municipality (reviewing actions plans, engagement with staff etc.), and where possible, quantifying the action;
    - Analysing existing policy that has potential impact for the Municipality, and where possible, quantifying the potential impact.

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

Data and Assumptions

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

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

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

Vehicle kilometers travelled	Baseline calibrated against origin-destination matrix modelled by the Municipality. BAU VKT projected by the model based on projected spatial buildings, population and employment.	*HRM 2031 Centre Plan OD Tables.xlsx*	Vehicle kilometres travelled projections are driven by buildings projections. The number and location of dwellings and non-residential buildings over time in the BAU drive the total number of internal and external person trips. Person trips are converted to vehicle trips using the baseline vehicle occupancy. Vehicle kilometres travelled is calculated from vehicle trips using the baseline distances between zones and average external trip distances.
Vehicle fuel efficiencies	Vehicle fuel consumption rates reflect the implementation of the U.S. Corporate Average Fuel Economy (CAFE) Fuel Standard for Light-Duty Vehicles, and Phase 1 and Phase 2 of EPA HDV Fuel Standards for Medium- and Heavy-Duty Vehicles.	EPA. (2012). EPA and NHTSA set standards to reduce greenhouse gases and improve fuel economy for model years 2017-2025 cars and light trucks. Retrieved from https://www3.epa.gov/otaq/climate/documents/420f12050.pdf http://www.nhtsa.gov/fuel-economy	Fuel efficiency standards are applied to all new vehicle stocks starting in 2016.
Vehicle share	Personal vehicle stock share changes between 2016-2050. Commercial vehicle stock unchanged 2016-2050.	CANSIM and Natural Resources Canada's Demand and Policy Analysis Division.	The total number of personal use and corporate vehicles is proportional to the projected number of households in the BAU.
Electric vehicles	20% of vehicles on the road in 2044 is an electric vehicle	NS Charging Network Insights & Grid Impact of Residential Charging, NSCC EnergyDATA Workshop Feb 2019, Sanjeev Pushkarna, Nova Scotia Power	Track on low EV scenario page 4 (=20% of vehicles on the road in 2044 is an electric vehicle), exponential growth continued to 2050.
WASTE			
Waste generation	Existing per capita waste generation rates unchanged.		Waste generation per capita held constant form 2016-2050.
Waste diversion	Existing waste diversion rates unchanged.		Waste diversion rates held constant form 2016-2050.
Waste treatment	Existing waste treatment processes unchanged.		No change in waste treatment processes assumed 2016-2050.

Sensitivity Analysis

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

Sensitivity analysis involves the process of adjusting certain selected variables within the model in order to identify variables that have the most significant impact on the model outcomes of a scenario. It is not a process of "scenario analysis", as the variables tested do not represent internally consistent scenarios. The approach to sensitivity analysis is to adjust those variables that were identified as having a higher potential to "move the curve", (ie. the factors that may be contributing significantly to the BAU scenario), in order to be better informed about the implications of future options.

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

Variables and Results

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

[1] One-factor-at-a-time (OFAT or OAT) involves changing only one variable at a time to see what effect it produces on the output; generally involves changing one input variable while keeping others at their baseline (nominal) values, then returning the variable to its nominal value, and repeating for each of the other inputs in the same way. Sensitivity is then measured by monitoring changes in the output.

Discussion

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

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

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

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

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

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

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

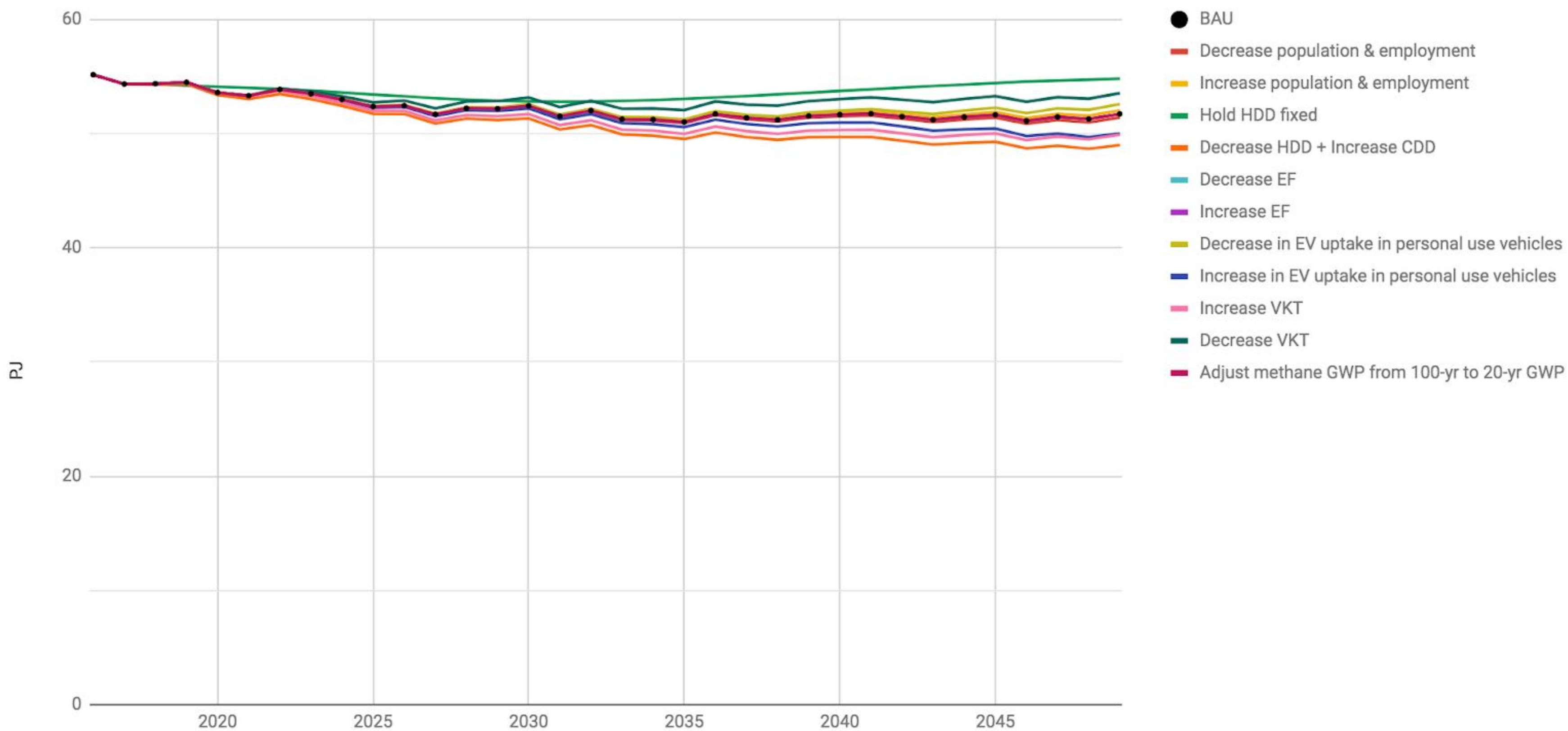


Figure S-1. BAU energy sensitivity, 2016-2050.

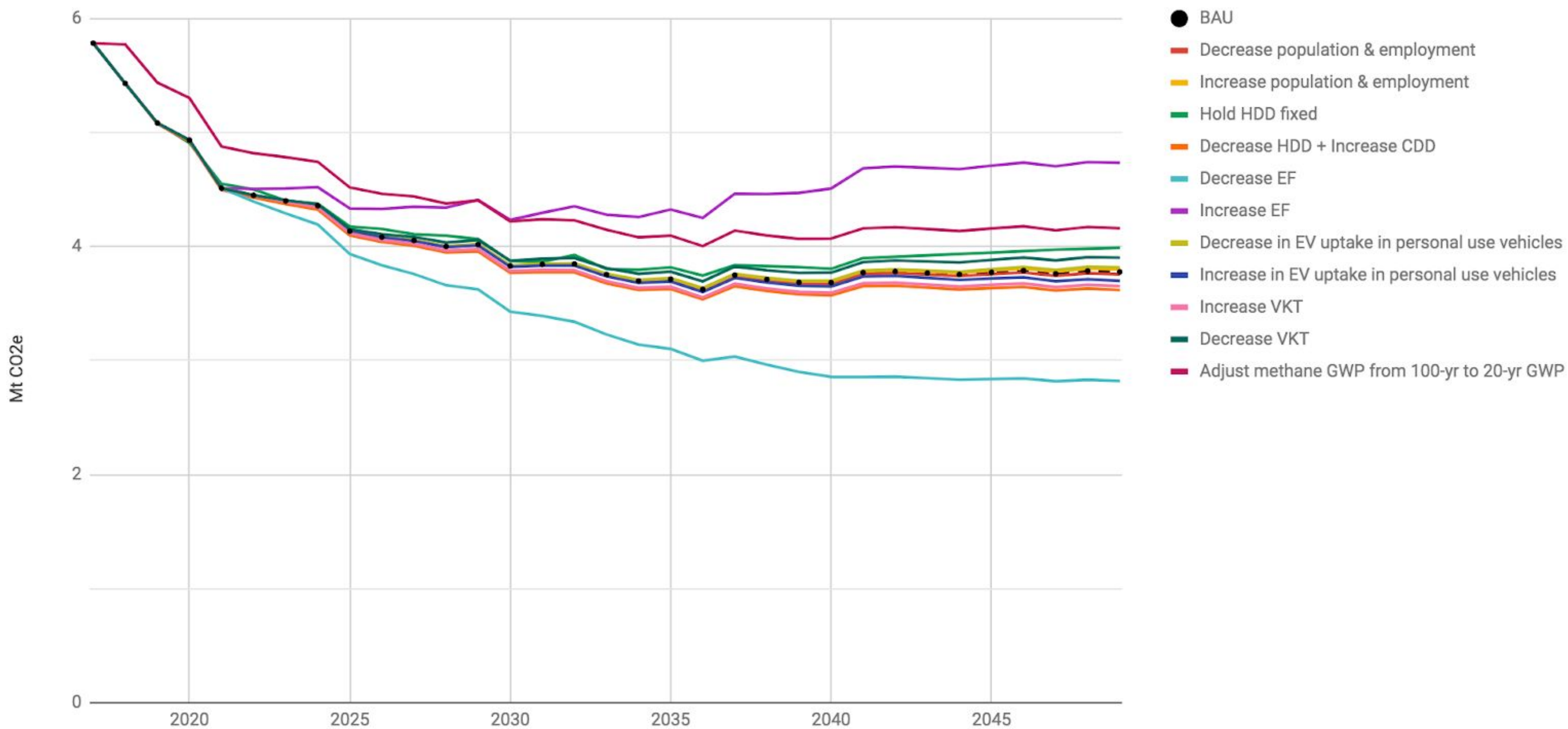


Figure S-2. BAU emissions sensitivity, 2016-2050.

Halifax Regional Municipality

Attachment C

Climate Adaptation Baseline Report

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

Completed by:

Sustainability Solutions Group

Table of Contents

Climate Adaptation

Introduction

The study of climate change adaptation borrowed from the area of disaster risk reduction at its inception and applied risk management approaches. Climate-related hazards create risks to someone or something, which then created the imperative for risk mitigation options. Climate change cannot solely be managed in relation to external climatic systems, but requires instead an understanding of the complex interaction among societies, ecosystems and hazards arising from climate change. This perspective stresses the importance of considering the concept of vulnerability.[1]

Figure 1 illustrates a schematic representation of the interaction among the physical climate system, exposure, and vulnerability, as defined in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) report.[2] Climate-related hazards interact with the exposure, sensitivity and adaptive capacity of human and ecological systems to determine changing levels of risk.

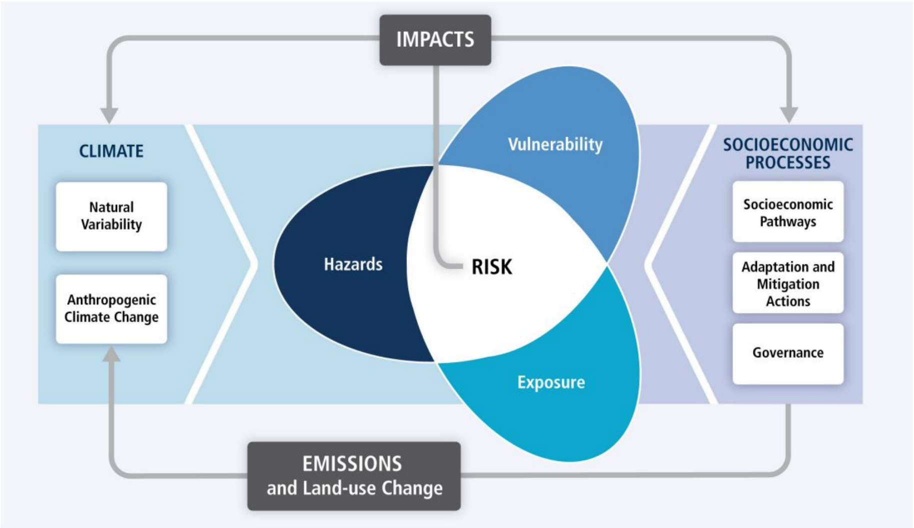


Figure 1. Climate Change Risk as a Function of Vulnerability, Exposure, and Hazard (IPCC).[3]

[1] Oppenheimer, M. et al. 2014: Emergent risks and key vulnerabilities. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. *Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.*

[2] IPCC, 2014: Summary for policymakers. In: Climate Change 2014: Impacts,Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

[3] IPCC, 2014.

Terminology

Climate hazards refer to the potential occurrence of climate-related physical **events**, such as extreme weather (heat wave or flood), or climate change **trends**, such as increasing temperatures, that result in an impact for natural, built or human systems.

Risk results from the interaction of vulnerability, exposure, and hazard, and in this context, the term primarily refers to the risks of climate-change impacts. Risk is also referred to as the potential for consequences where something of value is at stake and where the outcome is uncertain; it is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. This mathematical approach, however, requires the consideration of vulnerability and exposure.

Impacts, also referred to as consequences or outcomes, refers to the effects on natural, built, and human systems of climate hazards; this includes the effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure. Impacts generally manifest in some form of damage, disruption, or complete (irretrievable) loss, and can be generally categorized as physical, social, or economic. Impacts result due to the interaction of climate events or trends (occurring within a specific time period) and the vulnerability of an exposed society or system. Additionally, impacts can be considered direct (damage to a building) or indirect (loss of a job or income as a result of damage to a building).

Exposure refers to 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; for example, assets located in a flood plain, or people living in poor quality housing.

Vulnerability refers to the propensity or predisposition to be adversely affected, and refers to characteristics of human or social-ecological systems that are exposed to hazardous climatic events or trends; it is a function of sensitivity and adaptive capacity. **Sensitivity** or susceptibility to harm, refers to the degree to which a system or species is affected; while **adaptive capacity** refers to the ability to adjust or to respond to impacts. Ecosystems, geographic areas, assets or humans (amongst others) can be classified as vulnerable; this is of particular concern if vulnerability in one area (eg. humans) increases as a result of potential impairment or increased vulnerability in other areas (eg. assets).

Stressors refer to events and trends, which are often not climate-related, that have an important effect on the system exposed and can increase vulnerability to climate-related risk. For example, growing income inequality is a stressor that is pushing already low income families to their financial limits; this further increases these families' vulnerability, as they have less resources (and therefore decreased capacity) to respond to the impacts major climate event.

Adaptation refers to the process of adjustment in natural or human systems in response to actual or expected climatic change and its effects. The process of adaptation aims to moderate or avoid harm or exploit beneficial opportunities.[4]

Urban resilience refers to the **ability** of urban centers (populations, enterprises, and governments) and the systems on which they depend to anticipate, reduce, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner[5]; or the **capacity** of individuals, communities, institutions, businesses, and systems within a city to survive, adapt and grow no matter what kinds of chronic stresses or acute shocks they experience.[6] In this context, **climate resilience** is synonymous with the definitions above, but is more specific in that the hazardous events, shocks or stresses are those that are climate related. Climate resilience is often used interchangeably with adaptation, and can be viewed as a state, ability, or capacity, whereas adaptation is the process by which to accomplish this ideal. In other words, climate resilience can be achieved through the process of adaptation.

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[4] IPCC, 2014.

[5] IPCC, 2014.

[6] 100 Resilient Cities.

Context

Changing climate

Halifax is getting hotter, wetter and wilder.

Halifax has experienced a number of climate hazards with major impacts over the last decade, including the Sackville River floods in December 2014 and April 2015; a record heat in summer 2018; and, more recently from Hurricane Dorian in September 2019; a storm that caused significant damage to public and private property from high winds and heavy rain, uprooted hundreds of trees, caused a large crane to topple over onto neighbouring buildings downtown, and resulted in 75% of the provinces electrical customers losing power, many for several days.[7]

Many of these climate hazards are projected to increase in variability, frequency, and intensity as a result of projected changes in climate. In general, Halifax can expect to see, amongst other changes, higher average annual and maximum temperatures, more heat waves, higher annual precipitation, increases in extreme precipitation, and increases in the intensity and frequency of some extreme events, including storms, flooding and wildfires.

Further detail on climate projections for Halifax is included in the *Climate Projections* section.

These events have significant impacts for people, infrastructure, natural systems and economies, including health impacts, damage to property, disruption in critical infrastructure systems, business and service interruptions, and inhibiting mobility and access to services. This is discussed in more detail in the *Hazards, Risk and Impacts* section.

[7]Crane Toppled, Trees Uprooted As Dorian Hammers Nova Scotia | Cbc News https://www.cbc.ca/news/canada/nova-scotia/hurricane-dorian-nova-scotia-destruction-1.5274887

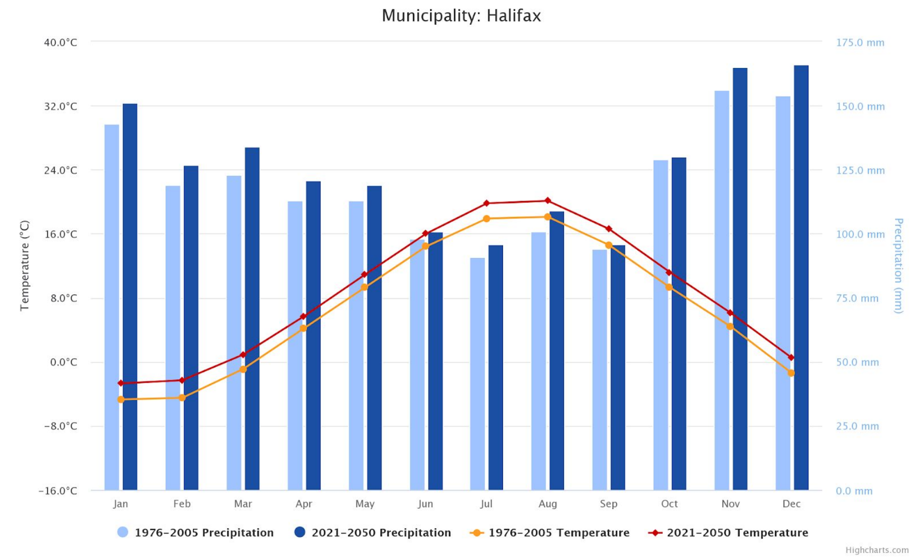

Figure 2. Halifax climograph for the periods 1976-2005 and 2021-2050.

Growing and aging region

While the climate is changing, the Halifax region is also growing. Currently home to just over 441,400 people, the region is projected to grow to approximately 572,600 people by 2050; a total growth of 30% over that period. In the context of climate change, this presents both new challenges and opportunities.

This growth will increase demand on existing infrastructure; infrastructure that in many cases is already at or over capacity, is aging rapidly, and is currently experiencing impacts of extreme climate events. It will also require significant investments in new infrastructure. As climate events become more extreme and occur more frequently, increases in disruption and damage to infrastructure, and the subsequent costs to repair or replace it will increase. Additionally, it is anticipated that the state of good repair (SOGR) backlog will increase exponentially, as already aging infrastructure that is subjected to these climate changes and extremes will age even faster and reach its lifetime more quickly than anticipated. In the absence of significant action and investment, the risk to existing and future infrastructure will exponentially increase.

This growth is also likely to result in urbanization, which is 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.

While the population of Halifax is growing, it is also aging. The number of seniors, a group that is more vulnerable to the impacts of climate change, is increasing in the region. The Canadian Institute for Health Information (CIHI) indicates that, as a cohort, seniors (65+ years) are growing rapidly in Nova Scotia, and more significantly, this is being outpaced by those aged 75+ years.[8] CIHI projects that seniors 75+ years will more than double in Nova Scotia by 2037.[9]

Inequality

Not all people will be affected equally by climate change. Certain groups, communities, or populations, referred to as climate vulnerable 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. The degree to which certain people are vulnerable to climate is driven by a variety of socio-economic characteristics or factors, including income, housing and living conditions, and ability to access services (including infrastructure and support services). Climate vulnerable populations are discussed in more detail *Vulnerability* section.

In the context of climate change, inequality is a major concern, as it exacerbates the vulnerability to climate of those who are already vulnerable.

While the Halifax region is generally prosperous and growing, this prosperity is not shared by all. Some areas enjoy higher incomes, better health, and better access to a mix of housing, transit, and public services. In other parts, poverty is more concentrated, health outcomes are poorer, services (like transit) are more sparsely located and people face barriers that prevent them from accessing services and employment.

Research from the Neighbourhood Change Research Project indicates that income inequality in Halifax Regional Municipality (CMA) (measured between 1970 and 2010) did not change significantly overall [in comparison with other cities such as Toronto and Vancouver where this has become a significant issue], but there was increasing income polarization in the Halifax Peninsula area.[10] There are currently areas of the city that are well below and well above the city average, and that while the between Halifax's lower and upper income earners is not as great as in some cities, Halifax is losing its middle earners.[11]

"Climate change is impacting the severity and frequency of extreme events, including the likelihood of flooding, droughts, storm surges, high winds, and heat waves. Without additional efforts to reduce risks, the increased frequency and severity of extreme weather events could lead to increased hardship for many Canadians and potentially unsustainable losses for governments and the financial sector."

-Government of Canada, Working Group on Adaptation and Climate Resilience (2016)

[8] Seniors Population Growth. Canadian Institute for Health. Accessed at https://www.cihi.ca/en/seniors-in-transition/web-tools/population-growth

[9] Infographic: Canada's Seniors Population Outlook: Uncharted Territory. Canadian Institute for Health. Accessed at https://www.cihi.ca/en/infographic-canadas-seniors-population-outlook-uncharted-territory

[10] Victoria Prouse, Jill L Grant, Martha Radice, Howard Ramos, Paul Shakotko. 2014. Neighbourhood Change in Halifax Regional Municipality, 1970 to 2010: Applying the "Three Cities" Model.

[11] Planning and Theory in Practice. Dalhousie University. Neighbourhood Change in Halifax: A Community Update. 2016. [Meeting minutes] http://theoryandpractice.planning.dal.ca/neighbourhood/working-papers.html

Climate Projections

About the climate projections

Climate projections data and content of this section was drawn directly from the Climate Atlas of Canada[12] and Canada's Changing Climate Report.[13]

Localized downscaled climate projections for temperature and precipitation for Halifax were sourced from the Climate Atlas of Canada. The Climate Atlas' primary source of climate model data is the Pacific Climate Impacts Consortium's (PCIC) statistically downscaled data derived from 24 CMIP5 global climate models, for two emissions scenarios (RCP4.5 and RCP8.5). The RCP4.5 and RCP8.5 are referred to as the "Low Carbon" and "High Carbon" scenarios, respectively.[14]

The temperature and precipitation projections data for Halifax that follows in this report is associated with the RCP8.5 scenario, or the "High Carbon" scenario. This scenario reflects a "business-as-usual" scenario that assumes global greenhouse gas emissions continue to increase at current rates through the end of the century. At present, based on the best available science, global emissions are on track to follow the High Carbon scenario.

The data displays information for three time periods, the *Recent Past* (1976-2005), the *Immediate Future* (2021-2050) and the *Near Future* (2051-2080).

Information and projections for extreme events were sourced from Canada's Changing Climate Report. Where applicable, data and information related to a high emissions scenario (RCP8.5), considered to reflect a "business-as-usual" scenario, is presented.

[12] Climate Atlas of Canada, version 2 (July 10, 2019), using BCCAQv2 climate model data. Accessed at https://climateatlas.ca/
[13] Bush, E. and Lemmen, D.S., editors (2019): Canada's Changing Climate Report; Government of Canada, Ottawa, ON.
[14] For further details on data and methods used by the Climate Atlas, refer to https://climateatlas.ca/data-sources-and-methods.

Temperature

Heat

	1976-2005	2021-2050	2051-2080
Average annual temperature	6.8℃	8.6℃	10.6℃
# summer days (+25℃)	18	39	66
# very hot days (+30℃)	1	3	12
# tropical nights (+20℃)	0	1	10
Typical hottest summer day	29.6℃	31.5℃	33.6℃
Hot season (# days from first to last +30℃ day)	6	22	50

High temperatures are important. They determine if plants and animals can thrive, they limit or enable outdoor activities, define how buildings are designed, and shape transportation and energy use. It is useful, for example, to know how high summer temperatures are likely to become in the future, to ensure cooling and air-conditioning systems can reliably deal with these extremes.

When temperatures are very hot, people - especially the elderly - are much more likely to suffer from heat exhaustion and heat stroke. Many outdoor activities become dangerous or impossible in very high temperatures. In general, Canadians are not used to extremely hot summers, and further warming will bring new and unusual risks as well as a very different experience of the summer season.

High, persistent temperatures increase the risk of drought, which can severely impact food production and increases the risk of wildfire. High temperatures can also lead to more thunderstorms, which means increased risks of flash flooding, lightning, hail and perhaps even tornadoes.

Hot summer days are physiologically stressful, especially if overnight temperatures do not provide cooling relief. For Halifax, hot "summer days" (+25℃) are projected to more than double from an average of 18 days in the period 1976-2005, to 39 days in 2021-2050; and up to 66 days in 2051-2080 (Figure 3).

Many people are at risk from suffering heat exhaustion or heat stroke when nighttime temperatures fail to drop below 20 °C. Elderly people, the homeless, and those who live in houses or apartments without air conditioning are especially vulnerable during these heat events, particularly if they last for more than a few days. For Halifax, hot "tropical nights" (+20℃) are projected to increase from an average of 0 days in the period 1976-2005, to 10 days in 2051-2080 (Figure 4).

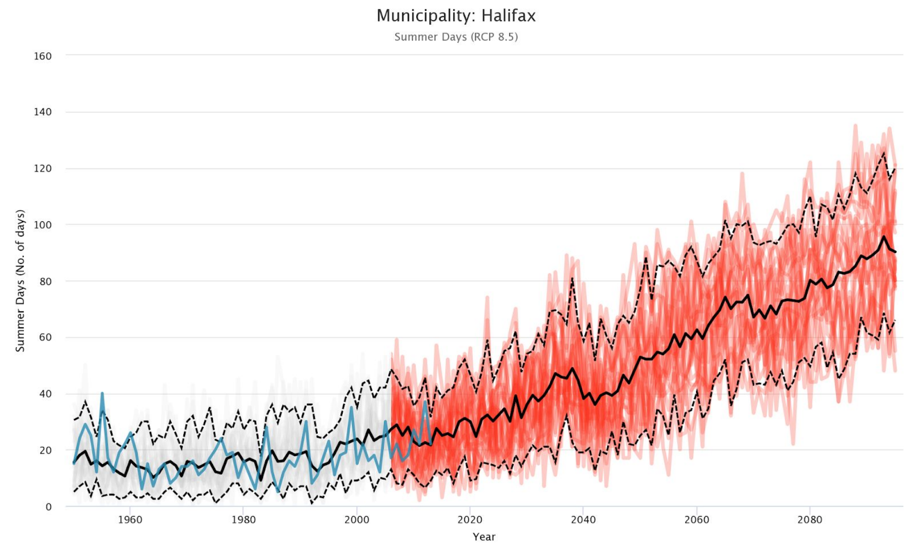

Figure 3. Projected number of summer days (+25℃) to 2100.

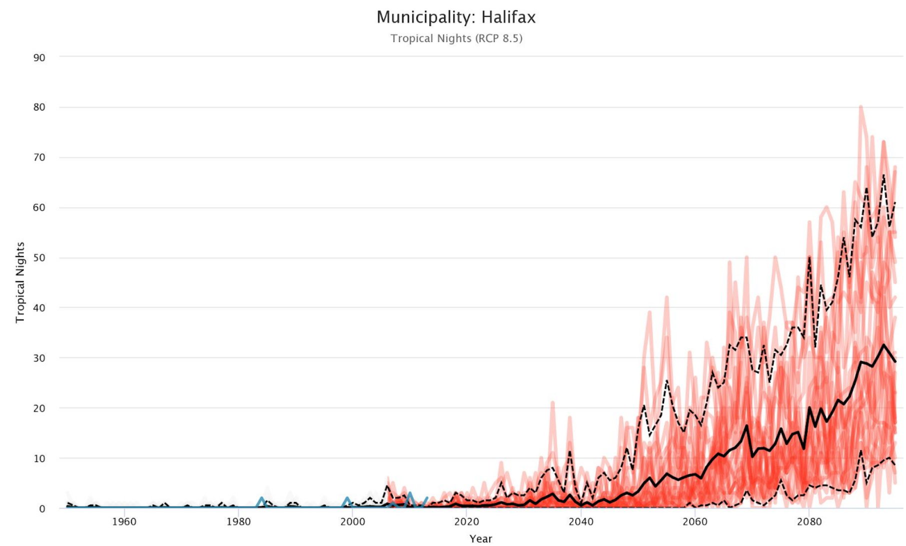

Figure 4. Projected number of tropical nights (+20℃) to 2100.

Cold

	1976-2005	2021-2050	2051-2080
Average winter temp	-3.5℃	-1.5℃	0.6℃
# mild winter days (-5℃)	77	59	41
# cold winter days (-15℃)	13	6	1
# icing days (# days air temp does not go above freezing/ 0 °C)	44	29	17

Cold weather is an important aspect of life in Canada, and many places are well adapted to very cold winters. Amongst others, cold weather plays a role in human health and safety, determines what plants and animals can live in the area, and limits or enables outdoor activities, as well as shapes our energy use, specifically for heating.

Halifax's winters are projected to get significantly warmer, with the average winter temperature increasing from -3.5℃ in the recent past, to -1.5℃ in the 2021-2050 period, and up to 0.6℃ in 2051-2080. Along with a decrease in heating degree days (HDD)[15], this has positive impacts for energy consumption, as less energy will need to be consumed for space heating

The number of mild winter days (-5℃) and cold winter days (-15℃) is also decreasing, along with the number of icing days (the number of days on which the air temperature does not rise above freezing) (Figure 5), and freezing degree days (FDD)[16]. These all indicate a decrease of the length and severity of winters into the future as temperatures increase, and have impacts for snow and ice accumulation.

Lower or decreasing FDD imply less or decreasing snow and ice accumulation, which is an important consideration for winter activities such as skiing, the building of winter roads, municipal and rural snow clearance, and many other aspects of winter life. Alongside increasing temperatures and changing precipitation patterns, decreased snow and ice accumulation is likely to impact groundwater recharge, runoff timing and stream flow.

