Carbon-Free Colchester

Municipality of the County of Colchester Community Energy and Emissions Plan

2021



Colchester
be centred here.

SSG

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Acknowledgements

Land Acknowledgement

In peace and friendship, and in the spirit of truth and reconciliation, the Municipality of Colchester acknowledges that it is located in Mi'kma'ki, the ancestral and unceded territory of the Mi'kmaq. The Mi'kmaq are a diverse and vibrant people who continue to live and thrive on this land.

All of us who are fortunate to live here in Mi'kma'ki are Treaty People, bound to the Peace and Friendship Treaties of the 18th century with an inherited responsibility to share this land in peace and friendship.

Indigenous communities across the globe — and throughout North America/Turtle Island — are among the most vulnerable to impacts of climate change, but they are also the best equipped to offer solutions and lead the way to a climate just future, since their ancestors lived in harmony with the land for millennia before settlers arrived.

The projects and initiatives resulting from the implementation of this Plan must be equitable, must benefit and respect everyone who lives here, and must aim to protect, sustain, and nurture our natural environment, which we all depend upon for survival. Achieving these objectives means listening to and collaborating with Mi'kmaw people and other groups who are unjustly affected by climate change and whose knowledge about how to live sustainably on this land is indispensable.

Contributors to the Plan

Artwork provided by students from École acadienne de Truro.

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Disclaimer

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A Note on the Impact of Coronavirus (COVID-19)

The analysis in this document was completed as COVID-19 began spreading rapidly in Canada, but doesn't include detailed considerations for changes in population, transportation, housing, and office building needs. Even so, the analysis continues to be relevant not only because the climate crisis persists, but also because this document provides solutions that can stimulate the economy during the pandemic-induced recession. The solutions the report recommends, ranging from retrofits to investing in renewable energy, are designed to decrease emissions and increase energy efficiency while creating jobs.

In the context of COVID-19, here are some key points to consider:

- A global health crisis: The pandemic has radically transformed societies and economies, resulting in tragedy and disrupting work and home life everywhere.[1]
- The impacts of coronavirus are unclear: The negative impact of COVID-19 on people, workplaces, and the economy, as well as the duration of those impacts, presents many uncertainties. The recovery will be affected by a combination of factors such as public health guidance for opening up society, the evolution of the pandemic, the design of public policy responses and the continuing response by global institutions.
- The climate emergency remains an emergency: A decline in activity has resulted in a short term reduction in GHG emissions but concentrations of GHG emissions in the atmosphere continue to climb and global temperatures continue to increase.[2] The pandemic has also disrupted international efforts to address climate change.
- There are challenges and opportunities: In the short term, the impacts of COVID-19 both challenge and reinforce actions outlined in the CFC Plan.
- Substantively addressing climate change is more relevant than ever: Investments made now lock in emissions for decades. The CFC Plan identifies investments that stimulate the economy and decarbonise the western region out until 2050.
- Alignment with green stimulus: As Canada initiates efforts to recover from the impact of the coronavirus, there is an opportunity to stimulate the economy with investments that simultaneously address the climate crisis. This Plan describes an investment opportunity that will generate jobs, stimulate businesses, reduce GHG emissions, and provide benefits for local communities and the Region.

[1] World Health Organisation (2020). World health statistics 2020: monitoring health for the SDGs, sustainable development goals. Retrieved from: https://apps.who.int/iris/bitstream/handle/10665/332070/9789240005105-eng.pdf

[2] World Meteorological Organisation (2020). The Global Climate in 2015-2019. Retrieved from: https://library.wmo.int/doc_num.php?explnum_id=10251

Abbreviations

BAP	Business as planned scenario
CES	Clean energy scenario
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalents
CDD	Cooling degree days
CH_4	Methane
DE	District energy
GHG	Greenhouse gas emissions
GPC	Global Protocol for Community Scale Greenhouse Gas Emissions Inventories
GWP	Global warming potential
HDD	Heating degree days
ICI	Industrial, commercial, and institutional buildings
IRP	Integrated Resource Plan
LCS	Low-carbon scenario
NPV	Net present value
O&M	Operations and maintenance
RNG	Renewable natural gas
PV	Photovoltaic
SCC	Social cost of carbon
VKT	Vehicle kilometers travelled

Units

GHG emissions

1 $ktCO_2e$ = 1,000 tCO_2e

Energy

1 MJ= 0.0001 GJ

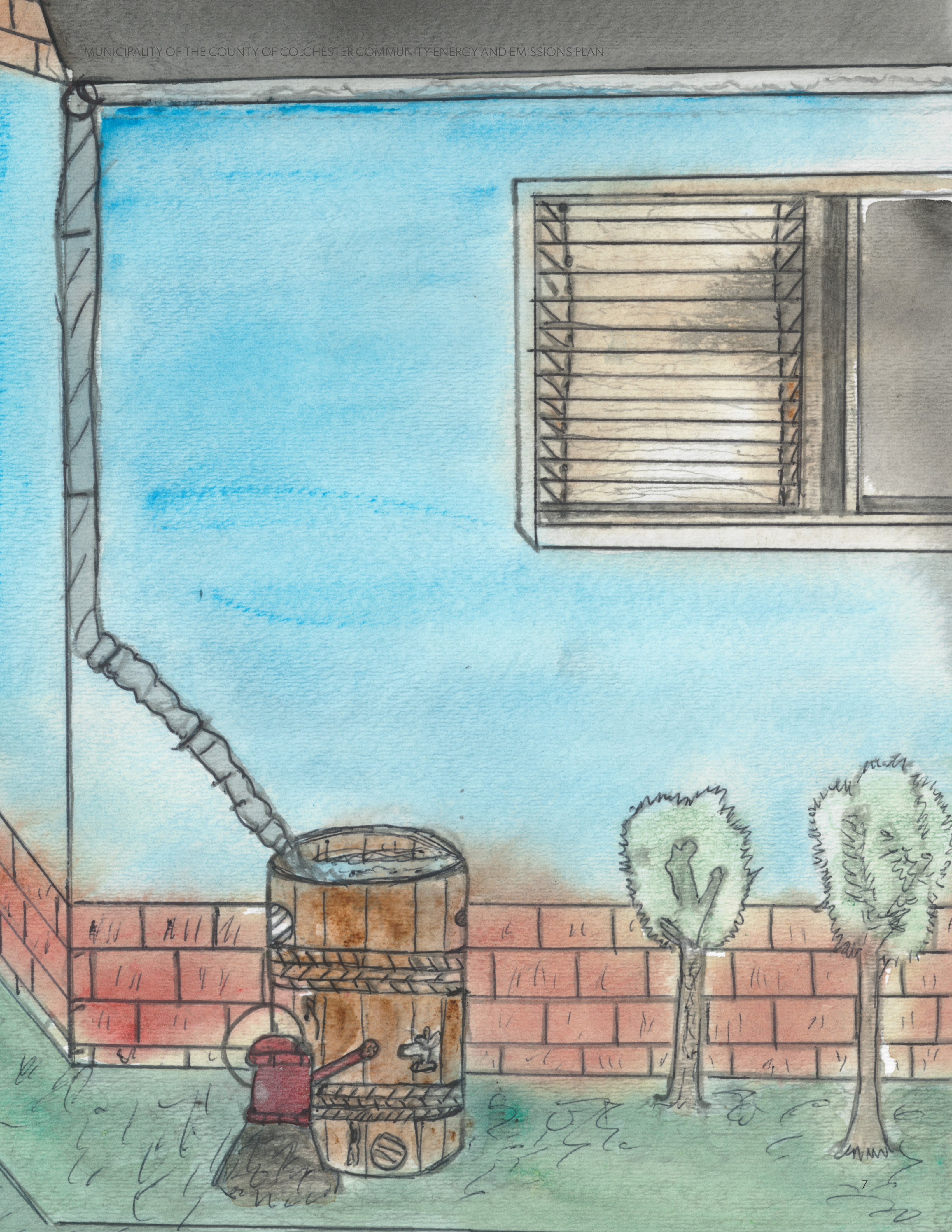
1 TJ= 1,000 GJ

1 PJ= 1,000,000 GJ

1 GJ= 278 kWh

1 MWh= 1,000 kWh

1 GWh=1,000,000 kWh



Letter from the Mayor

Dear community of Colchester,

After months of hard work by our staff, our consultants at Sustainability Solutions Group, and you, the community, Council is pleased to share this Community Energy & Emissions Plan with you. This Plan represents our next big step as a community toward a carbon-free, sustainable future.

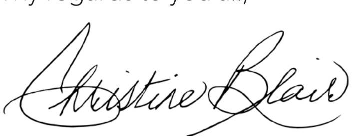
Decades of excessive energy consumption and burning fossil fuels have put our planet at a tipping point. Greenhouse gas emissions from fossil fuels, such as oil, gas, and coal, have gathered in the atmosphere, resulting in global warming – a phenomenon which is causing rapid changes to climates and weather patterns across the globe. In Nova Scotia, we are seeing more extreme and more frequent storms, increased contamination of fresh water from rising sea levels, more extreme rainfalls and flooding, higher average temperatures, and more. The effects of these changes include unpredictable agricultural growing seasons, expensive damage to infrastructure, advancement of invasive species into new territories, loss of biodiversity, and higher risk of heat stroke and heat exhaustion, especially to vulnerable populations, among other things.

There is no other way to put it: we are in a climate emergency. Our collective actions and decisions in the next few years will determine what our world looks like for our later years, our children, our grandchildren, and their grandchildren. The Mi'kmaq have a philosophy that all decisions must be assessed through a lens of seven generations; how will our actions today impact our descendants seven generations from now? It is time we all look ahead and decide what kind of future we want for our planet and our families.

Tackling climate change is a global effort, but our Municipality can make a difference and improve the well-being of our communities at the same time. While the primary goal of the Community Energy & Emissions Plan is to become more energy efficient and reduce our community's greenhouse gas emissions, it is designed to have many economic and social benefits for our community as well. These include, but are not limited to, cleaner air, job creation, reduced home energy costs, more comfortable homes, more money staying in the local economy, access to sustainable and affordable transportation options, and a more walkable and bikeable community.

Thank you to everyone in the community – community leaders, individuals, institutions, NGOs, businesses – who took time to sit on the Advisory Committee, attend engagement sessions, and participate in interviews. Your contributions to date are noticed and appreciated, and your ongoing commitment to Colchester's carbon-free future is essential as we begin to implement the Community Energy & Emissions Plan. This is a plan for everyone – for all of us, for our children, for our environment, for the future of the community we love – and we will need everyone's help to see it through.

My regards to you all,



Christine Blair, Mayor

Municipality of the County of Colchester

Letter from Colchester Students

Dear Mayor Blair,

We are a group of students from Colchester County. We are writing to you today to talk to you about the change we want to see in our community.

We would like to see strong local action on climate change.

To us, that looks like: seeing more parks and trails in our community to enjoy nature, more bikes and biking infrastructure instead of cars, electric cars and buses, more energy efficient homes and businesses, greater supply of renewable energy. We think transportation like buses should be free to help get people out of their cars. More trees planted will help sequester carbon dioxide in the future as well as make the community greener.

It is important to see support for local foods and businesses. Having community gardens for people to grow food is also what we would like in Colchester.

We want to keep our Earth safe and healthy for us and the generations that come after us. We want to use less fossil fuels to reduce the carbon pollution in the atmosphere.

Carbon-Free Colchester is an important opportunity to be ambitious. We want to see it implemented while we collaborate with other communities to learn from their climate action journeys, the way forward is through community action.

Signed,

Colchester Student Climate Group

Introduction

The Climate Emergency

Climate change is the greatest long-term global challenge that human society is facing. Human-induced climate change poses risks to health, economic growth, public safety, infrastructure, livelihoods, and the world's biodiversity and ecosystems. As local and global greenhouse gas (GHG) emissions increase, the Earth continues to warm at an unprecedented rate.

In December 2015, the Paris Agreement was adopted at COP21 by 196 countries. This legally binding international treaty on climate change set a goal to limit global warming to well below a 2°C, and preferably to a 1.5°C increase, above pre-industrial levels.[3] However, current global GHG emissions are not on a trajectory to meet these goals.

Despite a temporary decline in global emissions in 2020 due to the COVID-19 pandemic, the world is heading for 3°C or more of warming.[4] This degree of warming threatens human health, economic well-being, and the survival of the natural systems that humans and eight million other plant and animal species—already increasingly at risk—depend upon.[5]

The Municipality of the County of Colchester

The County of Colchester is located in the north central region of the province of Nova Scotia (total area of 3,628 square kilometres). The majority of the county is governed by the Municipality of the County of Colchester (total area of 3,572 square kilometres). The municipality's jurisdiction includes most of the county and the villages of Salmon River, Debert, Bible Hill, and Tatamagouche. However, it excludes the two towns of Stewiacke and Truro, because they are independently incorporated. Also excluded is the First Nations community of Millbrook.

In 2016, the County of Colchester had a total population of 50,585 according to the Census of that year. Of this total, the Municipality of the County of Colchester ("Colchester") had 36,091 inhabitants. Colchester's population is expected to grow slowly over the next 30 years.

3 United Nations Framework Convention on Climate Change. (2015) The Paris Agreement. Retrieved from: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

4 New UNEP Synthesis Provides Blueprint to Urgentaly Solve Planetary Emergencies and Secure Humanity's Future. 18 Feb. 2021. https://unfccc.int/news/new-unep-synthesis-provides-blueprint-to-urgently-solve-planetary-emergencies-and-secure-humanity-s

5 Ibid.

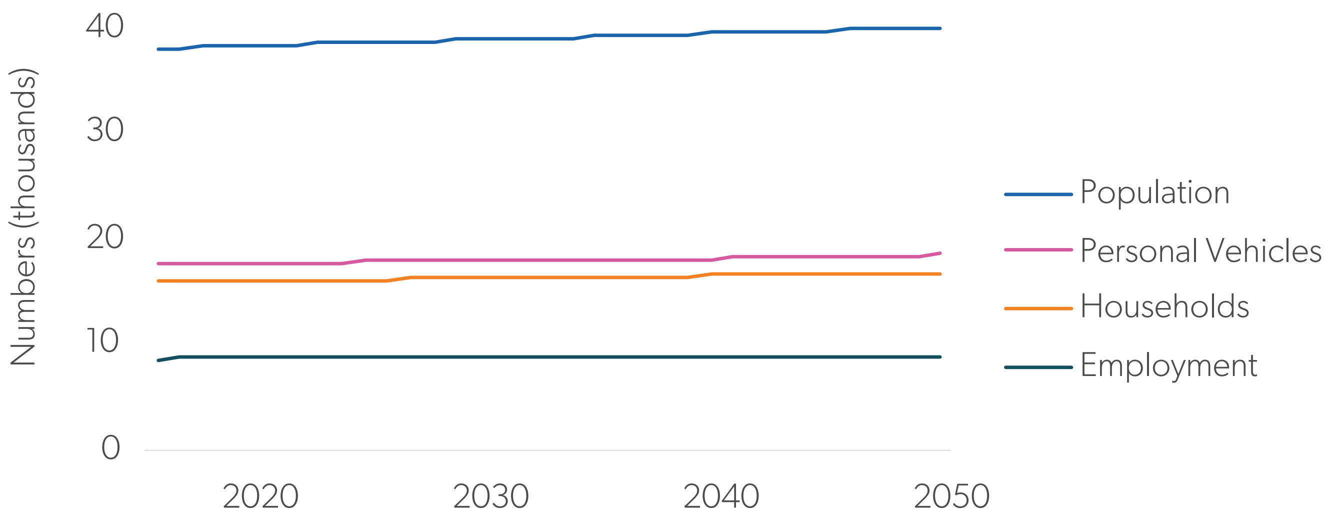
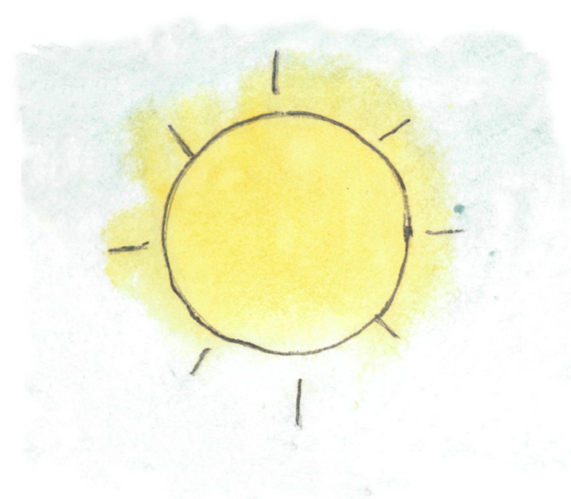


Figure 1. Population, personal vehicles, number of households, and employment (in full-time equivalent person-years) from 2016-2050.

Colchester is Heating Up

Due to climate change, Colchester has started to experience an increase in average temperatures, with wetter springs and winters, much warmer summers, and a longer growing season. These changes will increase in severity over the coming years and decades. Accompanying these changes will be more extreme weather, including more intense rain and snowfall events, flash floods, high winds, and stronger hurricanes. Sea level rise will threaten low-lying coastal areas, and storm surges will accompany storm events, increasing flooding, coastal erosion, and freshwater pollution from saltwater intrusion. This analysis has not undertaken a systematic assessment of the impacts of climate change on Colchester.

The number of heating degree days (HDDs) in a year is an indicator of the demand for thermal conditioning of buildings,[6] which directly influences energy consumption and therefore GHG emissions. The County's HDDs have been on the decline and are projected to decrease because of climate change (Figure 2). Conversely, the number of cooling degree days (CDD) is projected to rise from the present through to 2050,[7] increasing cooling demand in buildings. This will be particularly impactful for the occupants of buildings that are already prone to overheating.



[6] A heating degree day (HDD) is a measurement designed to quantify the demand for energy needed to heat a building. It is the number of degrees that a day's average temperature is below 18 °C, which is the temperature below which buildings need to be heated.

[7] A cooling degree day (CDD) is a measurement designed to quantify the demand for energy needed to cool buildings. It is the number of degrees that a day's average temperature is above 18 °C, which is the temperature above which buildings need to be cooled.

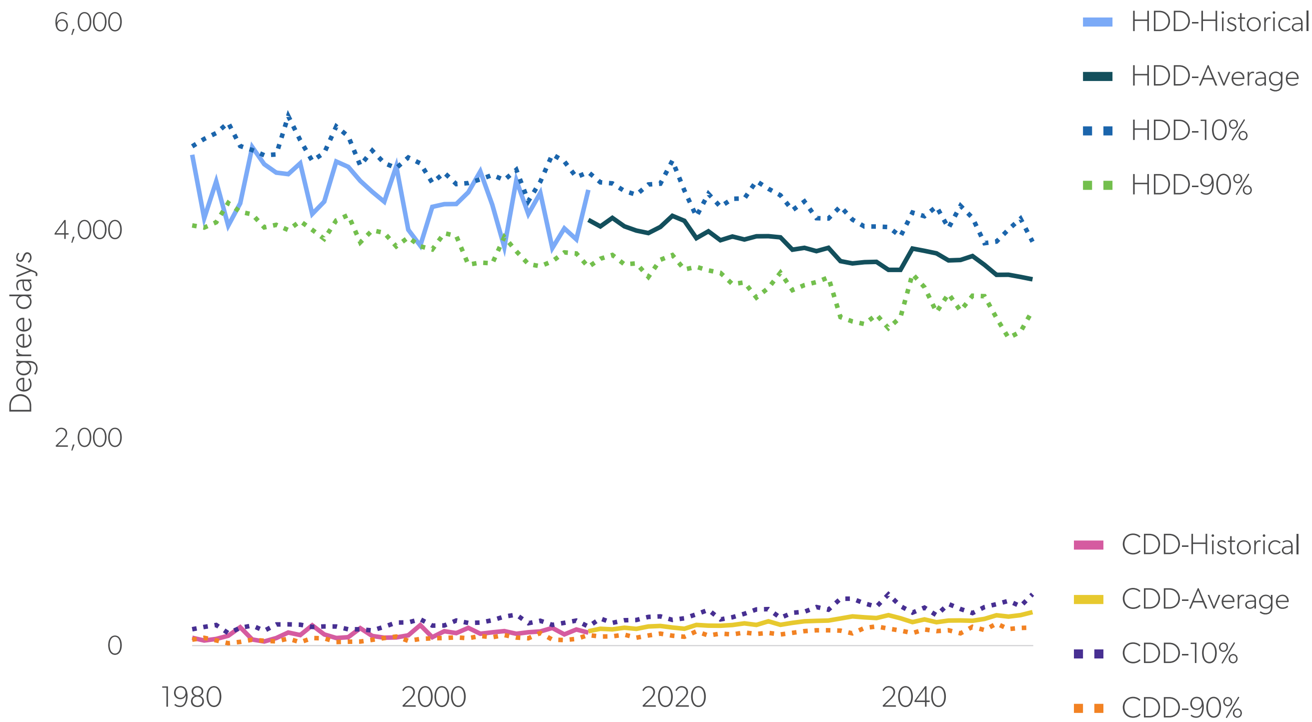


Figure 2. Projected Heating Degree Days and Cooling Degree Days for Truro, projected out to 2050 (IPCC AR5 RCP 8.5).[8] *Historical data are shown until 2013. The projection is an average of the results of several models. 10% and 90% percentiles of the results from these simulations are also included.*

An overall increase in total precipitation and an increasing severity of storms are predicted for the region. Precipitation is anticipated to increase from an annual 1,185.5 mm (2013) to 1,294 mm by 2050 (IPCC AR5 RCP 8.5).[9] Heavy precipitation days are also predicted to increase to an average of 15 days by 2050, compared to 12 days in 2013.[10] Mean annual temperature is projected to increase by almost 3 degrees Celsius (∘C) by 2050. The growing season is expected to become longer, however, extremely hot days (greater than 30°C) are also expected to increase in number from 5 (2013) to 16 days by 2050, so crops will experience more frequent heat stress conditions.

Seizing the Challenge—and the Opportunity

In response to climate change, Colchester has initiated Carbon-Free Colchester, a community energy and emissions plan to transition the municipality to renewable energy and to reduce Colchester's GHG emissions. Carbon-Free Colchester builds upon previous work by the municipality, including the Sustainable Colchester 2029 plan. Carbon-Free Colchester outlines the measures the Municipality, businesses, and residents need to take to achieve deep emissions reductions. The plan also explores how these measures can be funded, their economic benefits, and the governance structure and policies required for success.

[8] Climate Atlas of Canada, 2020. Truro Municipality. Heating Degree Days and Cooling Degree Days. Accessed September 2020: https://climateatlas.ca/data/city/265/hdd_2030_85/line ; https://climateatlas.ca/data/city/265/cooldd_2030_85/line

[9] Climate Atlas of Canada, 2020. Truro Municipality. Annual Precipitation (RCP 8.5). Accessed September 2020: https://climateatlas.ca/data/city/265/annual_precip_2030_85/line

[10] Climate Atlas of Canada, 2020. Truro Municipality. Heavy precipitation days (20 mm). Accessed September 2020: https://climateatlas.ca/data/city/265/precip20_2030_85/line

Colchester has established a climate target of producing net-zero emissions by 2050. To meet this target, Colchester will expand its existing programs to reduce emissions and conserve energy, develop new policies and programs, and invest in new infrastructure.

Mitigating GHG emissions on this scale is an economic and social challenge but it is also an opportunity for economic growth, for diversification of businesses and resources, and for establishing the region as a leader in climate change mitigation. Investment in actions to reduce GHGs across Colchester will save the community millions of dollars over time.

Net zero emissions is an opportunity—for economic growth, for diversification of businesses and resources, and for establishing the region as a leader in climate change management.

Net-zero Emissions by 2050

Colchester has set a target of producing net-zero GHG emissions by 2050. Net-zero means that the region either releases no GHGs or offsets the emissions it does release.[11] Colchester carried out a robust modelling exercise to investigate how the municipality uses energy and produces emissions today and into the future. The exercise also guided the development of a pathway to net-zero. This process involved developing a Business-as-Planned scenario of energy use and emissions production from 2016-2050, and then modelling a series of actions aimed at improving energy efficiency, reducing reliance on fossil fuels, and reducing overall GHG emissions across the region ("emissions-reduction pathway"). This second scenario, called the Low-Carbon Scenario (LCS), shows what the future could look like if Colchester were to carry out these actions. The modelling process is described in greater detail in Appendix A.

Partnerships are necessary to enable the Municipality to achieve its target of net-zero emissions by 2050.

Partnerships mobilise diverse skills, expertise, and capacity to implement Carbon-Free Colchester. They can also improve inclusion and social equity, by ensuring all members of the community have the opportunity to participate in the implementation of the Plan.

Funding, resources, and enabling policies from higher levels of government will also be critical to achieving Carbon-Free Colchester's targets. As a result, the Municipality will coordinate outreach and liaison with diverse partners.

[11] Canada has joined more than 120 countries in a pledge to move to a net-zero economy. For more information, see Canada's Climate Plan

The Voice of the Community

This Plan is influenced by:

- input from the Carbon-Free Colchester Stakeholder Advisory Committee;
- input from municipal staff and councillors;
- discussions with members of the community and business-owners;
- research on best practices; and
- the consulting team's experience working with other communities across Canada on similar projects.

Informed by this input, this Plan is designed to stream-line the implementation of the GHG reduction measures identified in this document, and to maximize co-benefits, including economic development, reduced energy poverty, and improved health and quality of life outcomes.

This Plan includes some key Municipality-led initiatives, but the majority of Carbon-Free Colchester's implementation will require resources and leadership from various actors in the community, including utilities, industry, businesses, and institutions (e.g., colleges and universities). Partnerships are critical to achieving the target of net-zero emissions by 2050.

Community members and representatives were interviewed about Carbon-Free Colchester. Their feedback revealed key concerns:

ENERGY POVERTY

Energy poverty—defined as when a household spends more than 6% of its total income on energy—affects more than 20% of Atlantic Canadian households.[12] Individuals experiencing energy poverty are often forced to compromise on food, medicines, and other essentials to pay for heat and transportation.

ACCESSIBLE TRANSIT/TRANSPORTATION FOR ALL

Colchester is a large, rural municipality, and for those community members without access to private vehicles, the lack of accessible, affordable transit is a major barrier for travel throughout the municipality and beyond.

CLEAR AND OPEN COMMUNICATION

Colchester is a community in which people have deep connections with each other and to adjacent communities including Truro and Millbrook. These relationships are based on trust and shared experiences and are fundamental to the character of the region. Any successful project or plan within the County as a whole will need to be based on clear and open communication with all members of the community, and allow for equal participation and feedback to establish new lines of trust.

[12] Canadian Urban Sustainability Practitioners, 2021. Energy Pover. Accessed: https://energypoverty.ca/#s2.

SOCIAL EQUITY

Climate change affects all of Colchester, but it doesn't impact everyone in the community equally. Vulnerable people[13] need to be prioritized in the implementation of Carbon-Free Colchester. This can take many forms, but can include prioritizing affordable housing units, or the homes of those on fixed incomes for building retrofit assistance programs, and evaluating the equity co-benefits of programs as well as their climate impacts.

The Toll of Energy Poverty

Households facing energy poverty or energy insecurity face difficult choices such as "pay the rent or feed the kids", "heat or eat", or "cool or eat".[14] In particular, energy insecurity disempowers low-income residents such as single parents, the elderly, persons with disabilities, and others with low or fixed incomes.[15] Energy insecurity leads to stresses such as utility-related debt, shutoffs, inefficient heating systems, antiquated appliances, and extreme home temperatures with significant health impacts.[16] Children may experience nutritional deficiencies, higher risks of burns from non-conventional heating sources, higher risks for cognitive and developmental behaviour deficiencies, and increased incidences of carbon monoxide poisoning.[17] Subsequent impacts include parents being unable to work in order to look after children, missed school days, and lost productivity.

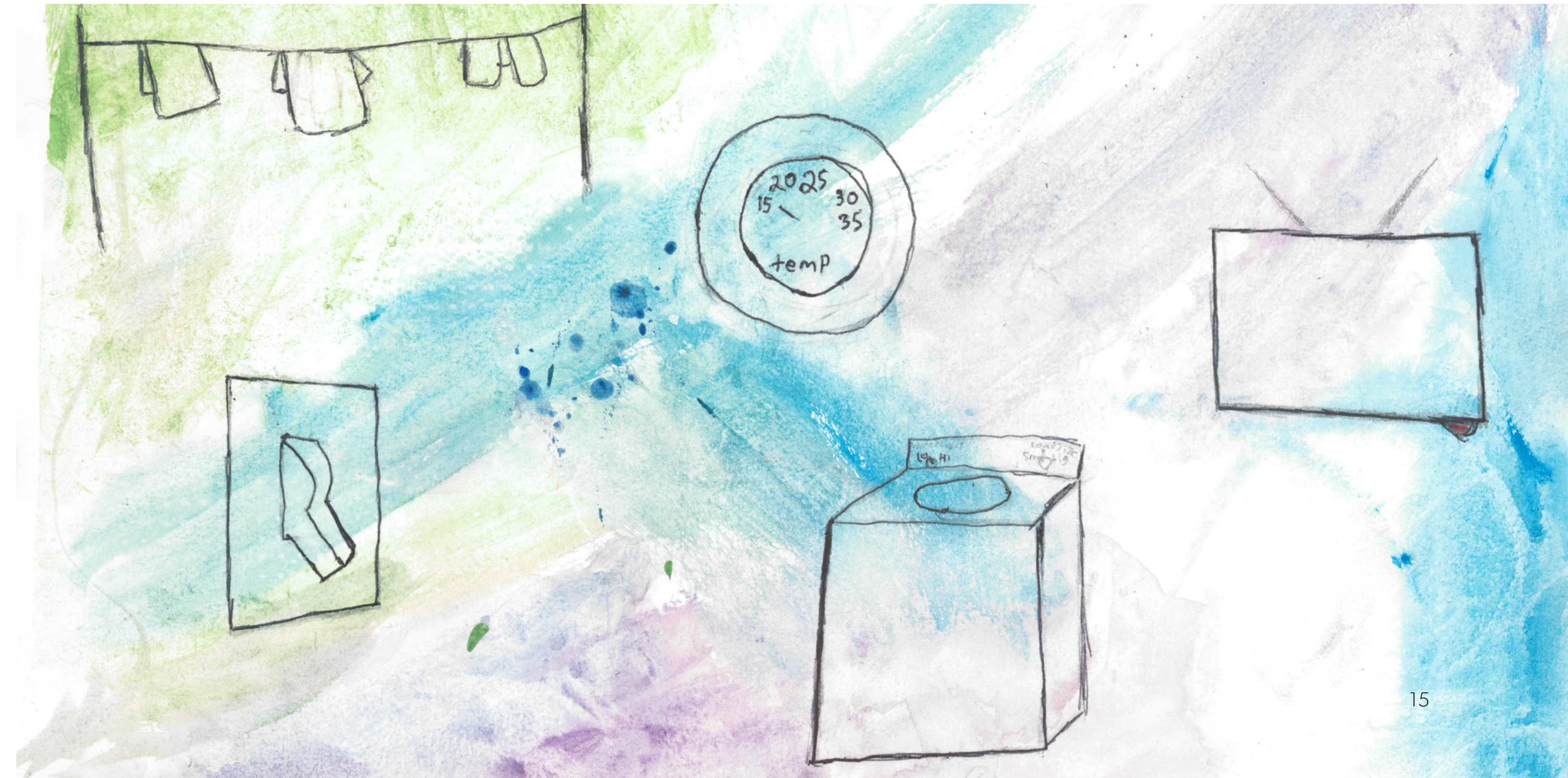
[13] Populations of people more vulnerable to climate change include children, seniors, people with fixed incomes or experiencing poverty, people experiencing homelessness, disabled people, and people who are chronically ill.

[14] Cook, J. T., Frank, D. A., Casey, P. H., Rose-Jacobs, R., Black, M. M., Chilton, M., ... Cutts, D. B. (2008). A brief indicator of household energy security: Associations with food security, child health, and child development in US infants and toddlers. PEDIATRICS, 122(4), e867–e875. https://doi.org/10.1542/peds.2008-0286

[15] Hernández, D. (2013). Energy insecurity: A framework for understanding energy, the built environment, and health among vulnerable populations in the context of climate change. American Journal of Public Health, 103(4), e32–e34. https://doi.org/10.2105/AJPH.2012.301179

[16] Hernández, D., & Bird, S. (2010). Energy burden and the need for integrated low-income housing and energy policy. Poverty & Public Policy, 2(4), 5–25. https://doi.org/10.2202/1944-2858.1095

[17] Ibid.



Colchester's Current Reality: Energy and Emissions in Major Sectors

Current Energy Use and Emissions in Colchester

In Colchester, residents, businesses, and the Municipality use energy to keep the lights on and the engines running. In turn, these energy sources release greenhouse gas emissions into the atmosphere.

In 2016, Colchester's total GHG emissions were 812,000 tCO_2e. That's an average of 21 tCO_2e/person. To provide context, 21 tCO_2e is equivalent to using nearly 9,000 litres of gasoline, or the amount needed to power a vehicle for 7 years (based on the average person's use in Nova Scotia).[18]

Within the region of Colchester, one major industrial entity, the Lafarge cement plant located in Brookfield, produces the largest share of the emissions. The cement plant is responsible for 95% of the industrial emissions shown in Figure 3. The next largest emitter is transportation, but instead of the emissions coming from a centralized source, the emissions come from all of the cars, trucks, boats, and off-road vehicles within Colchester.

Colchester relies on Nova Scotia's electrical grid for 94% of its electrical energy, and 18% of its total energy. As of 2021, the Nova Scotia provincial electricity grid generates around 60% of its electricity through the combustion of fossil fuels, including coal, natural gas, and fuel oil. The Province and the electrical utility (Nova Scotia Power Inc.) are making changes to reduce the emissions associated with electricity generation. They are purchasing electricity generated at the Muskrat Falls hydroelectric power station in Labrador and increasing the amount of local renewable energy that feeds directly into the grid.

Within the region of Colchester, one major industrial entity, the Lafarge cement plant located in Brookfield, produces the largest share of GHG emissions.

[18] Equivalency from the US EPA Greenhouse Gas Equivalencies Calculator. https://www.epa.gov/energy/greenhouse-gas-equivalenciescalculator

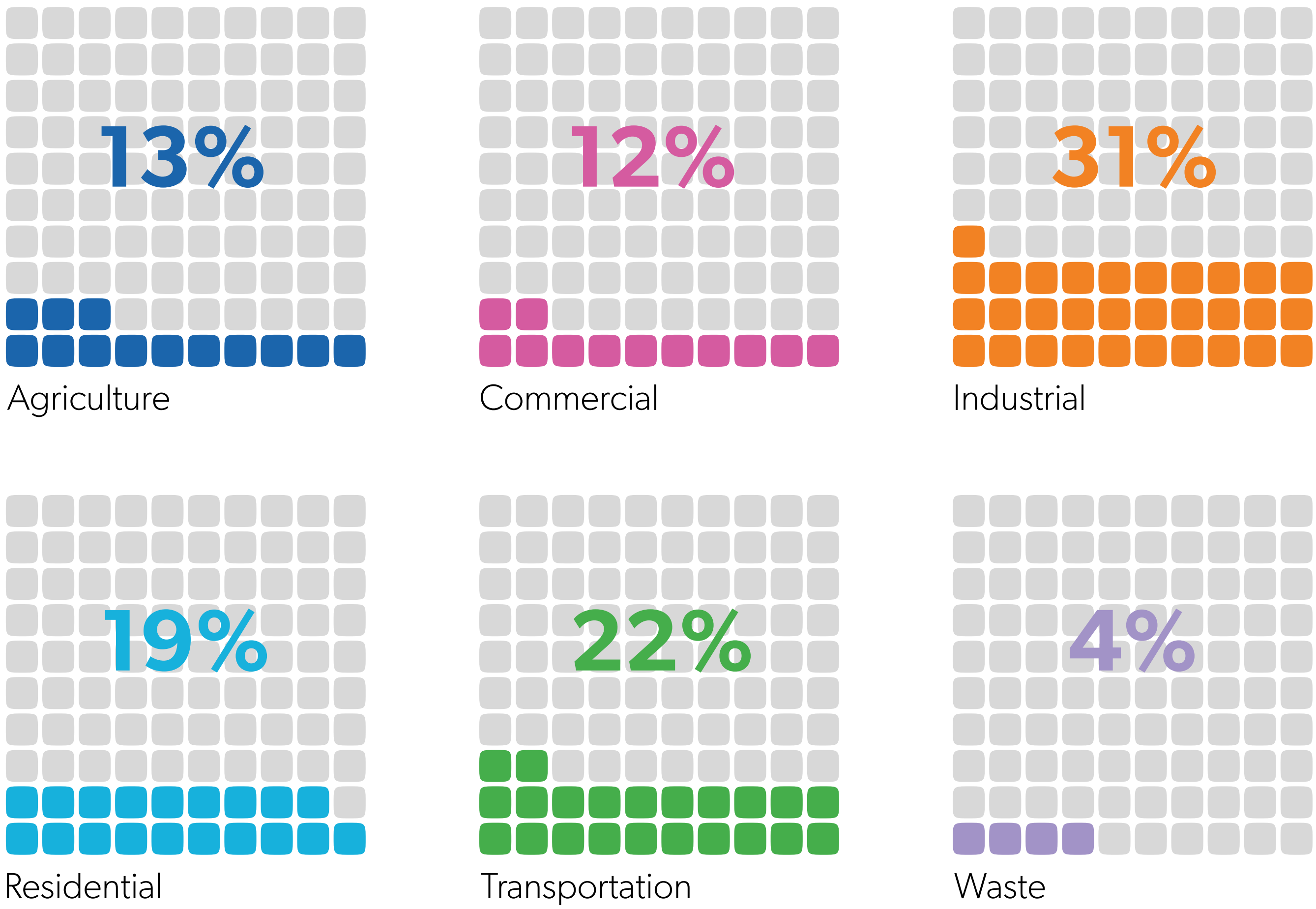
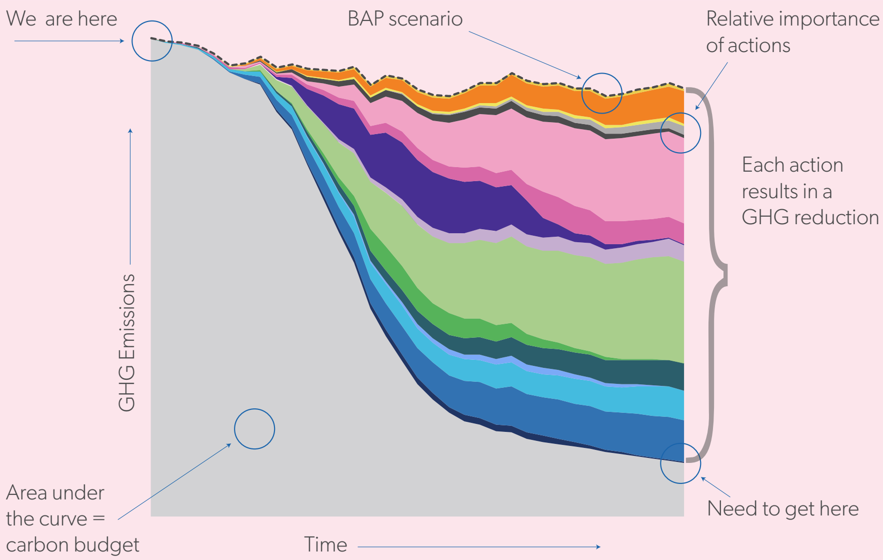


Figure 3. Community GHG emissions in Colchester, 2016.

Colchester's possible emissions futures

To project the future of GHG emissions in Colchester, a calibrated base year was developed that represents current activities across multiple sectors, including transportation, buildings, energy, agriculture, and land use. This scenario uses 2016 as its base year because demographic information derived from the Statistics Canada Census forms the basis of the model of people and their activities within Colchester. The most recent Census is from 2016. These activities were then combined with expected population growth and modelled until 2050 to develop a scenario that illustrates the GHG emissions in Colchester if the Municipality takes no action on climate change. This scenario is called the Business-as-Planned (BAP) scenario. Then low-carbon actions were modelled in a second future scenario—the Low-Carbon Scenario (LCS)—to identify a pathway to reach Colchester's net-zero emissions target.



Business-as-Planned leads to a 24% decline in emissions by 2050

Under a Business-as-Planned (BAP) scenario, GHG emissions in Colchester actually decline by 24% by 2050. This decline is a result of anticipated changes that are largely outside Colchester's control. The electrical utility plans to reduce the electricity grid's reliance on fossil fuels. The warming climate will reduce the need for space heating in buildings, and while this is accompanied by a small increase in space cooling needs, the overall trend is a reduction in total energy consumption. Car companies are expected to increase the efficiency of combustion engine vehicles, which, when combined with a small amount of vehicle electrification, will result in a 21% decrease in emissions associated with transportation.

While this 24% decrease in total emissions is important to note, Colchester's targetnet-zero across all sectors by 2050.

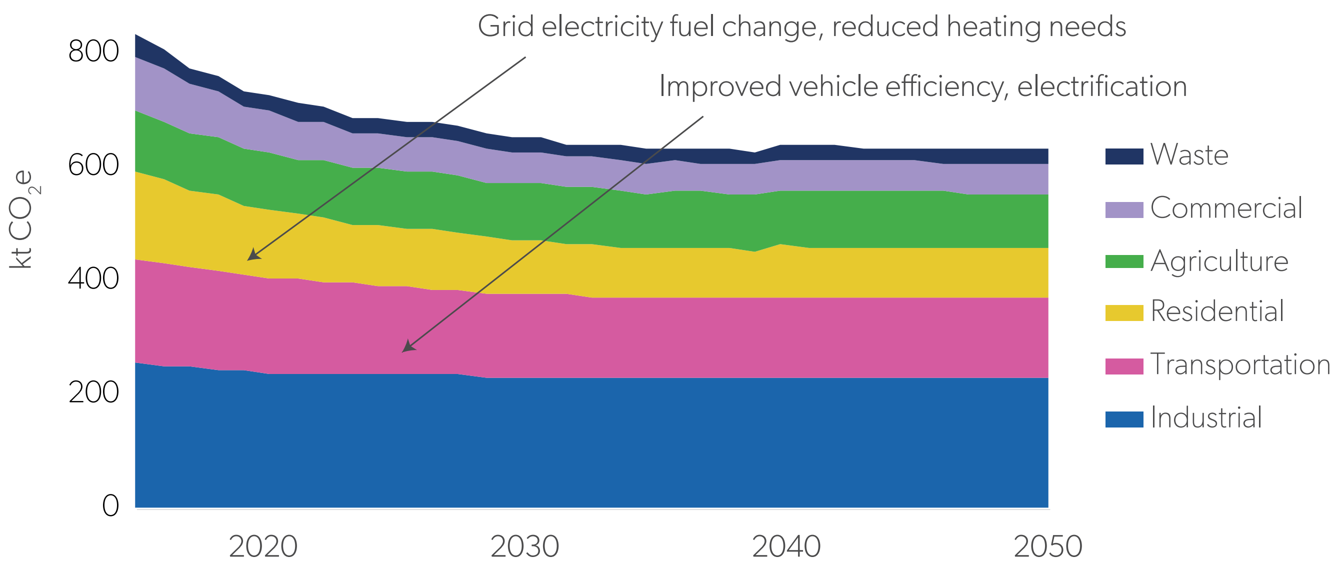


Figure 4. GHG emissions by sector, 2016-2050.

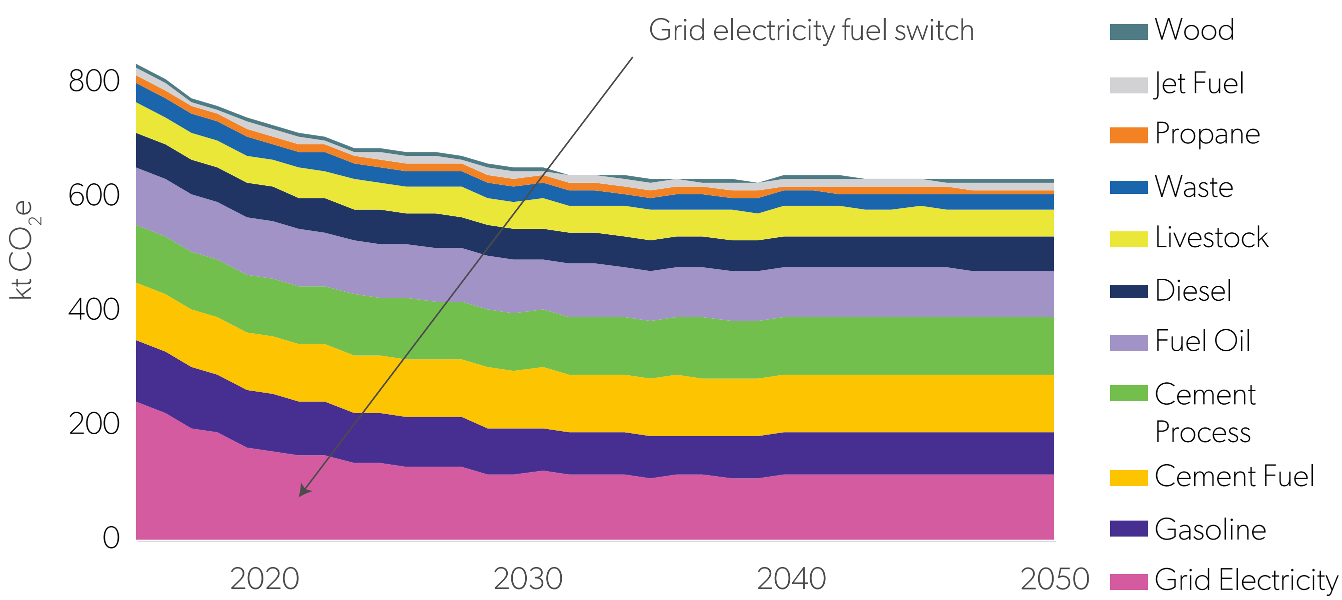


Figure 5. GHG emissions by fuel type, 2016-2050

Building Colchester's Low-Carbon Future

The project team identified a series of actions to help Colchester meet its emissions target of net zero by 2050. These actions were identified through a combination of best practice research, industry plans and innovation expectations, and consultation with the municipality, members of the Stakeholder Advisory Committee, and members of the public.

These actions were then modelled in sequence to 2050 to maximise their potential benefits to energy efficiency, emissions reductions, and community co-benefits. The model results create the Low-Carbon Scenario, or LCS, and paint a picture of what Colchester's energy consumption and GHG emissions could look like in 30 years.

Efficiency First

The underlying approach to the LCS is to order the actions according to a priority of 'Reduce, Improve, Switch': reducing energy consumption is the first step, then maximizing energy efficiency improvements, and finally switching to low-carbon energy sources for the remaining demand. Each kWh of electricity which is saved through efficiency is a kWh that need not be generated. In an electrified future, each trip shifted from gasoline vehicle to transit or walking constitutes an efficiency gain, which reduces the burden on the landscape to provide energy. Efficiency gains therefore have land benefits.

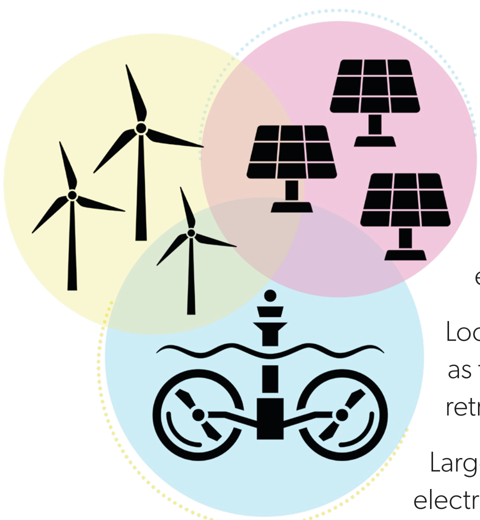
The Big Moves

Buildings:

The majority of buildings, including homes, commercial buildings, municipal buildings, and industrial buildings, must be retrofitted to dramatically improve energy efficiency.

New buildings will be built to net-zero standards, meaning they will be highly efficient, and generate electricity on-site.

All buildings, whether new or existing, will convert from fossil fuels to electricity for heating, cooling, and water heating.



Transportation:

All vehicles will be electric, with municipal vehicles leading the way. Walking and biking will be encouraged by building more trails and bike lanes, and regional transit options will be expanded.

Local renewable energy: Solar panels are installed on new buildings as they are constructed, and on existing buildings as they are retrofitted.

Large-scale solar and wind generation provides much of the electricity for Colchester, and any remaining electricity is purchased from renewable sources outside of the municipality.

Water and waste:

Overall waste generation is reduced, and waste diversion to composting and recycling facilities is improved. Water consumption is reduced with efficiency measures. Renewable natural gas is captured from waste sources, and used to replace fossil fuels.

Industry:

Carbon capture is implemented at the cement plant, and fuel switching to electricity is used to remove fossil fuels where possible.

Table 1 describes these actions in more detail, and Figure 6 illustrates the emissions reductions associated with each of the modelled actions from 2020 to 2050. The actions are described in even greater detail in Appendix A.

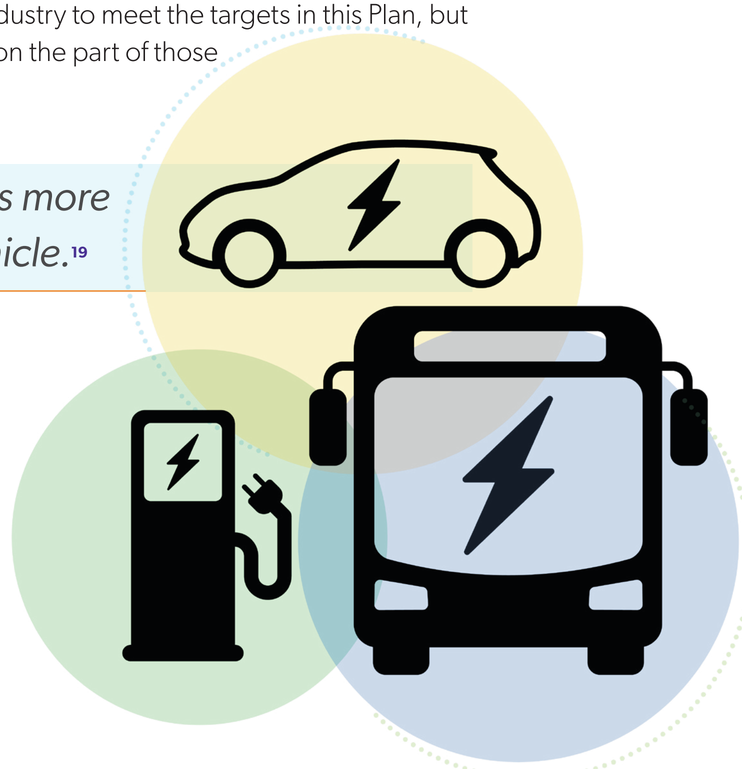
Implementation of the actions would result in a **52% reduction in annual energy consumption across the community, and a 92% reduction in GHG emissions by 2050**. Key pieces of the LCS include working with the Lafarge cement plant to implement carbon capture, switching away from fossil fuels, and improving efficiencies, as well as electrifying transportation, retrofitting houses and buildings, and removing fossil fuels from all sectors.

The remaining emissions are primarily from agricultural sources, and are challenging to remove entirely from the system. In the LCS, there are still some gas-powered cars on the road that have not yet been retired. Marine marine transportation still relies on fossil fuels, although this may change with technological advances in marine transportation.

The actions in Table 1 are summarized by sector, and represent what was modelled in the LCS. It is important to note that these modelled targets do not always align with the actions in the implementation strategy, below. Modelled actions show the potential changes that can be achieved by meeting set goals. In order to meet those goals, we need to develop programs, policies and initiatives. These programs, policies and initiatives require behaviour change, careful planning, and cross-municipal coordination. The implementatable actions are summarized to facilitate the development and deployment of logical and efficient programs, policies and initiatives, and include modelled targets from multiple sectors, and also non-modelled actions.