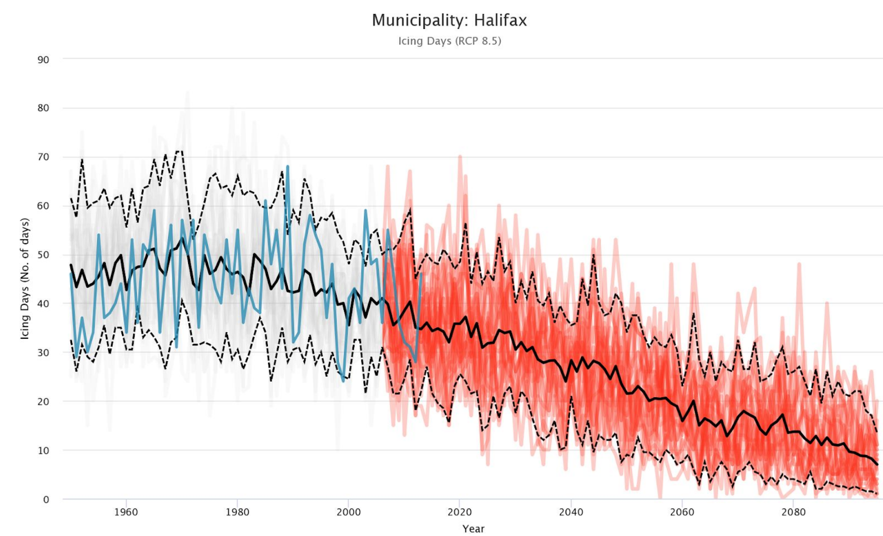

Figure 5. Projected number of icing days (<0℃) to 2100.

[15] Heating Degree Days (HDD) are equal to the annual sum of the number of degrees Celsius a given day's mean temperature is below 18 °C. For example, if the daily mean temperature is 12 °C, the HDD value for that day is equal to 6 °C. If the daily mean temperature is above 18 °C, the HDD value for that day is set to zero.

[16] Freezing degree days (FDD) are equal to the annual sum of the number of degrees Celsius that each day's mean temperature is below 0 °C. FDDs begin to accumulate when the daily mean temperature drops below freezing: if a day's mean temperature is -21 °C, for example, it increases the annual FDD value by 21. Days when the mean temperature is 0 °C or warmer do not contribute to the annual sum.

Growing season

	1976-2005	2021-2050	2051-2080
Frost free season (#days)	170	194	217
Date of last spring frost	May 2	Apr 21	Apr 9
Date of first fall frost	Oct 22	Nov 4	Nov 16
Frost days (# days <0℃)	145	118	92

A longer Frost-Free Season means plants and crops have a longer window to grow and mature. If projections show an increase in the length of the Frost-Free Season, then the annual growing season will be longer, and the period of cold weather correspondingly shorter.

The growth of most plants and crops is limited by the temperature of the air and soil; emergence and growth in the spring is limited by freezing temperatures.

As crops and plants need time to mature, the earlier in the spring they start to grow without the occurrence of frost, and the later in the fall they experience freezing temperatures, the more likely it is that they will be able to mature to their full potential. This time available for growth, maturity and productivity (determined by the Date of Last Spring Frost and the Date of First Fall Frost), determines the overall length of the frost-free season.

As a result of increasing average annual and seasonal temperatures, the length of the frost-free season is projected to increase in Halifax from an average of 170 days in the period 1976-2005, to 194 days in 2021-2050; and up to 217 days in 2051-2080 (Figure 6). This is to be accompanied by a projected decrease in annual frost days, and an increase in growing degree days (GDD).

Growing Degree Days (GDDs) are often used to determine whether a climate is warm enough to support plants and insects with temperature-dependent growth rates.

GDDs accumulate whenever the annual sum of the number of degrees Celsius that each day's mean temperature is above a specified base temperature (Tbase). Generally, 5°C GDDs are used for assessing the growth of canola and forage crops; 10°C GDDs are more appropriate for assessing the growth of corn and beans; and 15°C GDDs are used to assess the growth and development of insects and pests.

Compared to the average Growing Degree Days (Base 15°C) during the 1976-2005 period, GDD (Base 15°C) is projected to increase by 70% during the 2021-2050, and more than double by 2051-2080.

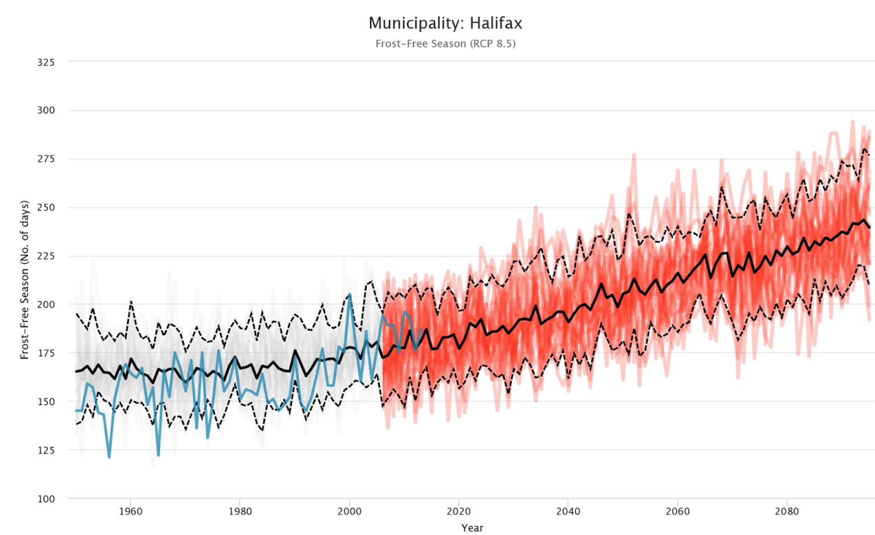

Figure 6. Projected frost free season (number of says) to 2100.

Precipitation

	1976-2005	2021-2050	2051-2080
Precipitation - annual (mm)	1440	1519	1571
Precipitation - spring (mm)	353	379	394
Precipitation - summer (mm)	291	306	310
Precipitation - fall (mm)	379	390	399
Precipitation - winter (mm)	416	445	468
Max 1-day precipitation (mm)	67	74	79

Precipitation patterns are critical for many important issues, including water availability, crop production, wildfire suppression, snow accumulation, seasonal and flash-flooding, and short- and long-term drought risk.

Very high precipitation totals and/or very high precipitation rates create many challenges. In cities and towns, high precipitation rates overwhelm storm drains and cause flash flooding. They can also cause problems in rural areas by drowning crops, eroding topsoil, and damaging roads. Heavy snowfall events can disrupt ground transportation, and very heavy snowfall events can cause damage to buildings if their roofs become overburdened.

Total annual precipitation and seasonal precipitation is projected to increase in Halifax out to 2050 and 2080, with the largest increases occurring during the spring and winter. Alongside increasing temperatures, specifically during the winter and spring, it is anticipated that more precipitation will fall as rain, not snow, compared to the most recent past, and contribute to earlier or more variable spring runoff.

While annual and seasonal precipitation is projected to increase, increasing temperatures in the summer (especially heat waves), along with more variable spring runoff and groundwater recharge patterns are likely to have implications for both the water availability and water demand.

Extended hot periods, combined with extended periods of dry days during the summer increases the likelihood of drought risk. These dry and hot periods are also likely to increase demand for water, putting further strain on water availability.

Additionally, increasing temperatures are likely to increase biological activity in surface waters and decrease available dissolved oxygen in lakes and deeper water; affecting both drinking water quality (and potentially water treatment processes), and overall ecosystem health.

Maximum 1-day precipitation indicates the most precipitation that falls in a single day, and is sometimes also called the “wettest day of the year”. This amount could be the result of a short but intense precipitation event such as a storm or because a moderate amount of snow/rain falls continuously all day, rather than all at once.

For Halifax, the average maximum 1-day precipitation is projected to increase by 5mm and 12mm for the 2021-2050 and 2051-2080 periods respectively (Figure 7).

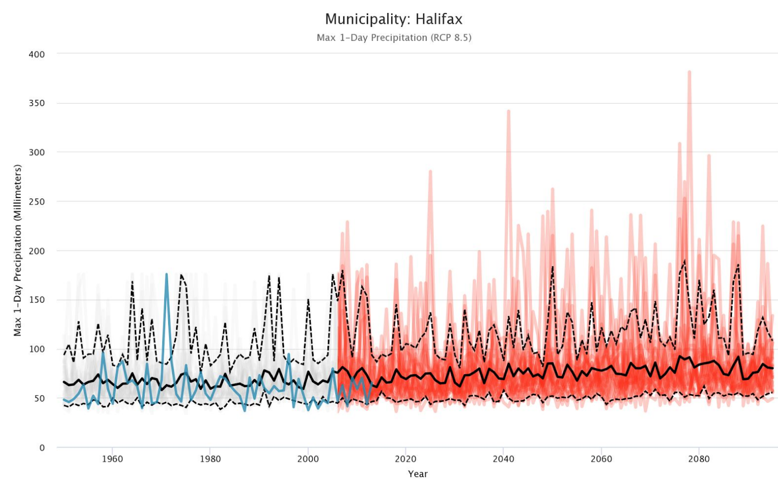

Figure 7. Projected maximum 1-day precipitation (mm) to 2100.

Extreme events[17]

Climate change is projected to increase the likelihood of extreme events, including extreme heat and extreme precipitation, and other events such as wildfires, storms and flooding that are attributable to changes in the climate system.

Extreme temperature changes, both in observations and future projections, are consistent with warming. Extreme warm temperatures have become hotter, while extreme cold temperatures have become less cold. Such changes are projected to continue in the future, with the magnitude of change proportional to the magnitude of mean temperature change.

For Canada as a whole, observational evidence of changes in extreme precipitation amounts, accumulated over periods of a day or less, is lacking. However, there is high confidence that daily extreme precipitation is projected to increase. The lack of a detectable change in extreme precipitation is not necessarily evidence of a lack of change. On one hand, this is inconsistent with the observed increase in mean precipitation. As the variance of precipitation is proportional to the mean, and as there is a significant increase in mean precipitation, one would expect to see an increase in extreme precipitation. On the other hand, the expected change in response to warming may be small when compared with natural internal variability. Warming has resulted in an increase in atmospheric moisture, which is expected to lead to an increase in extreme precipitation if other conditions, such as atmospheric circulation, do not change.

On the global scale, observations indicate an increase in extreme precipitation associated with warming. The median increase in extreme precipitation is about 7% per 1ºC increase in global mean temperature, consistent with the increase in the water-holding capacity of the atmosphere due to warming.

[17] Bush, E. and Lemmen, D.S., editors (2019): Canada's Changing Climate Report; Government of Canada, Ottawa, ON. https://changingclimate.ca/site/assets/uploads/sites/2/2019/04/CCCR_FULLREPORT-EN-FINAL.pdf

For Canada, extreme precipitation is projected to increase in the future. On average, extreme precipitation with a return period of 20 years in the late century climate is projected to become a once in about 10-year event in 2031–2050 under a high emission scenario (RCP8.5), and an extreme event that currently occurs once in 20 years is projected to become about a once in five-year event by late century. In other words, extreme precipitation of a given magnitude is projected to become more frequent. Moreover, the relative change in event frequency is larger for more extreme and rarer events. For example, an event that currently occurs once in 50 years is projected to occur once in 10 years by late 21st century under a high emission scenario (RCP8.5).

The amount of precipitation with a certain recurrence interval is projected to increase. The amount of 24-hour extreme precipitation that occurs once in 20 years on average is projected to increase by 12% under by 2031–2050, and to increase as much as 25% by 2081–2100 under a high emission scenario (RCP8.5).

Changes in temperature and precipitation each have impacts across many sectors. However, combined changes in temperature and precipitation can have additional impacts, and some sectors rely on information regarding concurrent changes in these two variables. An example is fire weather. Changing precipitation and temperature (along with changing wind) alter the risk of extreme wildfires that can result from hot, dry, and windy conditions. Understanding changes in both temperature and precipitation lends insight into changes in wildfire risk and how it might evolve in the future.

The Canadian Forest Fire Weather Index (FWI) System is a collection of indices that use weather variables, including temperature and precipitation, to characterize fire risk. It includes an index, labelled FWI, that synthesizes information from the collection of indices to quantify day-to-day changes in the risk of a spreading fire. Projected higher temperatures in the future will contribute to increased values of the FWI indices and, therefore, increased fire risk. The increase in precipitation that would be required to offset warming for most of the FWI indices exceeds both projected and reasonable precipitation changes.

The Atlantic region is subject to impacts from a wide range of seasonal and interannual events, including winter cyclonic storms and tropical cyclones. There is evidence of recent trends toward greater extremes and higher frequencies of such events.[18]

The U.S. National Oceanic and Atmospheric Administration (NOAA) funded Geophysical Fluid Dynamics Laboratory (GFDL) at Princeton University indicates that:

- Tropical cyclone rainfall rates will likely increase in the future due to anthropogenic warming and accompanying increase in atmospheric moisture content. Modeling studies on average project an increase in the order of 10-15% for rainfall rates averaged within about 100 km of the storm for a 2 degree Celsius global warming scenario;
- Tropical cyclone intensities globally will likely increase on average (by 1 to 10% according to model projections for a 2 degree Celsius global warming). This change would imply an even larger percentage increase in the destructive potential per storm, assuming no reduction in storm size. Storm size responses to anthropogenic warming are uncertain;
- The global proportion of tropical cyclones that reach very intense (Category 4 and 5) levels will likely increase due to anthropogenic warming over the 21st century. There is less confidence in future projections of the global number of Category 4 and 5 storms, since most modeling studies project a decrease (or little change) in the global frequency of all tropical cyclones combined.[19]

A full list of climate variables and associated projections for Halifax can be found in Appendix A.

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[18] Natural Resources Canada. Climate and Climate-related Trends and Projections. https://www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/reports/assessments/2008/10261

[19] Global Warming and Hurricanes. An Overview of Current Research Results. Summary Statement (2019). Geophysical Fluid Dynamics Laboratory. Princeton University. https://www.gfdl.noaa.gov/global-warming-and-hurricanes/

Hazards, Risk and Impact

The risk of climate-related impacts results from the interaction of climate-related hazards with the vulnerability and exposure of human and natural systems (Figure 8). Changes in both the climate system (left) and socio-economic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability.

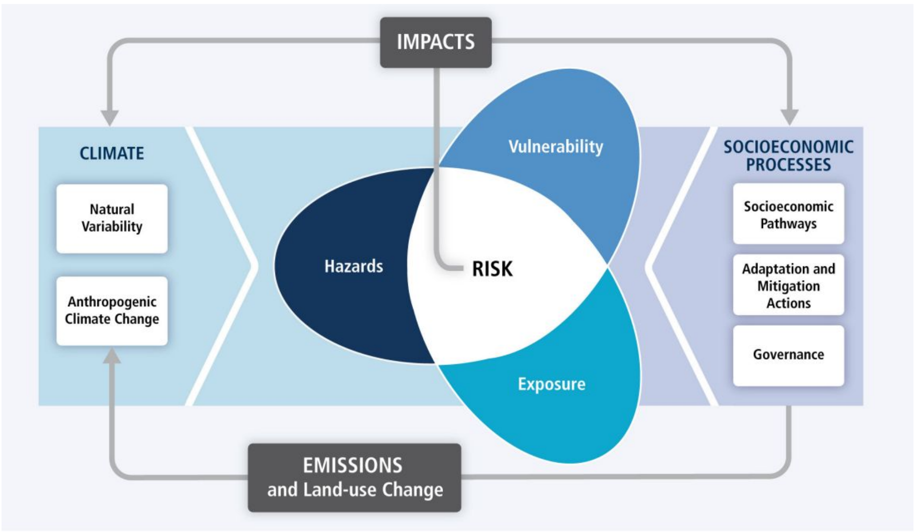

Figure 8. Climate Change Risk as a Function of Vulnerability, Exposure, and Hazard (IPCC).[20]

Hazards

Climate hazards arise from the climate system, and result from natural climate variability as well as change caused by human action. They refer to climate-related physical **events,** such as extreme weather (eg. heat wave or flood), or climate change **trends**, such as increasing temperatures, that result in an impact for natural, built or human systems.

As a result of changes in the climate system, Halifax faces an increase in both the intensity and frequency of several climate-related hazards (Figure 9). These include, amongst others, increased incidences of heatwaves, heavy precipitation events, rising sea levels, changing snow and ice conditions, and changes in streamflow.

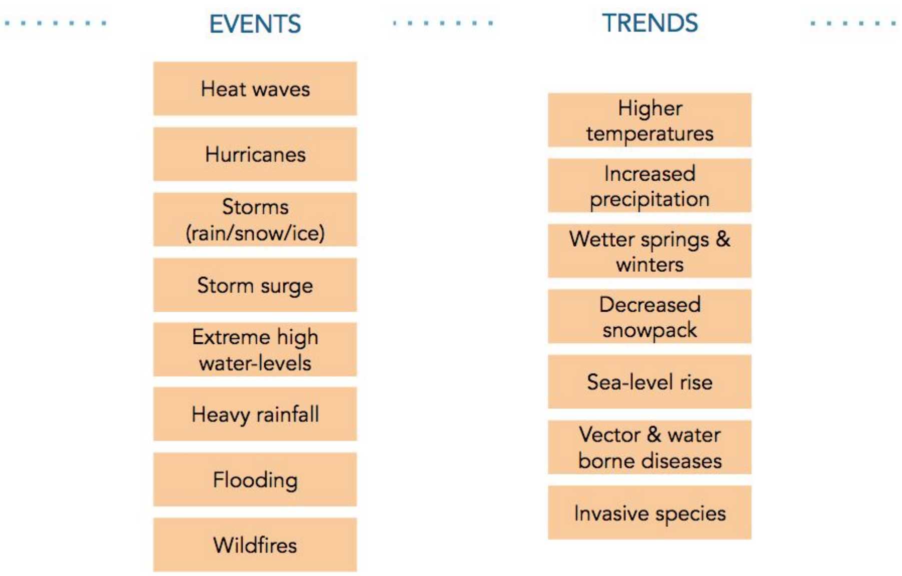

Figure 9. Climate hazard events and trends.

[20] IPCC, 2014.

Relative sea level in different parts of Canada is projected to rise or fall, depending on local vertical land motion. Due to land subsidence, parts of Atlantic Canada are projected to experience relative sea-level change higher than the global average during the coming century.

Where relative sea level is projected to rise (most of the Atlantic and Pacific coasts and the Beaufort coast in the Arctic), the frequency and magnitude of extreme high water-level events will increase. This will result in increased flooding, which is expected to lead to infrastructure and ecosystem damage as well as coastline erosion, putting communities at risk.

Extreme high water-level events are expected to become larger and occur more often in areas where, and in seasons when, there is increased open water along Canada's Arctic and Atlantic coasts, as a result of declining sea ice cover, leading to increased wave action and larger storm surges.[21]

Risk and Impact

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 are 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

[21] Bush, E. and Lemmen, D.S., editors (2019): Canada's Changing Climate Report, Chapter 7 Changes in Oceans Surrounding Canada; Government of Canada, Ottawa, ON.

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.

Vulnerability

Climate change will impact us all, but not all people will be affected equally. Certain groups, referred to as climate vulnerable 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.

Communities that are highly exposed or sensitive to climate risks, or have less capacity to respond to these risks are often referred to as climate vulnerable populations. The table below includes (but is not limited to) those considered to be more vulnerable to climate change in the literature.

Climate vulnerability as a function of >	**Exposure**	**Sensitivity**	**Adaptive Capacity**
	Physical / geographic	*Physical / social*	*Social / Economic*
Climate vulnerable populations	- Location (eg. in a hazard area - Poor quality housing/living conditions - Homeless or under-housed - Outdoor occupation	- Elderly - Young children - Persons with pre-existing illnesses/bad health - Persons with disabilities - Pregnant women	- Low Income - Racialized groups - Immigrants & refugees - Person without access to insurance - Homeless or under-housed - Non-english speakers - Aboriginal peoples - Women - Single-headed households - Public housing residents - Undocumented individuals - Socially isolated persons - Residents in neighbourhood improvement areas

While illustrating the variables that contribute to climate vulnerability, the table does however present a static interpretation of these concepts and runs the risk of oversimplifying this complex issue. Exposure, sensitivity, and adaptive capacity are not static, and in many cases are inextricably linked. Income is closely tied with living conditions and occupation, while health is frequently tied to age. Both historic and growing social and economic inequalities, and continued systemic and institutional inequity, are linked to and exacerbate underlying drivers of vulnerability to climate change.

Physical, social and/or structural barriers in accessing services and social supports, and frequent discrimination, directly influences the ability of a person or groups of persons to seek and receive help, in addition to influencing health and income.[22] For example, for racialized groups, structural and institutional racism negatively influence income, living conditions and health, all of which increase vulnerability to climate change.[23]

Similarly, racialized and low income communities are frequently underfunded, which can result in inadequate green space or community resources, increasing exposure to climate impacts.[24]

The intent of this table and analysis is less about classifying these groups according to climate vulnerability, and more about demonstrating the link between climate vulnerability and social equity.

Many groups have both historically faced, and continue to face, barriers and/or discrimination that further influence income, health, living conditions and other factors that contribute to climate vulnerability, inherently increasing vulnerability.

It is also worth noting that across the spectrum of climate vulnerable populations, some will experience climate impacts disproportionately. Those who experience multiple, overlapping factors of vulnerability are more likely to experience disproportionate effects compared with those who may only experience one factor. For example a racialized, low income, non-english speaking, elderly person in bad health, will be significantly more affected compared with someone who is a non-english speaking person, but otherwise in good health and does not face other barriers.

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[22] Swanson, D., & Bhadwal, S. (Eds.), 2009. Creating adaptive policies: A guide for policymaking in an uncertain world. IDRC.

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Appendix A: Climate variables and projections for Halifax

CLIMATE VARIABLE	DESCRIPTION		ABOUT THIS VARIABLE		RCP 8.5, mean values for the period indicated				
Name	**General description**	**Technical description**	**Short description**	**Long description**	**1976-2005**	**2021-2050**	**[+/-]**	**2051-2080**	**[+/-]**
Average Length of Heat Waves	The average length of a heat wave. A heat wave occurs when at least three days in a row reach or exceed 30 °C.	The average length of a heat wave (in days), where a heat wave is defined as three or more consecutive days with tmax ≥ 30 °C. Therefore, the minimum average length of heat waves will always be greater than or equal to three.		High temperatures are important. They determine if plants and animals can thrive, they limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use. It is useful to know how high summer temperatures are likely to become in the future, to make sure that our cooling and air-conditioning systems can reliably deal with these extremes. When temperatures are very hot, people - especially the elderly - are much more likely to suffer from heat exhaustion and heat stroke. Many outdoor activities become dangerous or impossible in very high temperatures. In general, Canadians are not used to extremely hot summers, and further warming will bring new and unusual risks as well as a very different experience of the summer season. High, persistent temperatures increase the risk of drought, which can severely impact food production and increases the risk of wildfire. High temperatures can also lead to more thunderstorms, which means increased risks of flash flooding, lightning, hail and perhaps even tornadoes.	0.1	0.7	0.6	2.9	2.8
Coldest Minimum Temperature	The very coldest temperature of the year.	The minimum temperature of the year.	Affects safety, recreation, buildings, transportation, energy use, etc.	Cold weather is an important aspect of life in Canada, and many places in Canada are well adapted to very cold winters. It is especially important to know how our winters will change in the future, because cold temperatures affect our health and safety, determine what plants and animals can live in the area, limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use.	-21.3	-18.3	3	-14.6	6.7
Cooling Degree Days	Cooling Degree Days (CDD) are equal to the number of degrees Celsius a given day's mean temperature is above 18 °C. For example, if the daily mean temperature is 21 °C, the CDD value for that day is equal to 3 °C. If the daily mean temperature is below 18 °C, the CDD value for that day is set to zero.	Annual sum of the number of degrees Celsius that each day's mean temperature is above 18 °C.	Often used to estimate how much air-conditioning is required in a year. An increase implies hotter or longer summers.	Cooling Degree Days are often used to estimate how much air-conditioning is required in a year. If a location shows an increase in projected CDD values, this implies that it will experience hotter or longer summers. 18 °C is the temperature at which air conditioning is required to maintain a comfortable temperature inside buildings. A place that gets many days with average temperatures above 18 °C or that gets mean temperatures much higher than 18 °C will require a relatively large amount of energy (and thus money) to cool buildings for comfort and safety.	76.1	183.8	107.7	352.1	276
Corn Heat Units	Corn Heat Units (CHU) is a temperature-based index often used by farmers and agricultural researchers to estimate whether the climate is warm enough (but not too hot) to grow corn.	An index of growing-season heat available to grow corn. It is the annual sum of daily corn heat units (CHU) derived from daily maximum and minimum temperatures, taking into account the temperatures that are optimal for corn growth. The starting date for the annual accumulation of CHUs is estimated as the last day of three consecutive days with a mean daily temperature greater than or equal to 12.8 °C; the ending date for CHU accumulation is the first date with a minimum temperature less than or equal to -2.0 °C.	Used by farmers and agricultural researchers to make planting decisions and maximize production.	One of the common climate indices used to assess the viability of growing a crop in a region is average annual CHUs. The CHUs expected in a region's growing season are used to assess whether corn, or a particular variety of corn, is likely to fully mature in that region. Very generally, at least 2200 CHUs are required to mature most varieties of corn. Note that this index is only based on temperature and does not take into account the availability of water to grow the crop.	2587	3205	618.3	3856	1270

CLIMATE VARIABLE	DESCRIPTION		ABOUT THIS VARIABLE		RCP 8.5, mean values for the period indicated				
Name	**General description**	**Technical description**	**Short description**	**Long description**	**1976-2005**	**2021-2050**	**[+/-]**	**2051-2080**	**[+/-]**
Date of First Fall Frost	The date of the first fall frost, which marks the approximate end of the growing season for frost-sensitive crops and plants.	The first date in the fall (or late summer) on which the daily minimum temperature is equal to or less than 0 °C (Tmin ≤ 0 °C). Because this variable is largely used to assess the end of the growing season in southern Canada, the earliest possible date for a fall frost was set as July 15; that is, the date of the first fall frost in any given year is determined by an assessment of minimum temperatures, one day at a time, forwards from July 15.	Marks the approximate end of the growing season and indicates the return of cold weather.	The arrival of frost marks the end of the growing season and announces the imminent return of winter. If projections show a later Date of First Fall Frost, then the seasonal transition from warmer to colder weather is happening later in the year. Changes in the length and timing of the frost-free season affect plant and animal life, but also our social, psychological, and physical experience of the changing seasons. The growth of most plants and crops is limited by the temperature of the air and soil. Since crops and plants need time to mature, the later in the fall they experience freezing temperatures, the more likely it is that they will be able to mature to their full potential. Of course, the time available for growth, maturity and productivity of these plants is also determined by the Date of Last Spring Frost that, together with the Date of First Fall Frost, determines the overall length of the frost-free season.	Oct 23	Nov 5	12.9 days	Nov 16	24.5 days
Date of Last Spring Frost	The date of the last spring frost, which marks the approximate beginning of the growing season for frost-sensitive crops and plants.	The spring date after which there are no daily minimum temperatures during the growing season less than or equal to 0 °C (Tmin > 0 °C). Because this variable is largely used to assess the beginning of the growing season in southern Canada, the latest possible date for a spring frost was set as July 15; that is, the date of the last spring frost in any given year is determined by an assessment of minimum temperatures, one day at a time, backwards from July 15.	Marks the approximate beginning of growing season and indicates the return of warm weather.	The final frost in the early spring marks the beginning of the growing season and announces the imminent return of summer. If projections show an earlier Date of Last Spring Frost, then the transition from colder to warmer weather is happening earlier in the year. Changes in the length and timing of the frost-free season affect plant and animal life, but also our social, psychological, and physical experience of the changing seasons. For most crops and plants, emergence and growth in the spring is limited by freezing temperatures in the air and soil. Since crops and plants need time to mature, the earlier in the spring they start to grow without the occurrence of frost, the more likely it is that they will grow to their full potential. Of course, the time available for growth, maturity and productivity of these plants is also determined by the Date of First Fall Frost that, together with the Date of Last Spring Frost, determines the overall length of the frost-free season.	May 3	Apr 22	-11 days	Apr 10	-22.8 days
Dry Days	The number of days in a year without rain/snow.	A Dry Day is a day with less than 0.2 mm of precipitation. A threshold value of 0.2 mm is used to be consistent with the Meteorological Service of Canada.		Precipitation patterns are critical for many important issues, including water availability, crop production, electricity generation, wildfire suppression, snow accumulation, seasonal and flash-flooding, and short- and long-term drought risk. Locations that experience precipitation frequently, such as along coasts, have a low number of Dry Days, whereas locations that experience precipitation infrequently have a high number of Dry Days.	194	193.9	0	194.6	0.6
Extremely Hot Days (+32 °C)	A day when the temperature rises to at least 32 °C.	A day with a maximum temperature (Tmax) greater than or equal to 32 °C.		High temperatures are important. They determine if plants and animals can thrive, they limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use. It is useful to know how high summer temperatures are likely to become in the future, to make sure that our cooling and air-conditioning systems can reliably deal with these extremes. When temperatures are very hot, people - especially the elderly - are much more likely to suffer from heat exhaustion and heat stroke. Many outdoor activities become dangerous or impossible in very high temperatures. In general, Canadians are not used to extremely hot summers, and further warming will bring new and unusual risks as well as a very different experience of the summer season. High, persistent temperatures increase the risk of drought, which can severely impact food production and increases the risk of wildfire. High temperatures can also lead to more thunderstorms, which means increased risks of flash flooding, lightning, hail and perhaps even tornadoes. Technical description:	0.1	0.8	0.7	4	3.9