Additionally, Colchester does not have direct influence over each sector that produces emissions in the region. The implementation section of the report outlines ways the Municipality can facilitate and encourage sectors like rail, aviation, and industry to meet the targets in this Plan, but ultimately meeting these targets will also require action on the part of those sectors.

An electric vehicle is more than 6 times more efficient than a gasoline-powered vehicle.[19]



[19] EVs convert over 77% of the electrical energy from the grid to power at the wheels. Conventional gasoline vehicles only convert about 12%–30% of the energy stored in gasoline to power at the wheels. US Department of Energy. All-Electric Vehicles. Retrieved from: https://www.fueleconomy.gov/feg/evtech.shtml.

Table 1. Low-Carbon Scenario Actions Summary

SECTOR	LOW CARBON TARGET	GHG REDUCTION ($KTCO_2E$) RELATIVE TO 2050 BAP	CONTRIBUTION TO TOTAL EMISSIONS REDUCTIONS[20]
LAND-USE	• 80% of new residential development is in the development zones; • 100% of non-residential development is in the development zones	3	1%
BUILDINGS	• 100% of new buildings are net-zero by 2030. • 80% of existing buildings have deep energy retrofits by 2040. • Most new homes are duplexes, townhouses, or apartments. • 100% of all municipal buildings are retrofitted to net-zero standard by 2035. • 100% of buildings use electric heat pumps by 2040. • 100% of water heating needs are electric by 2040.	108	24%
ZERO-EMISSION ENERGY	• 90% of new buildings and all existing buildings have solar PV installed by 2050 • 10 MW of ground-mount PV is installed by 2045 • 2MW/year of wind generation is added • Biomass district energy systems are installed in denser areas • Any remaining electricity needs are met by purchased green electricity by 2050	119	23%

[20] Relative to the 2050 BAP scenario emissions.

SECTOR	LOW CARBON TARGET	GHG REDUCTION ($KTCO_2E$) RELATIVE TO 2050 BAP	CONTRIBUTION TO TOTAL EMISSIONS REDUCTIONS[20]
ZERO-EMISSION TRAVEL	• 100% of on-road vehicles are electric or zero emissions by 2040 • Municipal vehicles, included buses, are electric by 2035 • 70% of off-road vehicles are electric by 2040 • Transit is expanded • E-bike and car sharing programs are developed in hubs • Walking and biking infrastructure is expanded • Airplanes are net-zero by 2050 • Trains convert to hydrogen by 2040 • Boats are converted to 50% electric	80	14%
WATER AND WASTE	• Water use decreases every year • 100% of waste is diverted to recycling and anaerobic digestion by 2050 • Per capita waste generation is reduced by 30% by 2050 • Anaerobic digestion of wastewater and organic waste and biogas capture from landfills is installed to produce renewable natural gas (RNG)	12	2%
OTHER	• Livestock emissions are reduced through livestock management changes • All agricultural equipment is converted to electric by 2050 • Industrial process improvements are implemented	33	7%
INDUSTRY	• Carbon is captured at the cement plant • Fuel switching is implemented to eliminate the use of fossil fuels	194	30%

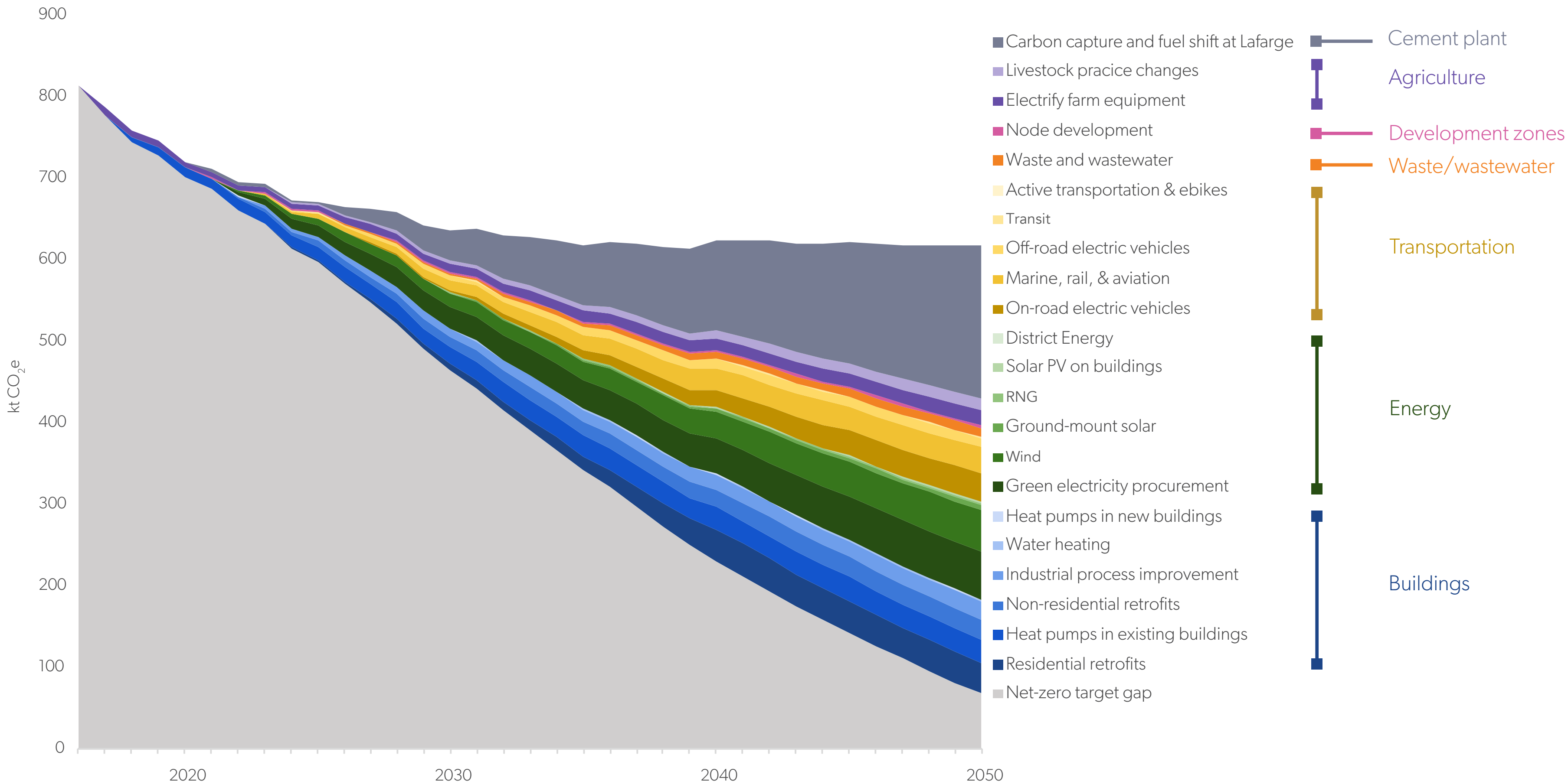


Figure 6. Emissions reductions by action within the low-carbon scenario for Colchester, 2020-2050

Emissions Reduction by Action

In the LCS, Colchester reduces its energy consumption by 52% compared to the baseline year of 2016, and reduces GHG emissions by approximately 92%. It is important to acknowledge that each action is interlinked with other actions. As illustrated in Figures 7 and 8, each action can only reach its full emissions reduction potential if all other actions are also carried out. The figures also show that changes to the cement industry will be essential, and that electric vehicles, residential and non-residential retrofits will drive the GHG reductions in the LCS.

Declining Energy Use in Colchester's Low-Carbon Future

Community energy use declines in all sectors in the Low-Carbon Scenario. Transportation and commercial sectors show the largest relative decreases. Energy savings come from a number of places, including reduced energy demand for space heating with building retrofits and the use of efficient heat pumps, and the conversion from gas-powered to electric vehicles.

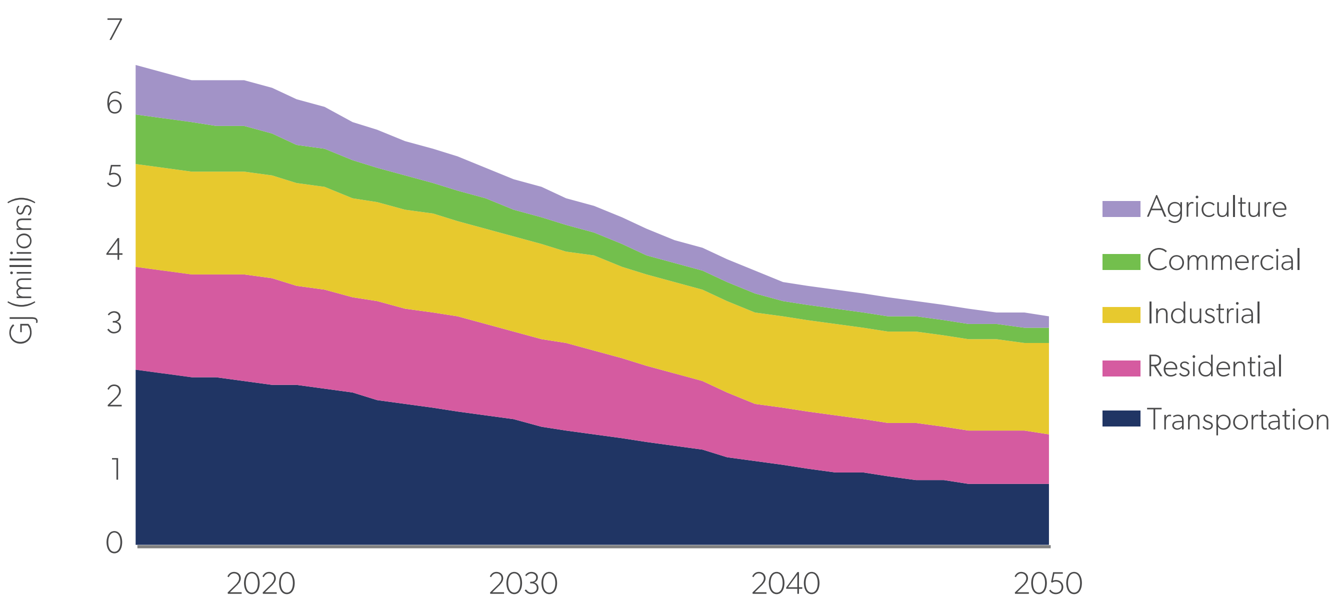


Figure 7. LCS community energy use by sector.

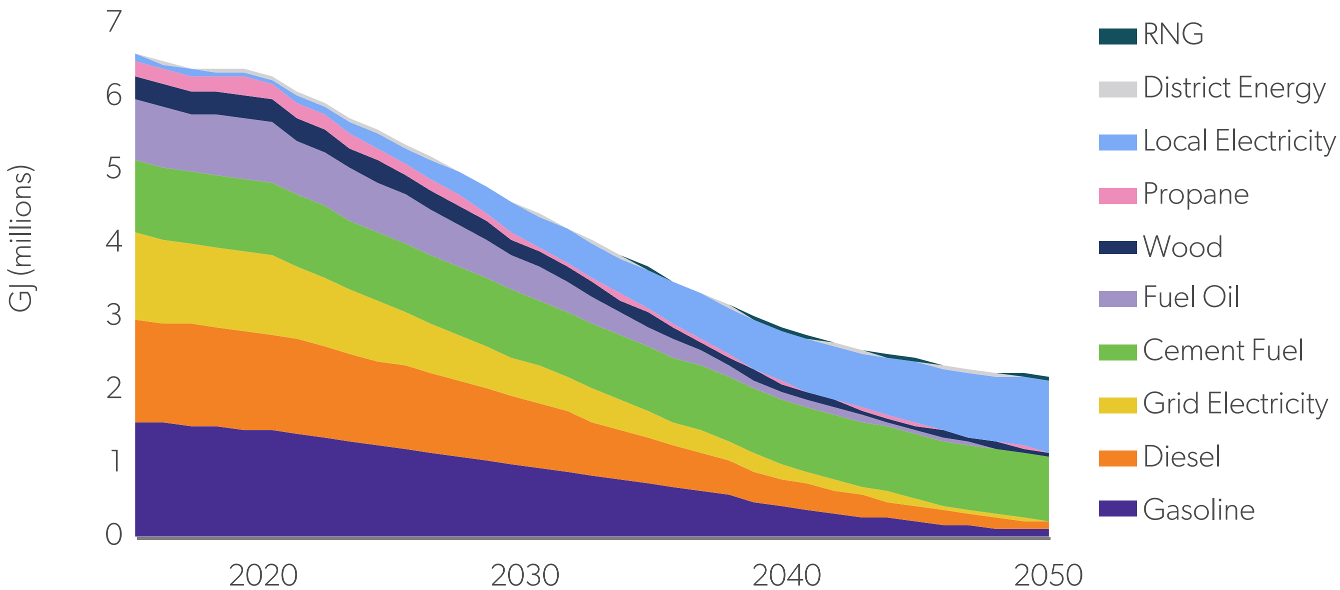


Figure 8. LCS community energy use by fuel.

Local electricity generation, through solar and wind, meets 30% of the total energy demand in 2050. Energy used in the cement industry comprises 28% of the total energy demand in 2050, some of which would be renewable electricity.

By 2050, almost all fossil fuels have been removed from the community, with some residual fuel oil and diesel being used for space heating and transportation that hasn't yet reached the end of its functional life to be replaced with a more efficient system.

Electricity not coming from local renewable sources is being replaced by renewable energy purchased from sources outside of Colchester.

Decreased Emissions in Colchester's Low-Carbon Future

GHG emissions across Colchester decrease a dramatic 92% by 2050 under the LCS. This is driven by the switch from fossil fuels to local electricity, improved efficiencies, and replacing residual grid electricity with purchased renewable electricity.

The remaining emissions in 2050 are from livestock, residual fuel oil and diesel use, and decomposing organic matter in landfills.

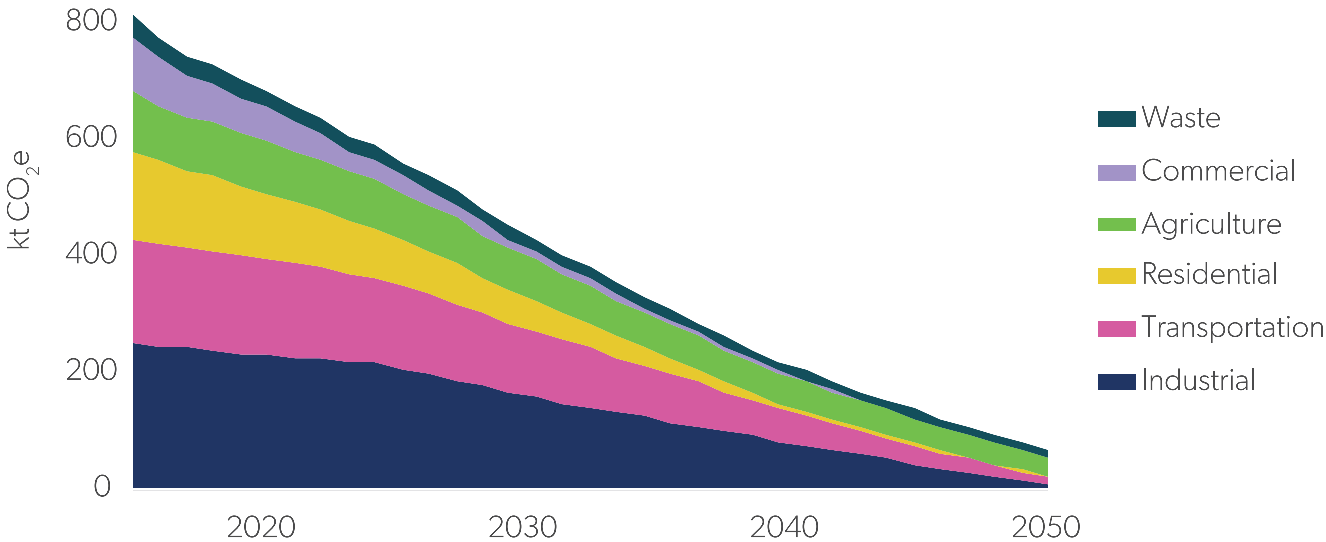


Figure 9. Community GHG emissions by sector in the LCS.

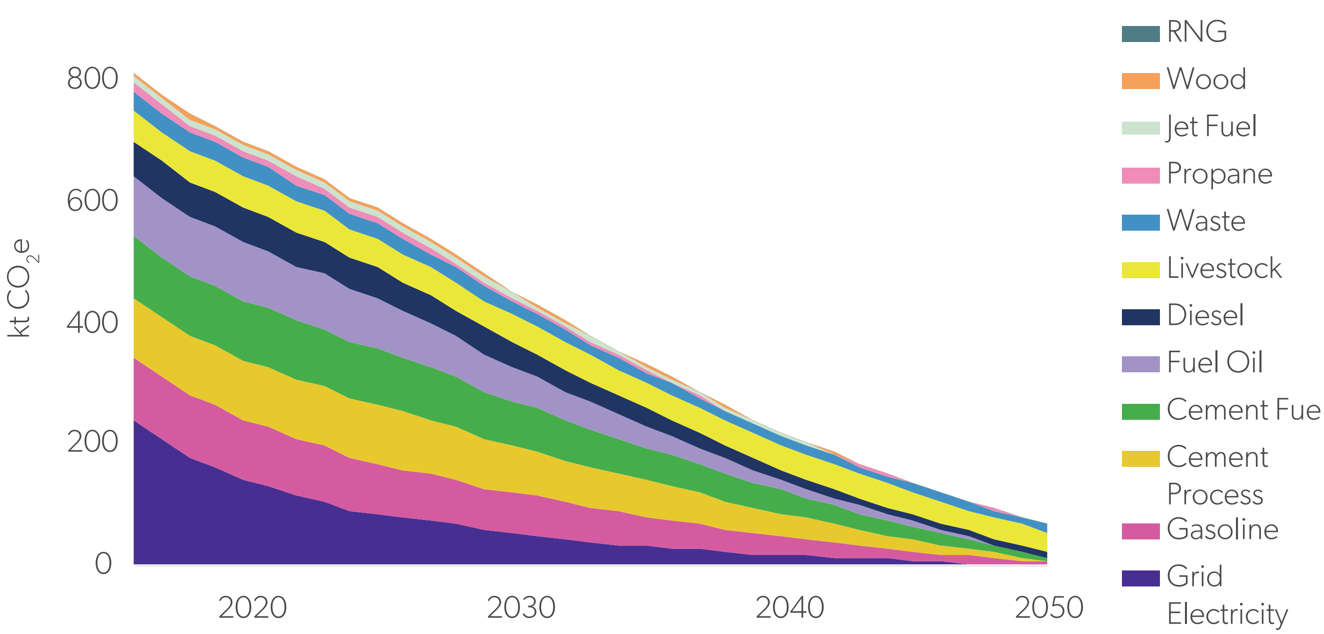


Figure 10. Community GHG emissions by source in the LCS.

The goal of Carbon-Free Colchester is to reach net-zero emissions by 2050. Although the activities in this plan result in a 92% reduction in emissions, some residual emissions remain. These are primarily from livestock and limited fossil fuels used in agriculture and transportation. This carbon gap will need to be addressed in future iterations of this work, with new technologies and shifts in behaviour making net-zero possible.

The difference between the reduction in energy use (52%) and in GHG emissions (92%) is a result of switching to lower-emissions fuels for all activities. Energy will still be required for space heating, transportation, and other activities, but by switching to electricity and clean fuels, Colchester will significantly reduce its GHG emissions.

The Economic Opportunities

The transition to a low-carbon economy requires investment from residents, businesses, the Municipality, and all levels of government.

The direct financial impacts of Carbon-Free Colchester provide important context for local decision-makers. However, it is important to note that the direct financial impacts are a secondary motivation for undertaking actions that reduce greenhouse gas emissions. First and foremost, GHG reductions are a critical response to the global climate emergency. In addition, most measures included in Carbon-Free Colchester provide social goods to the community, such as net job creation and positive health outcomes, which are only marginally captured in this financial analysis.

A Quick Guide to Key Financial Concepts

The following are key concepts that are used to analyze the financial impacts of Carbon-Free Colchester.

COSTS ARE RELATIVE TO THE BUSINESS-AS-PLANNED SCENARIO

This financial analysis tracks projected costs and savings associated with low-carbon measures that are above and beyond the assumed 'business-as-planned' costs.

DISCOUNT RATE

The discount rate represents the idea that money today is valued more than money in the future. It's kind of like how a car depreciates in value over time. A project is considered financially beneficial by an investor if it generates a real rate of return equal to or greater than its discount rate.

The discount rate varies with the type of project, the duration of the investment, the risk involved, and the availability of capital. The social discount rate is the discount rate applied when assessing the value to society of investments made for the common good. It is inherently uncertain and difficult to determine. Some argue that a very low or even zero discount rate should be applied in the evaluation of climate change mitigation investments— that is to say we should not be discounting the future. In this project, we evaluate investments in a low-carbon future with a 3% discount rate, which is low for business, but appropriate for community benefits.

NET PRESENT VALUE

The net present value (NPV) of an investment is the difference between the present value of the capital investment and the present value of the future stream of savings and revenue generated by the investment. Present value means that future dollars are discounted back to the current day. For example the present value of an investment in year 1 and year 2 of $100 each would be $100+ $97= $197.

Five aggregate categories are used to track the financial performance of the low-carbon actions in this analysis: capital expenditures, energy savings (or additional costs), carbon cost savings (assuming the carbon price reaches $170/tonne CO_2e in 2030 and is held constant thereafter), operation and maintenance savings, and revenue generation (associated with renewable energy production facilities and some transit actions). Administrative costs associated with implementing programs, as well as any energy system infrastructure upgrades that may be required are excluded. Similarly, the broader social costs that are avoided from mitigating climate change are not included in this financial analysis.

ABATEMENT COST

The abatement cost of an action is the estimated cost for that action to reduce one tonne of GHG emissions, which is calculated by dividing the action's NPV by the total GHG emissions reductions (tCO_2e) resulting from the action. For example, if a project has an NPV of $1,000 and generates 10 tCO_2e of savings, its abatement cost is $100 per tCO_2e reduced.

AMORTIZATION

The costs of major capital investments are typically spread over a period of time (e.g. a mortgage on a house commonly has a 25-year mortgage period). Amortization refers to the process of paying off capital expenditures (debt) through regular principal and interest payments over time. In this analysis we have applied a 25-year amortization rate to all investments.

ENERGY AND CARBON COST PROJECTIONS

Energy cost projections underlie the financial analysis. These projections were derived from:

- the Independent Electricity System Operator's (IESO) Long-Term Energy Plan (electricity),
- the US Energy Information Administration (propane), and
- Canada's Energy Regulator (all other fuels).

The financial analysis is sensitive to electricity and natural gas costs. Electricity costs are projected to increase more rapidly than natural gas; if natural gas costs increase more rapidly, then the financial benefit of many of the actions increases.

An escalating cost of carbon based on federal regulation was applied out to 2030 peaking at $170/$tCO_2e$ and was thereafter held constant.

Marginal Abatement Costs

Abatement costs provide an indication as to whether an action generates financial returns over its lifetime. If the abatement cost is negative it generates financial return, whereas if it costs money it will be positive. The width of each bar on the x-axis indicates the amount of GHG emissions that it saves.

Figure 11, below, shows the marginal abatement costs for grouped actions within Carbon-Free Colchester. Actions shown in blues and greens, on the left of the chart, are actions that create a financial return. The actions that cost money are shown in pink, on the right of the graph. The width of the bars indicate the relative reductions in GHGs from each grouped action. The action with the highest cost per tonne of carbon is the generation of Renewable Natural Gas (RNG) from organic waste, at $404/$tCO_2e$ reduced, and it represents a smaller opportunity for total GHG reductions, at only 32tCO_2e. The action with the largest savings is the expansion of transit and active transportation infrastructure, although the modelling has not accurately captured the costs associated with the expansion of transit. The exact style of transit for Colchester will require further exploration with the community and transit specialists, and so no capital costs for transit infrastructure were included in this analysis.

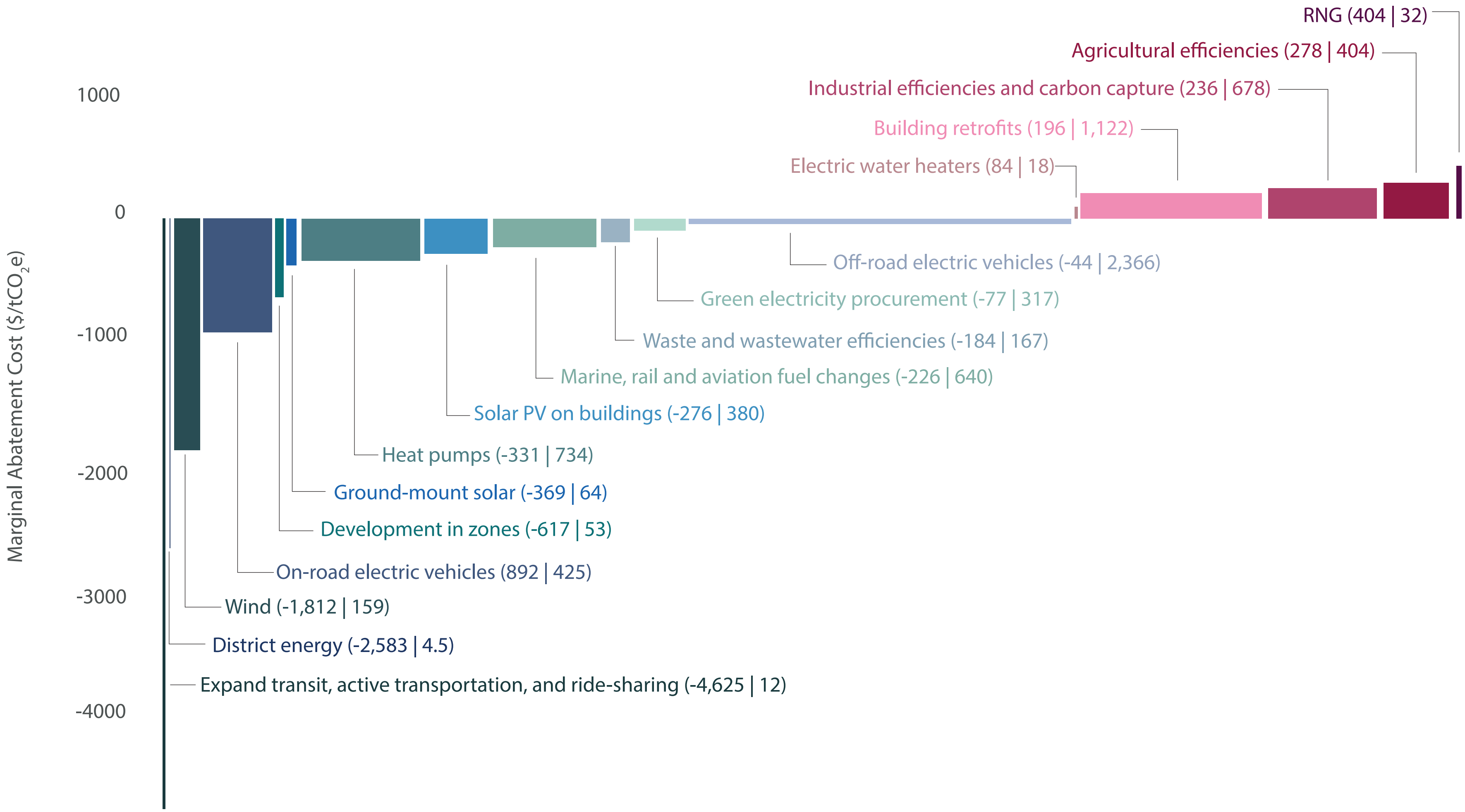


Figure 11. Marginal abatement cost curve for Colchester's low-carbon scenario actions

Table 2. Summary of financial results,.undiscounted (negative number = savings, positive number = cost)

FINANCIAL ESTIMATE	LCS
Total incremental capital investment, 2021-2050	$2,802 million
Total savings, 2020-2050[21]	-$4,280 million
Total revenue, 2020-2050	-$754 million
Net benefit, 2020-2050	-$2,230 million
Capital cost (undiscounted) to reduce each tonne of GHG	$370/t$CO_2$e
Abatement cost (NPV) per tonne of GHG	-$120/t$CO_2$e
Annual household savings on energy, 2050 over 2016	-$3,900
Investment $/person year of employment	$138,744

The undiscounted annual costs, savings, and revenue associated with fully implementing the actions in the low carbon scenario are shown in detail in Figure 8, with capital expenditures shown in full for the years in which they are incurred. As is characteristic of low-carbon transitions, the capital expenditures in the early years of the transition are greater than the savings and revenues generated, but show that by 2040, the savings outweigh the costs.

By 2040, savings from the low carbon transition are greater than costs.

The implementation of this plan represents a total investment of $2.802 billion from 2021–2050, averaging ~$9 million per year. This compares with a savings of $4.280 billion from avoided carbon costs, energy expense savings, and avoided maintenance costs. Combined with an anticipated revenue of $574 million, the implementation of the plan results in a benefit to the community of $2.230 billion.

Implementing this plan results in a benefit to the community of $2.230 billion.

[21] While the capital investments in the low carbon scenario all occur by 2050, the savings and revenue from many of those investments continue well beyond 2050 and are tracked in this analysis to the year 2089. This also accounts for why the gap between the NPV and undiscounted totals is higher for the non-capital categories.

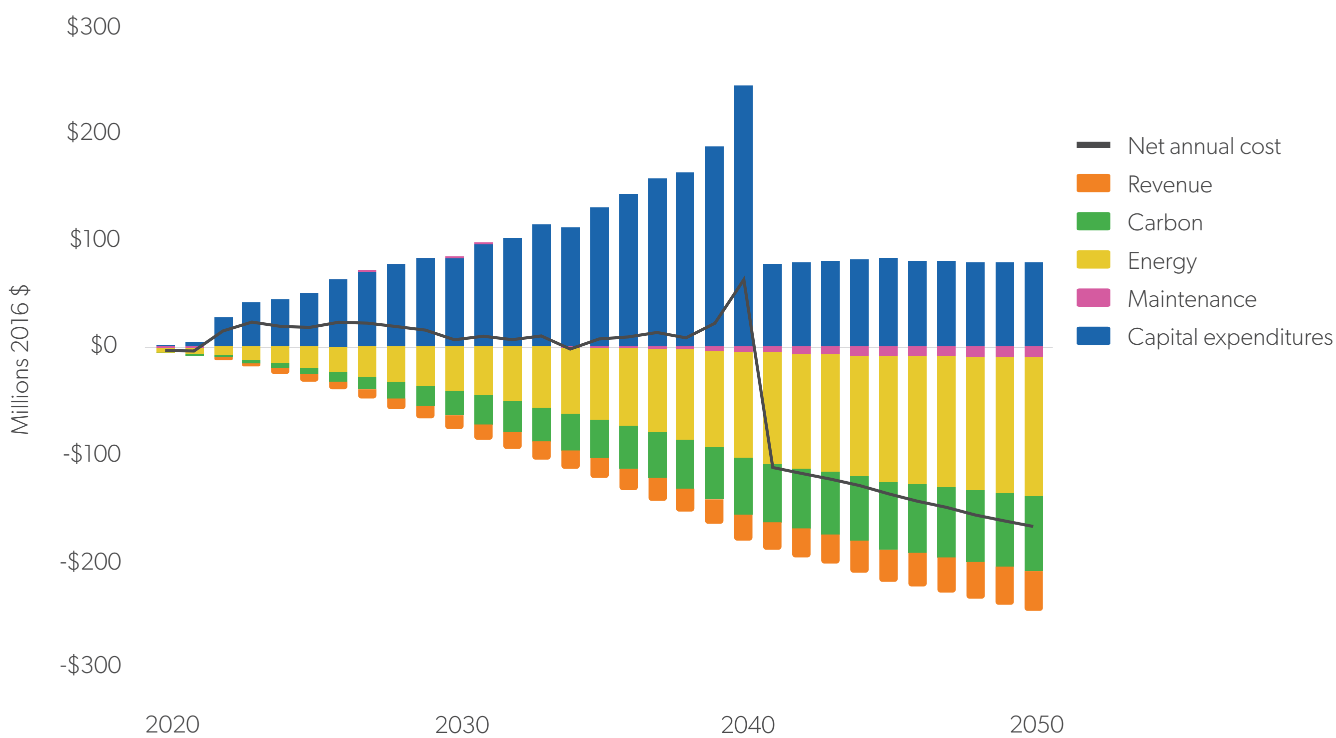
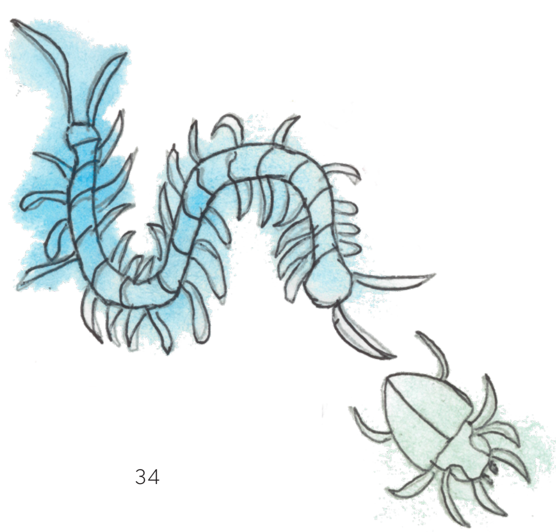


Figure 12. Year-over-year low-carbon scenario investments and returns



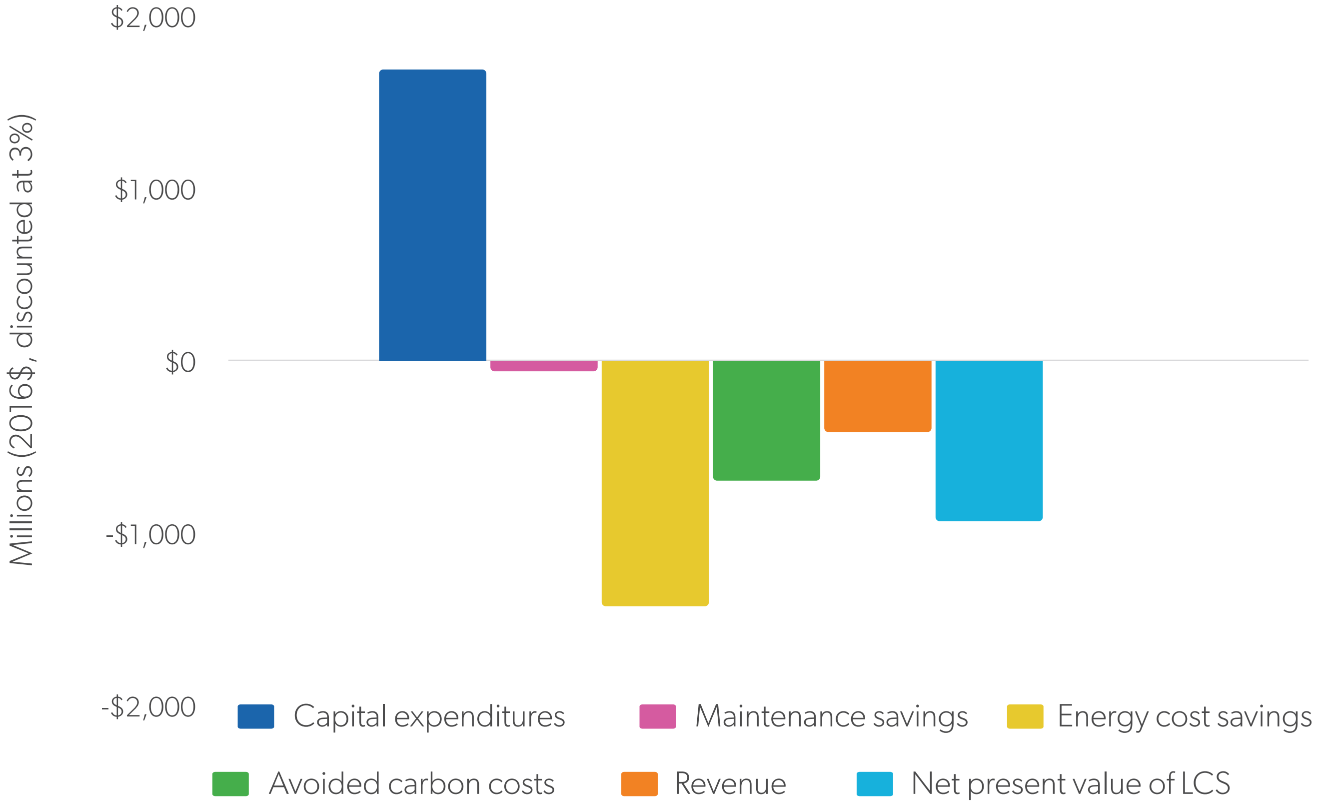


Figure 13. Present values of investments and returns for the low-carbon scenario (costs are positive in this convention, and revenue and savings are negative)

The average household spent nearly $5,000 per year on energy in 2016. If the actions in this plan are implemented, energy expenditures could fall to $1,000 per year by 2050.

Energy Savings for Households and the Community

Household expenditures on energy—fuel oil, electricity, gasoline and diesel—are projected to stay fairly consistent in the BAP and decline in the LCS (Figure 14). In the BAP, household energy expenditures are relatively flat because vehicles become more efficient due to national fuel efficiency standards and because of decreased heating requirements as the climate becomes milder due to climate change. The LCS involves shifting away from fuel oil and gasoline to electricity and using high efficiency space heating and cooling with heat pumps, while also improving the efficiency of homes. The carbon price also adds to the cost of using fossil fuels for heating and transport. In the LCS, an average household in 2050 spends 83% less on fuel and electricity (household energy and transportation expenditures) than they would have in the BAP scenario. Depending on the business, policy, and financing strategies used in the implementation of the actions, these savings will be partly offset by the incremental capital expenditures required.

Total expenditures on energy in 2016 in Colchester were approximately $140 million per year.

Community energy costs by fuel type are shown in Figure 15. Electricity becomes the dominant energy cost, as transportation and space heating are electrified. Expenses on fossil fuels are almost entirely eliminated by 2050, representing an 81% decrease in energy costs across the community of Colchester.

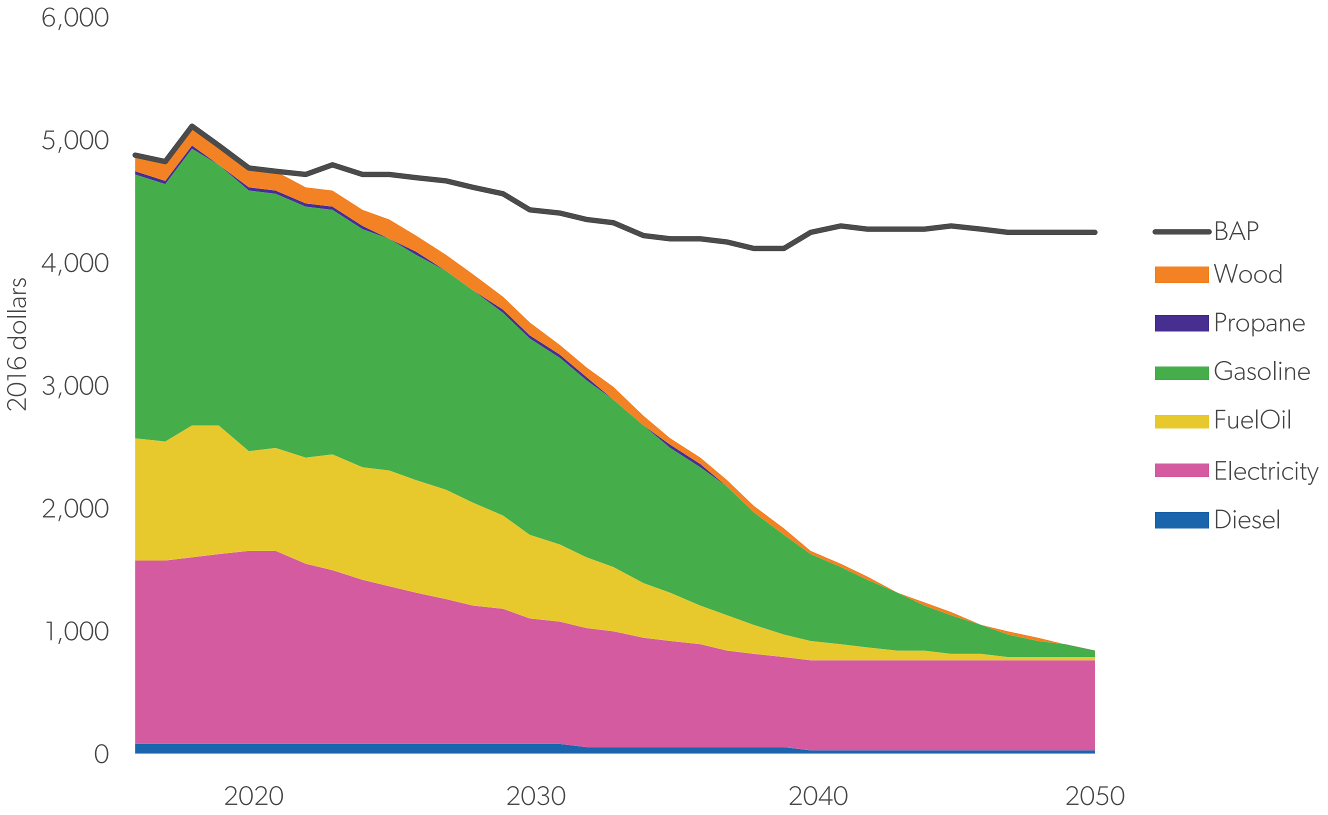


Figure 14. Household energy costs by fuel type for the low carbon scenario, compared to the BAP

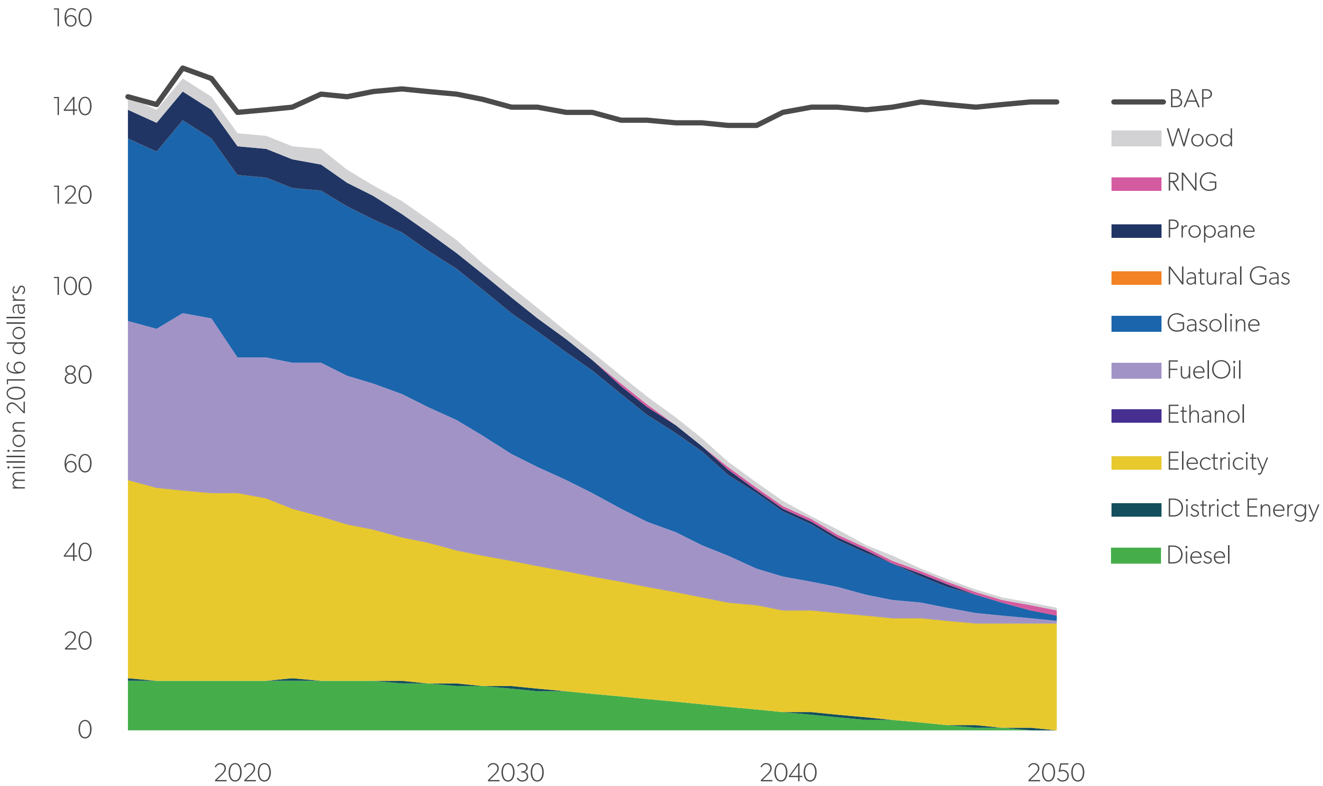


Figure 15. Community energy costs by fuel type in the low-carbon scenario, compared to the BAP.

Stimulating Jobs

Transitioning to a low- or zero-carbon economy is expected to have four categories of impacts on labour markets: additional jobs will be created in emerging sectors, some employment will be shifted (e.g. from fossil fuels to renewables), certain jobs will be reduced or eliminated (e.g. combustion engine vehicle mechanics), and many existing jobs will be transformed and redefined. The low carbon scenario adds 20,200 'person-years of employment', over the BAP Scenario between 2020 and 2050 (Figure 16).[22]

Implementing the LCS creates nearly 700 person years of employment each year.

Building retrofits present the largest opportunity for new employment, presenting options to partner with local education centres and the community college to develop programs to teach the skills required to complete deep energy retrofits, and install high-efficiency equipment.

[22] A person-year of employment represents one full-time employee for one year. This could, for example, be a single person working for 12 months, or 3 people working for 4 months.

Building retrofits are scheduled to be completed by 2040 in the modelling, so employment associated with this sector also ends in 2040. In reality, these skills will likely be in demand in the longer term, including in adjacent municipalities.

The sectors showing small losses in total person-years of employment are those which also show the most efficiency gains, including waste management, and vehicle maintenance with the switch to electric vehicles.

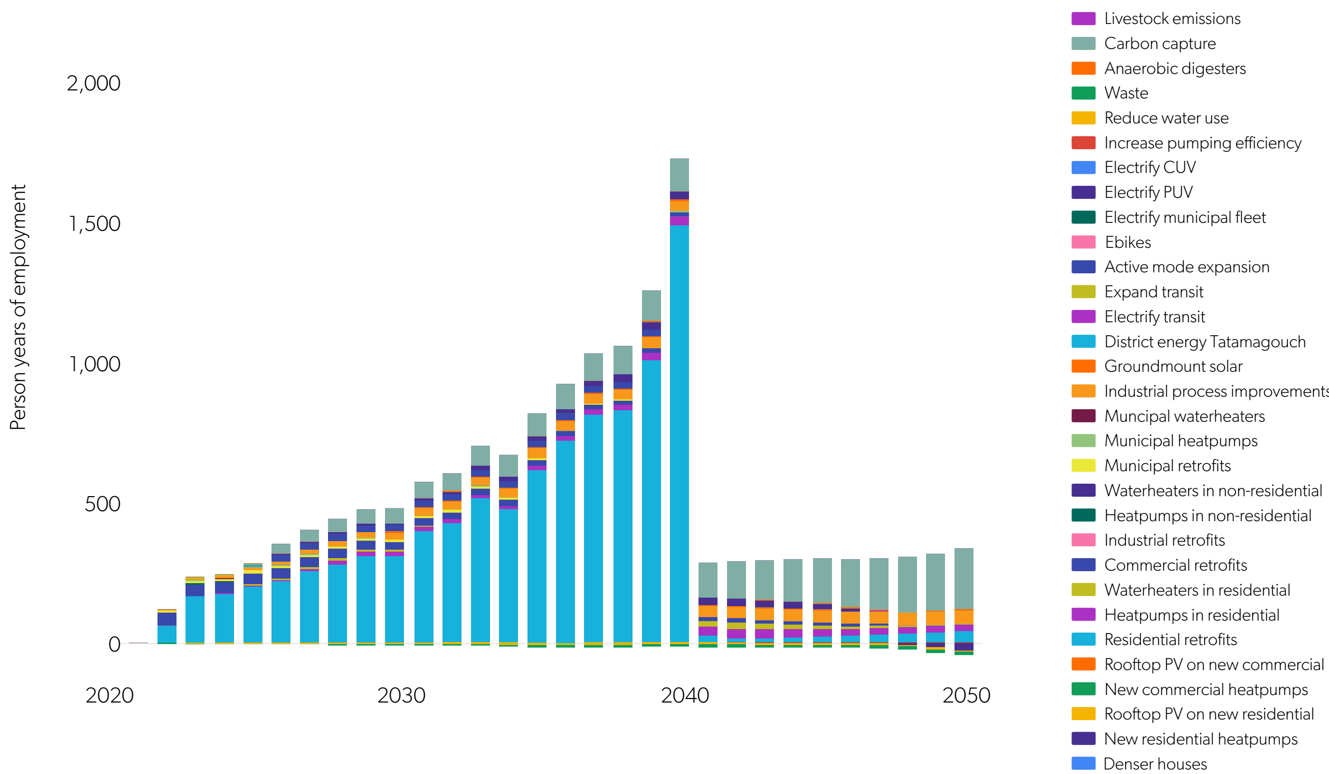


Figure 16. Annual person years of employment generated in the low carbon scenario

A Pathway for Implementation

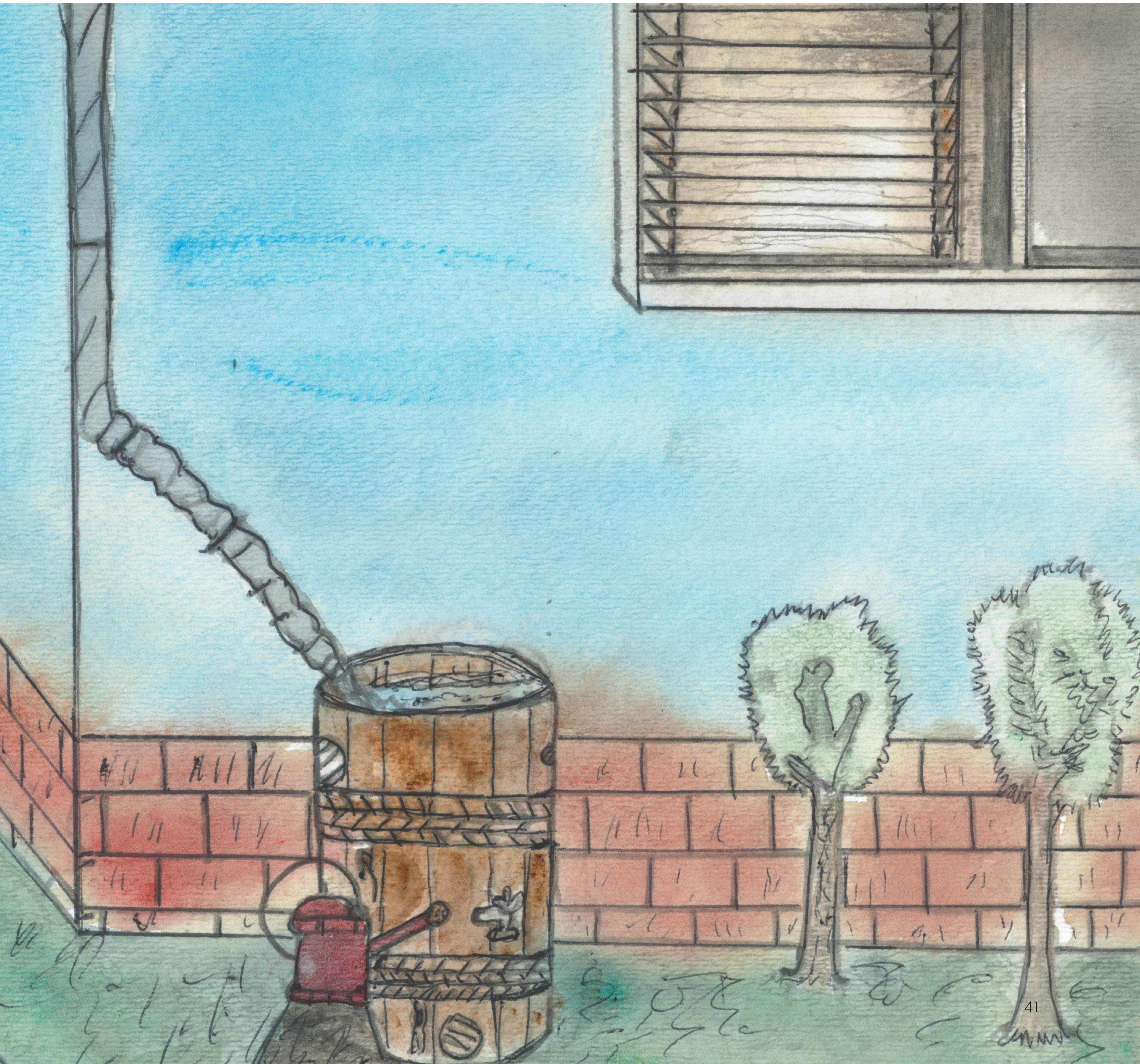
Co-benefit and Implementation Definitions

In addition to varying levels of greenhouse gas (GHG) reductions, actions included in this Plan result in additional benefits, which are described as co-benefits. These include: equity improvements, employment increases, and return on investment. For simplicity a code has been created for each potential co-benefit—enabler, low, medium, and high—which is described in the table below.