CLIMATE VARIABLE	DESCRIPTION		ABOUT THIS VARIABLE		RCP 8.5, mean values for the period indicated				
Name	**General description**	**Technical description**	**Short description**	**Long description**	**1976-2005**	**2021-2050**	**[+/-]**	**2051-2080**	**[+/-]**
Extremely Hot Days (+34 °C)	A day when the temperature rises to at least 34 °C.	A day with a maximum temperature (Tmax) greater than or equal to 34 ° C.		High temperatures are important. They determine if plants and animals can thrive, they limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use. It is useful to know how high summer temperatures are likely to become in the future, to make sure that our cooling and air-conditioning systems can reliably deal with these extremes. When temperatures are very hot, people - especially the elderly - are much more likely to suffer from heat exhaustion and heat stroke. Many outdoor activities become dangerous or impossible in very high temperatures. In general, Canadians are not used to extremely hot summers, and further warming will bring new and unusual risks as well as a very different experience of the summer season. High, persistent temperatures increase the risk of drought, which can severely impact food production and increases the risk of wildfire. High temperatures can also lead to more thunderstorms, which means increased risks of flash flooding, lightning, hail and perhaps even tornadoes.	0	0.2	0.2	1	1
Freeze-Thaw Cycles	This is a simple count of days when the air temperature fluctuates between freezing and non-freezing temperatures. Under these conditions, it is likely that some water at the surface was both liquid and ice at some point during the 24-hour period.	A freeze-thaw cycle occurs when the daily maximum temperature (Tmax) is higher than 0 °C and the daily minimum temperature (Tmin) is less than or equal to -1 °C. The minimum temperature of -1 °C (rather than 0 ° C) is used as the threshold for freezing to raise the likelihood that water actually froze at the surface.	Can have major structural impact on infrastructure such as roadways, sidewalks, etc.	Freeze-thaw cycles can have major impacts on infrastructure. Water expands when it freezes, so the freezing, melting and re-freezing of water can over time cause significant damage to roadways, sidewalks, and other outdoor structures. Potholes that form during the spring, or during mid-winter melts, are good examples of the damage caused by this process.	83.6	73.6	-10.1	62.5	-21.1
Freezing Degree Days	Freezing degree days (FDD) begin to accumulate when the daily mean temperature drops below freezing: if a day's mean temperature is -21 °C, for example, it increases the annual FDD value by 21. Days when the mean temperature is 0 °C or warmer do not contribute to the annual sum.	Annual sum of the number of degrees Celsius that each day's mean temperature is below 0 °C.	High values are associated with relatively cold conditions, and indicate many days with temperatures significantly below freezing.	High FDD values are associated with relatively cold conditions: places with high FDD values likely get many days with temperatures significantly below freezing. If projections show a decrease in FDDs, then that location is likely to experience shorter or less severe winters. High FDD likely imply greater snow and ice accumulation, which is an important consideration for winter activities such as skiing, the building of winter roads, municipal and rural snow clearance, and many other aspects of winter life. Such places would likely require a relatively large amount of energy for heating.	467	303.7	163.3	170.1	296.9
Frost Days	A frost day is one on which the coldest temperature of the day is lower than 0 °C. Under these conditions frost might form at ground level or on cold surfaces.	A day on which the daily minimum temperature (Tmin) is below 0 °C.	These conditions indicate frost might form at ground level or on cold services.	The number of frost days is an indicator of the length and severity of the winter season. A location with a large number of frost days is also likely to have a short growing season, since frost is harmful to many plants. Cold weather is an important aspect of life in Canada, and many places in Canada are well adapted to very cold winters. It is especially important to know how our winters will change in the future, because cold temperatures affect our health and safety, determine what plants and animals can live in the area, limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use.	144.9	117.5	-27.3	92	-52.9
Frost-Free Season	The Frost-Free Season is the approximate length of the growing season, during which there are no freezing temperatures to kill or damage plants.	The number of days between the date of the last spring frost and the date of the first fall frost, equivalent to the number of consecutive days during the 'summer' without any daily minimum temperatures equal to or below 0 °C.	Indicates when no freezing temperatures occur that might kill or damage plants or animals.	Changes in the length and timing of the Frost-Free Season affect plant and animal life, but also our social, psychological, and physical experience of the changing seasons. The average length of the growing season (and its year-to-year variability) is an important consideration when selecting or predicting what plants might grow well in a region. A longer Frost-Free Season means plants and crops have a longer window to grow and mature. If projections show an increase in the length of the Frost-Free Season, then the annual growing season will be longer, and the period of cold weather correspondingly shorter.	170.2	193.9	23.7	217.1	46.9

CLIMATE VARIABLE	DESCRIPTION		ABOUT THIS VARIABLE		RCP 8.5, mean values for the period indicated				
Name	**General description**	**Technical description**	**Short description**	**Long description**	**1976-2005**	**2021-2050**	**[+/-]**	**2051-2080**	**[+/-]**
Growing Degree Days (Base 10 °C)	Growing Degree Days (GDD) provide an index of the amount of heat available for the growth and maturation of plants and insects. Different base temperatures (5, 10 and 15 °C) are used to capture results for organisms that demand different amounts of heat.	Annual sum of the number of degrees Celsius that each day's mean temperature is above a specified base temperature (Tbase).	Helpful for crop selection, insect control, and other management.	Growing Degree Days (GDDs) are often used to determine whether a climate is warm enough to support plants and insects with temperature-dependent growth rates. GDDs accumulate whenever the daily mean temperature is above a specified threshold temperature. Generally, 5 °C GDDs are used for assessing the growth of canola and forage crops; 10 °C GDDs are more appropriate for assessing the growth of corn and beans; and 15 °C GDDs are used to assess the growth and development of insects and pests.	851.1	1144	292.6	1486	634.6
Growing Degree Days (Base 15 °C)	Growing Degree Days (GDD) provide an index of the amount of heat available for the growth and maturation of plants and insects. Different base temperatures (5, 10 and 15 °C) are used to capture results for organisms that demand different amounts of heat.	Annual sum of the number of degrees Celsius that each day's mean temperature is above a specified base temperature (Tbase).	Helpful for crop selection, insect control, and other management.	Growing Degree Days (GDDs) are often used to determine whether a climate is warm enough to support plants and insects with temperature-dependent growth rates. GDDs accumulate whenever the daily mean temperature is above a specified threshold temperature. Generally, 5 °C GDDs are used for assessing the growth of canola and forage crops; 10 °C GDDs are more appropriate for assessing the growth of corn and beans; and 15 °C GDDs are used to assess the growth and development of insects and pests.	267.2	452.9	185.7	690.8	423.6
Growing Degree Days (Base 5 °C)	Growing Degree Days (GDD) provide an index of the amount of heat available for the growth and maturation of plants and insects. Different base temperatures (5, 10 and 15 °C) are used to capture results for organisms that demand different amounts of heat.	Annual sum of the number of degrees Celsius that each day's mean temperature is above a specified base temperature (Tbase).	Helpful for crop selection, insect control, and other management.	Growing Degree Days (GDDs) are often used to determine whether a climate is warm enough to support plants and insects with temperature-dependent growth rates. GDDs accumulate whenever the daily mean temperature is above a specified threshold temperature. Generally, 5 °C GDDs are used for assessing the growth of canola and forage crops; 10 °C GDDs are more appropriate for assessing the growth of corn and beans; and 15 °C GDDs are used to assess the growth and development of insects and pests.	1736	2133	397.3	2590	854.1
Heating Degree Days	Heating Degree Days (HDD) are equal to the number of degrees Celsius a given day's mean temperature is below 18 °C. For example, if the daily mean temperature is 12 °C, the HDD value for that day is equal to 6 °C. If the daily mean temperature is above 18 °C, the HDD value for that day is set to zero.	Annual sum of the number of degrees Celsius that each day's mean temperature is below 18 °C.	Often used as a measure of how much heating is required in a year.	Heating Degree Days are a measure of how much heating is required in a year. 18 ° C is the temperature below which heating is required to maintain a comfortable temperature inside buildings. A place that gets many days with average temperatures below 18 °C or that gets mean temperatures much below 18 °C will require a relatively large amount of energy (and thus money) to heat buildings for comfort and safety. If a location shows a decrease in projected HDD values, this implies that it will experience shorter periods of cold weather, or that it will experience less severe cold.	4160	3597	-563.5	3061	-1099.5
Heavy Precipitation Days (10 mm)	A Heavy Precipitation Day (HPD) is a day on which at least a total of 10 mm (or 20 mm) of rain or frozen precipitation falls. Frozen precipitation is measured according to its liquid equivalent: 10 cm of snow is usually about 10 mm of precipitation.	Heavy Precipitation Days are defined in two ways: either as a day on which at least a total of 10 mm of rain and/or liquid-equivalent frozen precipitation is deposited at the surface, or a day with 20 mm.	Heavy rainfall can impact storm drains, flooding, erosion, roads, etc.	What counts as a Heavy Precipitation Day (HPD) depends on where you live: some places in Canada rarely get 10 mm of rain in a day, whereas others often do. The Climate Atlas offers two versions of HPD: days on which either 10 mm or 20 mm or more of rain (or its frozen equivalent, usually snow) falls. Heavy rainfall events can create many challenges. In cities and towns, heavy rainfalls can overwhelm storm drains and cause flash flooding. They can also cause problems in rural areas by drowning crops, eroding topsoil, and damaging roads. Heavy snowfall events can disrupt ground transportation, and very heavy snowfall events can cause damage to buildings if their roofs become overburdened.	47.5	49.5	2	50.3	2.8
Heavy Precipitation Days (20 mm)	A Heavy Precipitation Day (HPD) is a day on which at least a total of 10 mm (or 20 mm) of rain or frozen precipitation falls. Frozen precipitation is measured according to its liquid equivalent: 10 cm of snow is usually about 10 mm of precipitation.	Heavy Precipitation Days are defined in two ways: either as a day on which at least a total of 10 mm of rain and/or liquid-equivalent frozen precipitation is deposited at the surface, or a day with 20 mm.	Heavy rainfall can impact storm drains, flooding, erosion, roads, etc.	What counts as a Heavy Precipitation Day (HPD) depends on where you live: some places in Canada rarely get 10 mm of rain in a day, whereas others often do. The Climate Atlas offers two versions of HPD: days on which either 10 mm or 20 mm or more of rain (or its frozen equivalent, usually snow) falls. Heavy rainfall events can create many challenges. In cities and towns, heavy rainfalls can overwhelm storm drains and cause flash flooding. They can also cause problems in rural areas by drowning crops, eroding topsoil, and damaging roads. Heavy snowfall events can disrupt ground transportation, and very heavy snowfall events can cause damage to buildings if their roofs become overburdened.	20.5	22.4	1.9	23.7	3.2

CLIMATE VARIABLE	DESCRIPTION		ABOUT THIS VARIABLE		RCP 8.5, mean values for the period indicated				
Name	**General description**	**Technical description**	**Short description**	**Long description**	**1976-2005**	**2021-2050**	**[+/-]**	**2051-2080**	**[+/-]**
Hot (+30 °C) Season	The number of days when +30 °C temperatures can be expected.	The number of days from the first day of the year with tmax ≥ 30 °C to the last day with tmax ≥ 30 °C.		High temperatures are important. They determine if plants and animals can thrive, they limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use. It is useful to know how high summer temperatures are likely to become in the future, to make sure that our cooling and air-conditioning systems can reliably deal with these extremes. When temperatures are very hot, people - especially the elderly - are much more likely to suffer from heat exhaustion and heat stroke. Many outdoor activities become dangerous or impossible in very high temperatures. In general, Canadians are not used to extremely hot summers, and further warming will bring new and unusual risks as well as a very different experience of the summer season. High, persistent temperatures increase the risk of drought, which can severely impact food production and increases the risk of wildfire. High temperatures can also lead to more thunderstorms, which means increased risks of flash flooding, lightning, hail and perhaps even tornadoes.	5.6	22.1	16.5	50.3	44.6
Icing Days	An Icing Day is a day on which the air temperature does not go above freezing (0 °C).	An Icing Day is a day on which the daily maximum temperature (Tmax) is less than or equal to 0 °C.	Indicator of the length and/or severity of the winter season, which affects human health and safety, recreation, heating costs, and more.	The number of days on which the air temperature does not rise above freezing is a good indicator of the length and severity of the winter season. Cold weather is an important aspect of life in Canada, and many places in Canada are well adapted to very cold winters. It is especially important to know how our winters will change in the future, because cold temperatures affect our health and safety, determine what plants and animals can live in the area, limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use.	43.7	29.3	-14.3	17.2	26.5
Longest Spell of +30 ° C Days	The maximum number of days in a row with temperatures 30 °C or higher.	The longest series of consecutive days with tmax ≥ 30 °C. Here, there is no minimum threshold for number of days in a row that must be reached or exceeded to count as a spell. A year with zero +30 °C days will return a longest spell value of zero.		High temperatures are important. They determine if plants and animals can thrive, they limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use. It is useful to know how high summer temperatures are likely to become in the future, to make sure that our cooling and air-conditioning systems can reliably deal with these extremes. When temperatures are very hot, people - especially the elderly - are much more likely to suffer from heat exhaustion and heat stroke. Many outdoor activities become dangerous or impossible in very high temperatures. In general, Canadians are not used to extremely hot summers, and further warming will bring new and unusual risks as well as a very different experience of the summer season. High, persistent temperatures increase the risk of drought, which can severely impact food production and increases the risk of wildfire. High temperatures can also lead to more thunderstorms, which means increased risks of flash flooding, lightning, hail and perhaps even tornadoes. Technical description:	0.1	0.8	0.7	3.2	3.1
Max 1-Day Precipitation	The amount the precipitation that falls on the wettest day of the year.	The maximum precipitation that falls in single calendar day.		This value indicates the most precipitation that falls in a single day, and is sometimes also called the “wettest day of the year”. This amount could be the result of a short but intense precipitation event such as a storm or because a moderate amount of snow/rain falls continuously all day, rather than all at once. Very high precipitation totals and/or very high precipitation rates create many challenges. In cities and towns, high precipitation rates overwhelm storm drains and cause flash flooding. They can also cause problems in rural areas by drowning crops, eroding topsoil, and damaging roads. Heavy snowfall events can disrupt ground transportation, and very heavy snowfall events can cause damage to buildings if their roofs become overburdened.	67	74	10	79	18

CLIMATE VARIABLE	DESCRIPTION		ABOUT THIS VARIABLE		RCP 8.5, mean values for the period indicated				
Name	**General description**	**Technical description**	**Short description**	**Long description**	**1976-2005**	**2021-2050**	**[+/-]**	**2051-2080**	**[+/-]**
Max 3-Day Precipitation	The wettest three-day period.	The maximum total precipitation that falls over a consecutive three-day period.		In regions where snow and/or rain tends to fall for multiple days in a row, the Max 3-Day Precipitation total may be a better metric of the total volume of precipitation a region should expect to receive at one time than the 1-Day Precipitation total. Very high precipitation totals and/or very high precipitation rates create many challenges. In cities and towns, high precipitation rates overwhelm storm drains and cause flash flooding. They can also cause problems in rural areas by drowning crops, eroding topsoil, and damaging roads. Heavy snowfall events can disrupt ground transportation, and very heavy snowfall events can cause damage to buildings if their roofs become overburdened.	84	91	9	97	16
Max 5-Day Precipitation	The wettest five-day period.	The maximum total precipitation that falls over a consecutive five-day period.		In regions where snow and/or rain tends to fall for multiple days in a row, the Max 5-Day Precipitation total may be a better metric of the total volume of precipitation a region should expect to receive at one time than the 1-Day Precipitation total. Very high precipitation totals and/or very high precipitation rates create many challenges. In cities and towns, high precipitation rates overwhelm storm drains and cause flash flooding. They can also cause problems in rural areas by drowning crops, eroding topsoil, and damaging roads. Heavy snowfall events can disrupt ground transportation, and very heavy snowfall events can cause damage to buildings if their roofs become overburdened.	100	107	7	114	14
Maximum Temperature - annual	The highest temperature of the day.	The daily maximum temperature (Tmax).	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions.	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions. The average highest temperature is an environmental indicator with many applications in agriculture, engineering, health, energy management, recreation, and more. The maximum temperature is also used to compute a number of other maps and indices in this Atlas.	11.3	13.1	1.8	15	3.7
Maximum Temperature - spring	The highest temperature of the day.	The daily maximum temperature (Tmax).	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions.	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions. The average highest temperature is an environmental indicator with many applications in agriculture, engineering, health, energy management, recreation, and more. The maximum temperature is also used to compute a number of other maps and indices in this Atlas.	8.7	10.3	1.6	12.1	3.4
Maximum Temperature - summer	The highest temperature of the day.	The daily maximum temperature (Tmax).	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions.	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions. The average highest temperature is an environmental indicator with many applications in agriculture, engineering, health, energy management, recreation, and more. The maximum temperature is also used to compute a number of other maps and indices in this Atlas.	21.7	23.6	1.9	25.6	3.9
Maximum Temperature - fall	The highest temperature of the day.	The daily maximum temperature (Tmax).	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions.	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions. The average highest temperature is an environmental indicator with many applications in agriculture, engineering, health, energy management, recreation, and more. The maximum temperature is also used to compute a number of other maps and indices in this Atlas.	13.7	15.6	1.9	17.5	3.7

CLIMATE VARIABLE	DESCRIPTION		ABOUT THIS VARIABLE		RCP 8.5, mean values for the period indicated				
Name	**General description**	**Technical description**	**Short description**	**Long description**	**1976-2005**	**2021-2050**	**[+/-]**	**2051-2080**	**[+/-]**
Maximum Temperature - winter	The highest temperature of the day.	The daily maximum temperature (Tmax).	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions.	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions. The average highest temperature is an environmental indicator with many applications in agriculture, engineering, health, energy management, recreation, and more. The maximum temperature is also used to compute a number of other maps and indices in this Atlas.	0.8	2.6	1.8	4.5	3.7
Mean Temperature - annual	The average temperature of the day.	The average of the daily maximum temperature (Tmax) and the daily minimum temperature (Tmin).	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions.	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions. The average temperature is an environmental indicator with many applications in agriculture, engineering, health, energy management, recreation, and more. The average temperature is used to compute a number of other maps and indices in this Atlas.	6.8	8.6	1.8	10.6	3.8
Mean Temperature - spring	The average temperature of the day.	The average of the daily maximum temperature (Tmax) and the daily minimum temperature (Tmin).	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions.	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions. The average temperature is an environmental indicator with many applications in agriculture, engineering, health, energy management, recreation, and more. The average temperature is used to compute a number of other maps and indices in this Atlas.	4.2	5.9	1.7	7.7	3.5
Mean Temperature - summer	The average temperature of the day.	The average of the daily maximum temperature (Tmax) and the daily minimum temperature (Tmin).	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions.	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions. The average temperature is an environmental indicator with many applications in agriculture, engineering, health, energy management, recreation, and more. The average temperature is used to compute a number of other maps and indices in this Atlas.	16.8	18.7	1.9	20.6	3.8
Mean Temperature - fall	The average temperature of the day.	The average of the daily maximum temperature (Tmax) and the daily minimum temperature (Tmin).	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions.	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions. The average temperature is an environmental indicator with many applications in agriculture, engineering, health, energy management, recreation, and more. The average temperature is used to compute a number of other maps and indices in this Atlas.	9.4	11.3	1.9	13.2	3.7
Mean Temperature - winter	The average temperature of the day.	The average of the daily maximum temperature (Tmax) and the daily minimum temperature (Tmin).	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions.	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions. The average temperature is an environmental indicator with many applications in agriculture, engineering, health, energy management, recreation, and more. The average temperature is used to compute a number of other maps and indices in this Atlas.	-3.5	-1.5	2	0.6	4.1
Mild Winter Days (-5 °C)	A Mild Winter Day is a day when the temperature drops to at least -5 °C.	A Mild Winter Day is a day with a minimum temperature (Tmin) less than or equal to -5 °C.		Mild Winter Days indicate how much a location experiences moderately cold temperatures. Cold weather is an important aspect of life in Canada, and many places in Canada are well adapted to very cold winters. It is especially important to know how our winters will change in the future, because cold temperatures affect our health and safety, determine what plants and animals can live in the area, limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use. Ski slope operators generally require temperatures below -5 °C to make artificial snow.	76.7	58.9	-17.8	40.8	-35.9

CLIMATE VARIABLE	DESCRIPTION		ABOUT THIS VARIABLE		RCP 8.5, mean values for the period indicated				
Name	**General description**	**Technical description**	**Short description**	**Long description**	**1976-2005**	**2021-2050**	**[+/-]**	**2051-2080**	**[+/-]**
Minimum Temperature - annual	The lowest temperature of the day.	The daily minimum temperature (Tmin).	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions.	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions. The average lowest temperature is an environmental indicator with many applications in agriculture, engineering, health, energy management, recreation, and more. The average temperature is used to compute a number of other maps and indices in this Atlas.	2.3	4.2	1.9	6.2	3.9
Minimum Temperature - spring	The lowest temperature of the day.	The daily minimum temperature (Tmin).	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions.	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions. The average lowest temperature is an environmental indicator with many applications in agriculture, engineering, health, energy management, recreation, and more. The average temperature is used to compute a number of other maps and indices in this Atlas.	-0.2	1.5	1.7	3.3	3.5
Minimum Temperature - summer	The lowest temperature of the day.	The daily minimum temperature (Tmin).	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions.	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions. The average lowest temperature is an environmental indicator with many applications in agriculture, engineering, health, energy management, recreation, and more. The average temperature is used to compute a number of other maps and indices in this Atlas.	11.9	13.8	1.8	15.7	3.8
Minimum Temperature - fall	The lowest temperature of the day.	The daily minimum temperature (Tmin).	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions.	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions. The average lowest temperature is an environmental indicator with many applications in agriculture, engineering, health, energy management, recreation, and more. The average temperature is used to compute a number of other maps and indices in this Atlas.	5.2	7	1.9	8.9	3.8
Minimum Temperature - winter	The lowest temperature of the day.	The daily minimum temperature (Tmin).	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions.	The temperature range we expect within a season or year is a very important aspect of climate. Changes in average and extreme temperatures can dramatically affect our everyday lives as well as a wide range of planning and policy decisions. The average lowest temperature is an environmental indicator with many applications in agriculture, engineering, health, energy management, recreation, and more. The average temperature is used to compute a number of other maps and indices in this Atlas.	-7.9	-5.7	2.2	-3.4	4.5
Number of Heat Waves	The average number of heat waves per year. A heat wave occurs when at least three days in a row reach or exceed 30 °C.	The number of heat waves per year, where a heat wave is defined as three or more consecutive days with tmax ≥ 30 °C.		High temperatures are important. They determine if plants and animals can thrive, they limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use. It is useful to know how high summer temperatures are likely to become in the future, to make sure that our cooling and air-conditioning systems can reliably deal with these extremes. When temperatures are very hot, people - especially the elderly - are much more likely to suffer from heat exhaustion and heat stroke. Many outdoor activities become dangerous or impossible in very high temperatures. In general, Canadians are not used to extremely hot summers, and further warming will bring new and unusual risks as well as a very different experience of the summer season. High, persistent temperatures increase the risk of drought, which can severely impact food production and increases the risk of wildfire. High temperatures can also lead to more thunderstorms, which means increased risks of flash flooding, lightning, hail and perhaps even tornadoes.	0	0.3	0.3	1.5	1.5

CLIMATE VARIABLE	DESCRIPTION		ABOUT THIS VARIABLE		RCP 8.5, mean values for the period indicated				
Name	**General description**	**Technical description**	**Short description**	**Long description**	**1976-2005**	**2021-2050**	**[+/-]**	**2051-2080**	**[+/-]**
Precipitation - annual	The total amount of rain, drizzle, snow, sleet, etc. Frozen precipitation is measured according to its liquid equivalent: 10 cm of snow is usually about 10 mm of precipitation.	The depth of liquid and/or frozen water deposited on the surface, with frozen precipitation converted to its liquid water equivalent.	Affects water availability, crop viability, hydroelectric power generation, fire risk, snow accumulation, flooding, and drought.	Precipitation patterns are critical for many important issues, including water availability, crop production, electricity generation, wildfire suppression, snow accumulation, seasonal and flash-flooding, and short- and long-term drought risk.	1440	1519	79	1571	131
Precipitation - spring	The total amount of rain, drizzle, snow, sleet, etc. Frozen precipitation is measured according to its liquid equivalent: 10 cm of snow is usually about 10 mm of precipitation.	The depth of liquid and/or frozen water deposited on the surface, with frozen precipitation converted to its liquid water equivalent.	Affects water availability, crop viability, hydroelectric power generation, fire risk, snow accumulation, flooding, and drought.	Precipitation patterns are critical for many important issues, including water availability, crop production, electricity generation, wildfire suppression, snow accumulation, seasonal and flash-flooding, and short- and long-term drought risk.	353	379	26	394	41
Precipitation - summer	The total amount of rain, drizzle, snow, sleet, etc. Frozen precipitation is measured according to its liquid equivalent: 10 cm of snow is usually about 10 mm of precipitation.	The depth of liquid and/or frozen water deposited on the surface, with frozen precipitation converted to its liquid water equivalent.	Affects water availability, crop viability, hydroelectric power generation, fire risk, snow accumulation, flooding, and drought.	Precipitation patterns are critical for many important issues, including water availability, crop production, electricity generation, wildfire suppression, snow accumulation, seasonal and flash-flooding, and short- and long-term drought risk.	291	306	15	310	19
Precipitation - fall	The total amount of rain, drizzle, snow, sleet, etc. Frozen precipitation is measured according to its liquid equivalent: 10 cm of snow is usually about 10 mm of precipitation.	The depth of liquid and/or frozen water deposited on the surface, with frozen precipitation converted to its liquid water equivalent.	Affects water availability, crop viability, hydroelectric power generation, fire risk, snow accumulation, flooding, and drought.	Precipitation patterns are critical for many important issues, including water availability, crop production, electricity generation, wildfire suppression, snow accumulation, seasonal and flash-flooding, and short- and long-term drought risk.	379	390	11	399	20
Precipitation - winter	The total amount of rain, drizzle, snow, sleet, etc. Frozen precipitation is measured according to its liquid equivalent: 10 cm of snow is usually about 10 mm of precipitation.	The depth of liquid and/or frozen water deposited on the surface, with frozen precipitation converted to its liquid water equivalent.	Affects water availability, crop viability, hydroelectric power generation, fire risk, snow accumulation, flooding, and drought.	Precipitation patterns are critical for many important issues, including water availability, crop production, electricity generation, wildfire suppression, snow accumulation, seasonal and flash-flooding, and short- and long-term drought risk.	416	445	29	468	52
Summer Days	A Summer Day is a day when the temperature rises to at least 25 °C.	A Summer Day is a day with a maximum temperature (Tmax) greater than or equal to 25 °C.	Increased health risks to vulnerable people, limits outdoor recreation, increased energy use, increased drought and fire risk, changes to ecosystems and biodiversity, etc.	High temperatures are important. They determine if plants and animals can thrive, they limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use. It is useful to know how high summer temperatures are likely to become in the future, to make sure that our cooling and air-conditioning systems can reliably deal with these extremes. When temperatures are very hot, people - especially the elderly - are much more likely to suffer from heat exhaustion and heat stroke. Many outdoor activities become dangerous or impossible in very high temperatures. In general, Canadians are not used to extremely hot summers, and further warming will bring new and unusual risks as well as a very different experience of the summer season. High, persistent temperatures increase the risk of drought, which can severely impact food production and increases the risk of wildfire. High temperatures can also lead to more thunderstorms, which means increased risks of flash flooding, lightning, hail and perhaps even tornadoes.	18.4	39.2	20.8	66	47.6

CLIMATE VARIABLE	DESCRIPTION		ABOUT THIS VARIABLE		RCP 8.5, mean values for the period indicated				
Name	**General description**	**Technical description**	**Short description**	**Long description**	**1976-2005**	**2021-2050**	**[+/-]**	**2051-2080**	**[+/-]**
Tropical Nights	A Tropical Night occurs when the lowest temperature of the day does not go below 20 °C.	A Tropical Night occurs when the daily minimum temperature (Tmin) is greater than or equal to 20 °C.	Increased health risks to vulnerable people, limits outdoor recreation, increased energy use, increased drought and fire risk, changes to ecosystems and biodiversity, etc.	Hot summer days are physiologically stressful, especially if overnight temperatures do not provide cooling relief. Many people are at risk from suffering heat exhaustion or heat stroke when nighttime temperatures fail to drop below 20 °C. Elderly people, the homeless, and those who live in houses or apartments without air conditioning are especially vulnerable during these heat events, particularly if they last for more than a few days. High temperatures are important. They determine if plants and animals can thrive, they limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use. It is useful to know how high summer temperatures are likely to become in the future, to make sure that our cooling and air-conditioning systems can reliably deal with these extremes. When temperatures are very hot, people - especially the elderly - are much more likely to suffer from heat exhaustion and heat stroke. Many outdoor activities become dangerous or impossible in very high temperatures. In general, Canadians are not used to extremely hot summers, and further warming will bring new and unusual risks as well as a very different experience of the summer season. High, persistent temperatures increase the risk of drought, which can severely impact food production and increases the risk of wildfire. High temperatures can also lead to more thunderstorms, which means increased risks of flash flooding, lightning, hail and perhaps even tornadoes.	0.1	1.4	1.3	10.2	10.1
Very Cold Days (-30°C)	A Very Cold Day is a day when the temperature drops to at least -30 °C.	A Very Cold Day is a day with a minimum temperature (Tmin) less than or equal to -30 °C.	Indicator of winter severity that affects health, safety, recreation, ecosystems, etc.	Very cold days are an indicator of winter severity. Cold weather is an important aspect of life in Canada, and many places in Canada are well adapted to very cold winters. It is especially important to know how our winters will change in the future, because cold temperatures affect our health and safety, determine what plants and animals can live in the area, limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use.	0	0	0	0	0
Very Hot Days (+30°C)	A Very Hot Day is a day when the temperature rises to at least 30 °C.	A Very Hot Day is a day with a maximum temperature (Tmax) greater than or equal to 30 °C.	Increased health risks to vulnerable people, limits outdoor recreation, increased energy use, increased drought and fire risk, changes to ecosystems and biodiversity, etc.	Very Hot Days are an indicator of summer heat. High temperatures are important. They determine if plants and animals can thrive, they limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use. It is useful to know how high summer temperatures are likely to become in the future, to make sure that our cooling and air-conditioning systems can reliably deal with these extremes. When temperatures are very hot, people - especially the elderly - are much more likely to suffer from heat exhaustion and heat stroke. Many outdoor activities become dangerous or impossible in very high temperatures. In general, Canadians are not used to extremely hot summers, and further warming will bring new and unusual risks as well as a very different experience of the summer season. High, persistent temperatures increase the risk of drought, which can severely impact food production and increases the risk of wildfire. High temperatures can also lead to more thunderstorms, which means increased risks of flash flooding, lightning, hail and perhaps even tornadoes.	0.9	3.4	2.5	11.9	11.1

CLIMATE VARIABLE	DESCRIPTION		ABOUT THIS VARIABLE		RCP 8.5, mean values for the period indicated				
Name	**General description**	**Technical description**	**Short description**	**Long description**	**1976-2005**	**2021-2050**	**[+/-]**	**2051-2080**	**[+/-]**
Warmest Maximum Temperature	The highest temperature of the year.	The maximum temperature of the year.	Increased health risks to vulnerable people, limits outdoor recreation, increased energy use, increased drought and fire risk, changes to ecosystems and biodiversity, etc.	High temperatures are important. They determine if plants and animals can thrive, they limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use. It is useful to know how high summer temperatures are likely to become in the future, to make sure that our cooling and air-conditioning systems can reliably deal with these extremes. When temperatures are very hot, people - especially the elderly - are much more likely to suffer from heat exhaustion and heat stroke. Many outdoor activities become dangerous or impossible in very high temperatures. In general, Canadians are not used to extremely hot summers, and further warming will bring new and unusual risks as well as a very different experience of the summer season. High, persistent temperatures increase the risk of drought, which can severely impact food production and increases the risk of wildfire. High temperatures can also lead to more thunderstorms, which means increased risks of flash flooding, lightning, hail and perhaps even tornadoes.	29.6	31.5	1.9	33.6	3.9
Wet Days	The number of days in a year with rain/snow.	A Wet Day is a day with at least 0.2 mm of precipitation. A threshold value of 0.2 mm is used to be consistent with the Meteorological Service of Canada.		Precipitation patterns are critical for many important issues, including water availability, crop production, electricity generation, wildfire suppression, snow accumulation, seasonal and flash-flooding, and short- and long-term drought risk. Locations that experience precipitation frequently, such as along coasts, have a high number of Wet Days, whereas locations that experience precipitation infrequently have a low number of Wet Days.	170.7	170.7	0	170	-0.7
Winter Days (-15 °C)	A Winter Day is a day when the temperature drops to at least -15 °C.	A Winter Day is a day with a minimum temperature (Tmin) less than or equal to -15 °C.		Winter Days are an indicator of how cold winters are. Few places in Canada never see -15 °C temperatures, making this index a good indicator of how winter cold is projected to change across the country. Cold weather is an important aspect of life in Canada, and many places in Canada are well adapted to very cold winters. It is especially important to know how our winters will change in the future, because cold temperatures affect our health and safety, determine what plants and animals can live in the area, limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use.	13.2	5.5	-7.7	1.4	-11.8

Attachment D

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.