INDICATOR	ENABLER	LOW	MEDIUM	HIGH
Greenhouse gas emissions	Enables GHG Emissions	<100 $ktCO_2e$ reduction by 2050	100 to 3,000 $ktCO_2e$ reduction by 2050	>3,000 $ktCO_2e$ reduction by 2050
Costs	-	($0 - $100,000)	($100,000 - $1,000,000)	($1,000,000+)
Equity	No discernible effect	Without intervention, this action may favour certain groups or create a greater disparity between higher and lower income groups	This action is more likely to be implemented in the community fairly, but existing powerful groups may still be at an advantage	This action contributes to enhanced equity
Employment	Enables employment	0-5 person years of employment per $ million invested	5-10 person years of employment per $million invested	>10 person years of employment per $million invested
Cost-effectiveness	No cost associated with supporting action	This program will need incentives, loans, or grants in order to be completed	This action has the ability to break even, especially if paired with a more attractive investment vehicle	This action will be a driver of total cost-effectiveness of the entire program

For each implementation action, a primary implementation mechanism is listed (e.g., policy, program, initiative, or infrastructure), each is defined in the table below.

MECHANISM	DEFINITION
Policy	A policy developed by the Municipality, and approved by Council
Program	An ongoing effort by the Municipality, with staff and financing to support the effort
Initiative	A study or project, undertaken by the Municipality or private sector, with a specific focus, that is implemented for a set time period
Infrastructure	Investment in physical infrastructure by the municipality or private sector



The Focus Areas

Five key focus areas for Carbon-free Colchester were identified by the consultant through the combination of consultation with the public, and through technical modelling.

These include:

1. Affordable, zero-emissions buildings
2. Zero-emissions transportation
3. Renewable energy for everyone
4. An empowered community
5. A path to zero for business

There will be some overlap between the programs in each of the focus areas, as well as between program areas themselves. Systematic implementation of the programs ensures that one program will support another. For example, building retrofits increase the impact of solar PV installations by ensuring that there is more clean electricity for electric vehicles.

1. AFFORDABLE, ZERO EMISSIONS BUILDINGS

ACTION	GHG IMPACT	CO-BENEFITS	COSTS	IMPLEMENTATION MECHANISM	REPORTING METRICS	TIMING
1.1 All new buildings are net-zero by 2030	Medium	**Equity:** Enabler **Employment:** Medium **CE:** High	$$	Policy: Incentivise net zero new construction	GHG intensity of new buildings ($kgCO_2e/m^2$)	Immediate
1.2 Existing homes, ICI buildings, and municipal buildings are retrofit for deep energy savings	High	**Equity:** High **Employment:** High **CE:** Low	$$$	Program: Develop a deep retrofit program for all buildings Initiative: Pilot a neighbourhood retrofit Leading by example/ Infrastructure: Retrofit municipal buildings to net zero	# of buildings/ homes retrofit GHG intensity of new buildings ($kgCO_2e/m^2$)	Ongoing
1.3 Heat pumps and electric water heaters in all buildings	High	**Equity:** Enabler **Employment:** High **CE:** High	$$$		Number of non-electric systems replaced Total energy savings from space heating/ water heating	Ongoing

What is a deep retrofit?

Deep retrofits target energy savings greater than 50%. Retrofit programs are gaining popularity in Canada due to decreasing costs, simplicity of construction, and reduced time for completion; however retrofitting in Canada has not reached a scale where programs are easily available across the country. One possible solution for this is the Energiesprong program developed in the Netherlands. The EnergieSprong program provides a turn-key retrofit service to existing buildings to convert them to Net-Zero or Net-Zero ready when renewable energy becomes available.[23] Energiesprong retrofits can be completed in 10 days and have been successful in updating social housing without requiring upfront capital from tenants.[24] As the process has evolved for Energiesprong, costs have decreased by 60% in three years. [25]

The EnergieSprong model is quick and efficient by using prefabricated facades and building envelopes, efficient heating and cooling systems, and insulated roofs fitted with solar PV. In Nova Scotia, the ReCover Initiative is deploying EnergieSprong methods to achieve deep energy savings.[26] A pilot project by the ReCover Initiative reduced energy use in a four-story apartment building by 75%.

EnergieSprong House fitted with rooftop solar is between two other houses.[27] The next challenge is to scale this approach for large buildings.

[23] Sustainable Buildings Canada. (2016). Energiesprong Summary Report. Retrieved from: https://sbcanada.org/wp-content/uploads/2017/09/Energiesprong-Summary-Report.pdf

[24] "How-to-Guide: Net-Zero Retrofit Technical and Cost Benchmark Studies." Rocky Mountain Institute, n.d. https://www.rmi.org/rmi_techno_economic_study_how_to_guide/.

[25] Ibid

[26] ReCover Initiative, n.d. https://www.recoverinitiative.ca/our-story

[27] "EnergieSprong," n.d. http://energiesprong.eu/

While EnergieSprong has thus far focused on houses, New York State Energy Research and Development Authority (NYSERDA) announced a program called RetrofitNY based on EnergieSprong with the objective of creating a volume market for net-zero retrofits with larger buildings. Natural Resources Canada is currently working on a similar project titled Prefabricated Exterior Energy Retrofits (PEER) in the Ottawa area.

Irrespective of the technology or technologies applied, achieving a retrofit with the level of ambition of net zero requires a different type of process than a conventional retrofit, with a more intensive design program and greater upfront costs.

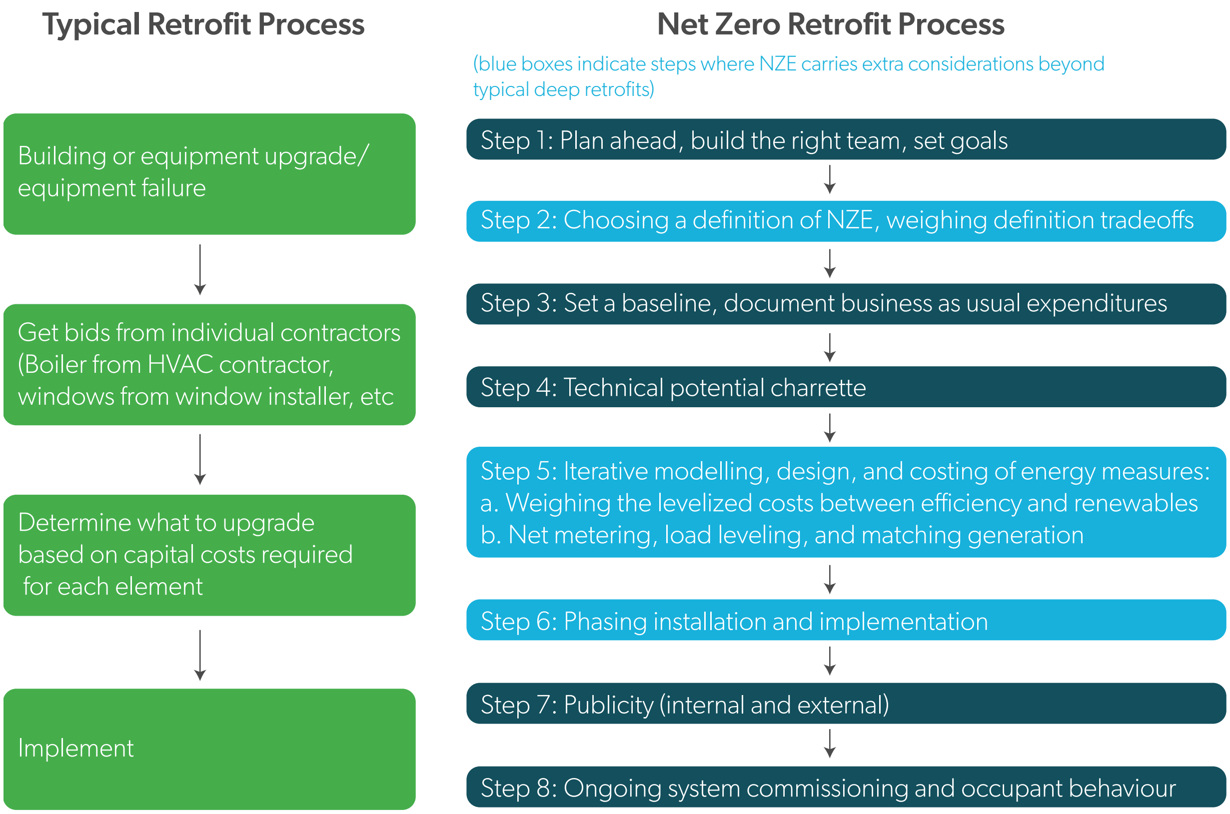
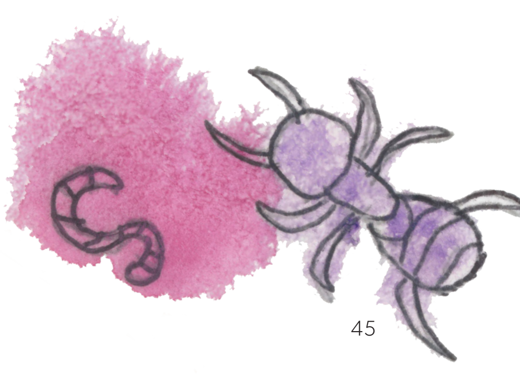


Figure 17. Comparison of the convention versus net zero approach to retrofits[28]



[28] Carmichael, C. (2018). Reinventing existing buildings: Eight steps to net zero energy. Rocky Mountain Institute.

PROGRAM: DEVELOP A DEEP RETROFIT PROGRAM FOR ALL BUILDINGS (INCLUDES POLICY, FINANCE, CAPACITY)

Building retrofits represent a major opportunity to reduce the emissions associated with energy use by buildings, while also improving the quality of homes for everyone in the community. A deep retrofit program will require supporting policies at the municipal level, as well as funding to support both the development and running of a program, and funding to ensure that the program is available to all members of the community. In each case the deep retrofit package will include thermal (envelope retrofits), renewable energy, and heat pumps. The program should include three streams:

- Affordable housing;
- Residential sector; and
- Commercial buildings.

Retrofitting all buildings will require a skilled labour force that is trained to assess the needs of a building and to complete the retrofit work. The Municipality can develop a partnership with the Nova Scotia Community College, the construction industry, and the Province to support the development of the workforce.

PARTNERS:

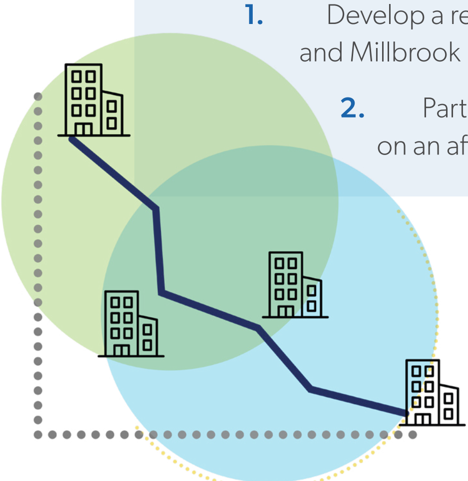
Local construction businesses, post-secondary education institutions, trade associates, EfficiencyOne, Nova Scotia Power.

POTENTIAL FUNDERS:

FCM, PACE programming led by the Municipality, revolving loans, provincial and federal governments.

NEXT STEPS:

1. Develop a regional retrofit consortium with EfficiencyOne, Truro, and Millbrook First Nations.
2. Partner with Housing Nova Scotia and EfficiencyOne on an affordable housing retrofit program.



INITIATIVE: PILOT A NEIGHBOURHOOD RETROFIT

A pilot program to retrofit all buildings within a neighbourhood will demonstrate the feasibility and cost savings associated with neighbourhood-level retrofits.

PARTNERS:

EfficiencyOne, local construction businesses, ReCover Initiative, Canada Green Building Council/ Passive House Institute Canada.

POTENTIAL FUNDERS:

FCM.

NEXT STEPS:

3. Develop a project concept and create criteria for selecting a neighbourhood. Identify a funding source, such as FCM.

LEADING BY EXAMPLE/INFRASTRUCTURE: RETROFIT MUNICIPAL BUILDINGS TO NET ZERO

To demonstrate leadership, and to demonstrate feasibility, all municipal buildings will be retrofitted to net-zero emissions by 2035. This will allow the Municipality to highlight the building retrofit businesses and industries within Colchester that can help the region achieve its retrofit goals, as well as to demonstrate the benefits of energy retrofits.

PARTNERS:

Local construction/renovation/energy efficiency companies, Canada Green Building Council, Passive House Institute Canada, Nova Scotia Power, EfficiencyOne.

POTENTIAL FUNDERS:

FCM, federal government, internal municipal funding.

NEXT STEPS:

4. Identify a building to target for Colchester's first net zero retrofit.

POLICY: INCENTIVISE NET-ZERO NEW CONSTRUCTION

New buildings need to meet net-zero standards, and the municipality will need to develop a building standard to support this. Colchester is projecting only moderate growth over the next 30 years. However, ensuring that new buildings meet net-zero standards will help the region achieve its climate goals and will help build required capacity within local industries to carry out net-zero building projects. By acting quickly to develop these new building standards and policies, the region can ensure that new developments meet net-zero energy use standards well into the future.

PARTNERS:

Local developers, suppliers of low-carbon building technologies, Canada Green Building Council, other cities undertaking similar actions.

POTENTIAL FUNDERS:

FCM, Colchester municipal staff time.

NEXT STEPS:

5. Identify incentives for net-zero retrofits such as expedited permits, financial incentives and access to PACE programs.

TARGETS:

	CURRENT-2025	2026-2030	2031-2040	2041-2050
% of new homes that are net zero	n/a	33%	100%	100%
Number of dwelling units built prior to 2016 that are retrofitted	907	2,822	12,750	12,750
Non-residential buildings constructed prior to 2016 that are retrofitted	125	256	437	553
Non-residential floor area constructed prior to 2016 that is retrofit (m^2)	102,759	210,531	358,583	451,201

2. ZERO EMISSIONS TRANSPORTATION

ACTION	GHG IMPACT	WCO-BENEFITS	COSTS	IMPLEMENTATION MECHANISM	REPORTING METRICS	TIMING
2.1 Complete Community Strategy directs new development into development zones	Enabler	**Equity:** Enabler **Employment:** Enabler **CE:** TBD	$	Policy: Integrate compact complete communities into Colchester's upcoming Municipal Plan	Update policy for all new development	Short
2.2 Electrify personal, municipal, and commercial vehicles	High	**Equity:** Low **Employment:** High **CE:** High	$$$	Infrastructure: Partner on the deployment of electric vehicle charging stations Initiative: Evaluate the opportunity for a zero-emissions plane testing facility at the Debert airport Initiative: Develop a zero emissions fleet strategy for Debert Leading by Example: Purchase electric vehicles for municipal fleet	Electric vehicle sales Transportation emissions # of charging stations by level	Ongoing

ACTION	GHG IMPACT	WCO-BENEFITS	COSTS	IMPLEMENTATION MECHANISM	REPORTING METRICS	TIMING
2.3 Expand and electrify transit	High	**Equity:** High **Employment:** High **CE:** High	$$	Infrastructure: Coordinate with Truro and Millbrook on a transit system	Ridership Vehicle kilometres travelled (VKT, km/year) Transit mode share in relevant areas	Medium
2.4 Improve and expand walking and cycling infrastructure	Medium	**Equity:** High **Employment:** High **CE:** Low	$$$	Policy: Update the active transportation strategy	Total kms of bike lanes and trails Total kms of sidewalks in development areas Traffic counter data (vehicle counts, and vehicle kilometers traveled) in key areas	Medium
2.5 Develop an e-bike sharing program	Medium	**Equity:** High **Employment:** Low **CE:** High	$	Initiative: Develop an E-bike share program	# e-bikes available # rides taken by e-bike annually	Short

INFRASTRUCTURE: COORDINATE WITH TRURO AND MILLBROOK ON A TRANSIT SYSTEM

Expanding public transit and connecting it with transit systems in adjacent municipalities will allow community members to travel within Colchester and throughout the region without having to rely on private vehicles. This transit system could be an on-demand transit system and could include ride-sharing or car-sharing to ensure maximum access across the wide geography of the municipality.

Expanded transit should initially focus on regions identified as Complete Community development areas. Transit should connect those regions to each other and to local hubs, including Truro and Millbrook.

PARTNERS:

Colchester Transportation Cooperative Limited (CTCL), the Town of Truro, Millbrook First Nation.

NEXT STEPS:

6. Conduct a feasibility and needs assessment for local transit across the region, and Identify incentives for purchasing zero-emissions buses.

POLICY: INTEGRATE COMPACT COMPLETE COMMUNITIES INTO COLCHESTER'S UPCOMING MUNICIPAL PLAN

Colchester covers a large area and is composed of many smaller communities, many of which pre-date the invention of the car. As such, these small villages and towns have a central core with shops and amenities, and homes and farmlands surrounding them.

By directing development into designated compact, complete communities, Colchester can build up these existing core regions.Colchester can enhance them with services like active transportation infrastructure and access to transit to travel to other key hubs and complete communities. In addition to reducing the emissions associated with transportation of both people and goods, the co-benefits of this style of community development include enhanced social well-being, deeper connections between community members, less social isolation, and increased public health from walking and cycling.

PARTNERS:

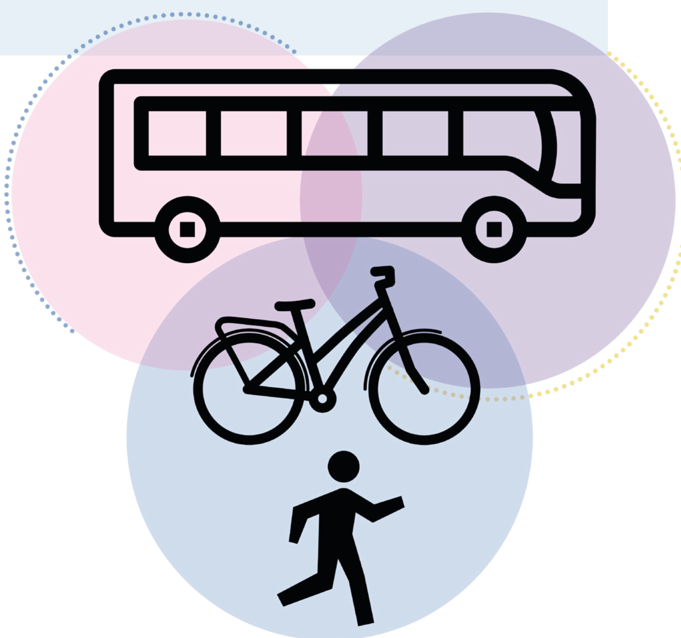
Municipal planning and development departments, local developers, towns and villages identified for development as compact, complete communities.

POTENTIAL FUNDERS:

Municipal staff time

NEXT STEPS:

7. Identify policies and targets that can be incorporated as policies into the Municipal Plan. Prepare a planning brief on climate action as an input into the Municipal Plan Process. Review the draft Municipal Plan from the perspective of climate action.



INFRASTRUCTURE: PARTNER ON THE DEPLOYMENT OF ELECTRIC VEHICLE CHARGING STATIONS

In the same way that gas stations are part of the fabric of our communities, electric vehicle charging stations will become an essential part of daily life. This will include home charging infrastructure, but also a wide-spread network of charging stations to allow for quick and full charging of vehicles throughout the region.

Unlike gas stations, charging stations require little extra infrastructure. They can be installed in parking lots, alongside street parking, and at facilities like libraries, restaurants, and gyms. Ownership of the charging stations can be dispersed, allowing local businesses to install chargers for their customers, while potentially reaping financial benefits from the chargers on their properties.

PARTNERS:

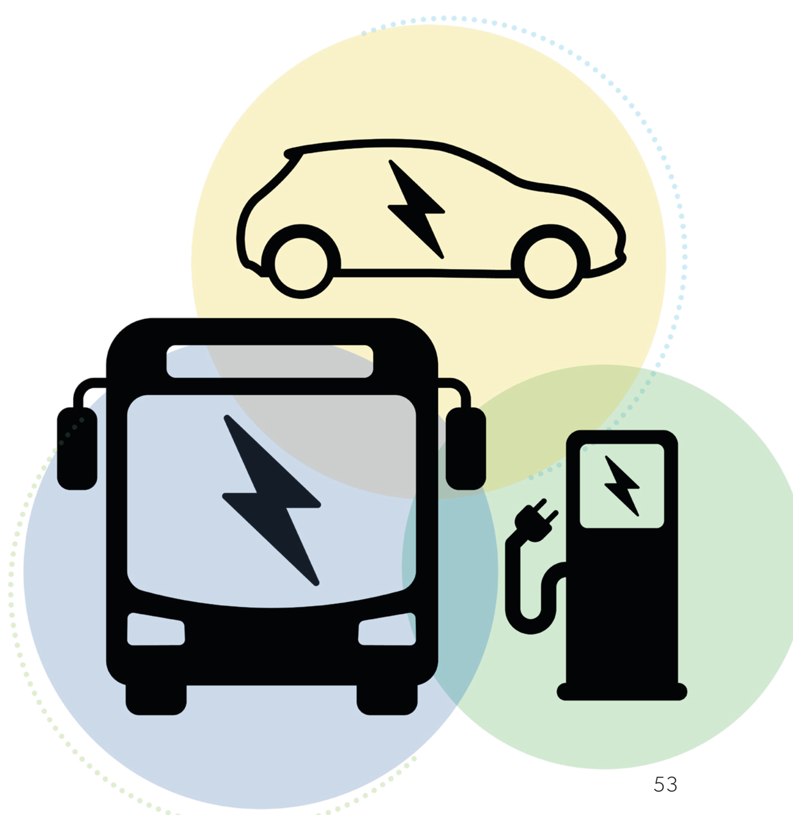
Nova Scotia Power, providers of charging stations including vehicle dealerships, local businesses.

POTENTIAL FUNDERS:

Nova Scotia Power, local businesses, provincial and federal government, local developers, incentive programs and rebates from the Municipality.

NEXT STEPS:

8. Apply for funding from the Zero Emission Vehicle Infrastructure Program.[29]



[29] This work is already underway in Colchester

INITIATIVE: DEVELOP AN E-BIKE SHARE PROGRAM

Combining the ideas of a car-share program and a bike-share program, an electric bike-sharing program will allow community members to hop on available e-bikes for their short- and medium-length trips, without worrying about hills and accessibility.

Combining this program with added active transportation infrastructure will allow community members to reduce the number of kilometres they travel by private vehicle.

PARTNERS:

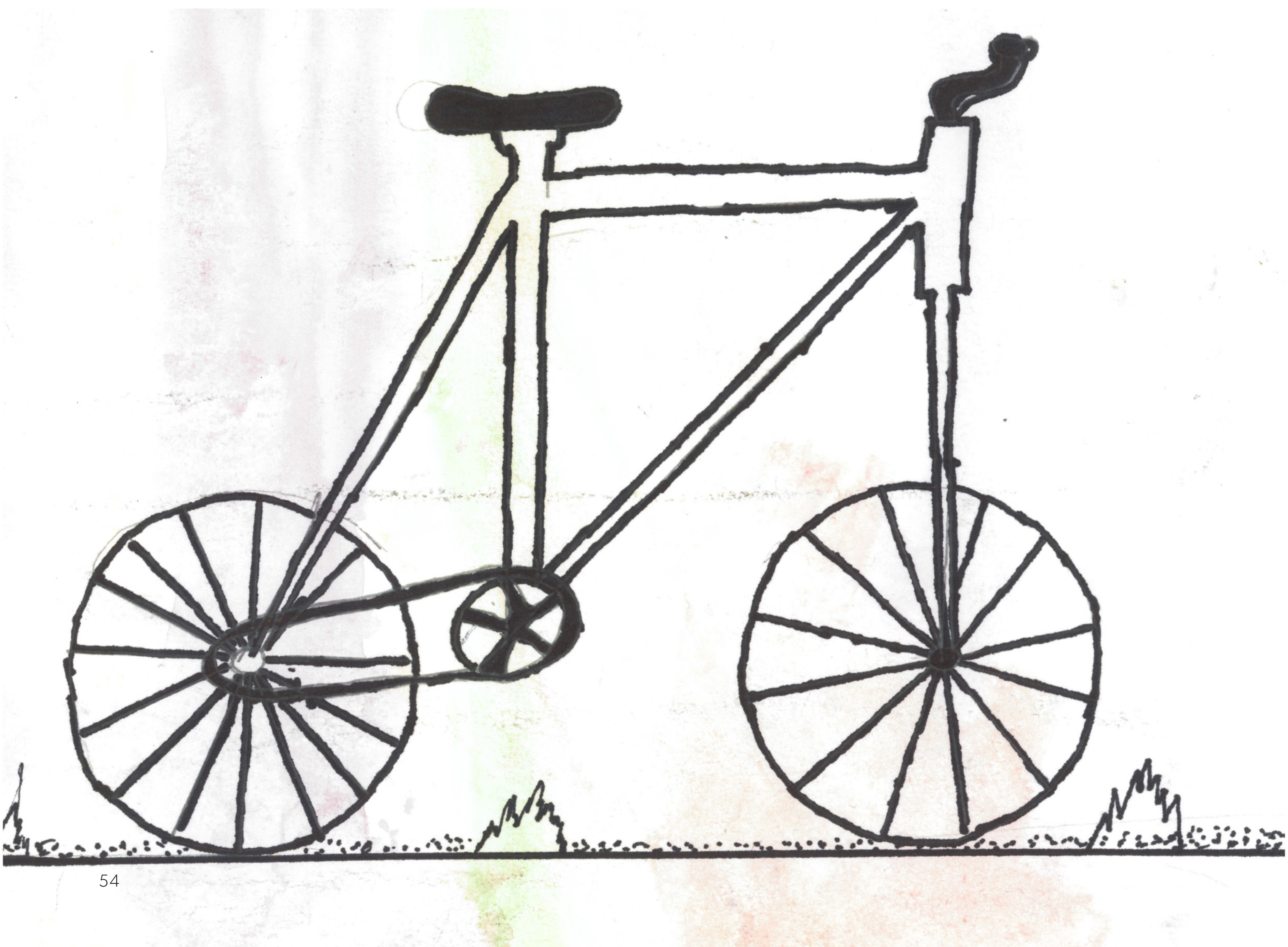
E-bike sharing companies, local transportation and active transportation non-profit organizations, provincial government

POTENTIAL FUNDERS:

Provincial government, e-bike sharing companies.

NEXT STEPS:

9. Issue an Expression of Interest to e-bike sharing companies.



INITIATIVE: DEVELOP A ZERO-EMISSIONS FLEET STRATEGY FOR DEBERT

Debert is a regional hub for heavy vehicle transportation with warehouses for provincial and national businesses. These trucks are primarily diesel-powered, and require large engines with significant power to pull heavy loads. While the pathway to zero emissions is more challenging for these vehicles than for smaller vehicles, fuel cell and electric trucks are becoming more prevalent.[30]

While the design and fuel standards of heavy vehicles are outside of the control of municipalities, local governments can work in ways to encourage activities to reduce emissions associated with the transportation of goods, including:

- Convening businesses to discuss how to modernize their fleets and switch away from fossil fuels;
- Coordinating a bulk purchase of EVs;
- Creating regulations on where and when heavy vehicles can access roads to eliminate peak traffic trips;
- Creating an "eco-zone" that prohibits heavy vehicle movement;[31]
- Supporting cycle-based co-ops to do final trip deliveries;
- Working with businesses to create a shared fleet of light electric trucks to complete deliveries; and
- Creating charging stations and areas for fuel cell replacements in distribution centres for heavy trucks.

PARTNERS:

Heavy vehicle dealers, provincial government, local businesses.

POTENTIAL FUNDERS:

Municipal staff time to develop strategies and working groups.

NEXT STEPS:

10. Convene a meeting of fleet managers from Debert. Secure funding from the Province and develop an RFP.

[30] Talebian, Hoda, Omar Herrera, Tran Martino, and Walter Merida. 2018. "Electrification of Road Freight Transport: Policy Implications in British Columbia." Energy Policy. Vancouver, BC: UBC.

[31] Net-Zero Technical Report. 2019. UK Committee on Climate Change. Retrieved from: https://www.theccc.org.uk/publication/behaviour-change-public-engagement-and-net-zero-imperial-college-london/

POLICY: UPDATE THE ACTIVE TRANSPORTATION STRATEGY

Keeping in mind that changes are occurring because of COVID, Colchester can update the active transportation strategy in coordination with adjacent municipalities to identify the best methods and locations to expand walking and cycling infrastructure. A coordinated strategy would allow the municipality to prioritize locations that will see immediate use, and help to increase the number of people within the communities who chose active transportation for short trips.

This strategy should be paired with other programs and plans, including the Complete Communities development strategy, and the expansion of transit.

Along with reducing emissions associated with vehicle transportation, expanded active transportation provides co-benefits including improved physical and mental health and increased social well-being.

PARTNERS:

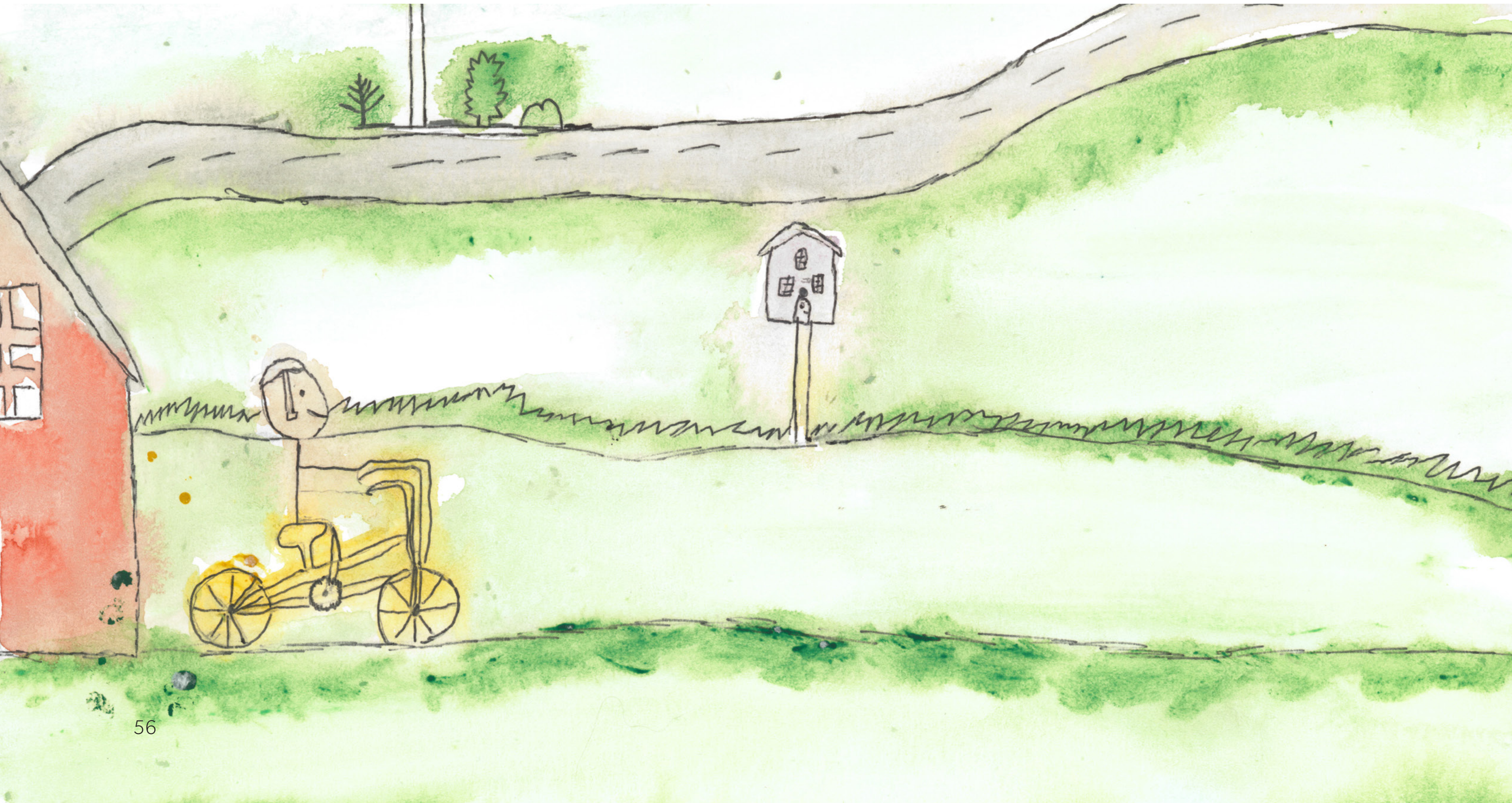
Transportation department, adjacent municipalities.

POTENTIAL FUNDERS:

Municipal staff time.

NEXT STEPS:

11. Update Colchester's Active Transportation Strategy to integrate e-bikes, support active modes for transportation, and assign appropriate resources that favour active modes versus cars.



LEADING BY EXAMPLE: PURCHASE ELECTRIC VEHICLES FOR MUNICIPAL FLEET

Similar to showing leadership by retrofitting municipal buildings, the Municipality can show leadership by converting the municipal fleet to electric vehicles. By ensuring that all new vehicles are electric, the Municipality can reduce the emissions associated with its activities, while also developing the local EV industry.

By being early adopters of the technology, the Municipality can show how EVs work in our climate and across large geographic distances.

PARTNERS:

Vehicle suppliers and dealerships, local vehicle mechanics and businesses, Nova Scotia Power.

POTENTIAL FUNDERS:

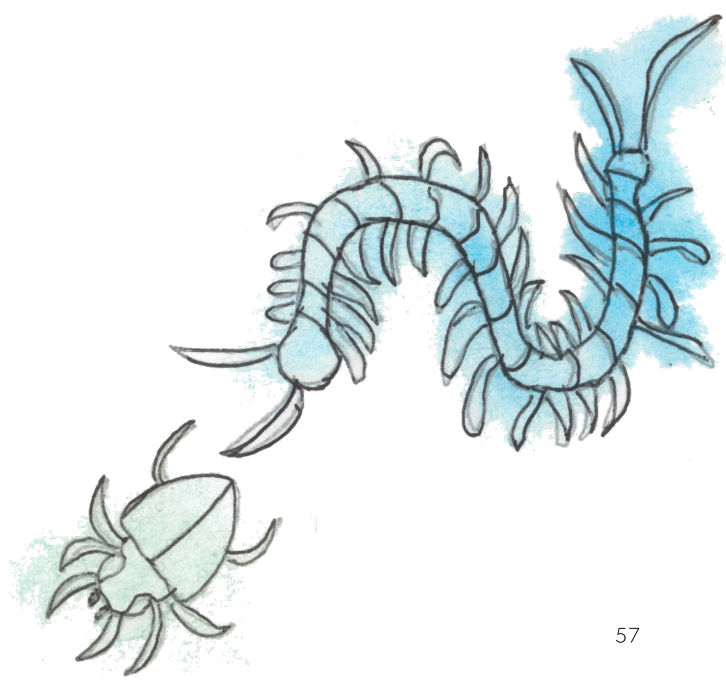
Municipal Government.

NEXT STEPS:

12. Establish a policy whereby all vehicle purchases are electric unless a justification otherwise can be made to Council.

TARGETS:

	2025	2030	2040	2050
% of personal vehicles that are electric	1%	10%	56%	95%
% of transit vehicles that are electric		92%		100%



3. RENEWABLE ENERGY FOR EVERYONE

ACTION	GHG IMPACT	CO-BENEFITS	COSTS	IMPLEMENTATION STRATEGIES	REPORTING METRICS	TIMING
3.1 Net-metering solar PV installed on new and existing buildings	High	**Equity:** Low **Employment:** High **CE:** High	$$$	Leading by Example/ Infrastructure: Deploy net-metered solar projects on municipal buildings	kW of solar PV installed # of solar installations	Ongoing
3.2 10 MW of ground-mount solar PV installed from 2030-2045	Medium	**Equity:** Enabler **Employment:** High **CE:** Medium	$$$	Policy: Incorporate renewable energy policies into the Municipal Plan Infrastructure: Create a solar garden	MW of solar installed	Medium
3.3 2 MW/ year of wind or tidal generation installed annually	High	**Equity:** Enabler **Employment:** High **CE:** High	$$$		MW of wind or tidal generation infrastructure installed	Ongoing
3.4 District energy system in Tatamagouche	Medium	**Equity:** Enabler **Employment:** Medium **CE:** High	$$	Infrastructure: Develop zero emissions district energy in community hubs (i.e. Tatamagouche)	tCO2 avoided	Short
3.5 Energy storage for renewable energy	Enabler	**Equity:** Low **Employment:** High **CE:** Enabler	$$		MW storage installed	Ongoing
3.6 RNG capture and use	Medium	**Equity:** Low **Employment:** Medium **CE:** Low	$$$		Tonnes of RNG captured	Short
3.7 Procurement of renewable electricity from outside of the municipality	High	**Equity:** High **Employment:** Low **CE:** Medium	TBD		MW of renewable electricity procured	Ongoing

POLICY: INCORPORATE RENEWABLE ENERGY POLICIES INTO THE MUNICIPAL PLAN

Renewable electricity is at the core of many of the actions within the Carbon-Free Colchester plan, including the adoption of electric vehicles and switching to electricity for efficient space and water heating. To meet this demand, the region will need to generate clean, renewable electricity to feed into the existing electricity grid or to fuel activities behind the meter.[32]

Colchester will need to decide where to locate renewable energy infrastructure. Land is a constrained resource that is subject to competing demands for food security, housing security, biodiversity, and access to water, among others.

Policies to allow for the smooth and simple expansion of renewable electricity infrastructure across the municipality will reduce barriers and hasten the reduction of emissions associated with electricity use in Nova Scotia. Colchester has established and expanded the Solar Colchester program, and this can be used as the basis for future renewable energy policies and programs. These policies should allow for the development of community solar gardens and wind generation cooperatives, which would allow all members of a community to benefit from the switch to renewable electricity.

PARTNERS:

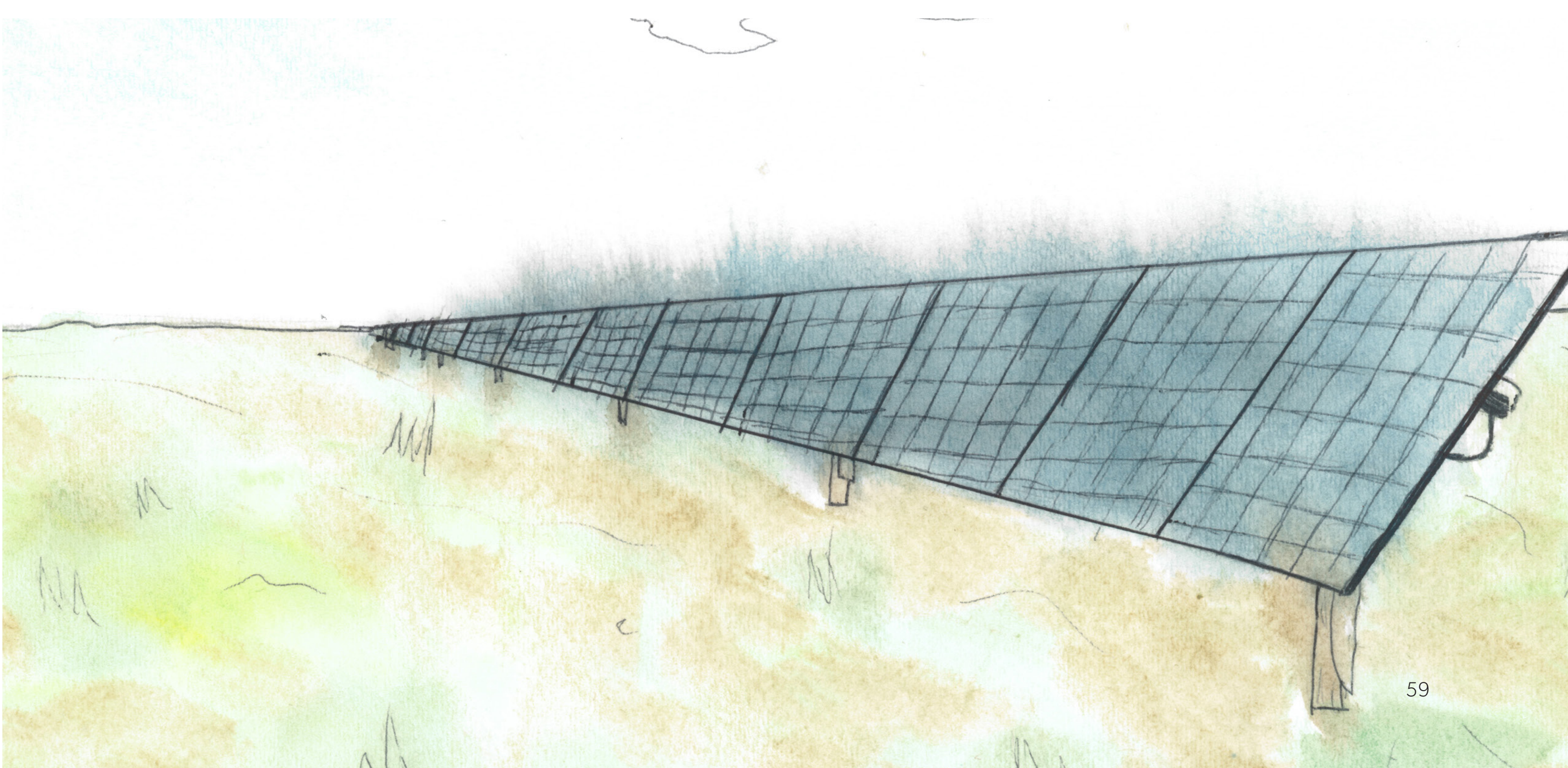
Municipal departments, Nova Scotia Power.

POTENTIAL FUNDERS:

Municipal staff time.

NEXT STEPS:

13. Prepare a briefing note on land-use policies for renewable energy to inform the Municipal Plan.



INFRASTRUCTURE: CREATE A SOLAR GARDEN

In the same way a community garden allows all members of a community to grow their own food, a community-scale solar generation facility would allow a community to generate its own renewable electricity. As a community project, local residents would invest in the facility, which would allow them to generate their own electricity, increase their resilience, and lower their emissions. By pooling resources, the community members would be able to reduce the costs associated with installing a solar PV system and share the costs of maintenance and operation.

PARTNERS:

Community members, Nova Scotia Power, other municipalities embarking on similar projects.

POTENTIAL FUNDERS:

Local community members and businesses.

NEXT STEPS:

14. Issue an Expression of Interest for developers of a solar garden on municipally-owned land.

INFRASTRUCTURE: DEVELOP ZERO EMISSIONS DISTRICT ENERGY IN COMMUNITY HUBS (I.E. TATAMAGOUCHE)

District energy systems allow for the efficient use of energy in dense building areas. By concentrating energy generation for space heating and cooling in a single system and circulating the heat and cooling to nearby buildings, the connected buildings can collectively use less energy than if they each had their own independent heating and cooling systems.

District energy systems can use waste heat from other activities, such as wastewater treatment, to power the system and circulate the result through connected buildings as either steam or hot water.

By developing zero-emission district energy systems in dense areas—e.g. Tatamagouche or other designated compact, complete communities—the connected buildings can save on energy costs, while also using waste heat efficiently.

PARTNERS:

Businesses in community hubs.

NEXT STEPS:

15. Convene a working group with major energy users (hospital, school, seniors housing) to explore options for zero emissions heating.

LEADING BY EXAMPLE/INFRASTRUCTURE: DEPLOY NET-METERED SOLAR PROJECTS ON MUNICIPAL BUILDINGS

By generating renewable electricity on-site, municipal buildings will be able to produce clean electricity to meet some or all of the energy needs of the buildings. This should be paired with building retrofits to ensure that solar arrays are not oversized for the energy demands of the building and should include an assessment of the energy demand for electric vehicle charging by municipal employees and community members.

Along with reducing the GHG emissions associated with municipal buildings, net-metered solar generation will save money by reducing the building's reliance on grid electricity.

PARTNERS:

Suppliers and installers of solar PV equipment, Nova Scotia Power.

POTENTIAL FUNDERS:

Municipal funds, FCM, provincial government.

NEXT STEPS:

16. Commission a feasibility study.

LEADING BY EXAMPLE/INFRASTRUCTURE: DEVELOP A BIOGAS FACILITY AT THE LANDFILL

Organic matter decomposition produces methane, a potent greenhouse gas in the near term. If captured, this gas can become a local source of energy and a sustainable alternative to natural gas. The Municipality can increase the efficiency of its existing landfill gas capture system, maximize resulting biogas use on-site, and, if the supply exceeds local energy needs, identify nearby sites to supply.

This biogas can be used to replace propane for space heating, including at the municipally-owned airplane hanger in Debert.

PARTNERS:

Municipality, DivertNS.

POTENTIAL FUNDERS:

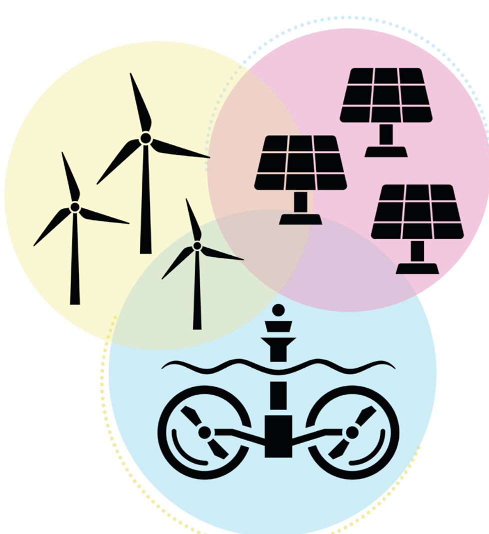
FCM, Colchester.

NEXT STEPS:

17. Revise the previous feasibility study to reflect updated carbon prices.

TARGETS:

	CURRENT-2025	2026-2030	2031-2040	2041-2050
Capacity of solar PV installed (MW)	11.13	11.77	21.14	19.04
Capacity of wind installed (MW)	8	10	20	20
Non-residential floor area connected to zero-emissions DE (m^2)	11,540	16,673	16,689	16,705



4. AN EMPOWERED COMMUNITY

In addition to actions which directly reduce GHG emissions, activities which support collaboration and build capacity in the community will build momentum.

PROGRAM: COLCHESTER LOW CARBON ROUNDTABLE WITH WORKING GROUPS ON EDUCATION, INDUSTRY, AGRICULTURE

Ensuring that all members of the community are involved and invested in Carbon-Free Colchester is essential to the successful implementation of the plan. Colchester will lead the development of a Low Carbon Roundtable to bring together representatives from the community to identify challenges and opportunities within the region, and work to fully include the community in the implementation of programs and initiatives.

The Roundtable will develop a number of working groups to tackle specific issues, including climate education, industry needs, and climate change in agriculture.

PARTNERS:

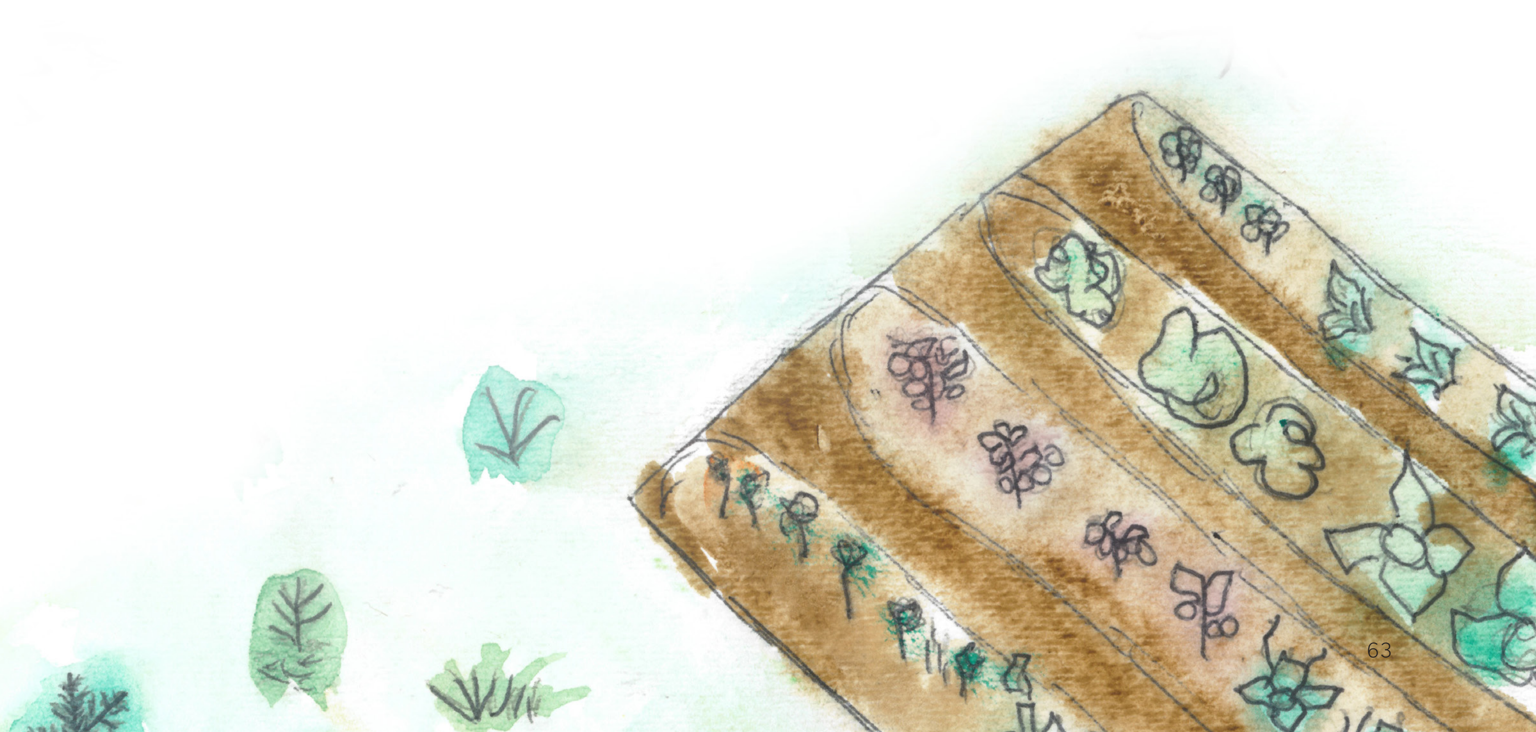
Local businesses, agricultural industry representatives, environmental non-profits.