Disclaimer

Reasonable skill, care and diligence have been exercised to assess information acquired during the preparation of this analysis, but no guarantees or warranties are made regarding the accuracy or completeness of this information. This document, the information it contains, the information and basis on which it relies, and factors associated with implementation are subject to changes that are beyond the control of the authors. The information provided by others is believed to be accurate but has not been verified.

This analysis includes high-level estimates of costs and revenues that should not be relied upon for design or other purposes without verification. The authors do not accept responsibility for the use of this analysis for any purpose other than that stated above and does not accept responsibility to any third party for the use, in whole or in part, of the contents of this document.

This analysis applies to the geographic area of the Halifax Regional Municipality and cannot be applied to other jurisdictions without analysis. Any use by the Halifax Regional Municipality, project partners, sub-consultants or any third party, or any reliance on or decisions based on this document are the responsibility of the user or third party.

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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^{o}C, 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^{o}C 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.

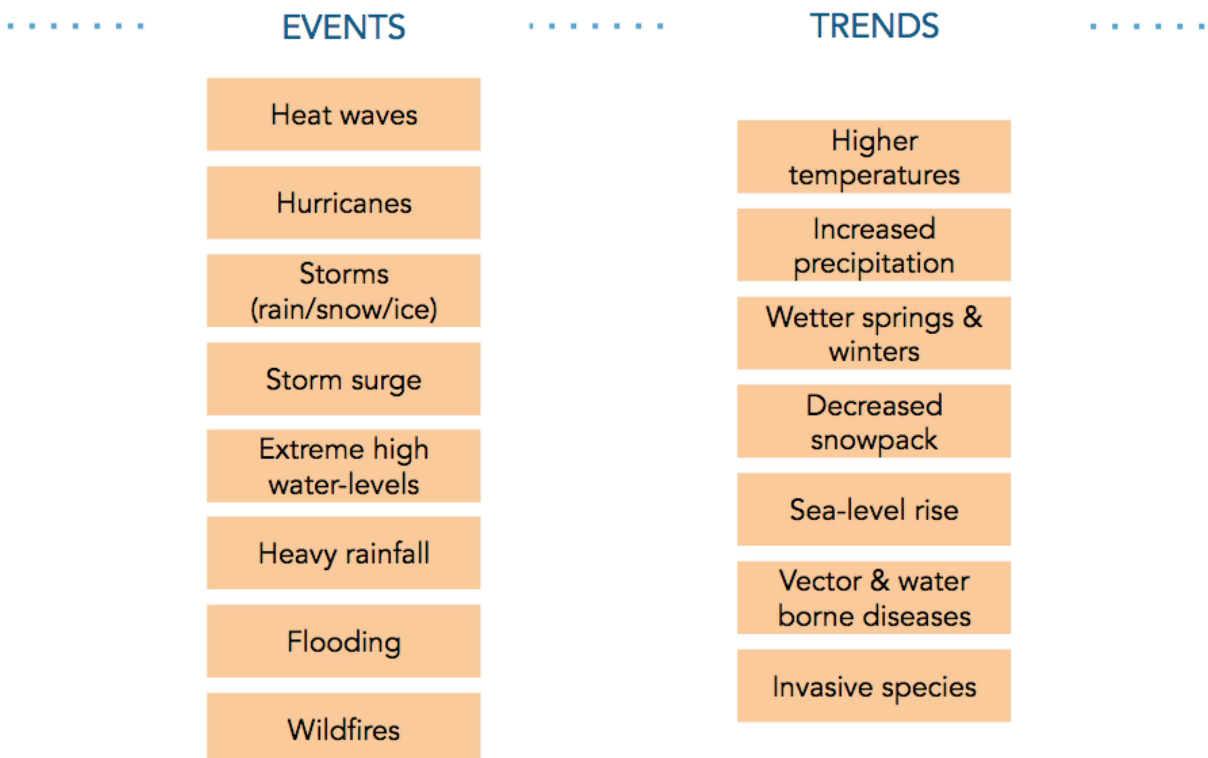


Figure 2. Climate hazard events and trends.

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.

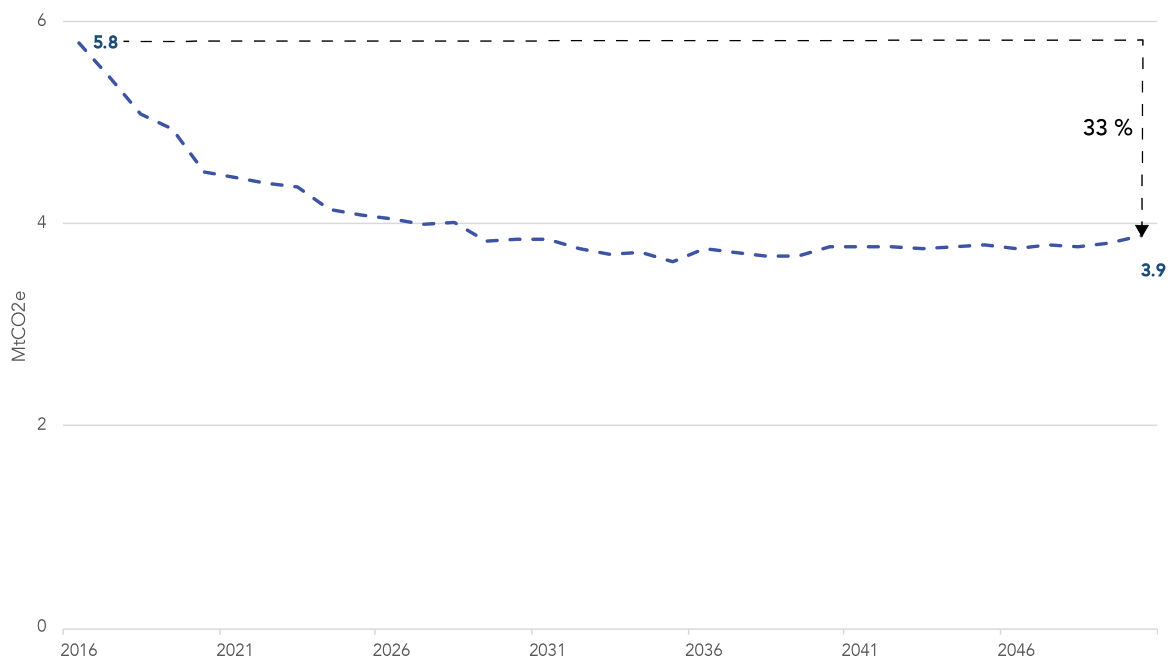


Figure 3. Projected BAU emissions (MtCO2e), 2016-2050

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).

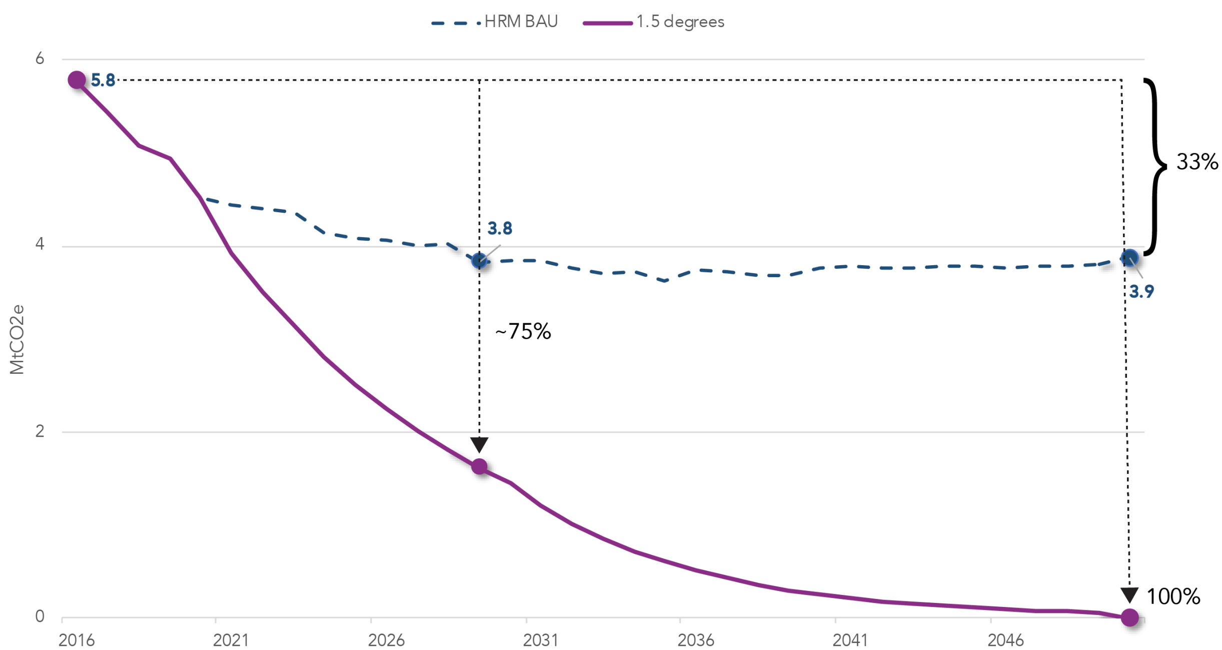


Figure 4. Percentage reductions to align with 1.5C.

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.

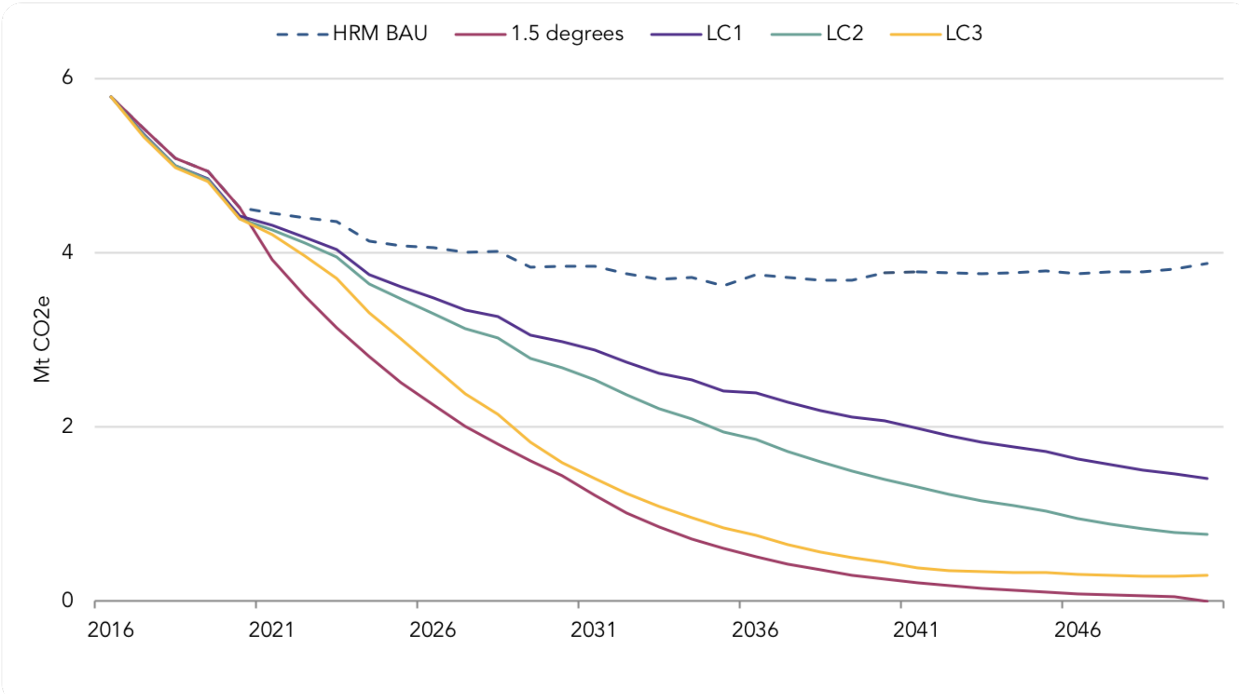
Results

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.

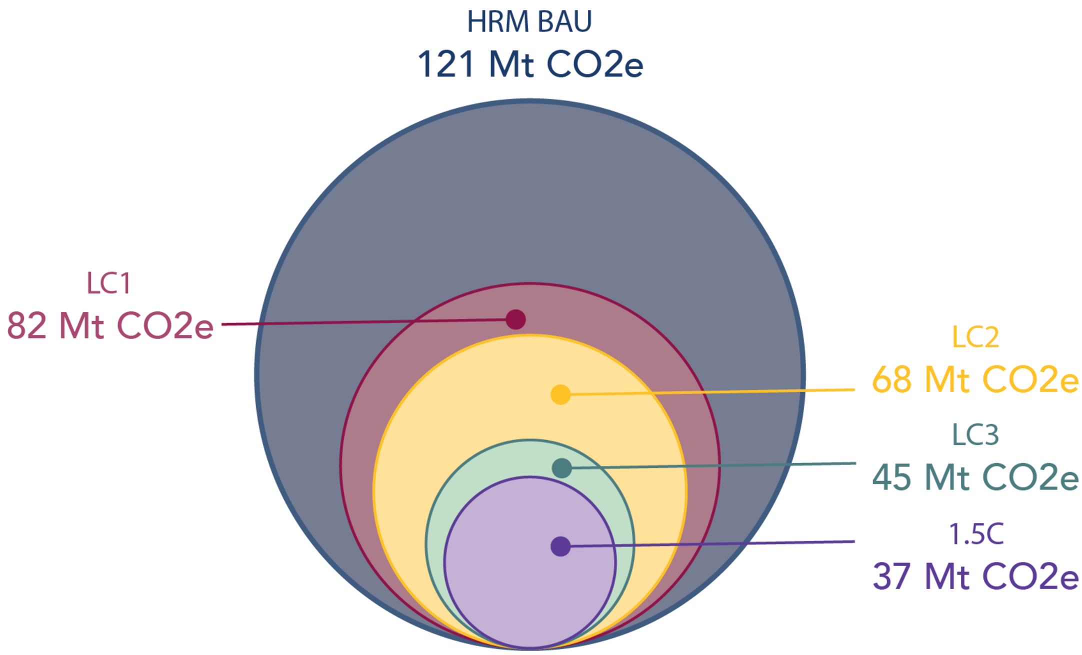


Figure 7. Cumulative carbon [carbon budget] 2020-2050 (Mt CO2e) for HRM BAU, LC1, LC2, LC3, and 1.5C.

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

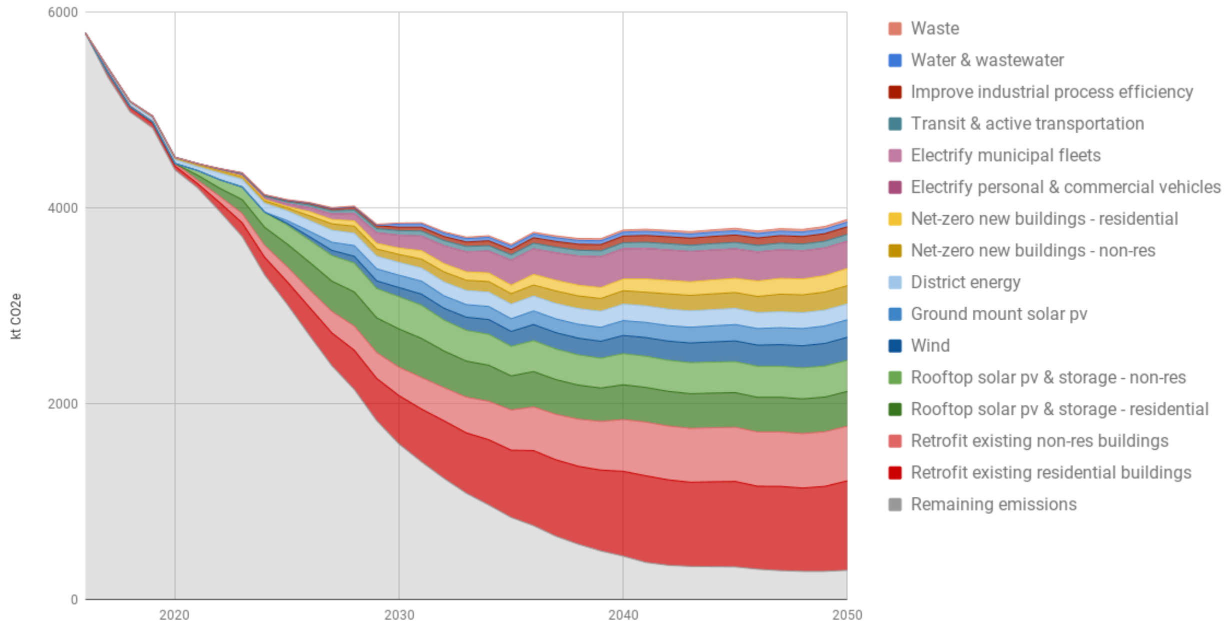


Figure 8. Wedge diagram showing emissions reduction by action area to 2050 in the LC3 scenario.

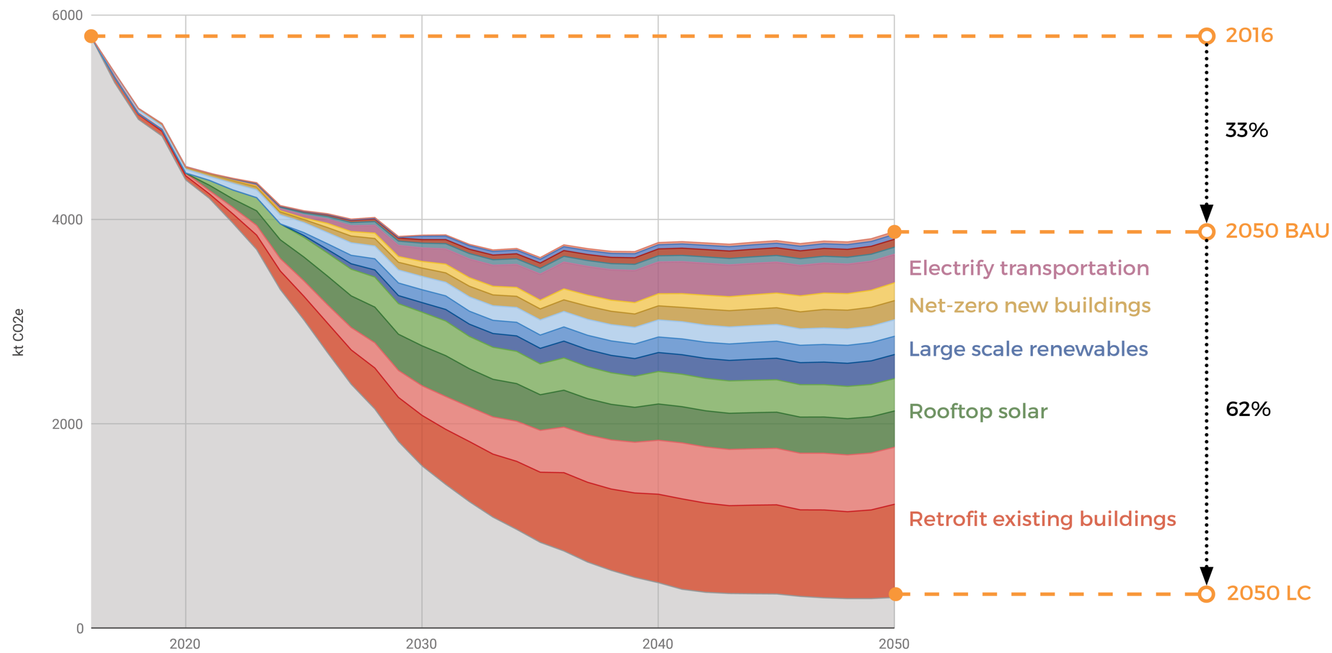


Figure 9. Wedge diagram showing the relative emission reduction (kt CO2e) by action area and percentage reduction to 2050 in the LC3 scenario.

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.

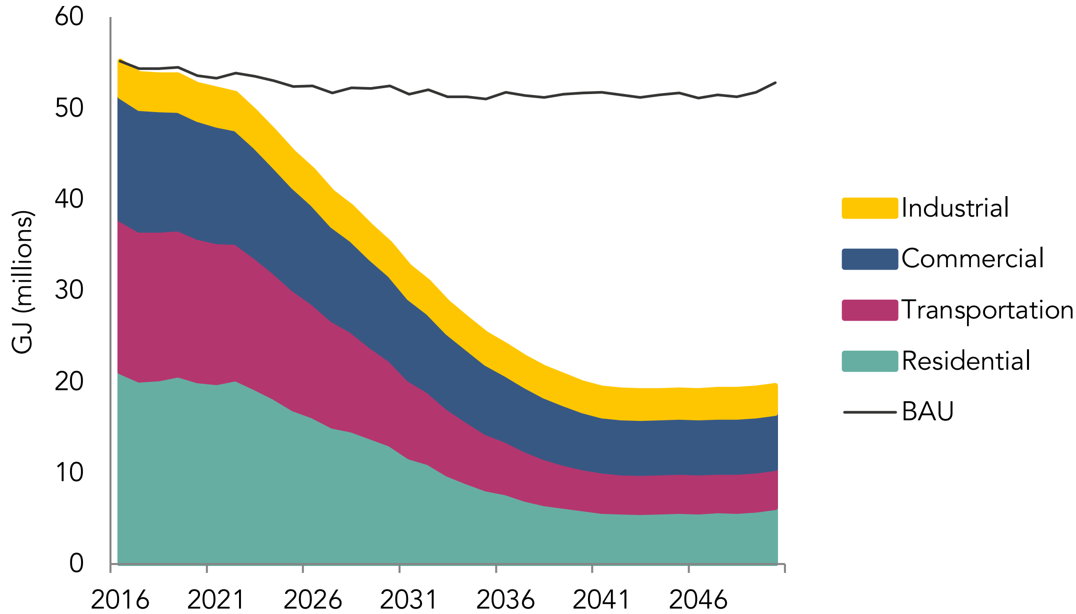


Figure 10. LC3 energy consumption (PJ) by sector, 2016-2050.

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.

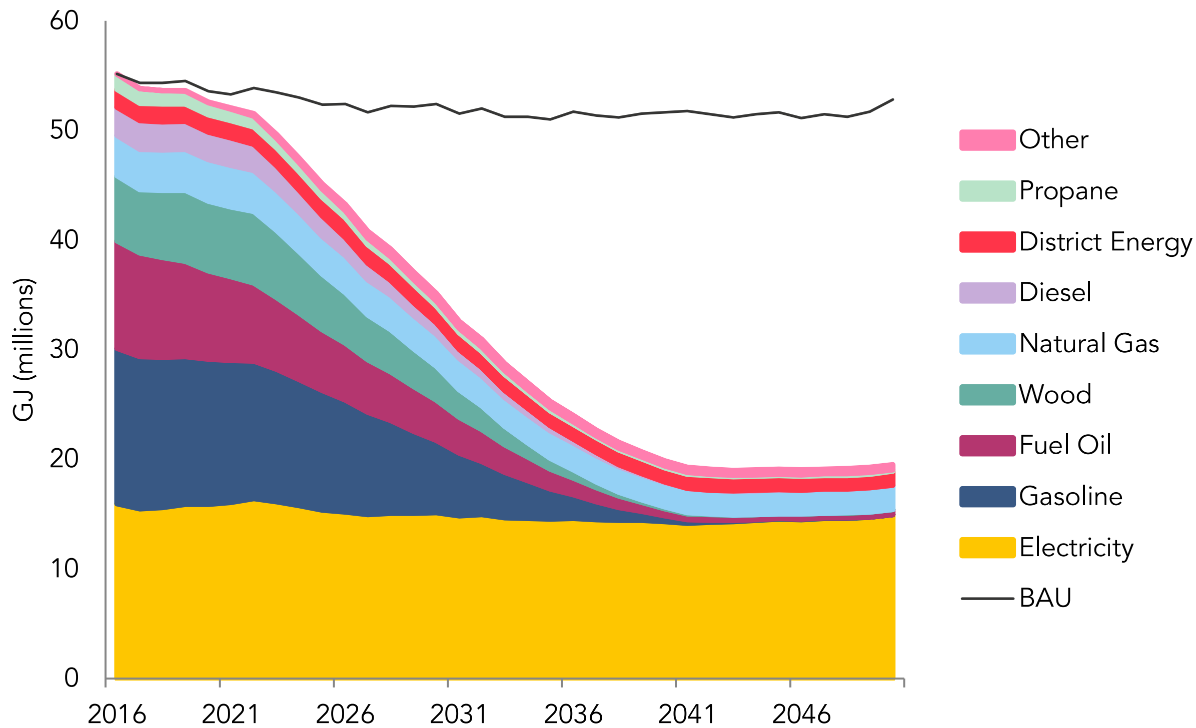


Figure 11. LC3 energy consumption (PJ) by fuel, 2016-2050.

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.

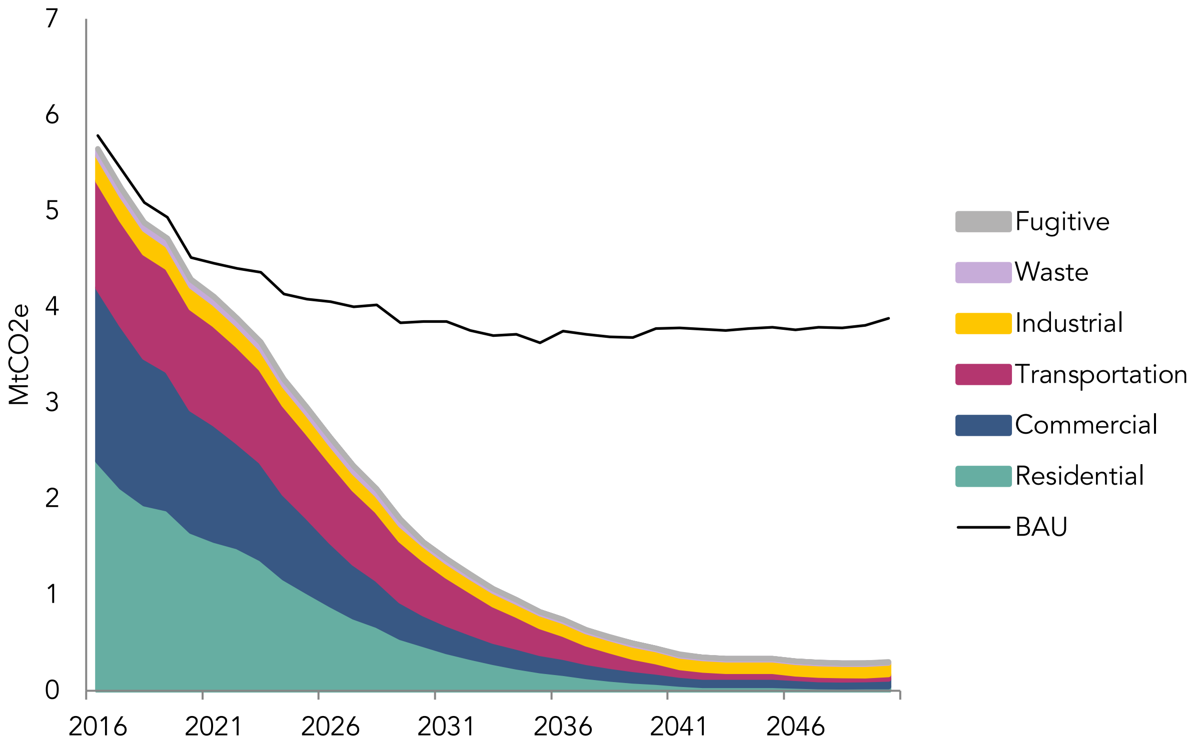


Figure 12. LC3 emissions (MtCO2e), by sector, 2016-2050.

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.

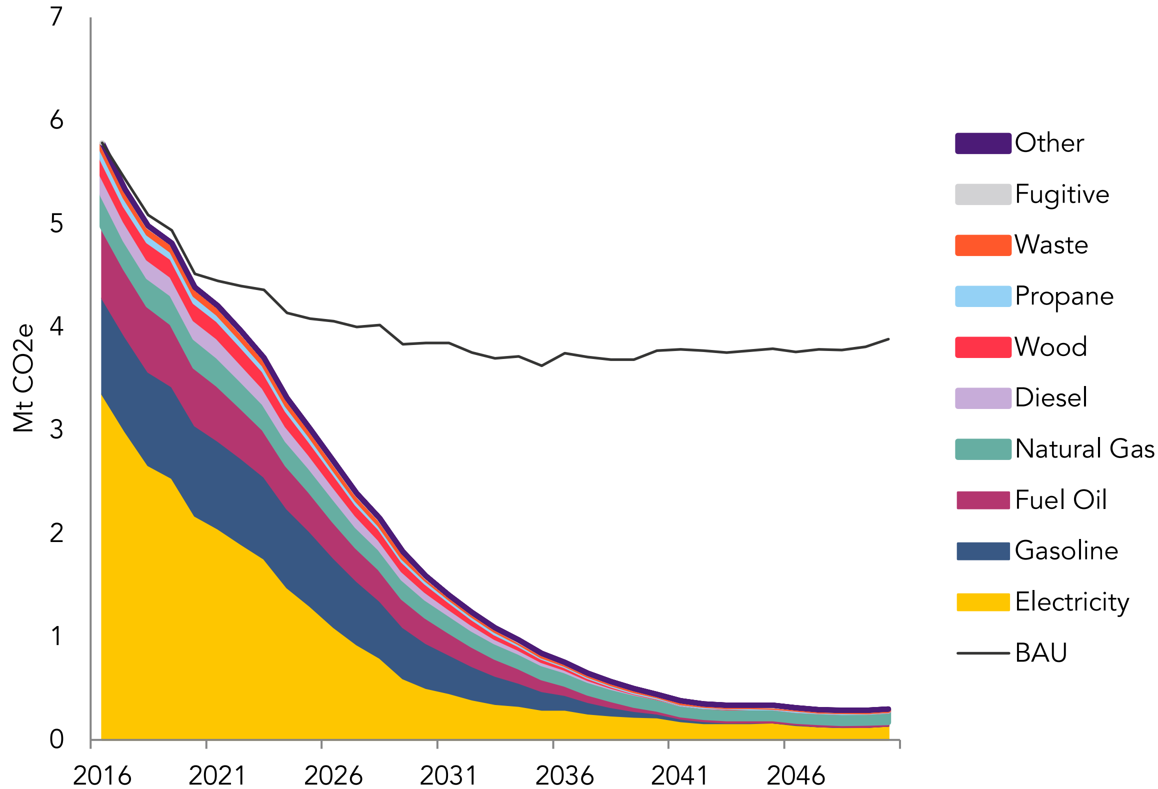


Figure 13. LC3 emissions (MtCO2e), by fuel, 2016-2050.