POTENTIAL FUNDERS:

Municipal staff time.

NEXT STEPS:

18. Develop a terms of reference for the Low Carbon Round Table.



POLICY: FOCUS COLCHESTER'S ECONOMIC DEVELOPMENT STRATEGY ON CLIMATE ACTION

Embedding climate action in Colchester's economic development strategy will allow the municipality to prioritize projects, programs, and policies that will help Colchester meet its climate targets. It will also maximize the region's ability to foster a green economy. A focus on climate action will help the Municipality avoid making investments in infrastructure that will rapidly become outdated, such as inefficient infrastructure or equipment that runs on fossil fuels.

A focus on climate change will allow the County to place itself as a leader in climate action, while also allowing for the development of employment and investment opportunities for the whole community.

PARTNERS:

Colchester municipal departments.

POTENTIAL FUNDERS:

Municipal staff time.

NEXT STEPS:

19. Integrate Carbon-Free Colchester into the Economic Development Strategy.

PROGRAM: CREATE AN ENERGY CORPORATION IN PARTNERSHIP WITH OTHER MUNICIPALITIES

Using the AREA partnership as an example, Colchester can partner with other municipalities in Nova Scotia to develop an energy corporation with a focus on renewable electricity generation and energy services. By developing a partnership with other municipalities, Colchester can share costs and maximize economies of scale.[33]

PARTNERS:

AREA, other municipalities, renewable energy technology suppliers.

POTENTIAL FUNDERS:

Local municipalities, including Colchester.

NEXT STEPS:

20. Develop and sign an MOU with the neighbouring municipalities.

[33] Alternative Resource Energy Authority (AREA), 2021. Accessed June 2021: www.areans.ca

INITIATIVE: DEVELOP COMMUNITY BONDS FOR FINANCING LOW-CARBON ACTIONS IN PARTNERSHIP WITH CREDIT UNIONS

Green bonds are a funding mechanism designed to support the implementation of climate-positive activities. These bonds can be developed in partnership with credit unions to allow community members to pay for initiatives like building retrofits or renewable energy infrastructure. Reduced costs from energy savings can then be used to repay the loan. These bonds can be issued in any value, which allows the community to invest in its own projects.

PARTNERS:

Colchester, local credit unions.

POTENTIAL FUNDERS:

The community, Colchester Municipality.

NEXT STEPS:

21. Form a working group on climate finance and community bonds with the Town of Bridgewater.

INITIATIVE: DEVELOP EDUCATIONAL PROGRAMS WITH MUSEUMS AND ART GALLERIES

Colchester is home to a variety of museums and art galleries, some of which are owned and operated by the Municipality itself. By working with these institutions, Colchester will be able to present information on how climate change affects the region and engage the community in public-facing Carbon-Free Colchester activities.

By engaging all the senses, more of the community will be brought into the project, which improves community buy-in and the project's success.

PARTNERS:

Local museums and art galleries, local artists, educational non-profits.

POTENTIAL FUNDERS:

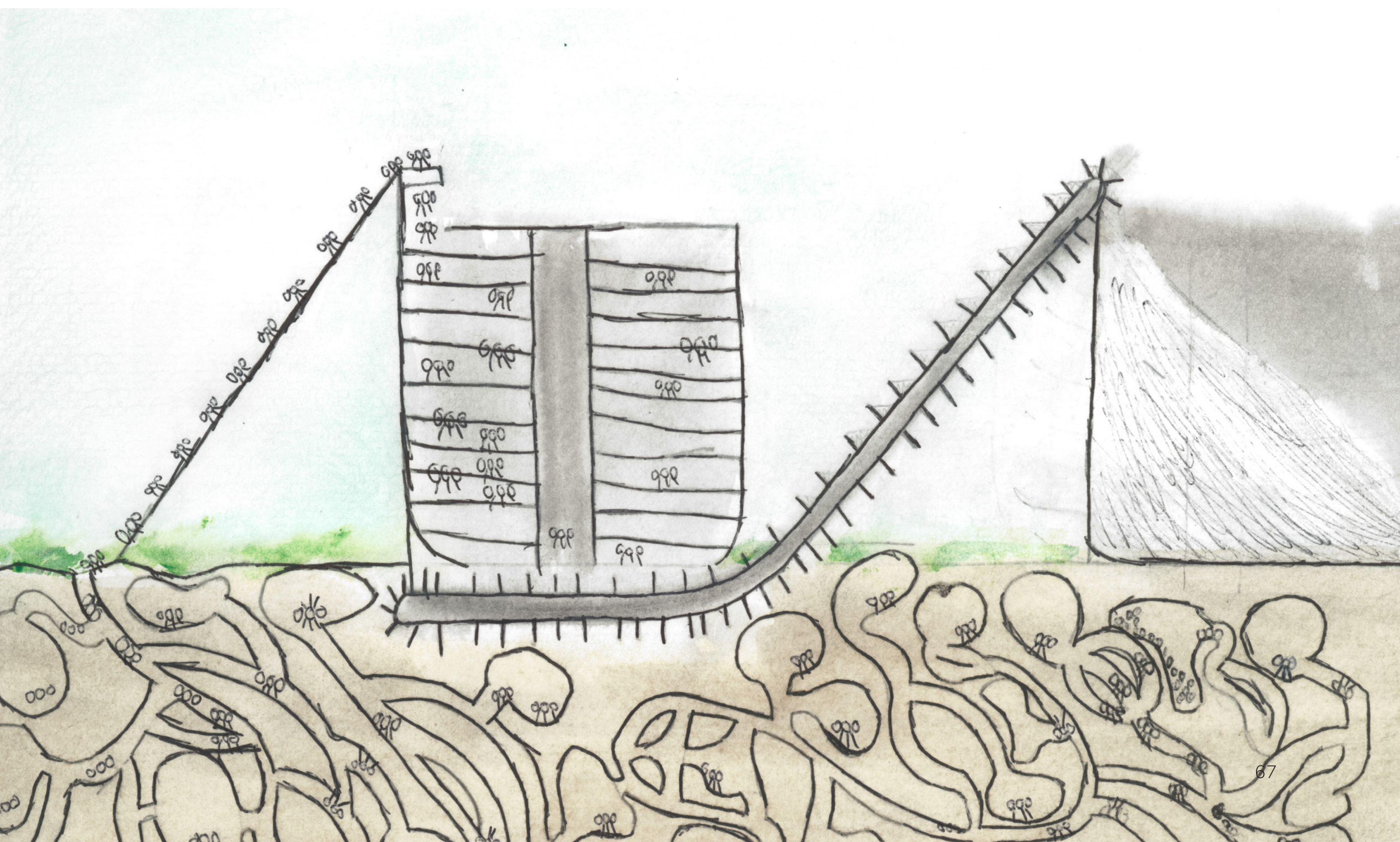
Provincial government grants, municipal funding.

NEXT STEPS:

22. Convene a working group of the museums and art galleries and provide a small grant for program design.

5. A PATH TO ZERO FOR BUSINESS

ACTION	GHG IMPACT	CO-BENEFITS	COSTS	IMPLEMENTATION MECHANISM	REPORTING METRICS	TIMING
5.1 Fuel shifting and carbon capture at cement plant	High	**Equity:** Low **Employment:** Low **CE:** Low	$$$	Initiative: Coordinate with Lafarge Canada on zero-emissions concrete partnership	tCO_2e/year of avoided emissions	Immediate
5.2 Agricultural fuel shifting and livestock management changes to reduce emissions	High	**Equity:** Low **Employment:** Low **CE:** Low	$$$	Initiative: Partner with Dalhousie University, the Organic Agriculture Centre of Canada on low or zero carbon agricultural practices	tCO_2e/year of avoided emissions	Immediate
5.3 Fuel shifting in marine, rail, and aviation to low or zero-emissions fuels	High	**Equity:** Low **Employment:** Low **CE:** Medium	TBD	Initiative: Evaluate the opportunity for a zero-emissions plane testing facility at the Debert airport	tCO_2e/year of avoided emissions	Long



INITIATIVE: COORDINATE WITH LAFARGE CANADA ON ZERO-EMISSIONS CONCRETE PARTNERSHIP

The Lafarge Canada cement plant is a major producer of GHG emissions within Colchester, and so working closely with the company to reduce emissions and improve efficiency will have a large impact on Colchester's overall emissions profile. Additionally, cement itself is a producer of GHG emissions, but technological developments are working to convert it from an emissions source to an emissions sink.

LafargeHolcim has stated a goal of reaching net-zero carbon emissions by 2030. This partnership would help the plant align itself with that goal.[34] By working with local companies like CarbonCure and nearby educational institutions like Nova Scotia Community College and Dalhousie University, Larfarge can position itself as a leader in low- and zero-emissions cement while also meeting its climate goals.

PARTNERS:

Municipal staff, Lafarge Canada, local education institutions, CarbonCure, local businesses.

POTENTIAL FUNDERS:

LafargeHolcim, municipal staff time.

NEXT STEPS:

23. Convene a meeting between the Mayor and the Manager of Lafarge Canada to share the objectives of Carbon-Free Colchester and develop an MOU.

[34] LafargeHolcim, 2021. Our net zero climate pledge. Accessed June 20201: https://www.lafargeholcim.com/climate-energy

POLICY/LEADING BY EXAMPLE: ADOPT AN EMBODIED CARBON POLICY FOR GOODS AND SERVICES

Embodied carbon—the emissions associated with the materials, construction, transportation, and disposal of a product or service— rounds out a complete life-cycle perspective of the climate impact of goods and services purchased by the Municipality. Embodied carbon is larger than the emissions tracked in Carbon-Free Colchester and is thus a more accurate measure of the global impact of activities undertaken by the municipality.

Adopting an embodied carbon policy for all goods and services purchased or consumed by the Municipality will have an impact on development, zoning, and activities within the region, and will allow Colchester to make choices that have a positive climate impact beyond the municipal boundary.

PARTNERS:

Carbon Neutral Cities Alliance, Lafarge Canada.

POTENTIAL FUNDERS:

Municipal staff time, Federal government.

NEXT STEPS:

24. Develop a list of high-carbon materials to avoid for construction projects.

INITIATIVE: PARTNER WITH DALHOUSIE UNIVERSITY, THE ORGANIC AGRICULTURE CENTRE OF CANADA, AND NS AGRICULTURAL FEDERATION ON LOW- OR ZERO-CARBON AGRICULTURAL PRACTICES

The Municipality will work with the University to identify strategies to reduce emissions from agriculture and store GHG emissions in the soil. The program will promote best practices and local agriculture.

PARTNERS:

Dalhousie University, Organic Agricultural Centre of Canada, NS Agricultural Federation.

POTENTIAL FUNDERS:

Department of Agriculture, Agriculture Canada.

NEXT STEPS:

25. Meet with Dalhousie University to explore options.

INITIATIVE: PARTNER WITH NORTH NOVA FORESTRY ON A FOREST CARBON PROGRAM TO CONSERVE FORESTS AND SUPPLY CARBON OFFSETS

North Nova Forestry is a forest management cooperative that works with landowners and foresters to promote effective and sustainable woodlot management in Cumberland and Colchester counties. Climate-friendly forest management practices can maximize carbon storage and facilitate the contientiousharvest of materials.

By using the techniques and methods pioneered by Community Forests International, Colchester and partners can work to identify key forested ecosystems for conservation and management for use as carbon offsets.[35] These nature-based solutions stand to benefit the local community economically and environmentally by maximizing the climate adaptation benefits from healthy intact forests and supporting sustainable forestry practices across the region.

PARTNERS:

Municipal staff, Community Forests International, North Nova Forestry, woodlot owners.

POTENTIAL FUNDERS:

Province of NS, Government of Canada's tree planting program.

NEXT STEPS:

26. Develop a pilot carbon sequestration project on a municipally-owned property.

[35] Community Forests International, 2021. Forest Carbon Offsets. Accessed June 2021: https://forestsinternational.org/conservation/forest-carbon-offsets/

INITIATIVE: EVALUATE THE OPPORTUNITY FOR A ZERO-EMISSIONS PLANE TESTING FACILITY AT THE DEBERT AIRPORT

Aviation energy and emissions represent a large portion of global GHG emissions. While the aviation industry is working on strategies to improve the fuel efficiency of air travel, and to change to lower-emissions fuels, this is still an area of active research.

Debert airport is centrally located and is situated near to the Debert Business Park. Additionally, the airport is home to a flight school that trains local pilots.

The smaller size and lower traffic demands of Debert airport would make it an ideal location for a testing facility for low- and zero-emissions airplanes.

PARTNERS:

Debert Flight Centre, Debert Business Park, Halifax International Airport, aviation industry leaders, local businesses.

POTENTIAL FUNDERS:

Aviation industry, federal government.

NEXT STEPS:

27. Coordinate a meeting with Halifax International Airport and Transport Canada to explore options.

The Journey Begins

Carbon-Free Colchester is an ambitious plan to get Colchester to net-zero by 2050 while stimulating economic opportunities. Every tonne of GHG emissions released today will have even greater impacts in the future, so the entire community of Colchester needs to act swiftly and decisively to implement the actions identified in the LCS.

In the immediate future, the next steps for Colchester are:

1. Develop building retrofit programs that can address all types of buildings, including rentals, those heated by fossil fuels, and commercial and industrial buildings;
2. Expand the Solar Colchester program to rapidly increase the amount of solar PV in Colchester, and to include wind generation and community solar gardens;
3. Develop community working groups with industry, businesses, and agricultural groups;
4. Develop partnerships with other local municipalities to pool resources and share learnings about the implementation of low-carbon actions;
5. Explore development guidelines to direct new development into designated compact, complete communities; and
6. Work directly with communities to establish open lines of communication within Colchester, and to dig deeper into local understanding of program needs.

Climate science, technology, and local conditions change rapidly. Because of this, it is recommended that communities track their progress along the low-carbon pathway in open and transparent communication with the public. Reportable metrics for each action within the plan are found in the implementation section of this report. Additionally, communities will need to revisit their targets, programs, and climate planning regularly, and the next round of planning for Colchester could include a carbon budget to track cumulative emissions over time.

Carbon-Free Colchester represents the first step on a long journey to transform the region immediately and for future generations. How Colchester faces this challenge will define the safety, economic security, and stability of the region for decades to come while enhancing the well-being and livelihoods of the current generation. Climate change is the biggest challenge faced by humanity, and by working together we can ensure a fair and equitable future for all members of society.

APPENDICES

Appendix A: Modelling Scope

Geographic Boundary

The geographic boundary of the modelling assessment is the municipal boundary of the Municipality of the County of Colchester (Figure 1). The model will use the county boundary, with the municipalities of Truro and Stewiacke removed, for the assessment of energy and emissions.

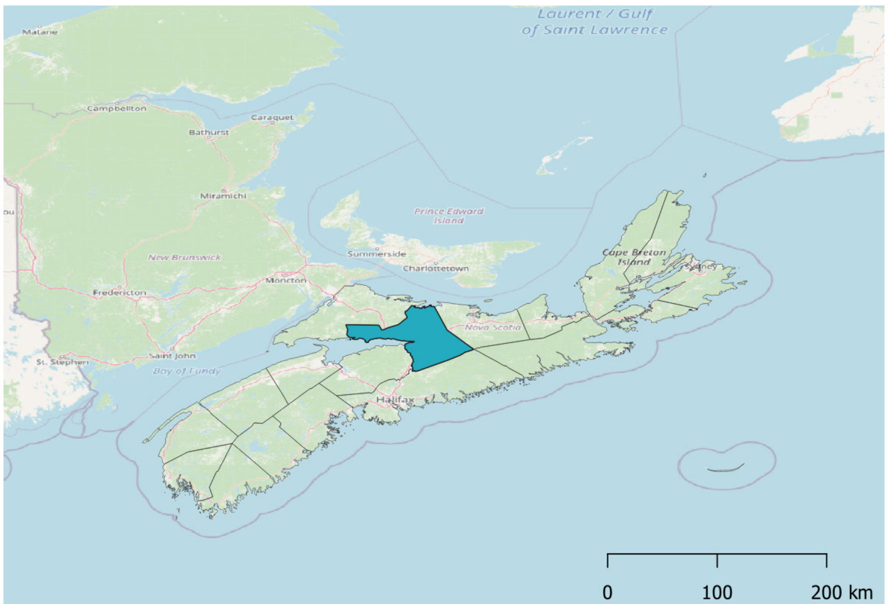


Figure 1. Assessment boundary for the Municipality of the County of Colchester

Time Scope

- The assessment will cover the years from 2016 to 2050.
- The year 2016 will be used as the base year within the model. The rationale for using this as the base year is that:
    - The model requires the calibration of a base year system state (initial conditions) using as much observed data as possible in order to develop an internally consistent snapshot of the city.
    - A key data source for the model is census data. At the time of modelling, the most recent census year for which data is available is 2016.
- 1-year increments are modelled from the 2016 base year. 2016 is the first simulation period/ year, as it is the most recent Statistics Canada Census year.
- Projections will extend to 2050.

Emissions Scope

The relevant emissions sources for Colchester and their emissions scope are detailed in Table 1. Of note is treatment of local electricity supplied to the grid: all emissions reductions from new local energy generation are accounted for locally, rather than distributed through the central electricity grid. However, central electrified generation facilities located within municipal boundaries, are only accounted for through the electricity grid emissions factor. This distinction is made because the current central electricity generation is already accounted for through the grid emissions factor. Reporting on such a facility is not required under GPC Protocol BASIC or BASIC+. New local energy generation projects are not included in electricity emissions factor projections.

Table 1. Sources included in the Colchester model.

	SCOPE 1	SCOPE 2	SCOPE 3	NOTES
Stationary Energy				
Residential buildings	Y	Y		
Commercial and institutional buildings and facilities	Y	Y		
Manufacturing industries and construction	Y	Y		
Energy industries	Y	Y		
Energy generation supplied to the grid				Additional renewable electricity is included beyond what is currently included in emissions factors projections
Agriculture, forestry, and fishing activities	Y	Y		
Non-specified sources				NA
Fugitive emissions from mining, processing, storage, and transportation of coal				NA
Fugitive emissions from oil and natural gas systems				N/A
Transportation				
On-road	Y	Y		
Railways	Y	Y		
Waterborne navigation	Y	Y		
Aviation	Y	Y		
Off-road	Y	Y		
Waste				
Disposal of solid waste generated in the city			Y	
Disposal of solid waste generated outside the city				NA
Biological treatment of waste generated in the city			Y	
Biological treatment of waste generated outside the city				NA
Incineration and open burning of waste generated in the City				NA
Incineration and open burning of waste generated outside the city				NA
Wastewater generated in the city	Y		Y	
Wastewater generated outside the city				NA

	SCOPE 1	SCOPE 2	SCOPE 3	NOTES
Industrial processes and product use (IPPU)				
Industrial processes	Y			
Product use				NA
Agriculture, forestry and other land use (AFOLU)				
Livestock	Y			
Land	Y			
Aggregate sources and non-CO_2 emissions sources on land	Y			
Other Scope 3			Y	

Emissions Factors

Table 2. Emissions accounting framework and global warming potential.

CATEGORY	BASE YEAR DATA/ASSUMPTION	SOURCE
ACCOUNTING FRAMEWORK		
Emissions accounting		
Accounting Framework	Global Protocol for Community-Scale GHG Emission Inventories (GPC)	Global Protocol for Community-Scale GHG Emission Inventories (GPC)
Emissions scope	Scope 1, 2 and partial scope 3	See GPC emissions scope table for scope 3 items included.
Sectors	Stationary energy (buildings) Transportation Waste	See GPC emissions scope table for sectors and sub-sectors included.
Boundary	Municipal boundary of Colchester	Municipality
Reporting	GPC BASIC & partial BASIC+	Global Protocol for Community-Scale GHG Emission Inventories (GPC)
Transportation methodology	GPC induced activity method	Global Protocol for Community-Scale GHG Emission Inventories (GPC)
Base year	2016	N/A
Projection year	2050	N/A
Global Warming Potential		

CATEGORY	BASE YEAR DATA/ASSUMPTION	SOURCE
Greenhouse gases	Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_20) are included. GWP: CO_2 = 1 CH_4 = 34 N_2O = 298 Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) are not included.	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.

Table 3. Emissions factors for fuels in the Colchester model.

CATEGORY	BASE YEAR DATA/ASSUMPTION	SOURCE
Emissions Factors		
Electricity	2016: CO_2: 700 g/kWh CH_4: 0.03 g/kWh N_2O: 0.01 g/kWh 2050: CO_2: 313.37 g/kWh CH_4: 0.03 g/kWh N_2O: 0.01 g/kWh	Electricity generation projections for 2017-2040 are sourced from NEB's Energy Future 2018 projected electricity generation for Nova Scotia. Environment Canada lists historic emissions and generation numbers by fuel, and combined these result in emission factors for electricity generation by fuel out to 2040. Emission factor held constant after 2040.
Gasoline	g / L CO_2: 2316 CH_4: 0.32 N2O: 0.66	2016 NIR Part 2 Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Diesel	g / L CO_2: 2690.00 CH_4: 0.07 N_2O: 0.21	2016: NIR Part 2 Table A6–12 Emission Factors for Energy Mobile Combustion Sources

CATEGORY	BASE YEAR DATA/ASSUMPTION	SOURCE
Fuel oil	Residential g/L CO_2: 2560 CH_4: 0.026 N_2O: 0.006 Commercial g/L CO_2: 2753 CH_4: 0.026 N_2O: 0.031 Industrial g/L CO_2: 2753 CH_4: 0.006 N_2O: 0.031	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–4 Emission Factors for Refined Petroleum Products
Wood	Residential kg/GJ CO_2: 299.8 CH_4: 0.72 N_2O: 0.007 Commercial kg/GJ CO_2: 299.8 CH_4: 0.72 N_2O: 0.007 Industrial kg/GJ CO_2: 466.8 CH_4: 0.0052 N_2O: 0.0036	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–56 Emission Factors for Biomass
Propane	g/L Transport CO_2: 1515.00 CH_4: 0.64 N_2O: 0.03 Residential CO_2: 1515.000 CH_4 : 0.027 N_2O: 0.108 All other sectors CO_2: 1515.000 CH_4: 0.024 N_2O: 0.108	NIR Part 2 Table A6–3 Emission Factors for Natural Gas Liquids Table A6–12 Emission Factors for Energy Mobile Combustion Sources

CATEGORY	BASE YEAR DATA/ASSUMPTION	SOURCE
Waste/WW	wastewater emissions factors 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 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), .05 kg CH_4 / tonne solid waste not accounting for recovery K values are sourced from IPCC table 3.3, temperate wet column	CH4 wastewater: IPCC Guidelines Vol 5 Ch 6, Tables 6.2 and 6.3, we use the MCF value for anaerobic digester N2O from advanced treatment: IPCC Guidelines Vol 5 Ch 6 Box 6.1 N2O from wastewater discharge: IPCC Guidelines Vol 5 Ch 6 Section 6.3.1.2 Landfill emissions: IPCC Guidelines Vol 5 Ch 3, Equation 3.1

Modelling Method

About CityInSight

CityInSight is an integrated, spatially-disaggregated energy, emissions, and finance model developed by Sustainability Solutions Group and whatIf? Technologies. The model enables bottom-up accounting for energy supply and demand, including renewable resources, conventional fuels, energy consuming technology stocks (e.g., vehicles, heating systems, dwellings, buildings), and all intermediate energy flows (e.g. electricity and heat).

CityInSight incorporates and adapts concepts from the system dynamics approach to complex systems analysis. Energy and GHG emissions are derived from a series of connected stock and flow models. The model accounts for physical flows (i.e., energy use, new vehicles, vehicle kilometres travelled) as determined by stocks (i.e., buildings, vehicles, heating equipment, etc). 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) to end uses (e.g., personal vehicle use, space heating) to energy costs and to GHG emissions. The flows evolve on the basis of current and future geographic and technology decisions/assumptions (e.g., EV uptake rates). 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. Characteristics of CityInSight are described in Table 1.

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. Where applicable, a zone type system can be applied to break up the city 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 city mapping systems.

Table 4. Characteristics of CityInSight.

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.

CHARACTERISTIC	RATIONALE
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 (sub-models), and the first level of modelled relationships (influences), are represented in Figure 1. These sub-models are all interconnected through various energy and financial flows. Additional relationships may be modelled in CityInSight 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.