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.

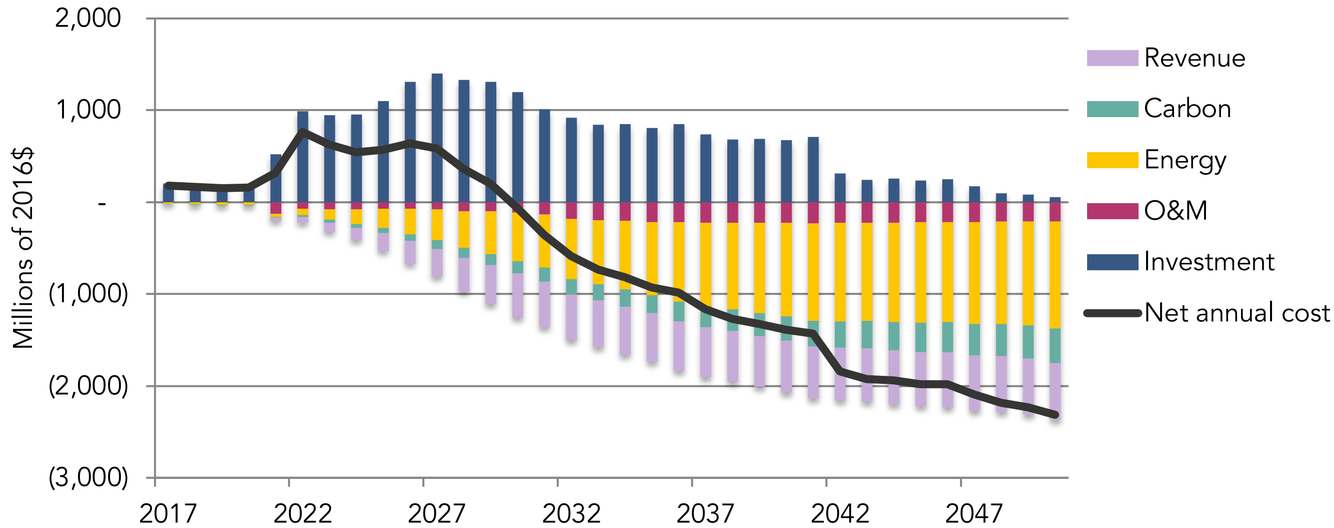


Figure 14. Summary of annual LC3 costs (above x-axis) and savings (below x-axis) relative to the BAU scenario.

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

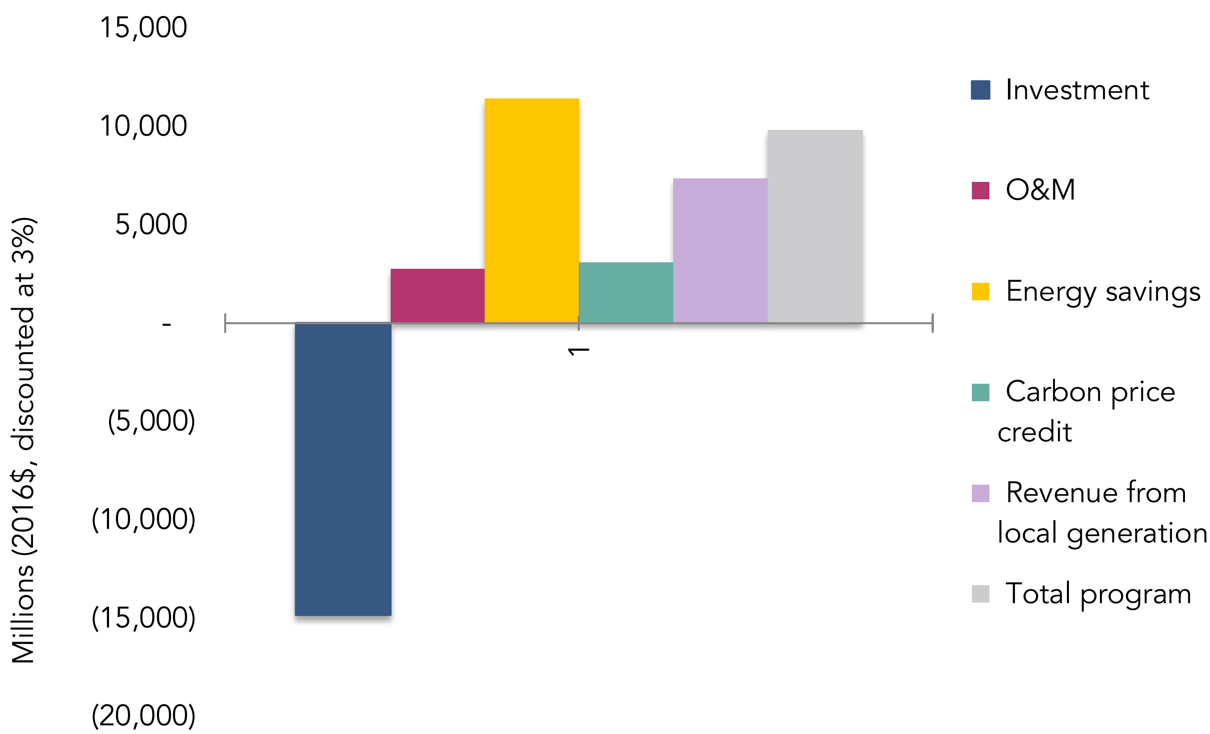


Figure 15. Net present value of costs (negative) and savings (positive) of LC3 over the BAU scenario.

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.

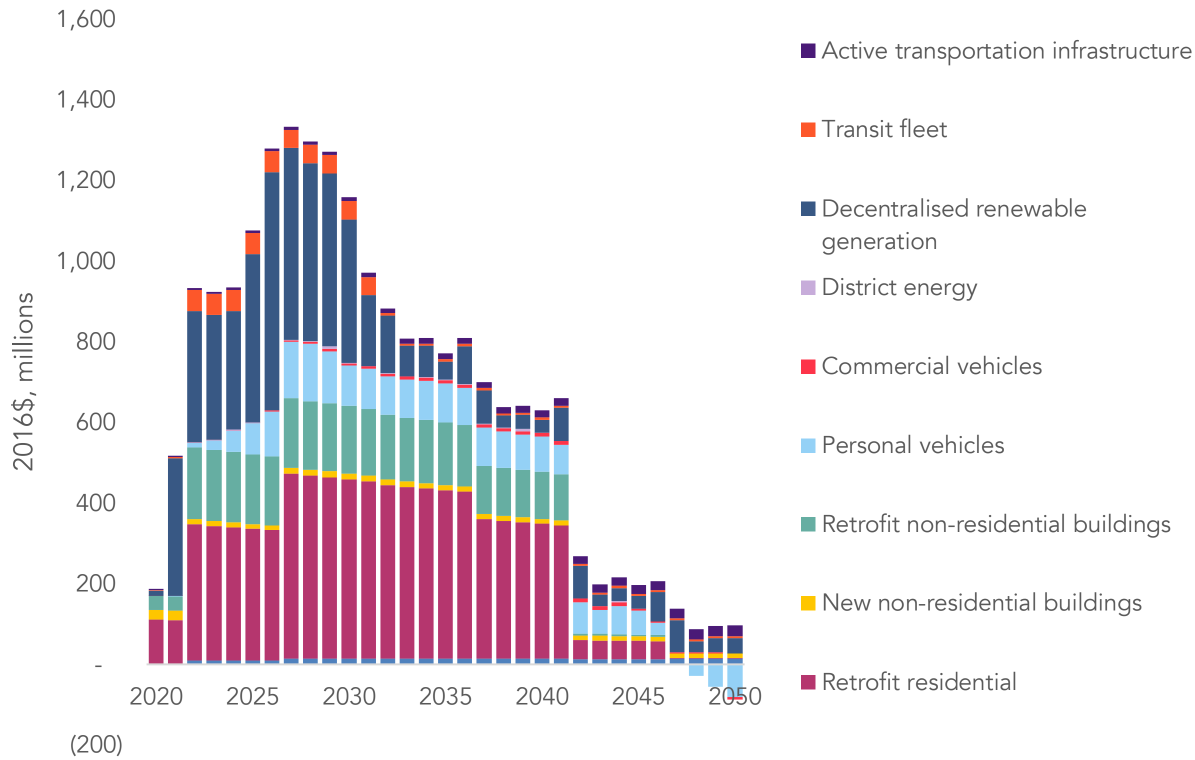


Figure 16. Annual incremental LC3 capital costs over BAU capital costs.

Energy Costs

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

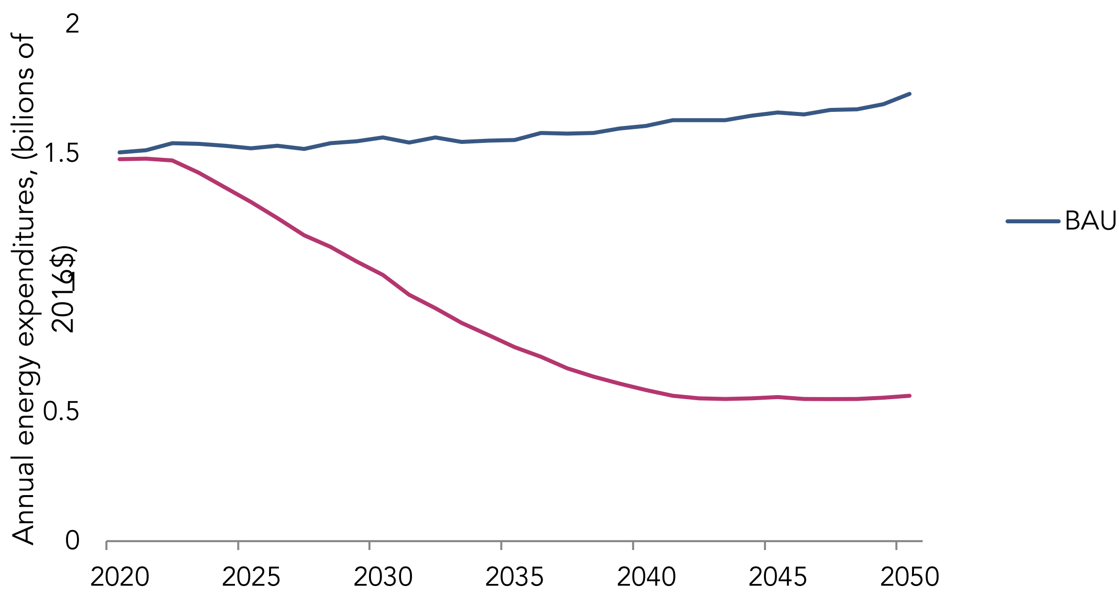


Figure 17. Estimated total annual energy costs for the BAU scenario (blue) and LC3 (green).

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.

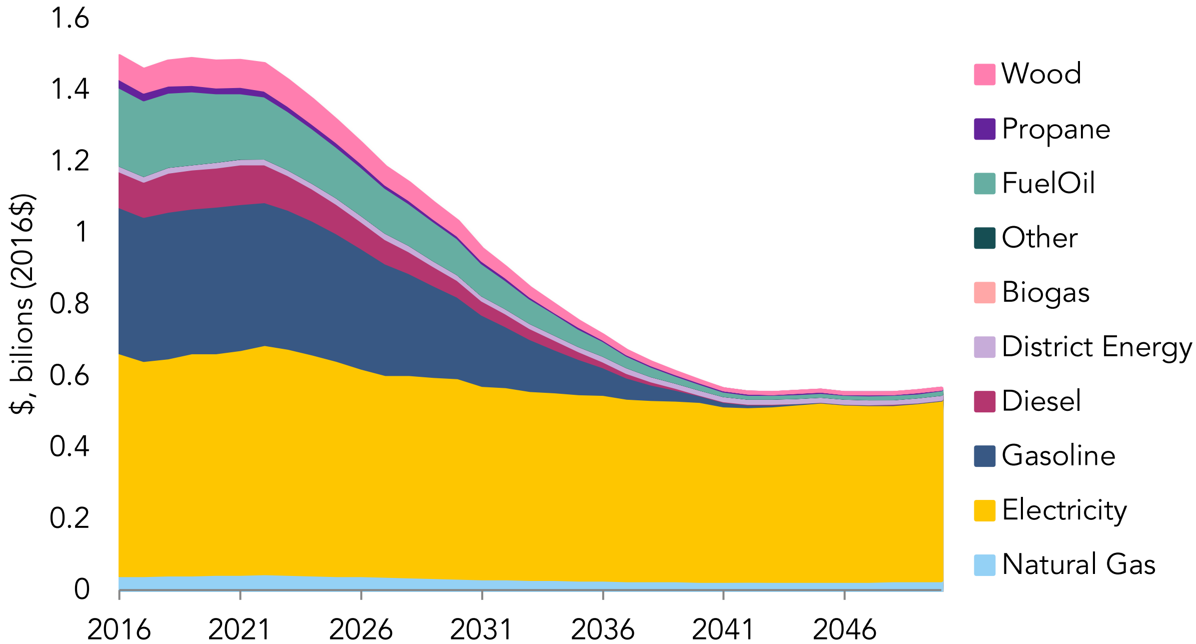


Figure 18. Total LC3 annual energy costs by energy source.

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.

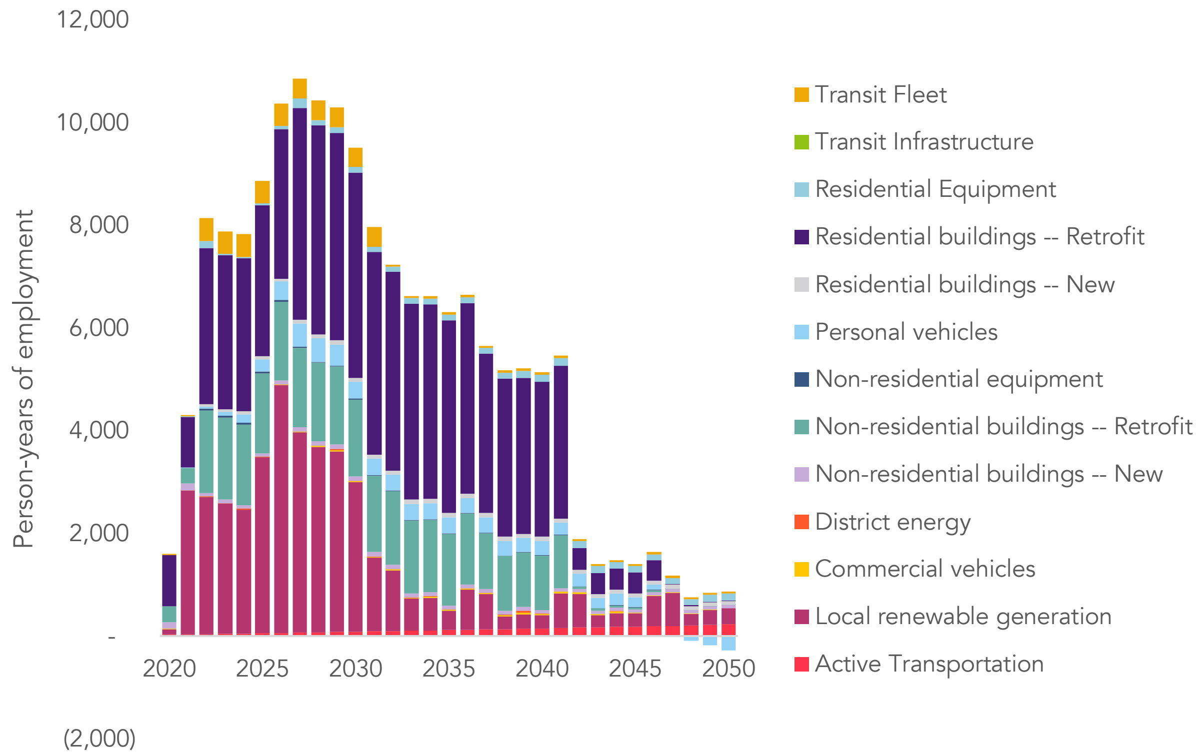


Figure 19. Employment generated by LC3 implementation.

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

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	BETTER PREPARE FOR INCREASED CLIMATE-RELATED EMERGENCIES
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	ENHANCE THE CAPACITY OF NEIGHBOURHOODS TO PREPARE FOR AND RECOVER FROM CLIMATE EVENTS
33	Neighbourhood action planning	ENHANCE THE CAPACITY OF NEIGHBOURHOODS TO PREPARE FOR AND RECOVER FROM CLIMATE EVENTS
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	PREPARE AND LEVERAGE BUSINESS FOR THE TRANSITION
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	INTEGRATE CLIMATE THINKING INTO MUNICIPAL DECISION-MAKING AND GOVERNANCE
40	Green municipal investments	INTEGRATE CLIMATE THINKING INTO MUNICIPAL DECISION-MAKING AND GOVERNANCE
Governance and capacity for action		
41	Governance	ESTABLISH GOVERNANCE AND CAPACITY FOR COLLABORATIVE, FLEXIBLE AND DISTRIBUTED CLIMATE ACTION
42	Capacity	ESTABLISH GOVERNANCE AND CAPACITY FOR COLLABORATIVE, FLEXIBLE AND DISTRIBUTED CLIMATE ACTION
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 (CH_4)	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

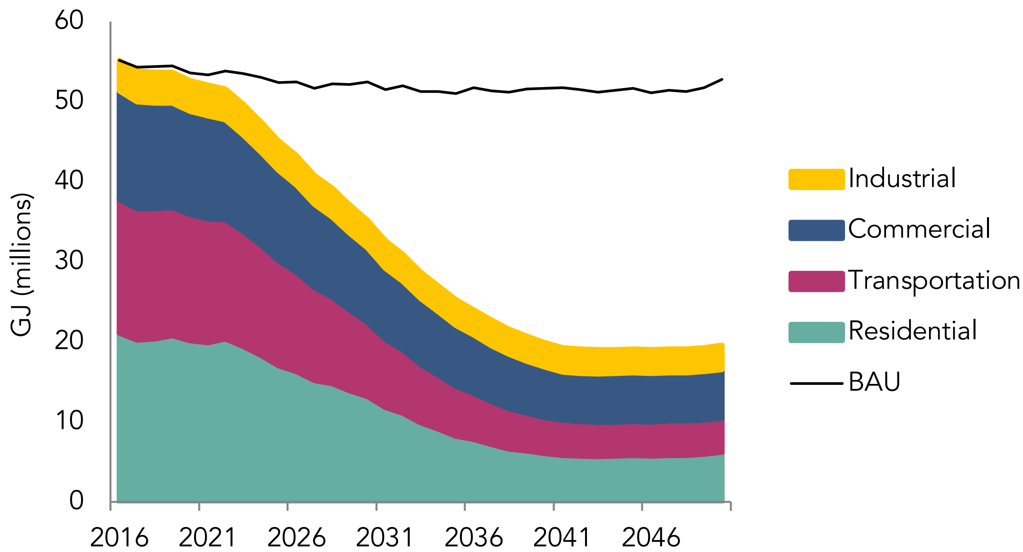


Figure A1. Projected LC3 energy consumption (million GJ) by sector, 2016-2050.

Energy by fuel

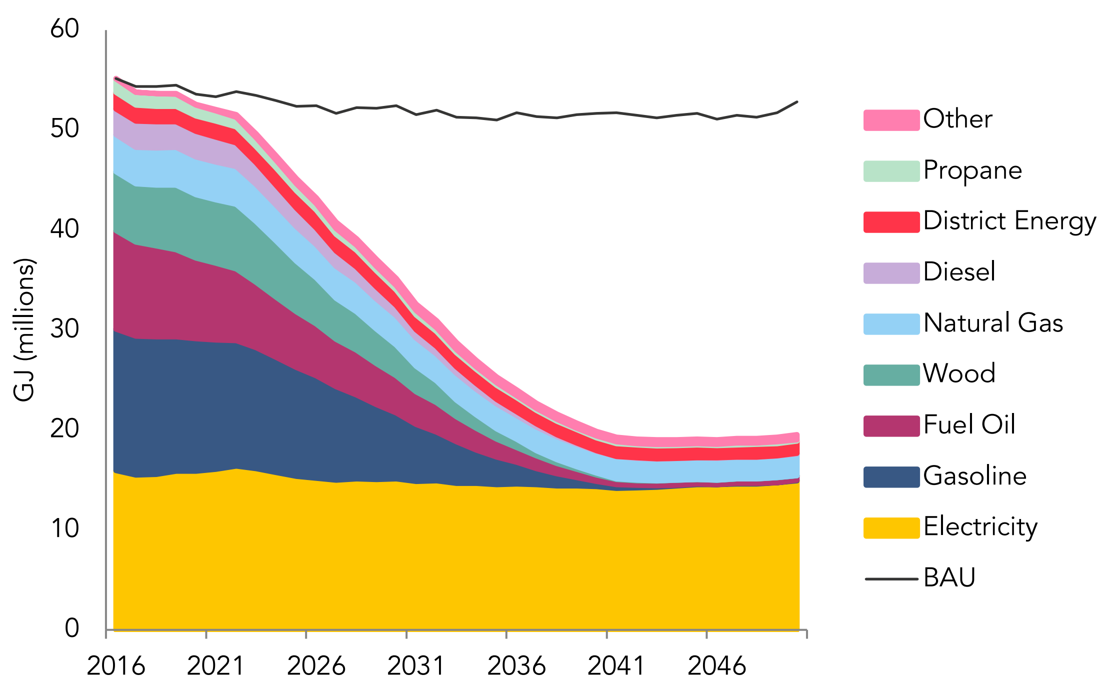


Figure A2. Projected LC3 energy consumption (million GJ) by fuel, 2016-2050.

Per Capita Energy

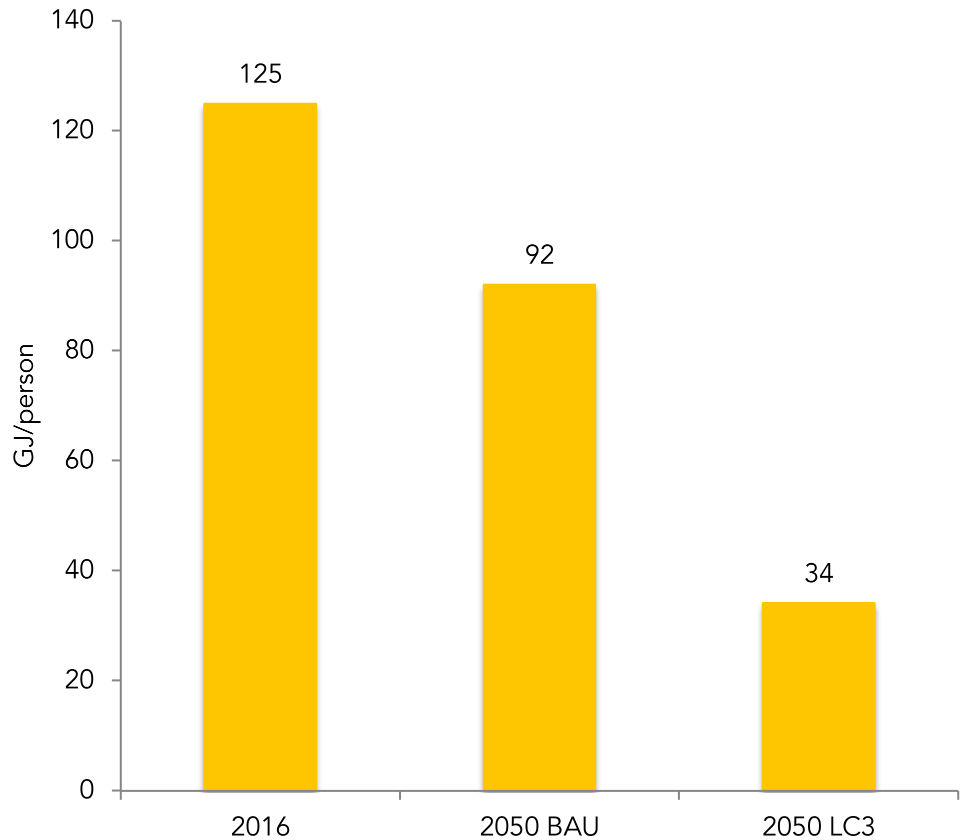


Figure A3. Projected BAU and LC3 energy per capita (GJ/person), 2016 & 2050.

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

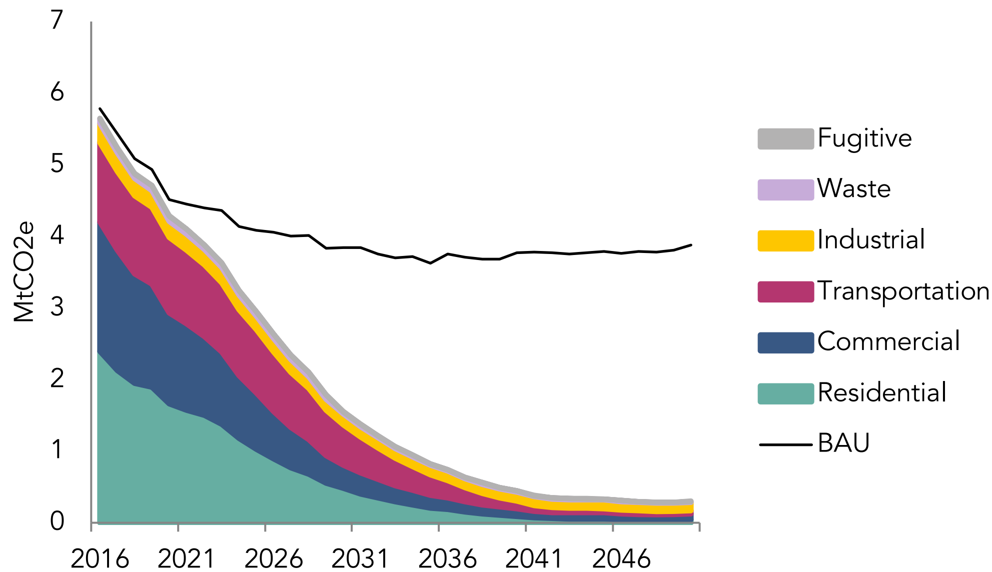


Figure A4. Projected LC3 emissions (MtCO2e) by sector, 2016-2050.

Emissions by source

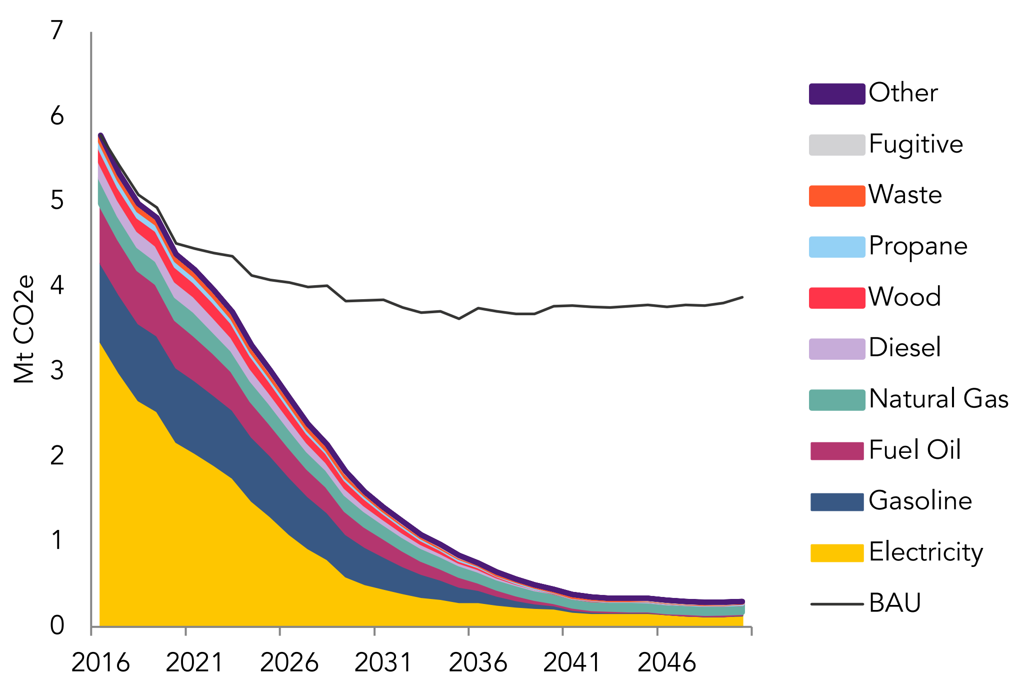


Figure A5. Projected LC3 emissions (MtCO2e) by source, 2016-2050.

Per Capita Emissions

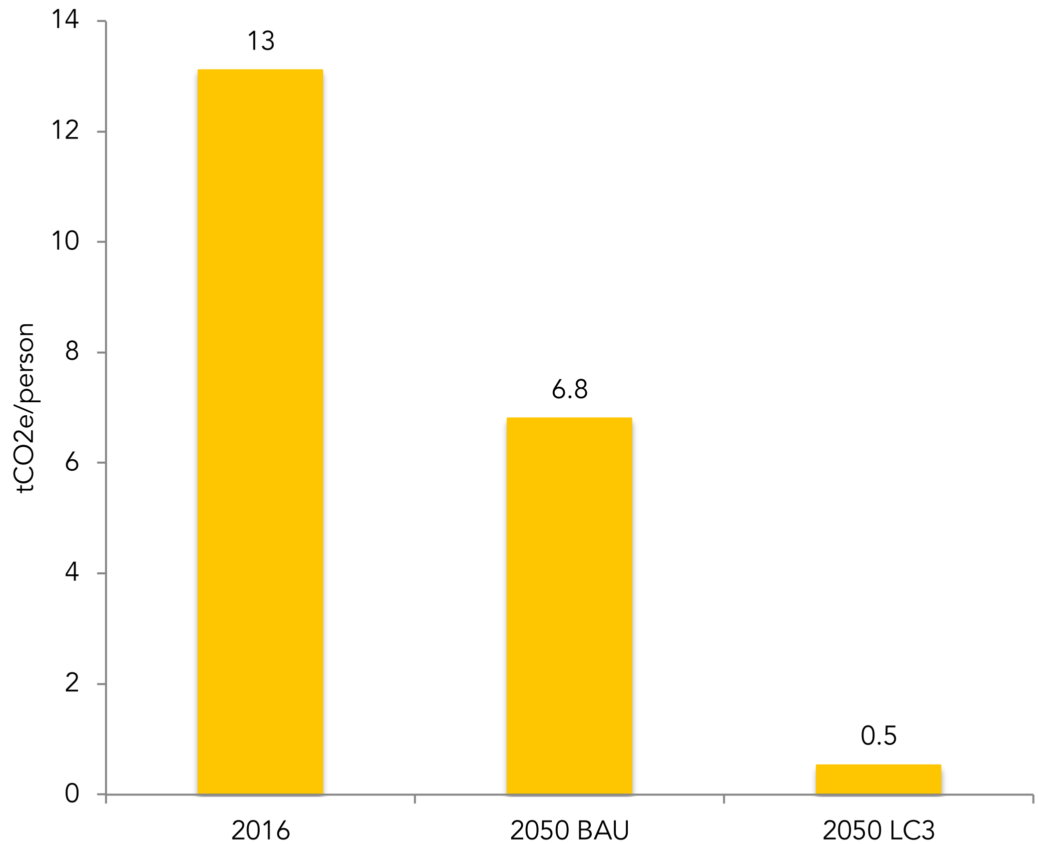


Figure A6. Projected 2016, 2050 BAU and 2050 LC3 emissions per capita (tCO2e/person), 2016 & 2050.

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

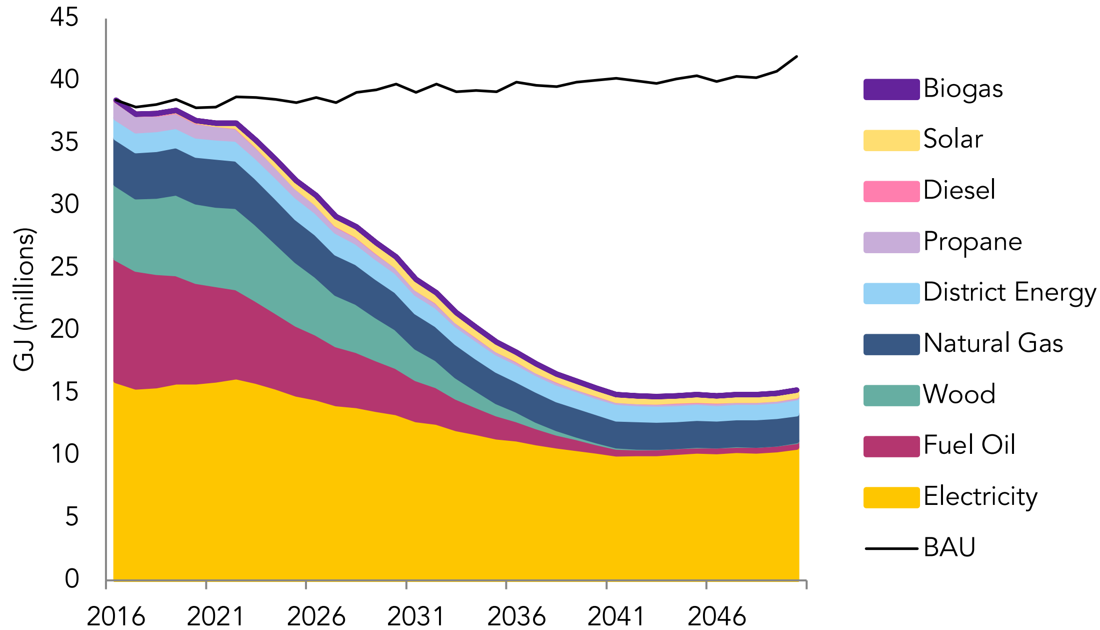


Figure A7. Projected LC3 buildings energy use (million GJ) by fuel, 2016-2050.

Buildings energy by end use

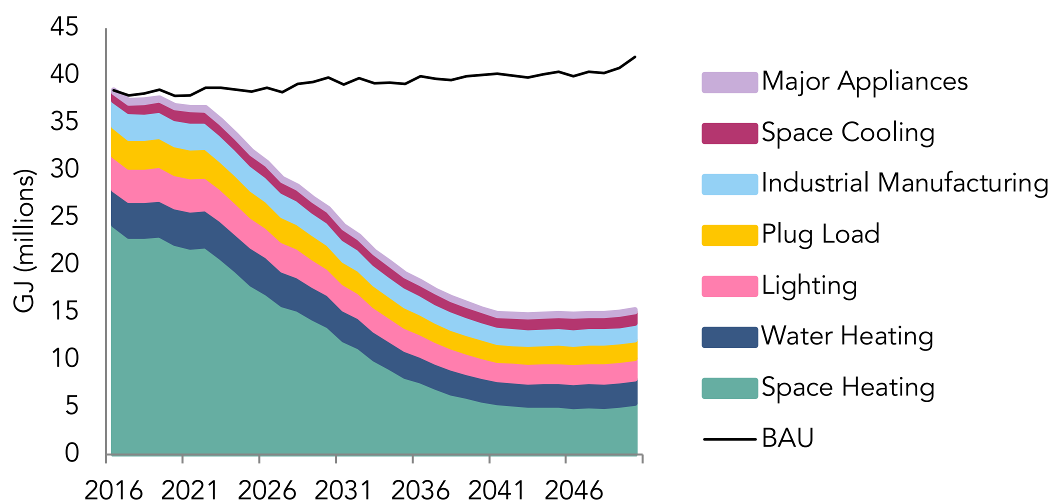


Figure A8. Projected LC3 buildings energy use (million GJ) by end use, 2016-2050.

Buildings energy by building type & fuel

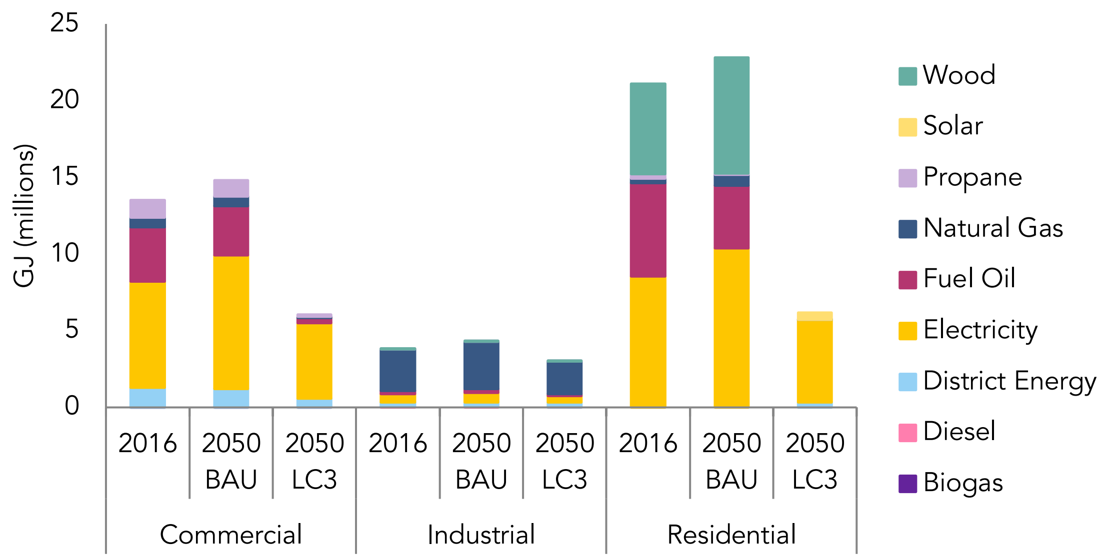


Figure A9. Projected buildings energy use (million GJ) by building type and fuel, 2016, 2050 BAU and 2050 LC3.

Buildings energy by building type & end use

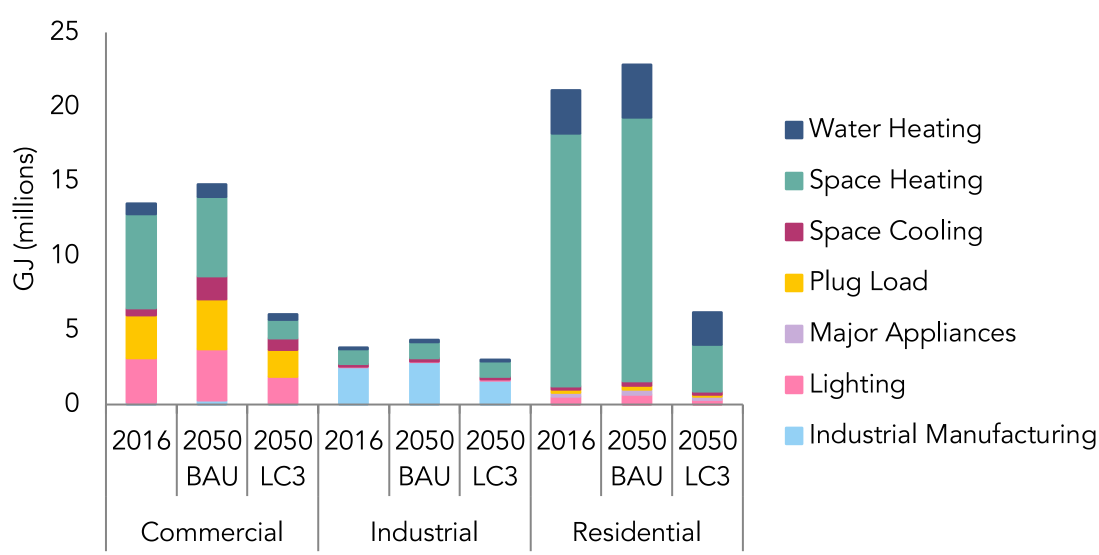


Figure A10. Projected BAU buildings energy use (million GJ) by building type and end use, 2016, 2050 BAU and 2050 LC3.

Per household energy

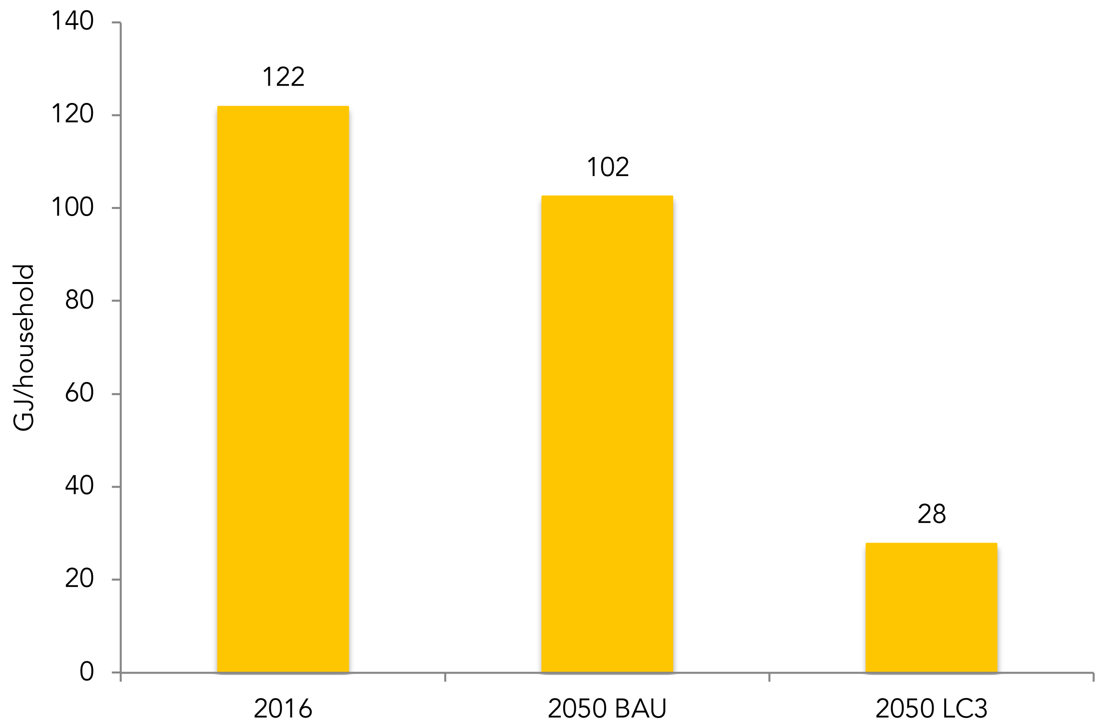


Figure A11. Projected residential energy per household (GJ/household), 2016, 2050 BAU and 2050 LC3.

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

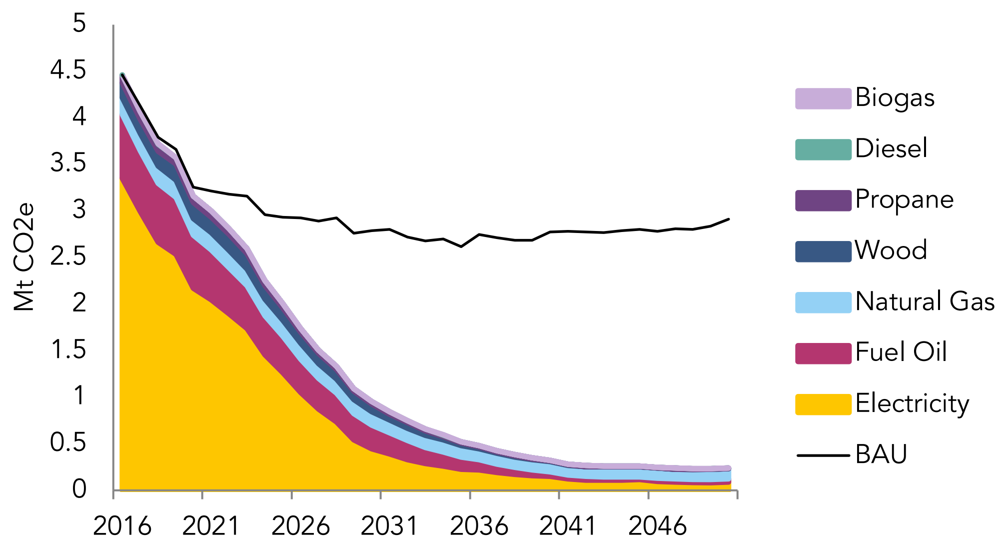


Figure A12. Projected LC3 buildings emissions (Mt CO2e) by source, 2016-2050.

Buildings emissions by end use

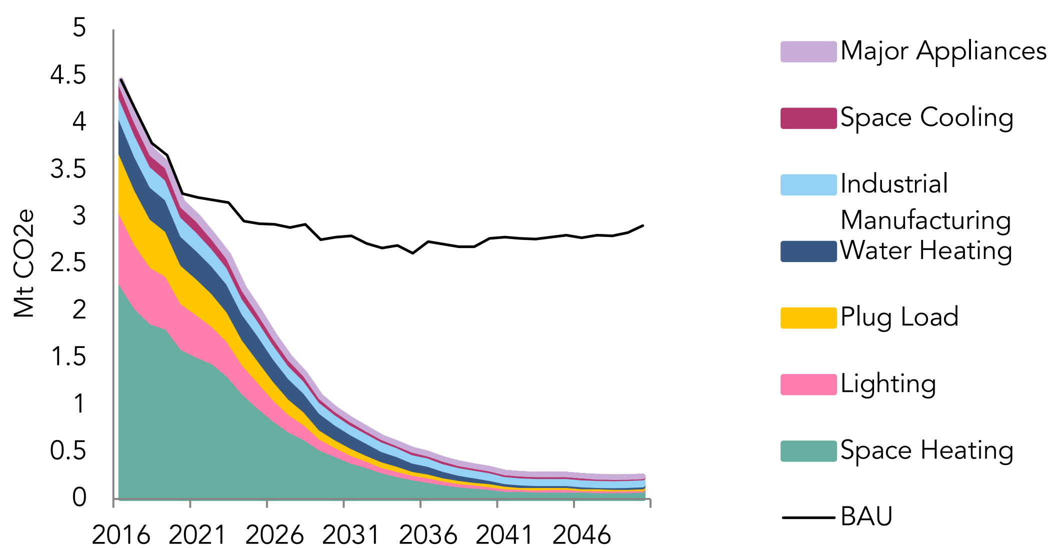


Figure A13. Projected LC3 buildings emissions (Mt CO2e) by end use, 2016-2050.

Buildings emissions by building type & source

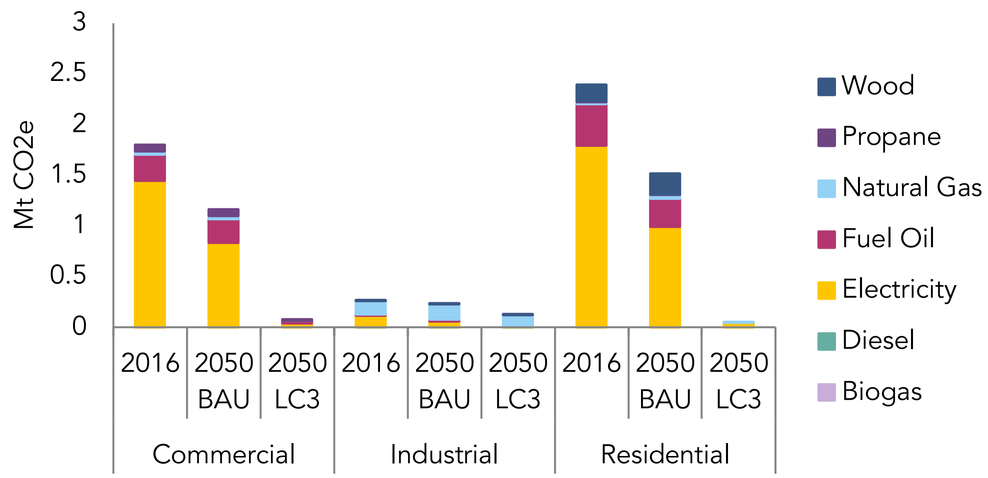


Figure A14. Projected BAU buildings emissions (Mt CO2e) by building type and source, 2016, 2050 BAU and 2050 LC3.

Buildings emissions by building type & end use

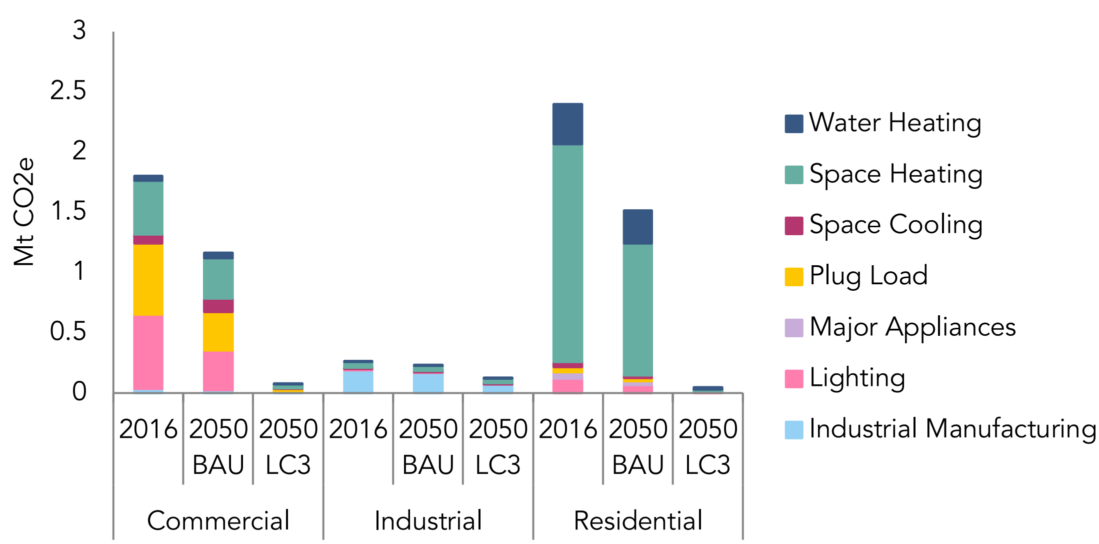


Figure A15. Projected BAU buildings emissions (Mt CO2e) by building type and end use2016, 2050 BAU and 2050 LC3.

Per household emissions

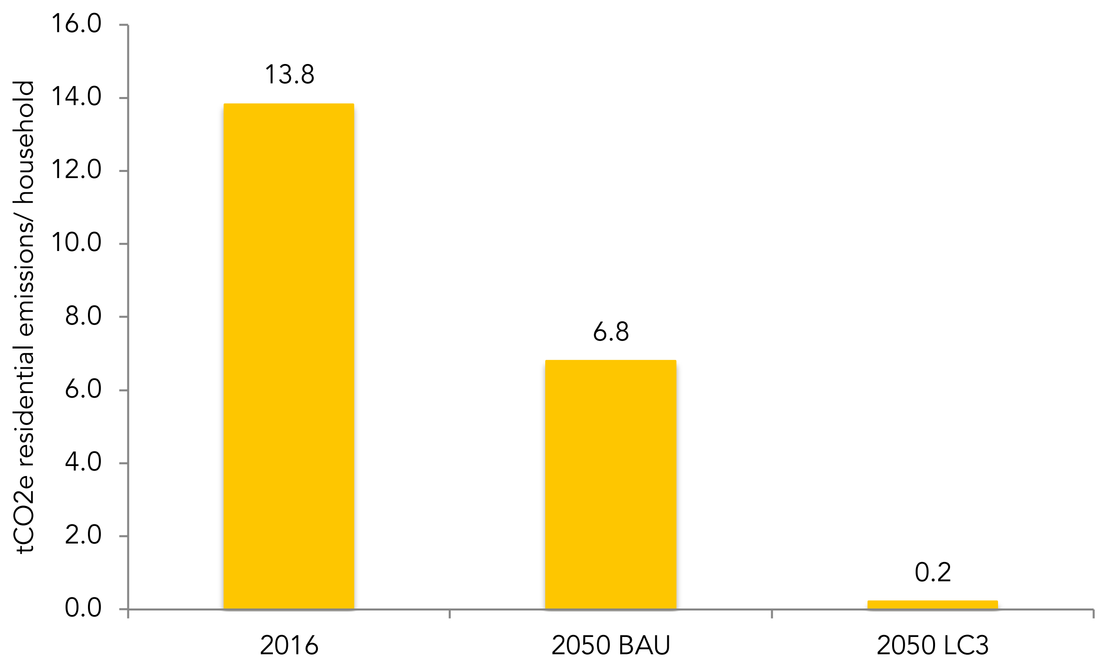


Figure A16. Projected BAU residential emissions per household (tCO2e/household), 2016, 2050 BAU and 2050 LC3.

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

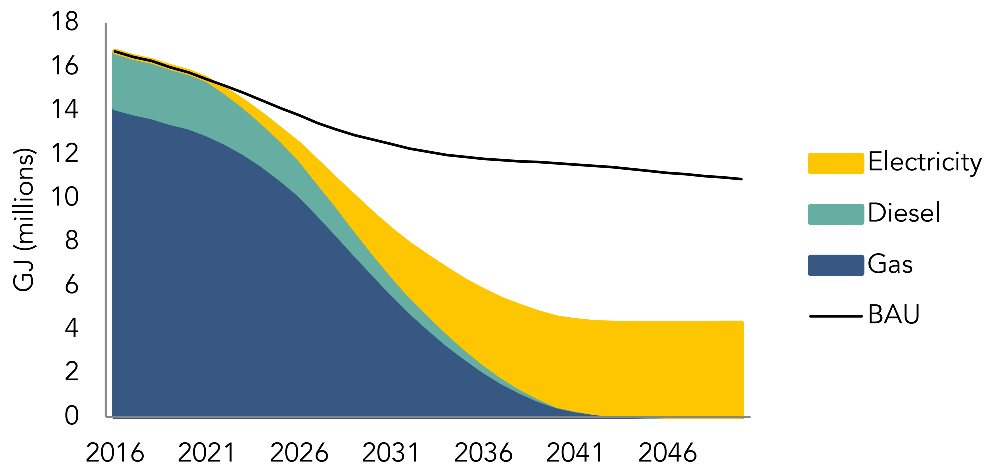


Figure A17. Projected LC3 transportation energy use (million GJ) by fuel, 2016-2050.

Transportation energy by vehicle type

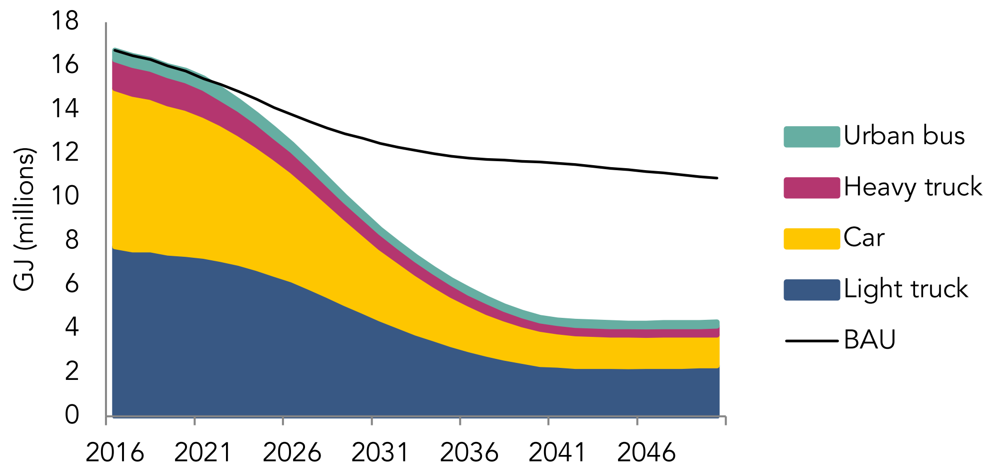


Figure A18. Projected LC3 transportation energy use (million GJ) by vehicle type, 2016-2050.

Transportation energy by vehicle type & fuel

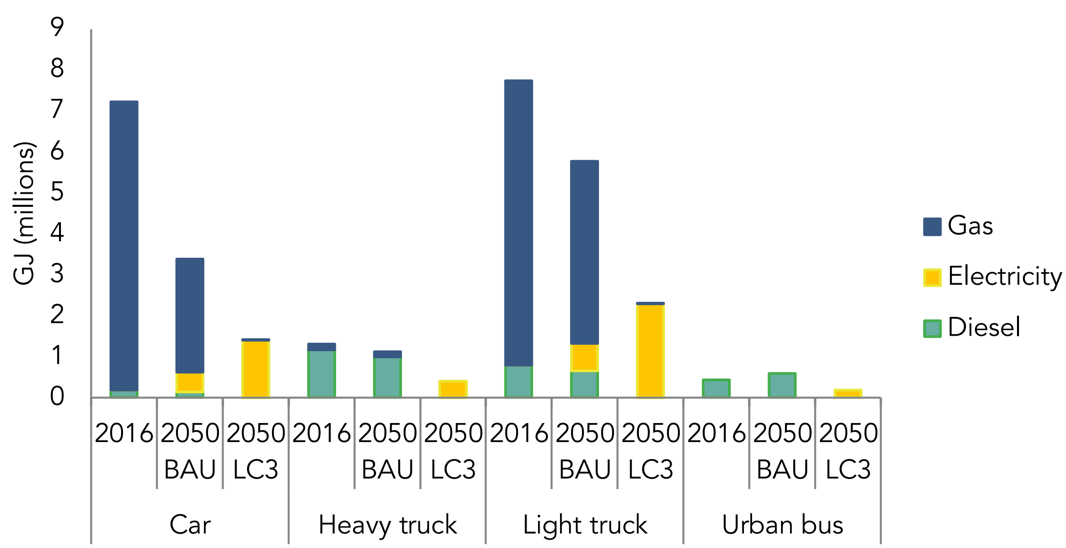


Figure A19. Projected transportation energy use (million GJ) by vehicle type and fuel, 2016, 2050 BAU and 2050 LC3.

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

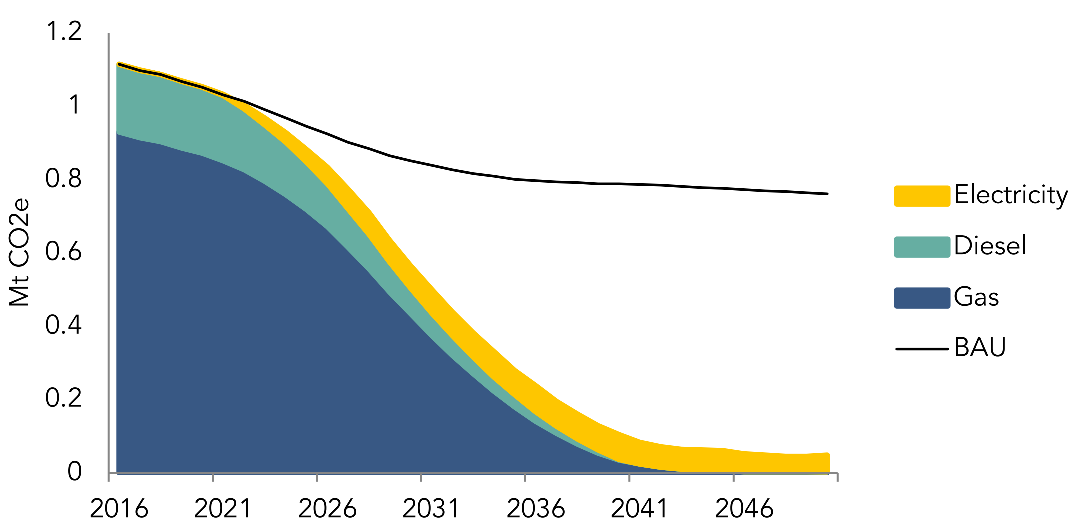


Figure A20. Projected LC3 transportation emissions (Mt CO2e) by source, 2016-2050.

Transportation emissions by vehicle type

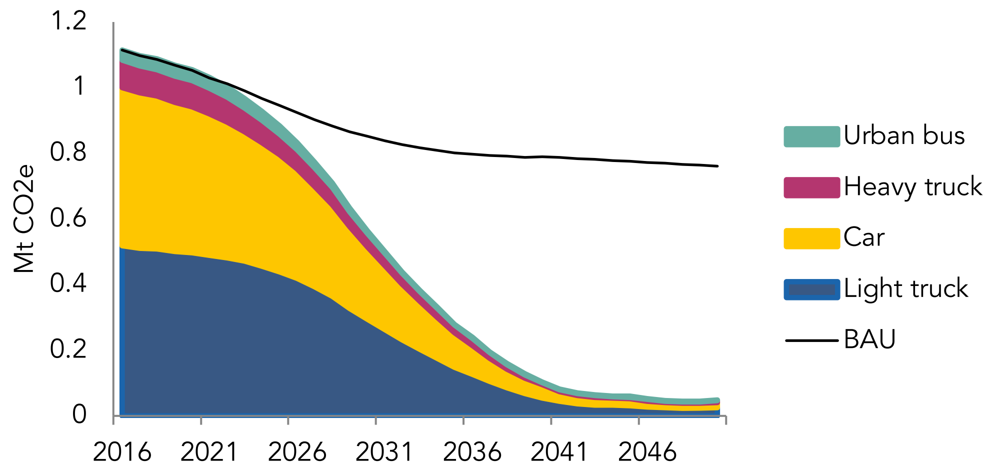


Figure A21. Projected LC3 transportation emissions (Mt CO2e) by vehicle type, 2016-2050.

Transportation emissions by source & vehicle type

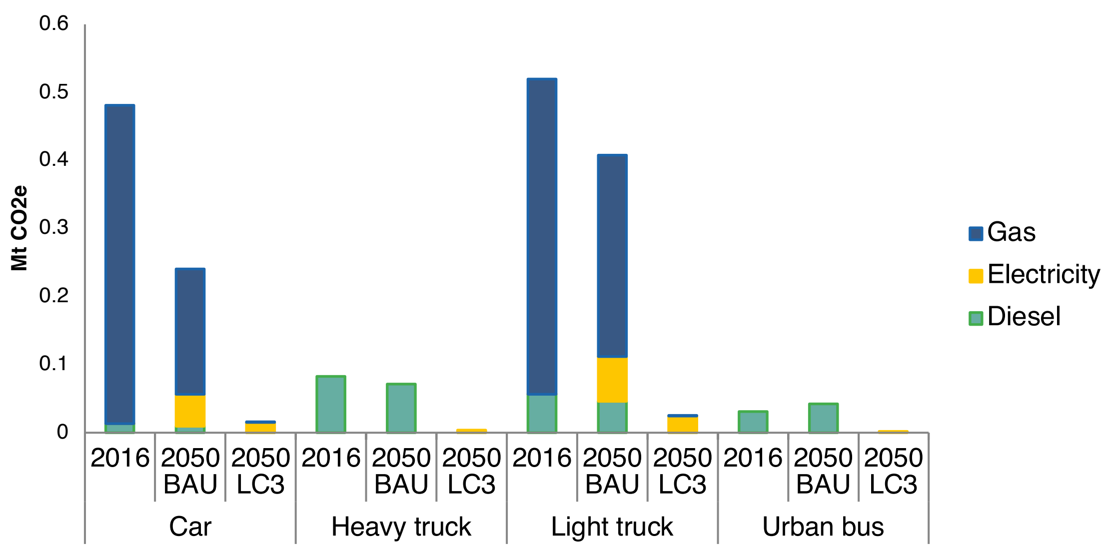


Figure A22. Projected transportation emissions (MtCO2e) by source and vehicle type2016, 2050 BAU and 2050 LC3.

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

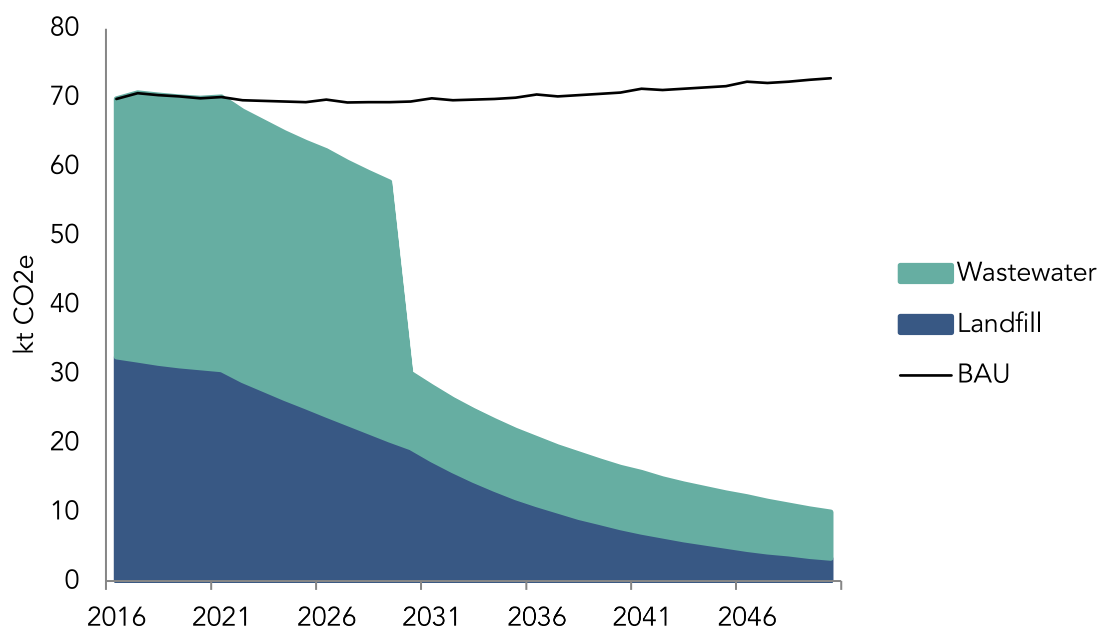


Figure A23. Projected LC3 waste emissions (ktCO2e), 2016-2050.

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

$/GJ	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Gasoline	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
Diesel	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

$/GJ	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Residential	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
Commercial	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
Industrial	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

$/GJ	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Residential	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
Commercial	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
Industrial	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

$/GJ	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Residential	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
Commercial	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
Industrial	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

Attachment E

HalifACT 2050: Acting on Climate Together

Community Engagement Report

March 2020

SSG

whatIf?

Contents

Community Engagement Report

Introduction

As the success of HalifACT 2050 relies on collective action, stakeholder and public engagement was critical in the development of the priority actions and strategies outlined in the climate action plan. As such, over the past year, the HalifACT project team has led an in-person and online engagement strategy that involved hundreds of internal and external stakeholders and community members across the region. The objectives of the engagement were to raise awareness about climate change and the urgency for action; facilitate discussions about strategies, tools and barriers to adaptation and mitigation; and to strengthen existing and build new networks and partnerships that will ultimately support the implementation of HalifACT.

Public Engagement Overview

The project team hosted five large workshops and over 35 pop up sessions; presented to over 25 groups at conferences, stakeholder organizations and/or university classrooms; and met with three Joint Emergency Management (JEM) teams. HalifACT's online presence through Shape Your City saw more than 2,800 visitors, 1,300 survey respondents, and 23,000 votes cast for priority actions. Social media channels were used to raise awareness and spark conversation with Facebook receiving 228,817 views, Instagram receiving 23,520, and Twitter reaching 163,052 unique users.

The following report presents an overview of the engagement process including high-level summaries of the information and ideas discussed at each engagement session.

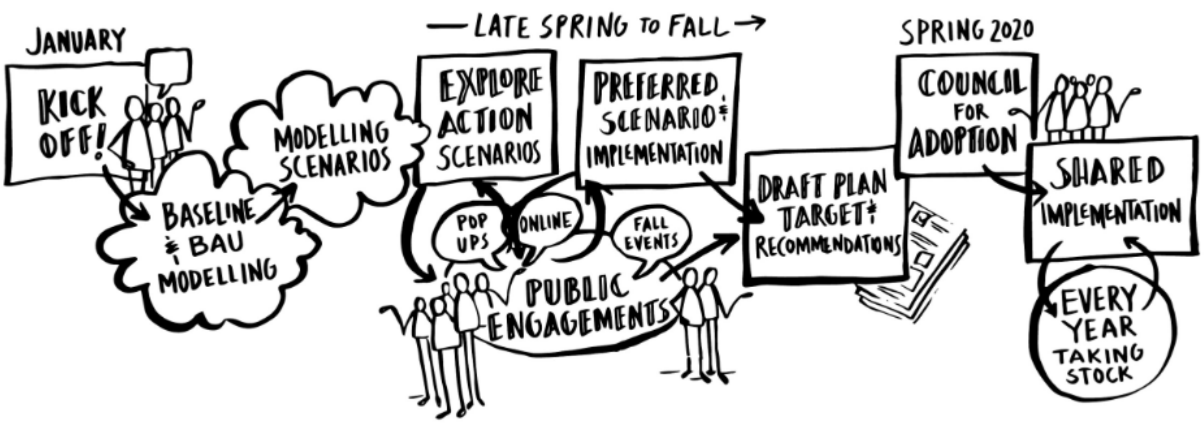
5 stakeholder workshops

35 pop-up sessions

23,000+ votes on All Our Ideas

25 formal presentations

2,800+ visits to Shape Your City



Community Leadership Team Workshops

Early in the project, the HalifACT project team invited a diverse group of stakeholders representing all sectors interested in climate change and energy to join the Community Leadership Team (see Appendix A). Members of the Community Leadership Team were from the following sectors: transportation, energy, government, academia, commercial, industrial, and non-governmental. In addition to attending meetings and workshops to discuss priority adaptation and mitigation actions and strategies, team members were also asked to share information back to their respective organizations and sectors. The mandate for this team was to guide municipal staff in the development of draft actions, including recommendations for long-term mitigation targets and adaptation objectives. The Community Leadership Team met in January 2019 for a one-day workshop and again in June for a half-day workshop. The objectives of these meetings were to build relationships and understanding across sectors; share information with the Team about scenarios, actions, co-benefits and emission reduction pathways; engage Team members about actions, solutions, strengths, and barriers to meeting targets; and galvanize commitment to the project and to climate action.

Summary of What We Heard

At both Community Leadership Team workshops, participants discussed adaptation priorities, emission reduction targets and pathways, and mitigation actions. Common themes discussed at many of the engagement sessions included: the need for policies and standards; funding and subsidies; equity and social justice; land use and transportation planning; collaboration across jurisdictions and sectors; knowledge, capacity and community building; and ongoing research, monitoring and innovation. The following list further describes some of the common themes heard through the workshops:

- Policies, regulations, standards and codes are integral tools and strategies needed to reach our targets. Reviewing existing and creating new policies and regulations will be key to success.
- A strong call to consider and address inequity, the unequal distribution of wealth and the potential uneven consequences of climate change on individuals living in poverty and other vulnerable populations. Continued concerted effort to engage vulnerable groups throughout implementation will be required.

- While concrete action is required, stakeholders also expressed the importance of planning, including transportation planning, food systems planning, and land use planning.
- Existing technologies are not sufficient and investment in new technologies (innovation funding, research and development, etc.) are needed.
- The financial costs are huge and new funding opportunities are needed.
- Government leadership is required in the form of not only funding opportunities and subsidies, but also in convening partners, developing a supportive policy environment, leveraging government assets, and supporting ongoing research efforts.
- While many understand the impacts and actions needed to address climate change, continuing to address knowledge gaps across communities, sectors and governments is critical. Building community knowledge, action and resiliency is key.
- Ongoing investment in surveillance, data collection, and research is needed to support widespread understanding of the current situation; understanding of risks, hazards and opportunities; and to support monitoring and evaluation of actions and achievements.

Corporate Leadership Team Workshops

The Corporate Leadership Team included representatives from each municipal Business Unit, including the Office of Diversity and Inclusion, Planning and Development, Parks and Recreation, Halifax Transit, Transportation and Public Works, Halifax Regional Fire and Emergency, and Finance, Asset Management and ICT. The purpose of forming the Corporate Leadership Team was to engage staff in the development of corporate emission targets, foster ownership for actions and targets, build an understanding about how the Municipality can influence community-wide emission reduction and adaptation targets, and to provide an opportunity for staff and Business Units to reflect on how their work can enhance community resiliency. The Corporate Leadership Team met in March 2019 for a one day workshop and again in June for a half-day workshop.

Summary of What We Heard

At both Corporate Leadership Team workshops, participants discussed adaptation priorities, emission reduction targets and pathways, and mitigation actions. Common themes discussed at many of the engagement sessions included the need for buy-in, resolving conflicting priorities, the need for leadership, establishing and maintaining project scope, accurate data collection, effective communication, collaboration, and coordination, proper resourcing and implementation of the plan, and overcoming jurisdictional limitations. The following list further describes some of the common themes heard through the workshops:

- Ensure broad understanding and knowledge about the link between Business Unit and climate change
- Need for strong champions among Senior Leaders
- Continued opportunities, supports and training for Business Units to build internal capacity, foster collaboration, support organizational change, and to break down silos.
- Need for a dedicated, multi-faceted task team to continue to lead implementation (e.g., seek solutions, identify conflicting priorities, and emphasize co-benefits)

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Community and Corporate Leadership Teams Joint Workshop

Members from both the Corporate and Community Leadership Teams were invited to a joint full-day workshop at the St. Mary's Boat Club in October 2019. The purpose of this workshop was to share the modelling results, provide a rationale for the preferred carbon scenario, identify key levers and actions, build commitment to actions, and to support connections between internal and external stakeholders.

Summary of What We Heard

During the morning session, small groups focussed on what is needed to support mitigation and build momentum for success. The following list of needs and actions related to mitigation were discussed:

- Life Cycle Analysis for all buildings
- Address barriers and create incentives for retrofits
- Explore regulatory framework required to succeed
- Details on how to generate large scale renewable energy
- System change is needed
- Considerations for equity and social justice
- Empowering citizen action
- Data sharing and collaborative monitoring
- Continue to link transportation and land use planning

During the afternoon session, groups were asked to discuss what a well-adapted and resilient municipality looks like. This included exploring what actions are needed and how they rate in terms of urgency and importance. The actions discussed included:

- Vulnerability mapping and emergency planning
- Regulations, education and awareness about water supply
- Low impact development and green infrastructure
- Food action planning and coordinated effort to strengthen the local food system
- Protection and restoration of ecosystems
- Social and environmental justice at all levels
- Government support for businesses to adapt
- Capacity building within government and communities

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Pop-Up Sessions

The HalifACT 2050 project team conducted more than 35 informal “pop-up” events throughout the summer and fall of 2019. These informal engagement sessions provided an opportunity to raise awareness about HalifACT 2050 and to gain insights with respect to public opinion on climate change and community-level climate hazards and impacts. Staff attended each pop-up session for 1-2 hours, displayed project posters and banners, and distributed postcards that informed residents where they could obtain more information about the project. Pop-up sessions were hosted in a variety of public spaces including ten different Halifax Public Libraries, the Public Gardens, Sullivan’s Pond, Chocolate Lake Beach Park, Long Lake Provincial Park, Sir Sandford Flemming Park, Captain William Spry Centre, Kearney lake Beach Park, Dartmouth Ferry Terminal, Cole Harbour Place, Scotia Square, and the Halifax Seaport Market. Project team members also shared information and engaged with the public at the following community events: Mawita’jikl Gathering, Portland Estates Homeowner’s Association, Bedford Days, Halifax Water’s Water Shed, Multi Fest, Clam Harbour Sandcastle Festival, Switch Dartmouth, and the Acadian Flag Raising.

Summary of What We Heard

The following list presents common themes heard across the pop-up sessions:

- <u>Lack of understanding</u>: Many people were unaware that the Municipality was working on a climate plan. There was some hesitation to participate in online surveys, as many people thought they did not have enough information to provide valuable feedback.

- General support for action: Many people were supportive of having a plan, happy that this work was being done, and felt that it was an urgent issue. Others felt the plan was too late and the timeframe (2050) was too far. Further, some residents felt that the plan did not have enough of a global impact.
- Transportation solutions: Residential streets should be accessed only by local traffic (residents that live on the street) in order to encourage other modes of transportation; provide facilities for people to park bike/electric scooters; more car-share infrastructure; electric busses; incentives to encourage less GHG intensive vehicles and more hybrid cars and bicycles in the urban core. Some respondents also advocated for a complete ban of all cars in the urban core.
- Renewable energy generation: There was interest in Solar City and the need for more renewable energy generation to offset emissions. Some residents were not aware of the program and others mentioned concerns that the program was not equitable for low and medium income earners.
- General ideas about sustainability: Need to revert to self-sustainable communities (e.g. mom & pop run stores and growing our own food); need for broader understanding of environmental impacts of communities and decisions; need for government-subsidized community-building programs in rural/semi-urban areas.

Community Presentations

Staff attended a number of events, meetings, and conferences to represent HalifACT 2050 and to raise awareness of the plan development. These included:

- Blue Line Initiative Panel Discussion
- A to B 2019 - Move Into the Future Conference
- East Preston Rate Payers Association
- AKOMA Family Centre
- Canadian Oil Heat Association
- Teens Talk Now Youth Expo
- Smart Energy Conference
- Housing Symposium
- Wild Islands Tourism Advancement Partnership
- African United Baptist Association
- Climate Risks for Coastal Transportation Infrastructure in Atlantic Canada

- Joint Emergency Management Council Meeting
- Transition Bay St. Margaret's Bay Climate Emergency Preparedness Event
- Parternariat Acadien et francophone de Halifax
- Youth Advisory Committee
- Canada's Ambassador for Climate Change
- MacEachern Institute for Public Policy and Governance
- Salon d'exploration d'emplois bilingue
- Canadian Parents for French NS Chapter
- Design and Construction Institute of Nova Scotia Education Day
- Dalhousie University class presentations
- International Oceans Institute Policy and Governance Program in Halifax
- Liveable Cities Forum
- United Way Face of Poverty Consultation
- Conference Board of Canada's Emergency Management and Security Councils' Climate Change workshop

Joint Emergency Management Team Meetings

In the fall of 2019, the project team met with Joint Emergency Management Teams for the Eastern Shore, Western Shore, and Mainland North regions of the municipality. The purpose of these meetings was to better understand climate change-related hazards and potential risks in communities and explore how to prepare and adapt to climate-related hazards. JEM volunteers and community members were asked to identify hazards, vulnerabilities, and exposures to climate risks on maps and articulate their experiences during extreme weather events.

Summary of What We Heard

In addition to mapping hazards within the community, discussions were held to identify what hazards and risks the community faced as well as highlight their strengths. The following list presents common themes heard across the JEM workshops:

Potential Risks and Hazards

- Vulnerable Infrastructure - concerns related to vulnerable infrastructure were identified (roads, dams and bridges vulnerable to flooding and damage)
- Isolation – many communities have one access point which can make it difficult to evacuate during an emergency, some individuals may be

reluctant to leave their homes, or neighbours may not know one another or know who requires assistance
- Natural hazards – there is increasing damage from coastal erosion, coastal flooding, saltwater intrusion, heavy snow and road clearing
- Power outages – many communities need to be prepared for prolonged power outages
- Communication – the need for effective communication of critical information during emergencies, a need for regular updates

Community Strengths and Solutions
- Neighbourhood action – organize teams to assist families during evacuation for isolated homes or homes with only one access point (as well as farm animals that may need evacuation), establish a community freezer truck, establish community shared portable generators, identify muster points along the roads for evacuation, simulated emergencies or practice evacuations
- Infrastructure – investigate alternative methods to protect vulnerable infrastructure such as roads and bridges, prioritize critical infrastructure for repairs, establish on-site components to build make-shift bridge during an emergency
- Education – the need for more education about climate change and climate adaptation

Online Engagement

The communications strategy for HalifACT included an extensive social media campaign and online engagement tools: Halifax.ca and Shape Your City. This strategy was designed to spark conversation and create awareness.

These online engagement platforms hosted an interactive map, resources, and surveys to gather general public opinion on climate consciousness within the municipality. During the online engagement, HalifACT Facebook ads have been seen by 228,817 people, our Instagram ads by 23,520 and our Twitter ads have been viewed by 163,052. These informal engagement sessions have been beneficial in providing the team with key insights on the public opinion of climate change and historic climate hazards and impacts.

Further, the site featured an interactive map where respondents could add place-based information on local climate change hazards (e.g., flooding, drought), as well as a mitigation survey exploring their willingness to undertake mitigation actions and the barriers they may encounter in doing so. This survey received a total of 1,382 responses, energy diversification was the action that respondents voted to be the most important mitigation action and selected incentives at the action most likely to be acted on. This survey will continue to inform the development of detailed programs and actions. A survey called “All our Ideas” was also used to develop criteria (priorities) against which the mitigation and adaptation actions could be evaluated. This site has received more than 21,500 votes, with clean water, clean air, greenhouse gas emissions reduction, food security, and public health ranking as top areas of interest.

Conclusions / Final Note

The project team received an incredible amount of information at each workshop, presentation, pop up session, and through online engagement platforms. The final plan and summary of actions are stronger because of all the different ideas shared by the many stakeholders and residents. The project team extends a sincere thank you to all who took part in this engagement effort.

Appendix A – Invited Stakeholders

HalifACT 2050 Community Leadership Team Participating Organizations
ACOA Atlantic Cda Energy Office
Affordable Housing Association of Nova Scotia
Africville Heritage Museum
Akoma Family Centre / Akoma Holdings
Ambassatours Gray Line
Assembly of Nova Scotia Mi'kmaq Chiefs
Atlantic Policy Congress of FN Chiefs Sectariat
Atlantic Provinces Association of Landscape Architects
Atlantic Provinces Trucking Association
Black Cultural Centre of Nova Scotia
Building Owners & Managers Association of NS
Canada Green Building Council
Canadian Automobile Association, Atlantic Office
Canadian Centre for Policy Alternatives
Canadian Home Builders' Assoc - NS
Canadian Oil Heat Association, NS Chapter
Canadian Solar Industry Association
Canadian Wind Energy Association
CarShare Atlantic
Citizens Climate Lobby Halifax Chapter
Clean Foundation
CN Rail Atlantic Canada
Coastal & Ocean Information Network Atlantic
Confederacy of Mainland Mi'kmaq
Conseil communautaire du Grand Havre
Conseil de développement économique de la Nouvelle-Écosse
Conseil de la jeunesse de la Nouvelle-Écosse
Conseil scolaire acadien provincial
Dalhousie Department of Electrical and Computer Engineering
Dalhousie Office of Sustainability
Dalhousie Transportation Collaboratory (DalTRAC)
Dalhousie University
Dalhousie University School of Nursing
Downtown Halifax Business Commission

Ducks Unlimited Canada
East Preston Ratepayers' Association
Eastern Shore JEM Team
Ecology Action Centre
Efficiency Nova Scotia
Electric Vehicle Association of Nova Scotia
Environment & Climate Change Cda
ExxonMobil Canada Ltd - Maritime Fuels Ltd
Fisheries & Oceans Canada
Fusion Halifax
Halifax Chamber of Commerce
Halifax Food Policy Alliance
Halifax International Airport Authority
Halifax Partnership
Halifax Port Authority
Halifax Regional Water Commission
Heritage Gas
Hope Blooms
Housing Nova Scotia
IKEA Halifax
Immigrant Services Association of Nova Scotia
iMatter Youth Movement Halifax
Insurance Bureau of Canada
Investment Property Owners' Assoc NS
Irving Oil Limited
It's More Than Buses
Lucasville Greenway Society
Maritime Aboriginal Peoples' Council
MARLANT Safety & Environment Office (DND)
Mi'kmaw Native Friendship Centre
Mount Saint Vincent University
Musquodoboit Trailways Association
Nova Scotia Business Inc
Nova Scotia Health Authority
Nova Scotia Museum
Nova Scotia Nature Trust
Nova Scotia Power
Nova Scotia Woodlot Owners & Operators Association (NSWOOA)
NRCan CanmetENERGY Office

NRCan Cdn Hydrographic Service
Nova Scotia Association of Black Social Workers
Nova Scotia Coalition for the Decade for People of African Descent (DPAD)
Nova Scotia Energy & Mines
Nova Scotia Environment - Climate Change Unit
Nova Scotia Federation of Municipalities
Nova Scotia Lands & Forestry - Forest Management Planning
Nova Scotia Municipal Affairs
Nova Scotia Transportation & Infrastructure Renewal
Nova Scotia Communnity College Ivany Campus
Public Safety Canada
Quality Concrete Ltd
QUEST Canada
Railway Association of Canada
Réseau Santé
Sackville Rivers Association
Saint Mary's University
Sipekne'katik First Nation
Solar Nova Scotia
Superior Gas Liquids
Thinkwell Shift
Transport Action Atlantic
United Way Halifax
Urban Development Institute
VIA Rail
Waterfront Development Nova Scotia
Wilson Fuel Company Ltd

Attachment F

Clean Foundation
Inspiring Environmental Change

126 Portland • Dartmouth • NS • B2Y 1H8 • Phone: (902) 420-3474

Shannon Miedema
Energy and Environment Program Manager
Planning and Development
Halifax
miedems@halifax.ca

January 9, 2020

Dear Shannon and the HalifACT team,

Thank you for your continued efforts to guide Halifax Regional Municipality toward achieving the ambitious goals of the HalifACT 2050: Acting on Climate Together plan. As an active stakeholder and contributor in this process, Clean Foundation is pleased to provide a letter of support for the actions required to achieve a 95% GHG emission reduction by 2050 – specifically, those actions outlined under the LC3 model (pg. 8 from the November 7, 2019 Summary of Progress). The actions outlined in the LC3 model are achievable, and indeed necessary – we strongly encourage you to stay the course.

You are not alone. Many of the listed actions are well underway - led by your team, your colleagues across municipal and provincial governments, and the many groups and organizations who work in the sector and support the HalifACT plan. Clean has a long and positive history helping Haligonians and Nova Scotians reduce their energy demand, improve energy efficiencies, safeguard our coasts and biodiversity, drive innovative environmental programs and projects, and educate and train the current and next generation for a sustainable future. We provide individuals and communities with the means, knowledge, and opportunity to make responsible environmental choices. We have been doing this work for 30+ years.

As you know, accessing funding or resources requires a plan like HalifACT and the collaborative, multisectoral support that currently exists in HRM. At Clean, we have experience with all levels of government and understand how to take broad funding and develop and implement on-the-ground programs that achieve measurable impact in communities. We are ready to help – please let us know how.

Together, and we can build a sustainable future in Halifax.

Sincerely,

[redacted]

Scott Skinner
President and CEO

DALHOUSIE
UNIVERSITY

December 9, 2019

By E-mail: meidems@halifax.ca

Shannon Meidema
Energy & Environment Program Manager
Planning & Development
HALIFAX

RE: HalifACT 2050

Dalhousie has had a Climate Change Plan for operations since 2010. In 2019, a second version was. The University participates international Sustainability reporting systems, such as STARS, which publishes performance data related to curriculum, governance, research and operations.

Strategies in the Dalhousie Climate Change Plan align with many of the actions outlined in the HalifACT 2050 plan including focuses on energy efficiency and renewable energy, transportation, green and resilient buildings, biodiversity, water and waste reduction and management.

Our plan outlines specific mitigation and adaptation goals, actions and targets. Annual greenhouse gas inventories are published to monitor ongoing performance. Every three years a broader Sustainability Progress Report is published. This report and STARS includes tracking information on a number of indicators related to climate and other action areas.

Dalhousie University has been involved in environment and sustainability issues in its operations, curriculum, and research for decades. Dalhousie has signed international and national declarations including the Halifax Declaration, the Talloires Declaration, the UNEP International Declaration on Cleaner Production and the University and College's Climate Change Statement for Canada. In 2008, the College of Sustainability, the Office of Sustainability, and the Dalhousie Student Union Sustainability Office were formed and the President's Advisory Council on Sustainability (PACS) was created.

Dalhousie faculties incorporate progressive research, courses and programs at the undergraduate and graduate levels advancing sustainability knowledge and perspectives. Over 250 courses offered on campus have sustainability-focused content offerings. Some programs

VICE-PRESIDENT, FINANCE AND ADMINISTRATION
Room 108, Henry Hicks Academic Administration Building | 6299 South Street | PO Box 15000 | Halifax NS B3H 4R2 Canada
902.494.3862 | FAX: 902.494.1658
DAL.CA

are centrally focused on the topic such as the College of Sustainability, School for Resource and Environmental Studies, Environmental Science (Agriculture and Science), and Environmental Engineering. Other programs offer course content related to the topic in Faculties such as Architecture and Planning, FASS, Science, Law, Engineering, and Agriculture.

Over 220 faculty members are involved in sustainability related research crossing multiple Faculties. Key research centres focus on sustainability related topics such as the Ocean Frontier Institute, Clean Technologies Research Institute, Centre for Water Resource Studies, Marine and Environmental Law Institute, Healthy Populations Institute, and the Organic Agriculture Centre of Canada. Dalhousie's Signature research Clusters are organized for impact around the UN Sustainable Development Goals. Clusters include Sustainable Ocean, Healthy People, Healthy Communities, Healthy Populations, Clean Tech, Energy, the Environment, Culture, Society, Community Development, Food Security.

Strong relationships and partnerships that support these collective actions will be paramount as we work together on significant climate strategies.

Sincerely,

[redacted]

Ian Nason
Vice-President
Finance and Administration

NOVA SCOTIA
Energy and Mines

1690 Hollis Street
Joseph Howe Building, 11th Floor
PO Box 2664
Halifax, Nova Scotia, Canada B3J 3P7
902-424-4575 T 902-424-3265 F
novascotia.ca

February 3rd, 2020

Taylor Owen
HaliACT 2050
Halifax Regional Municipality
40 Alderney Drive
Dartmouth, NS B3J 3A5

Dear Mrs. Owen,

It is my great pleasure to provide you with this letter of support in principle for climate action in the Halifax Regional Municipality and the high-level goals of HalifACT 2050. The Department of Energy and Mines looks forward to opportunities to advance shared climate action objectives with the implementation of this plan.

The Province of Nova Scotia is committed to combatting climate change through sustainable and renewable energy initiatives. The HalifACT 2050 plan strongly aligns with our priorities which include reducing our greenhouse gas emissions, ensuring rate stability while reducing energy costs for low income families, and continuing our work in renewable energy.

The Department also works to support community driven projects that reduce greenhouse gas emissions through our many programs, such as the Low Carbon Communities Program, the Connect2 Program, and the Solar for Community Buildings Program.

We are committed to working with our partners to achieve shared goals in greenhouse gas reduction. We look forward to the launch of HalifACT 2050 and to the opportunities that it will bring for Halifax and for the province of Nova Scotia.

Sincerely,

[redacted]

Keith Collins
Executive Director
Sustainable and Renewable Energy Branch

CANADA GREEN BUILDING COUNCIL • CONSEIL DU BÂTIMENT DURABLE DU CANADA
Building with purpose • Bien bâtir pour l'avenir

CANADA GREEN BUILDING COUNCIL • CONSEIL DU BÂTIMENT DURABLE DU CANADA
CHAPTER
ATLANTIC

A proud Chapter of the CaGBC since 2005

December 9, 2019

Shannon Miedema
Energy & Environment Program Manager
Planning & Development
Halifax Regional Municipality

By email: miedems@halifax.ca

Dear Shannon,

The Canada Green Building Council (CaGBC) supports Halifax Regional Municipality in its goals outlined in HalifACT 2050 to protect the environment, reduce greenhouse gas (GHG) emissions and create economic opportunity.

The CaGBC is a not-for-profit, national organization that has been working since 2002 to advance green building and sustainable community development practices in Canada through market-based solutions. We are an industry-led organization providing value-added solutions that benefit the environment, economy, and public health. Our in-depth market research and analysis, building certification programs (i.e. LEED®, Zero Carbon Building Standard), and capacity building efforts have accelerated the transformation to high-performing green buildings, homes, and communities throughout Canada. Our reach is enhanced by the work of eight provincial Chapters that provide regionally tailored market education and advocacy.

We appreciate the opportunity to provide support to the efforts of the HalifACT 2050 committee and look forward to continuing to participate in discussions that relate to buildings on behalf of the green building industry in the region and across Canada.

[redacted]re one of the most cost-effective ways to reduce GHG emissions as [redacted]ey for HRM's homeowners and businesses. Buildings also represent [redacted]ial for economic growth through innovation, investments and job creation. Nova Scotia's built environment is a significant contributor to GHG emissions at 13 per cent, the third largest emitting sector in Nova Scotia with electricity generation at 42 per cent of emissions being the largest.

By constructing low-emission buildings and retrofitting existing building stock, Halifax will lower emissions, create new jobs, and scale-up investments and innovation. At the same time, these investments will ensure its building stock is more resilient to future climate conditions such as extreme weather, forest fires, flooding or droughts. Over 80 per cent of existing buildings will still be in operation in 2030 and 50 per cent in 2050, and therefore it is essential that existing buildings are addressed to meet GHG reduction targets for the building sector.

The Confederacy of Mainland Mi'kmaq

Member Mi'kmaw Communities

Acadia • Annapolis Valley • Bear River • Glooscap • Millbrook • Paqtnkek • Pictou Landing • Sipekne'katik

Main Office:
57 Martin Crescent, Millbrook Mi'kmaw Community
PO Box 1590 Truro, Nova Scotia Canada B2N 5V3
Tel (902) 895-6385 Fax (902) 893-1520
Toll free: 1-877-892-2424

Hospital Interpreters Liaison Program (902) 471-2988
Website Address: www.cmmns.com

January 9th, 2020

Ashley Childs
Department of Environment and Natural Resources
The Confederacy of Mainland Mi'kmaq
P.O. Box 1590
Truro, NS, B2N 5V3

To the HalifACT 2050 project team,

The Confederacy of Mainland Mi'kmaq (CMM) would like to strongly affirm our commitment to supporting the climate change mitigation and adaptation planning taking place within Halifax Regional Municipality through the HalifACT 2050 process. Climate change is a present and urgent threat to human health and wellbeing, the natural environment, and all manner of built infrastructure, the impacts of which will be felt acutely at the local level and will disproportionately burden the most vulnerable populations.

The Confederacy of Mainland Mi'kmaq (CMM) is a Tribal Council representing the eight Mi'kmaw communities in mainland Nova Scotia: Acadia, Annapolis Valley, Bear River, Glooscap, Millbrook, Sipekne'katik, Paqtnkek, and Pictou Landing First Nations. Our mission is to proactively promote and assist Mi'kmaq community initiatives towards self-determination and enhancement of community. CMM has been actively engaged in climate change programming since 2014, and we continue to strengthen the support we provide to communities on climate initiatives.

Some highlights of our adaptation work include vulnerability assessments to gather local knowledge on hazards, LiDAR and GIS modelling to generate flood risk model, developing adaptation strategies for priority vulnerabilities, and various outreach initiatives. Our emergency management project has conducted needs assessments and increased preparedness through providing necessary emergency response equipment and organizing numerous training opportunities. To improve food security our pollinator recovery project works to augment native pollinator habitat and establish community gardens. Our climate monitoring team interviews traditional knowledge holders on the impacts of climate change and builds capacity for communities to monitor changing weather, precipitation, air quality, and ecosystem changes. In 2020 we are also eager to begin supporting Mi'kmaw communities in their transition to a low carbon future through outreach and engagement initiatives on energy efficiency and renewable energy along with providing practical skills training in the green energy sector. Through these initiatives and more CMM will continue to work with its communities to prepare for the ongoing impacts of climate change.

Main Office:
57 Martin Crescent, Millbrook Mi'kmaw Community
PO Box 1590 Truro, Nova Scotia Canada B2N 5V3
Tel (902) 895-6385 Fax (902) 893-1520
Toll free: 1-877-892-2424

Hospital Interpreters Liaison Program (902) 471-2988
Website Address: www.cmmns.com

The goals set forth in the HalifACT 2050 plan are ambitious yet undeniably essential, and CMM will continue to support these climate action initiatives as a participant in the HalifACT 2050 process.

Sincerely,

[redacted]

Ashley Childs
Senior Director, Department of Environment and Natural Resources

CHAPTER
ATLANTIC

A proud Chapter of the CaGBC since 2005

Through the goals defined in HalifACT 2050 around the built environment, Halifax is well positioned to demonstrate leadership that will drive change, inform policy development and enable job creation and GDP growth in Halifax by strengthening the capabilities of the green building sector and its workforce, informing investment and export opportunities.

The CaGBC Atlantic Chapter will continue to convene and support the green building industry by providing education and training on high-performing zero carbon new buildings and retrofits as well as voluntary industry standards such as LEED®, WELL or the Zero Carbon Building Standard. As Canada's green building advocate, we will continue to support Halifax and the NS provincial government in meeting climate goals related to building stock.

We applaud Halifax's ambitious goals of net-zero new construction for all buildings within the municipality by 2030, carbon-neutral new and existing municipal buildings by 2030, and deep retrofits for all existing buildings within the municipality by 2040.

CaGBC's research confirms that a goal of zero carbon for new construction buildings by 2030 is financially and technically viable for the industry. Setting the objective also provides long-term clarity to developers, designers, and builders about future performance expectations and help them assemble the expertise, processes, and investments needed to be successful. Further, a goal of zero carbon for all buildings within the municipality by 2040 would make Halifax more ambitious than the 2050 recommendation of the World Green Building Council to address global climate goals.

Congratulations on the work to date in addressing the climate emergency. We look forward to continuing to set new municipal building related short, mid and long-term goals together.

Sincerely,

[redacted]

Lara Ryan
Regional Director, Atlantic Chapter
Canada Green Building Council
902-440-0296
lryan@cagbc.org

Heritage Gas

December 20, 2019

Shannon Miedema
Energy & Environment Program Manager
Planning & Development
Halifax Regional Municipality

RE: HERITAGE GAS SUPPORT FOR HRM'S CLIMATE ACTION PLAN

Heritage Gas supports HRM's ambitious climate change plan to be carbon neutral by 2050 and to help communities adapt to climate change. No single type of energy will enable HRM to achieve these goals - we'll need transformative and collaborative solutions that conserve energy, improve energy efficiency, increase energy resiliency, and offer cleaner energy sources for buildings, industries, and transportation.

Heritage Gas is already taking action and developing plans to address climate change in Nova Scotia. Natural gas has helped reduce GHG emissions in Nova Scotia by over 200,000 tonnes per year through the conversion of homes, commercial buildings, and industries from oil to cleaner-burning natural gas. Looking forward, Heritage Gas will be doing much more to reduce GHG emissions and increase energy resiliency in HRM at relatively low cost compared to other alternatives. We're working on projects and developing plans that will support HRM to:

- improve the energy efficiency of buildings;
- transition to a mix of cleaner energy sources, including cleaner electricity, renewable energy, and lower-carbon fuels for buildings, industries, and transportation; and
- adapt to climate change by improving the reliability and resiliency of HRM's energy infrastructure.

We track and report GHG emissions from the use of natural gas in Nova Scotia as part of the Province's cap & trade system. As the lowest emitting fossil fuel, including electricity generation in Nova Scotia for the next several years, the carbon footprint from the combustion of natural gas is relatively small compared to other fuels.

To promote sustainability and help our customers evaluate alternatives to reduce their household carbon footprint, a GHG emissions calculator is posted on the Heritage Gas website at https://www.heritagegas.com/for-home/savings-calculator/. We also report the year-to-date GHG emissions reduction from the use of natural gas in Nova Scotia on the homepage of the Heritage Gas website.

So far in 2019, our customers have reduced Nova Scotia's carbon emissions by:

174,868.169 tonnes

Heritage Gas supports the benefits that densification through land use planning offers to reduce GHG emissions in HRM. Energy use per resident is significantly lower for households in multi-unit residential buildings compared to single-family homes, and building higher density residential and commercial developments improves the feasibility of district energy.

Park Place 1, 200-238 Brownlow Ave.
Dartmouth, Nova Scotia B3B 1Y2
heritagegas.com 1-877-836-7427

clickbeforeyoudig.com

Forward *Energy.*

Heritage Gas also plays a role in climate adaption by improving energy resiliency in HRM, and this role will become more important as the frequency and severity of storms increases. The natural gas distribution system in HRM is over 99.99% reliable and widespread service disruptions are extremely rare, which can help HRM build resilient multi-grid energy systems. Furthermore, Heritage Gas is working with building owners and industries to complete feasibility and implementation studies for combined heat & power (CHP) generators. CHP improves energy security and reduce energy costs in buildings, by producing on-site electricity and heat that can be available during grid power disruptions.

Details of specific actions and programs that Heritage Gas is working on or planning to undertake that support the themes outlined in the HalifACT 2050 Actions Catalogue are outlined below:

BUILDINGS

Building codes and standards for new construction:

- ***District heating/cooling connection*** – Heritage Gas supports district energy in new large, high density developments in HRM, including the Cogswell redevelopment project, Shannon Park, Dartmouth Cove, and the former St. Patrick's high school lands on Quinpool Rd.

Building performance rating and reporting:

- ***Advanced metering (smart meters, sub-metering)*** – Heritage Gas has installed Automatic Meter Reading (AMR) devices on meters for all natural gas customers that can support monitoring, analyzing and reducing energy use. Energy efficiency and retrofit measures for existing buildings:
- ***Heating efficiency*** – Heritage Gas helps building owners replace older, low-efficiency oil furnaces and boilers with new natural gas condensing boilers and furnaces that are up to 97% efficient and improve energy efficiency by up to 20%.

Industrial carbon emissions reduction:

- ***Energy efficiency or waste energy recovery in industrial processes*** – Heritage Gas is advocating for the development of policies and programs to improve the energy efficiency of industries through the installation of combined heat & power (CHP) generation for industrial processes and large commercial or institutional buildings.

TRANSPORTATION

Fuel economy - public transport:

- ***Improve transit vehicle fuel economy through switching to low or zero carbon fuels*** – Heritage Gas has supported Halifax Transit's study of the conversion of the bus fleet to compressed natural gas (CNG) to reduce bus GHG emissions by 20% compared to the current diesel bus fleet, or by 100% with renewable natural gas (RNG) produced from one of HRM's organics management facilities, landfills, or wastewater treatment plants.

Heritage Gas

Fuel economy - private transport & Freight Systems:

- ***Switch City authority fleet of vehicles to electric/hybrid/low-carbon*** – If the carbon intensity of electricity generation in Nova Scotia is reduced significantly from current levels, electric vehicles will be an effective action to reduce GHG emissions from light-duty vehicles. However, it is not feasible to electrify heavy-duty vehicles including waste vehicles, construction equipment, and heavy tractors used to haul freight. Heritage Gas has completed a feasibility study and is working with the Province of Nova Scotia to develop a Natural Gas Vehicle (NGV) strategy for heavy-duty vehicles.

ENERGY SUPPLY

Local low or zero carbon energy generation (community scale):

- ***Anaerobic digestion of organic wastes*** – Heritage Gas is working with proponents for HRM's new organics management facility to enable the production, distribution, and sale of renewable natural gas (RNG) through anaerobic digestion from the proposed new facility.
- ***Biogas / landfill gas recapture*** – We have supported HRM to evaluate the feasibility of upgrading biogas from the Otter Lake Landfill to RNG and injecting it into the natural gas distribution grid.
- ***District energy (electricity, heating or cooling) with renewable energy source*** – Heritage Gas has identified several new developments in HRM that could use district energy + combined heat & power (CHP) produced from natural gas, or RNG for heating, cooling, and electricity.
- ***Large scale purchases of renewable energy on behalf of the community*** – Heritage Gas has estimated that up to 500,000 GJ of RNG could be produced locally in HRM (enough to supply 20% of total natural gas demand in HRM). The RNG could be purchased by HRM to meet the heating needs of all buildings owned by HRM and to fuel Halifax Transit's conventional bus fleet. Conversely, this volume of RNG could provide space heat and domestic hot water for 6,000 homes in HRM.
- ***Explore & support provincial regulatory requirements for renewable energy generation*** – Heritage Gas is advocating for policies and programs to support and promote the production of RNG in HRM.

On-site (building scale) energy generation:

- ***Combined heat and power*** – Heritage Gas is supporting large commercial, institutional, and multi-unit residential building owners in HRM to evaluate the installation of on-site combined heat & power (CHP) generators that can improve energy efficiency in buildings to 80-90%, resulting in a 30-40% reduction in GHG emissions, lower energy costs, and greatly improved energy resiliency.
- ***Hydrogen*** – Heritage Gas is evaluating the role that 'green' hydrogen produced from renewable electricity could play to help achieve net-zero GHG emissions in HRM by 2050. Green hydrogen could be used for hydrogen fuel cells in Halifax Transit buses and ferries, heating and cooling homes and businesses. The existing natural gas infrastructure can be effectively used as a 'battery' to store surplus renewable electricity to significantly reduce GHG emissions while reducing the increase in peak electric demand that will be created by increased electrification. Green hydrogen

infrastructure is currently being developed in Ontario and a major expansion in the use of green hydrogen is anticipated to help meet 2050 net-zero GHG emission targets.

- ***Heat pumps (water, ground, air)*** – Heritage Gas is supporting the development of several new heating systems including natural gas heat pumps for space heat and domestic hot water, micro-combined heat and power generators, and natural gas-electric hybrid heating systems that provide the benefits of electric heat pumps during milder temperatures, while minimizing the impact on peak electric load during the colder winter months.
- ***Biogas recapture from industrial processes*** – Biogas is already being recaptured from a few industrial facilities in HRM and used for heating in buildings. Heritage Gas is interested in identifying more biogas recapture opportunities.

WASTE

Energy recovery & landfill management:

- ***Landfill gas to energy (carbon capture, methane capture)*** - Heritage Gas has collaborated with HRM to evaluate the feasibility of upgrading biogas from the Otter Lake Landfill to RNG and injecting it into the natural gas distribution grid.

WATER & WASTEWATER

Energy recovery:

- ***Methane/biogas recovery for reuse*** – Heritage Gas supports Halifax Water's studies to evaluate the production of RNG through anaerobic digestion at local wastewater treatment facilities. The RNG could be injected into HRM's natural gas distribution system to enable buildings, heavy trucks, and transit buses in HRM to displace their conventional natural gas use with renewable energy.

Heritage Gas has been pleased to participate in the development of HalifACT 2050's recommendations and we're looking forward to working with HRM to implement its climate change action plan.

Regards,

[redacted]

Derek Estabrook
Vice President, Business Development
HERITAGE GAS LIMITED

COINAtlantic
COASTAL AND OCEAN INFORMATION NETWORK

COINAtlantique
RÉSEAU D'INFORMATION SUR LA ZONE CÔTIÈRE ET L'OCÉAN

December 6th, 2019

Dear Senior Leaders and Elected Officials,

I am writing on behalf of COINAtlantic in support of the HalifACT 2050 initiative. COINAtlantic staff members have attended the HalifACT 2050 meetings and we believe this is a vital initiative that needs your support. While the work our organization undertakes is largely focused on the coast and oceans, climate change is a transcending issue, affecting many aspects of our work in some way.

One initiative that COINAtlantic will be undertaking in 2020 is promoting the Atlantic Chapter of *Canada in a Changing Climate: Advancing our Knowledge for Action* report issued by Natural Resource Canada. Themes within this chapter include sea-level rise, overland flooding, critical infrastructure, natural resource industries, collaboration and capacity building, physical and mental health, education, communication, and outreach as it relates to climate change, as well as knowledge gaps and emerging challenges.

As we move forward with this deliverable, drawing from the expertise and dialog exchange provided through HalifACT 2050 will be invaluable for building community support and effectively engaging leaders in climate change action and mitigation in Atlantic Canada.

Yours truly,

Lydia Ross
Project Officer

Christina Macdonald
Executive Director

6414 Coburg Road, P.O. Box 15000, Halifax, Nova Scotia, Canada B3H 4R2
Tel 902-494-7162 - Fax 902-494-1334 – Email: COINAtlantic@dal.ca – Web: coinatlantic.ca

902.H2O.WATR
902.420.9287
450 Cowie Hill Road
P.O. Box 8388 RPO CSC
Halifax, Nova Scotia
Canada B3K 5M1

January 13, 2020

Mr. Jacques Dubé
Chief Administrative Officer
Halifax Regional Municipality
PO Box 1749
Halifax, NS B3J 3A5

Dear Mr Dubé:

Letter of Commitment - HalifACT 2050: Acting on Cimate Change Together

Halifax Water was asked to provide a letter of support for the HalifACT 2050 long-term cilmate change mitigation and adaptation plan for HALIFAX.

Halifax Water participated in the stakeholder consultation process, and recognizes the urgency to take action to to reduce GHG emissions from the business as usual (BAU) projection. The consulting team identified nine action areas, including one for water, wastewater and stormwater.

There are several existing Halifax Water intiatives that will assist achievement of the broad reduction target for the community:

- Halifax Water has an Energy Management Committee that plans and delivers energy efficiency iniatives that have resulted in annual reductions of 2 – 4% per year since inception. The focus of this committee is being broadened to include GHG emission reduction, developing specific targets and actions for Halifax Water that will support HalifACT 2050.

- Halifax Water has taken positive actions towards adaptation through development of an updated Integrated Resrouce Plan to understand our climate vulnerabilities and reduce risk to our infrastructure and service delivery.

- Halifax Water is championing implementation of the Cogswell District Energy System as part of the Cogswell redevelopment. This will lead to significant reductions in GHG emissions versus the BAU case for new development.

- Halifax Water is planning anaerobic digestion for treating residual biosolids, to generate renewable gas and continuing to process the residual biosolids into Class A fertilizer for beneficial reuse. This could result in a reduction in conventional fossil fuel use and therefore GHG emissions.

- In 2000, Halifax Water was the first utility in North America to adopt what is now the AWWA M36 methodology for Water Loss Control. Through these efforts, Halifax Water has has reduced system inputs by 40 million litres per day, resulting in a reduction of $700,000 per year in operating expense, primarily from reduced consumtion of electricity and water treatment chemicals. Halifax Water remains a leader in Water Loss Control.

- Halifax Water has developed a Wet Weather Flow Management Program that focuses on reducing inflow of clear water into its sewer system. This program not only reduces energy and chemical requirements to transport and treat wastewater but also creates additional capacity to accommodate increase in flows because of population growth.

The consultant engaged by the municpality, Sustainability Solutions Group (SSG), used assumptions and examples to show how reduced GHG emissions could be achieved in the water and wastewater area. Those assumptions and examples have not been assessed or validated by Halifax Water.

Halifax Water will continue moving forward with the above noted initatives, developing an action plan to support GHG emission reductions associated with water, wastewater and stormwater services provided by the utility.

Sincerely,

[redacted]

Cathie O'Toole
General Manager, Halifax Water

CC: Craig MacMullin- Chair, Halifax Water Board
Russell Walker - Vice-Chair, Halifax Water Board

December 10, 2019

Halifax
Attn: Shannon Miedema
PO Box 1749
Halifax, NS
B3J 3A5

Dear Shannon,

Re: BOMA Nova Scotia Support for HalifACT 2050

On behalf of the Building Owners and Managers Association (BOMA) Nova Scotia I would like to express our support for actions taken to address climate change at a municipal level.

As you may be aware BOMA is an association of professionals involved in the management and maintenance of commercial buildings. BOMA has long been aware that more sustainable management practices in the management of commercial buildings make a difference in emission reduction.

In 2007 BOMA Canada introduced a nation-wide environmental certification program BOMA BEST, which is offered by BOMA Locals across Canada including BOMA Nova Scotia. BOMA BEST provides owners and managers with a consistent framework for assessing the environmental performance and management of existing buildings of all sizes. It covers ten key areas: Energy, Water, Air, Comfort, Health and Wellness, Custodial, Purchasing, Waste, Site, Stakeholder Engagement.

BOMA BEST allows building managers to constantly improve the efficiency of existing buildings and identify what retrofitting measures should be undertaken. Members who have undertaken BOMA BEST certification typically see improvements in all areas, but especially in energy and water consumption and waste diversion.

BOMA Nova Scotia remains committed to actions that improve the environmental performance of commercial buildings and the infrastructure that supports them, including electric powered transit.

Sincerely,

[redacted]

Dan Bourque, RPA
President
BOMA Nova Scotia

Ecology Action Centre
tel. 902.429.2202 2705 Fern Lane,
fax. 902.405.3716 Halifax, NS, B3K 4L3

Shannon Miedema
Energy and Environment Program Manager
Planning and Development
Halifax
miedems@halifax.ca

December 9, 2019

Dear Shannon and the HalifACT team,

As a stakeholder in the HalifACT 2050 process, the Ecology Action Centre is pleased to write a letter of commitment to HalifACT 2050's collective goals. We are fully supportive of the actions outlined and will be executing many complementary actions within our own work and organization.

The Ecology Action Centre is a member-based environmental charity in Nova Scotia. We take leadership on critical environmental issues from biodiversity protection to climate change to environmental justice.

Since 1971, the Ecology Action Centre has been working at the local, regional, national and more recently, international level to build a healthier and more sustainable world.

We are grounded in community, and a strong voice and watchdog for our environment. We work to catalyze change through policy advocacy, community development, and building awareness. We take a holistic approach to the environment and our economy to create a just and sustainable society.

EAC has several planned actions that are related to the themes outlined in the table of recommendations.

Regarding transit and active transportation, the EAC works with schools, community groups and municipalities to develop plans to build capacity, knowledge and resilience in communities and municipalities around active transportation (AT). We also advance policies, plans and strategies that support safe, accessible and connected AT use through communications strategies and government relations. We are dedicated to continuing this work.

The EAC also leads the Making Tracks program, which aims to increase AT access, safety, skills and confidence among Nova Scotian families. In addition to the continuation of this program, we will be piloting urban cycling workshops throughout Nova Scotia, including in HRM.

We will also be using our capacity to support the electrification of transportation. We currently lead advocacy efforts for a Zero Emissions Vehicle (ZEV) mandate in Nova Scotia. In addition to our advocacy for ZEVs, we are partnering with HRM to increase the use and distance travelled using of active transportation through an e-bicycle pilot project, "Easy Ride".

In relation to buildings, the EAC building is an example of what can be done elsewhere and it is representative of the kind of building initiatives and policies that the EAC is committed to advocating for. These include, but are not limited to retrofitting of existing builds, net-zero new builds, and increased industrial efficiency. We participate in the meetings and conversations at the Canadian Commission on Fire and Building Codes, in order to influence the development of Canada's Net Zero Energy Ready Building Codes. We work with local allies to promote local industry and stakeholder engagement in building code

tel. 902.429.2202 2705 Fern Lane,
fax. 902.405.3716 Halifax, NS, B3K 4L3

consultations. We are working with national allies to catalyze the retrofit market transformation in Canada and are about to undertake a deep energy retrofit feasibility study. We continue to advocate for better building policies in Nova Scotia and HRM, through government relations, and advocacy for stronger policies including training programs, incentives and programs. We will continue our Culture of Efficiency work throughout Nova Scotia to promote efficiency as a climate and energy poverty solution. Finally, we will continue to intervene in regulatory hearings that lay our efficiency targets and funding for the province, and we will continue to advocate that we double and triple our energy efficiency targets in Nova Scotia.

EAC is one of the province's strongest proponents of renewable energy. We recently released a report outlining how the province can achieve 90% renewable energy by 2030. This includes deep energy retrofits of 80% of the existing building stock, 800 megawatts of wind power, and 480 megawatts of solar generation. We also released a complimentary Green Jobs Report earlier this year, that shows the costs and benefits of moving to 90% renewables, increasing electrification of transit, increasing public transit, and tripling down our efficiency efforts.

EAC's office is the most energy efficient office retrofit in Canada. We encourage any representatives from HRM to come tour our buildings and learn about how we achieved the such high performing results. We increased our square footage by 50% and reduced energy consumption by 89%. We also have plans to install photovoltaic solar panels on our roof to further demonstrate our commitment to renewable energy.

As a community member and stakeholder, the EAC is committed to contributing to the recommendations outlined by HalifACT 2050. The EAC also remains committed to the original objectives of HalifACT (then the Climate Action and Community Energy Plan) "…helping communities sustainably and equitably adapt" by engaging in "inclusive solutions to mitigation and adaptation". As such we would like to highlight that EAC is a provincial leader in coastal climate change adaptation and coastal projection initiatives, striving to mitigate the impacts of climate change for more than a decade. EAC has partnered with NS Environment on the creation of the Coastal Protection Act, which will restrict inappropriate coastal development and protect our coastal ecosystems. EAC's Educating Coastal Communities about Sea Level Rise (ECoAS) Project (www.sealevelrise.ca) has enabled our organization to work with municipalities across the province to enhance adaptive capacity by educating and empowering coastal citizens and communities. EAC actively communicates with HRM staff to highlight community coastal climate adaptation and protection issues within the municipality, such as undersized lots, inappropriate infilling and rezoning plan issues in dangerous areas. Along with a commitment to the HalifACT 2050 mitigation recommendations, the EAC commits to working with HalifACT 2050 to further its adaptation recommendations and strategies (e.g. to advancing coastal climate change adaptation for the municipality's 2,400 kilometres of coastline).

All of EAC's work relates to the HalifACT 2050 vision. Some of our work, on issues such as food security and wilderness conservation, is more indirectly related to the recommendations outlined by HalifACT 2050, but they are of equal importance.

In relation to food, the Halifax Food Policy Alliance, which we co-chair, is currently working with HRM to develop a Food Action Plan in order to build on HRM'S momentum, coordinate existing policies with action, and established trackable outcomes. By maximizing locally available resources and supporting the inherent community connections historically created by food, this Food Action Plan will help restore more sustainable and productive connections with nature in the region, increase resiliency of communities and support both climate mitigation and adaptation.

tel. 902.429.2202 2705 Fern Lane,
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In relation to terrestrial ecosystem preservation, the EAC's work has included advocating for more protected areas, including Regional Parks in HRM. Currently 12.4% of Nova Scotia's landmass is protected. We are advocating that 17% of Nova Scotia's landmass be formally protected for nature conservation by 2030. These new protected areas are needed for ecosystem resilience in a time of rapidly changing climate. They also help combat biodiversity loss, as protected areas have been shown (globally) to have higher species diversity and higher wildlife populations than areas not under formal protection.

Thank you very much for the opportunity to participate in the HalifACT community and stakeholder engagement process and to express our support for your efforts. We congratulate the entire HalifACT 2050 team for their hard work, vision, and efforts.

Sincerely,

[redacted]

Marla MacLeod

Managing Director
Ecology Action Centre

NOVA SCOTIA
Environment

Barrington Place, Suite 2085
1903 Barrington Street,
PO Box 442
Halifax, Nova Scotia
Canada B3J 2P8

902-229-5494t
902-424-6925f
novascotia.ca

Our File No.:

December 17, 2019

HalifACT 2050
Halifax Regional Municipality
40 Alderney Drive
Dartmouth, NS B3J 3A5
owent@halifax.ca

Dear HalifACT 2050:

We are pleased to provide you with this letter of support in principle for climate action in the Halifax Regional Municipality and the high-level goals of HalifACT 2050. Nova Scotia Environment looks forward to opportunities to advance shared climate action objectives with the implementation of this plan.

Nova Scotia Environment is committed to advancing climate change mitigation and adaptation in the province. As you know, the Government of Nova Scotia released the *Sustainable Development Goals Act* on October 30, 2019, which sets new goals to address climate change and to continue advancing Nova Scotia's economic, social and environmental well being. The *Act* commits Nova Scotia to ambitious new greenhouse gas reduction targets - 53% below 2005 levels by 2030 and to net zero emissions by 2050. These are the most ambitious targets in the country.

The *Act* also requires the development of a Climate Change Plan for Clean Growth by December 2020. In the coming months, we will be consulting on the development of this plan with stakeholders and members of the public. The Plan will chart our pathway to achieving our greenhouse gas reduction targets, building a resilient province that can adapt to the impacts of climate change, accelerating the integration of sustainable technologies and promoting clean inclusive growth.

We will also continue to implement existing initiatives that reduce provincial greenhouse gas emissions and that increase our resiliency to the impacts of climate change, such as the Cap-and-Trade and the Climate Adaptation Leadership programs.

We are committed to working with partners to achieve shared goals in climate change mitigation and adaptation. We look forward to the launch of HalifACT 2050 and to the opportunities that it will bring for Halifax and for the province of Nova Scotia.

Sincerely,

[redacted]

Jason Hollett
Executive Director
Climate Change Unit

/JH

230 Brownlow Avenue, Suite 300
Dartmouth, Nova Scotia
Canada B3B 0G5
efficiencyone.com
T +1 902 470 3500
F +1 902 470 3599

March 4, 2020

Shannon Miedmema, MES
Energy & Environment Program Manager
Planning & Development
Halifax City Hall
1841 Argyle Street
Halifax NS, B3J 3A5

Dear Shannon,

I am writing on behalf of EfficiencyOne, the operator of Efficiency Nova Scotia, to highlight our support for HalifACT 2050 and our commitment to taking climate action by continuing to provide Nova Scotians with energy efficiency programming that will help save money and reduce their carbon footprint while creating more green jobs in Nova Scotia.

We know that cities produce about half of Canada's carbon emissions; a strong commitment to climate action is critical to ensuring that Canada is able to meet the targets set out in the Paris Accord. We also know that strong leadership and partnerships will be key as we aim to identify and accelerate action in cities to achieve our climate targets.

Halifax has shown, and continues to show, great leadership on climate action and has long been a valued partner. Working with Efficiency Nova Scotia, Halifax hired an On-Site Energy Manager in 2018 that works with staff to identify and obtain funding and financing opportunities, and plan, implement and evaluate energy saving projects. To date through this work, over 52 projects have been completed realizing over $750,000 in savings and over 5.5 eGWh savings. This equals roughly 3500 tonnes of CO_2e avoided annually. Halifax has also demonstrated great leadership through programs like Solar City and ensuring that climate actions is top of mind for Haligonians.

As Halifax looks to the future, energy efficiency can and should continue to play a major role in reducing greenhouse gas emissions. It is a fast, cost-effective way for individuals and businesses to save money by reducing energy costs, while also reducing their climate impact.

In Nova Scotia, the energy efficiency industry is a growth industry. With over 1,400 Nova Scotians employed full-time in the energy efficiency sector and over 175 businesses in Halifax working in the energy efficiency industry as part of our Efficiency Trade Network, it is a respected contributor to economic growth and continues to develop more partnerships, more employees, more suppliers and more customers every year.

Nova Scotia also leads the country in energy efficiency programs. Through Efficiency Nova Scotia we achieve high energy savings and are working to reduce energy poverty with innovative products and services. To date we have helped Nova Scotians save more than $1 billion in energy costs, while avoiding 1 million tonnes of CO_2 annually. We've also helped low income homeowners and tenants save more than $27 million on their energy bills.

Shortly, EfficiencyOne and the Federation of Canadian Municipalities will be partnering with Halifax to launch Low Carbon Cities Halifax (LC3 Halifax). Through LC3 Halifax we will accelerate urban climate solutions by investing in solutions or initiatives that will build community resiliency. LC3 Halifax will help commercialize urban low-carbon solutions that would otherwise not get off the ground and focus on taking proven low-carbon solutions to full-scale adoption by supporting and undertaking incubation, demonstration, and de-risking of low-carbon solutions and by working with diverse partners within urban areas.

While Halifax has made significant progress, there is much more we can do to help Canada, and Halifax, achieve its emission reduction targets. The energy efficiency sector is a significant contributor to Nova Scotia's sustainability goals and is eager to continue to play a major role in reducing greenhouse gas emissions and contribute to economic and environmental prosperity.

Regards,

Stephen MacDonald
Chief Executive Officer