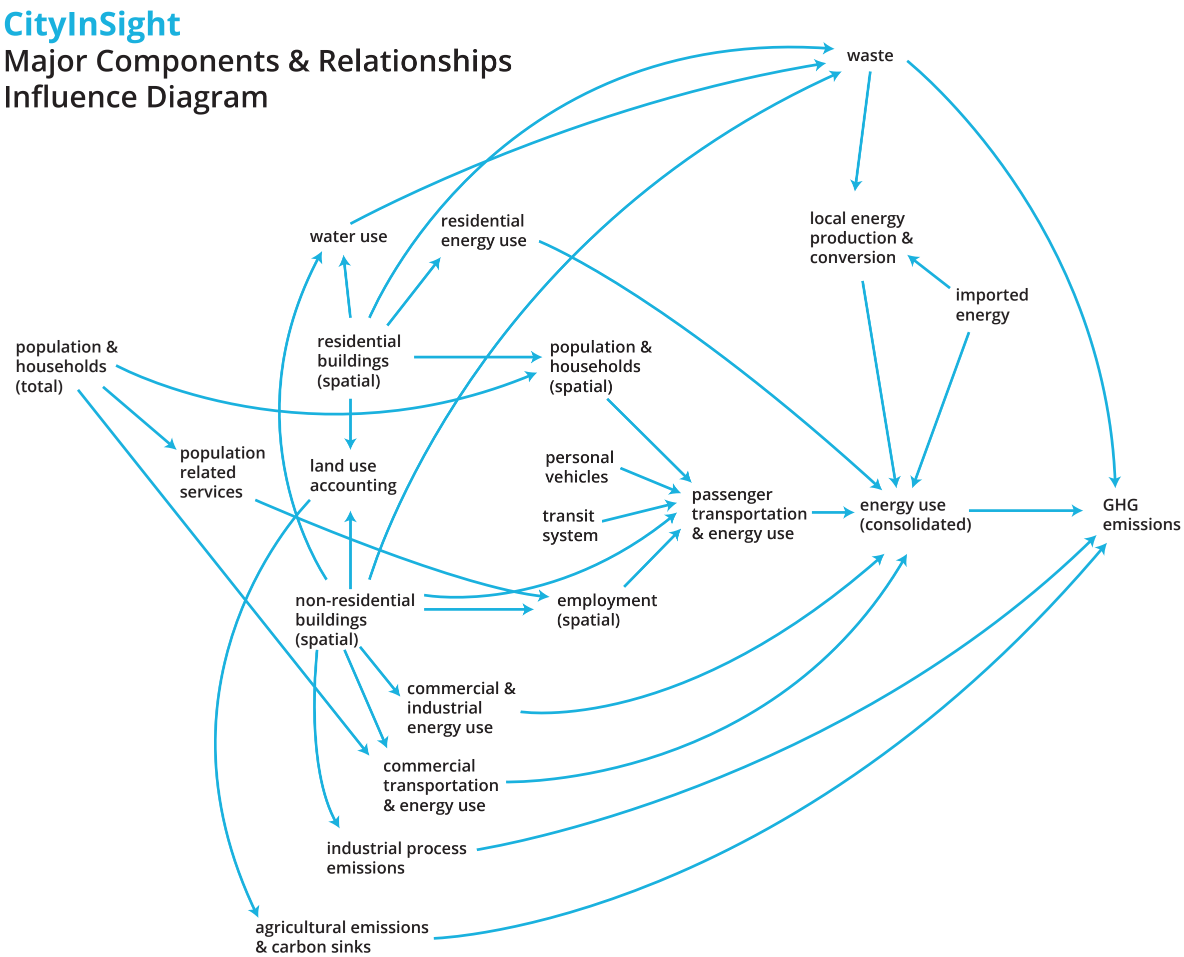


Figure 2. Representation of CityInSight's structure.

Stocks and Flows

Within each sub-model is a number of stocks and flows that represent energy and emissions processes in cities. For any given year various factors shape the picture of energy and emissions flows in a city, 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—making up 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).

Sub-models

The stocks and flows that make up each sub-model are described below.

POPULATION, HOUSEHOLDS, AND DEMOGRAPHICS

- City-wide population is modelled using the 'standard population cohort-survival method', which tracks population by age and gender on a year-by-year basis. It accounts for various components of change: births, deaths, immigration and emigration.
- Population is allocated to households, and these are placed spatially in zones, via physical dwellings (see land-use accounting sub-model).
- The age of the population is tracked over time, which is used for analyzing demographic trends, generational differences and implications for shifting energy use patterns.
- The population sub-model influences energy consumption in various sub-models:
  - School enrollment totals (transportation)
  - Workforce totals (transportation)
  - Personal vehicle use (transportation)
  - Waste generation

BUILDING LAND-USE ACCOUNTING

Land use accounting identifies buildings in space and over time, through construction, retrofits and demolitions. In the baseline, this is often directly informed by building-related geospatial data. Land use accounting consists of the follow elements:

- Quantitative spatial projections of residential dwelling units, by:
  - Type of residential structure (single detached, semi detached, row house, apartment, etc);
  - Development type (greenfield, intensification); and
  - Population is assigned to dwelling units.
- Quantitative spatial projections of non-residential buildings, by:
  - Type of non-residential structure (retail, commercial, institutional);
  - Development type (greenfield, intensification);

  - Buildings are further classified into archetypes (such as school, hospital, industrial - see Table 2).1 This allows for the model to account for differing intensities that would occur in relation to various non residential buildings; and
  - Jobs are allocated to zones via non-residential floor area, using a floor area per worker intensity.
- Land-use accounting takes "components of change" into account, year over year:
  - New development;
  - Removals / demolitions; and
  - Year of construction.
- Land use accounting influences other aspects of the model, notably:
  - Passenger transportation: the location of residential buildings influences where home-to-work and home-to-school trips originate, which in turn also influences their trip length and the subsequent mode selected. Similarly, the location and identification of non-residential buildings influences the destination for many trips. For example, buildings identified as schools would be identified in home-to-school trips.
  - Access to energy sources by buildings: building location influences access to energy sources, for example, a rural dwelling may not have access to natural gas or a dwelling may not be in proximity to an existing district energy system. It can also be used to identify suitable projects: for example, the location and density of dwellings is a consideration for district energy development.
  - Non-residential building energy: the identification of non-residential building archetypes influences their energy consumption based on their use type. For example, a building identified as a hospital would have a higher energy use intensity than a building identified as a school.

[1] Where possible, this data comes directly from the municipality.

Table 5. Non-residential archetypes represented in the model.

- College, university
- School
- Retirement or nursing home
- Special care home
- Hospital
- Municipal building
- Fire station
- Penal institution
- Police station
- Military base or camp
- Transit terminal or station
- Airport
- Parking
- Hotel motel inn
- Greenhouse
- Greenspace
- Recreation
- Community centre
- Golf course
- Museums, art gallery
- Retail
- Vehicle and heavy equipment service
- Warehouse retail
- Restaurant
- Commercial retail
- Commercial
- Commercial residential
- Retail residential
- Warehouse commercial
- Warehouse
- Religious institution
- Surface infrastructure
- Energy utility
- Water pumping or treatment station
- Industrial generic
- Food processing plants
- Textile manufacturing plants
- Furniture manufacturing plants
- Refineries all types
- Chemical manufacturing plants
- Printing and publishing plants
- Fabricated metal product plants
- Manufacturing plants miscellaneous processing plants
- Asphalt manufacturing plants
- Concrete manufacturing plants
- Industrial farm
- Barn

RESIDENTIAL AND NON-RESIDENTIAL BUILDING ENERGY

Building energy consumption is closely related to the land use accounting designation it receives, based on where the building is located, its archetype, and when it was constructed. Building energy consumption is calculated in the model by considering:

- Total energy use intensity of the building type (including the proportion from thermal demand) is built from energy end uses in the building. End uses include heating, lighting, auxiliary demand, etc. The energy intensity of end uses is related to the building or dwelling archetype and its age.
- Energy use by fuel is determined based on the technologies used in each building

(e.g. electricity, heating system types). Heating system types are assigned to building equipment stocks (e.g., heating systems, air conditioners, water heaters).

- Building energy consumption in the model also considers:
    - Solar gains and internal gains from sharing walls;
    - Local climate (heating and cooling degree days); and
    - Energy losses in the building.
- Building equipment stocks (water heaters, air conditioners) are modelled with a stock-turnover approach that captures equipment age, retirements, and additions. In future projections, the natural replacement of stocks is often used as an opportunity to introduce new (and more efficient) technologies.

The model has residential and non-residential building energy sub-models. They influence and produce important model outputs:

- Total residential energy consumption and emissions and residential energy and emissions by building type, by end use, and by fuel;
- Total non-residential energy consumption and emissions and residential energy and emissions by building type, by end use, and by fuel; and
- Local/imported energy balance: how much energy will need to be imported after considering local capacity and production.

Figure 3 details the flows in the building energy sub-model at the building level.

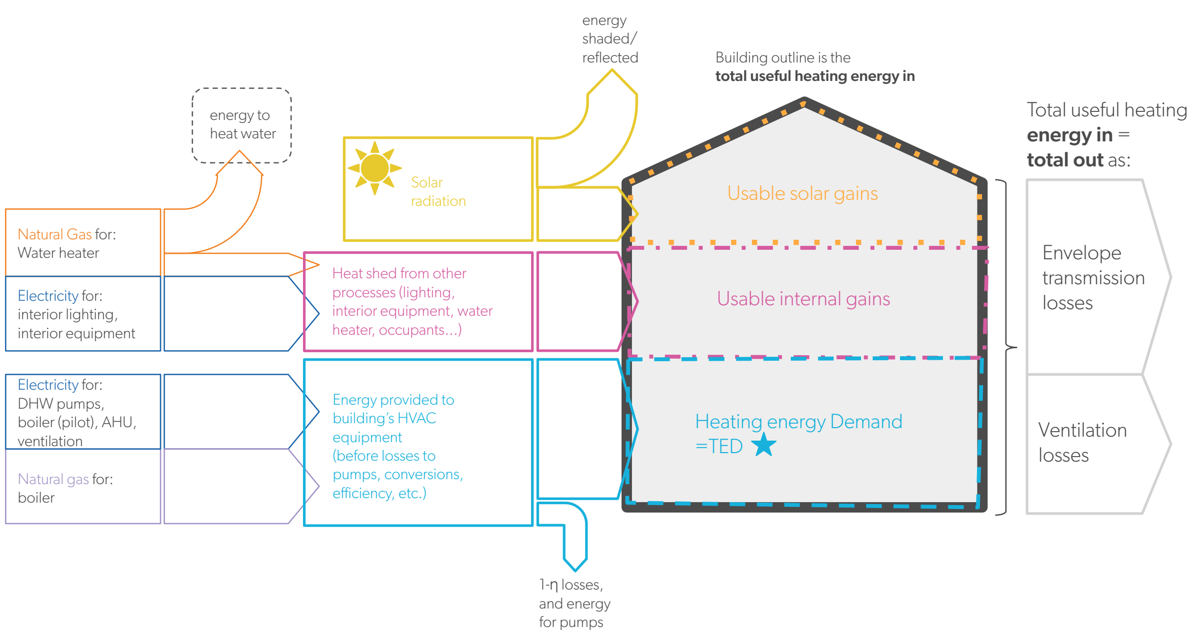


Figure 3. Building energy sub-model schematic.

TRANSPORTATION

CityInSight includes a spatially explicit passenger transportation sub-model that responds to changes in land use, transit infrastructure, vehicle technology, travel behavior changes and other factors. It has the following features:

- CityInSight uses the induced method for accounting for transportation related emissions; the induced method accounts for in-boundary tips and 50% of transboundary trips that originate or terminate within the city boundary. This shares energy and GHGs between municipalities.
- The model accounts for "trips" in the following sequence:

    1. Trip generation. Trips are divided into four types (home-work, home-school, home-other, and non-home-based), each produced and attracted by different combinations of spatial influences identified in the land-use accounting sub-model: dwellings, employment, classrooms, non-residential floorspace.
    2. Trip distribution. Trips are then distributed with the number of trips specified for each zone of origin and zone of destination pair. Origin-Destination (O-D) matrix data is based on local travel surveys and transportation models.
    3. Mode share. For each origin-destination pair, trips are shared over walk/bike, public transit and automobile.

        a. Walk / bike trips are identified based on a distance threshold: ~2 km for walking, ~5-10 km for biking.

        b. Transit trips are allocated to trips with an origin or destination within a certain distance to a transit station.

    4. Vehicle distance. Vehicle kilometres travelled (VKT) are calculated based on the number of trips by mode and the distance of each trip based on a network distance matrix for the origin-destination pairs.

- VKT is also assigned to a stock of personal vehicles, based on vehicle type, fuel type, and fuel efficiency. The number of vehicles is influenced by the total number of households identified in the population sub-model. Vehicles also use a stock-turnover approach to model vehicle replacements, new sales and retirements.
- The energy use and emissions associated with personal vehicles is calculated by VKT of the stock of personal vehicles and their type, fuel and efficiency characteristics.
- Personal mobility sub-model is one of the core components of the model. It influences and produces important model outputs:
    - Total transportation energy consumption by fuel, including electricity consumption
    - Active trips and transit trips, by zone distance.

Trips accounted for in the model are displayed in Figure 4.

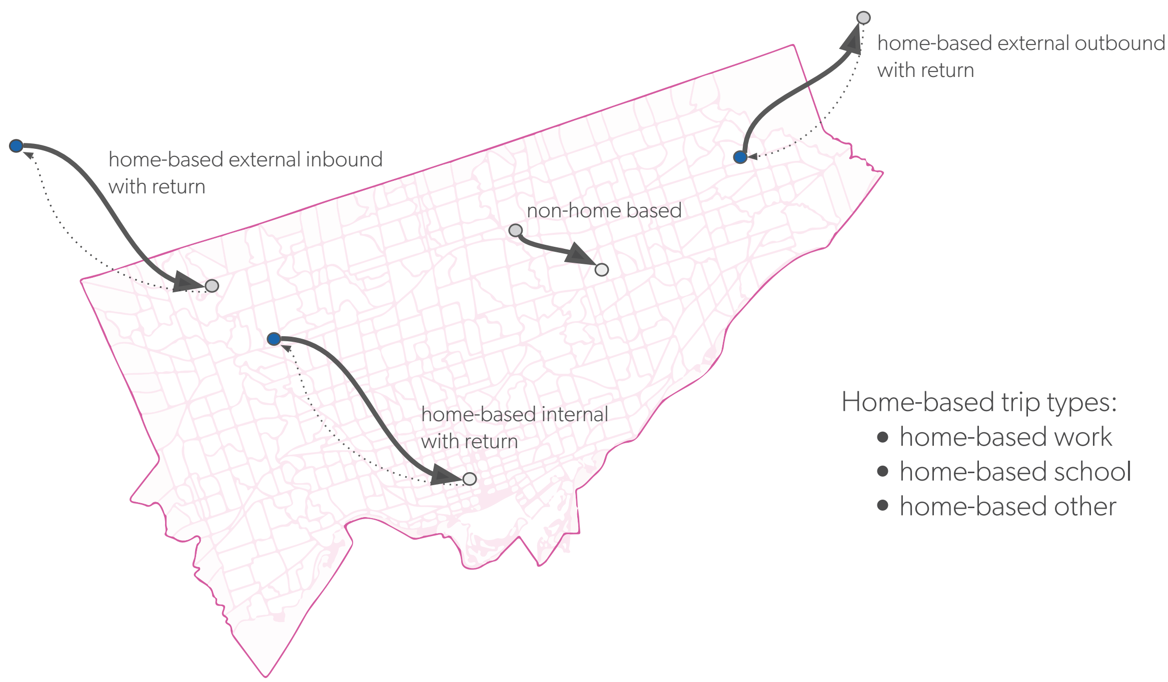


Figure 4. Trips assessed in the personal mobility sub-model.

Google Environmental Insights Explorer (EIE) data is used to inform average trip length for internal (6 km) and cross boundary trips (19 km outbound, 20 km inbound).

WASTE

Households and non-residential buildings generate solid waste and wastewater, and the model traces various pathways to disposal, compost and sludge. If present in the city, the model can also capture energy recovery from incineration and biogas. Waste generation is translated to landfill emissions based on first order decay models of carbon to methane.

LOCAL ENERGY PRODUCTION

The model accounts for energy generated within city boundaries. Energy produced from local sources (e.g., solar, wind, biomass) is modelled alongside energy imported from other resources (e.g., the electricity grid and the natural gas distribution system). The model accounts for conversion efficiency. Local energy generation can be spatially defined.

FINANCIAL AND EMPLOYMENT IMPACTS

Energy related financial flows and employment impacts are captured through an additional layer of model logic. Costs are calculated as new stock is incorporated into the model, through energy flows (annual fuel costs), as well as other operating and maintenance costs. Costs are based on a suite of assumptions that are input into the model. See Section 6 for financial variables tracked within the model.

Employment is calculated based on non-residential building archetypes and their floor area. Employment related to investments are calculated using standard employment multipliers, often expressed as person-years of employment per million dollars of investment.

Energy and GHG Emissions Accounting

CityInSight accounts for the energy flows through the model, as shown in Figure 6.

Source fuels crossing the geographic boundary of the city are shown on the left. The four "final demand" sectors—residential, commercial, industrial, and transportation—are shown towards the right. Some source fuels are consumed directly in the final demand sectors (e.g., natural gas used by furnaces for residential heating, gasoline used by personal vehicles for transportation). Other source fuels are converted to another energy carrier before consumption in the final demand sectors (e.g., solar energy converted to electricity via photovoltaic cells, natural gas combusted in heating plants and the resulting hot water distributed to end use buildings via district energy networks). Finally, efficiencies of the various conversion points (end uses, local energy production) are estimated to split flows into either "useful" energy or conversion losses at the far right side of the diagram.

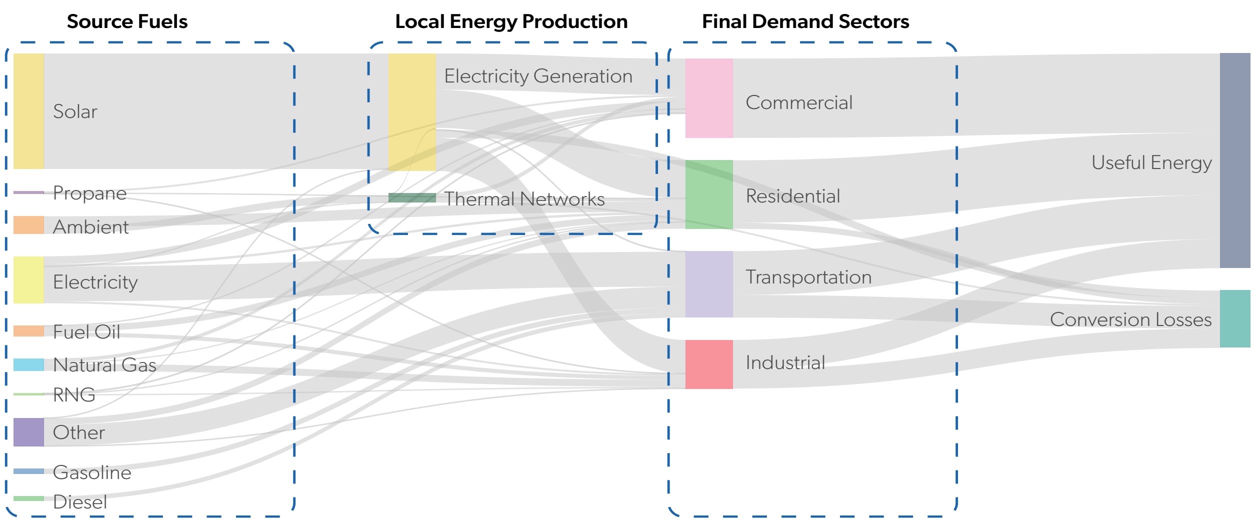


Figure 5. Energy flow Sankey diagram showing main node groups

Figure 5 above shows the potential for ambiguity when energy is reported: which of the energy flows circled are included and how do you prevent double counting? To address these ambiguities, CityInSight defines two main energy reports:

- Energy Demand, shown in Figure 5. Energy Demand includes the energy flows just before the final demand sectors (left of the dotted red line). Where the demand sectors are supplied by local energy production nodes, the cut occurs after the local energy production and before demand.
- Energy Supply, shown in Figure 6. Energy Supply includes the energy flows just after the source fuel nodes (left of the dotted red line). Where the source fuels supply local energy production nodes, the cut occurs between the source fuels and local energy production.

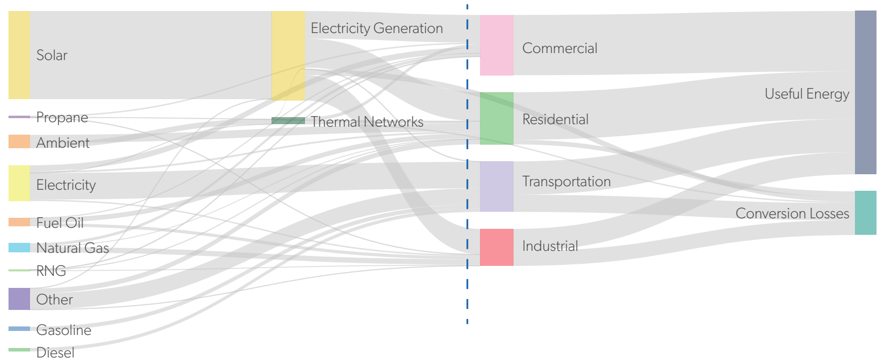


Figure 6. Energy Demand report definition

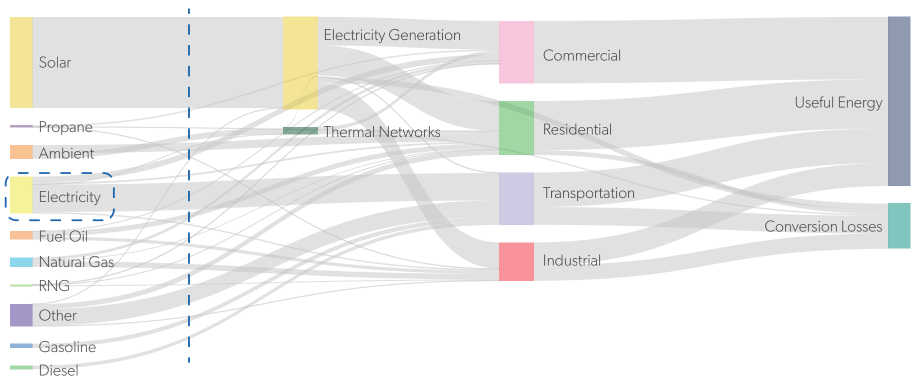


Figure 7. Energy Supply report definition.

In the integrated CityInSight energy and emissions accounting framework, GHG emissions are calculated after energy consumption is known.

Financial Accounting

The model also has a financial dimension expressed for most of its stocks and flows. Costs and savings modelling considers:

- Upfront capital expenditures: this is related to new stocks, such as new vehicles or new building equipment.
- Operating and maintenance costs: Annualized costs associated with stocks, such as vehicle maintenance.
- Energy costs: this is related to energy flows in model, accounting for fuel and electricity costs, and
- Carbon pricing: Calculated by on emissions generation.

Expenditure types that are evaluated in the model are summarized in Table 6.

Table 6. Categories of expenditures.

CATEGORY	DESCRIPTION
Residential buildings	Cost of dwelling construction and retrofitting; operating and maintenance costs (non-fuel).
Residential equipment	Cost of appliances and lighting, heating and cooling equipment.
Residential fuel	Energy costs for dwellings and residential transportation.
Residential emissions	Costs resulting from a carbon price on GHG emissions from dwellings and transportation.
Commercial buildings	Cost of building construction and retrofitting; operating and maintenance costs (non-fuel).
Commercial equipment	Cost of lighting, heating and cooling equipment.
Commercial vehicles	Cost of vehicle purchase; 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.
Municipal capital	Cost of the transit system additions (no other forms of municipal capital assessed).
Municipal fuel	Cost of fuel associated with the transit system.
Municipal emissions	Costs resulting from a carbon price on GHG emissions from the transit system.
Energy production revenue	Revenue derived from the sale of locally generated electricity or heat.
Personal use vehicles	Cost of vehicle purchase; operating and maintenance costs (non-fuel).
Transit fleet	Costs of transit vehicle purchase.
Active transportation infrastructure.	Costs of bike lane and sidewalk construction.

FINANCIAL REPORTING PRINCIPLES

The financial analysis is guided by the following reporting principles:

1. Sign convention: Costs are negative, revenue and savings are positive.
2. The financial viability of investments will be measured by their net present value.
3. All cash flows are assumed to occur on the last day of the year and for purposes of estimating their present value in Year 1 will be discounted back to time zero (the beginning of Year 1). This means that even the initial capital outlay in Year 1 will be discounted by a full year for purposes of present value calculations.
4. We will use a discount rate of 3% in evaluating the present value of future government costs and revenues.
5. Each category of stocks will have a different investment horizon
6. Any price increases included in our analysis for fuel, electricity, carbon, or capital costs will be real price increases, net of inflation.
7. Where a case can be made that a measure will continue to deliver savings after its economic life (e.g. after 25 years in the case of the longest lived measures), we will capitalize the revenue forecast for the post-horizon years and add that amount to the final year of the investment horizon cash flow.
8. In presenting results of the financial analysis, results will be rounded to the nearest thousand dollars, unless additional precision is meaningful.
9. Only actual cash flows will be included in the financial analysis.

Inputs and Outputs

The model relies on a suite of assumptions that define the various stocks and flows within the model for every time-step (year) in the model.

BASE YEAR

For the baseline year, many model inputs come from calibrating the model with real energy datasets. This includes real building and transportation fuel data, city data on population, housing stock and vehicle stock etc. Other assumptions come from underlying relationships between energy stocks and flows identified through research, like the fuel efficiency of personal vehicles, the efficiency of solar PV.

FUTURE PROJECTIONS

CityInSight is designed to project how the energy flow picture and emissions profile will change in the long term by modelling potential change in:

- the context (e.g. population, development patterns),
- emissions reduction actions (that influence energy demand and the composition of stocks).

Potential changes in the system are also based on a suite of input assumptions, and are frequently referred to as “actions”. Actions are an intervention point in the model that changes the relationship between a certain stock and flow at a certain time. Action assumptions can be based on existing projections and on proposed policy design, and can be as wide ranging the stocks and flows present in the model.

Stock-turnover models enable users to directly address questions about the penetration rates of new technologies over time constrained by assumptions such as new stock, market shares and stock retirements. Examples of outputs of the projections include energy mix, mode split, vehicle kilometres of travel (VKT), total energy costs, household energy costs, GHG emissions and others. Energy, emissions, capital and operating costs are outputs for each scenario. The emission and financial impacts of alternative climate mitigation scenarios are usually presented relative to a reference or "business as planned" scenario.

For example, an action may assume: "Starting in 2030, all new personal vehicles are electric." This assumption would be input into the model, where, starting in 2030, every time a vehicle is at the end of its life, rather than be replaced with an internal combustion engine vehicle, it is replaced with an electric vehicle. As a result, the increase in the electric vehicle stock means greater VKT allocated to electricity and less to gasoline, thereby resulting in lower emissions.

Spatial Disaggregation

As noted above, a key feature of CityInSight is the geocoded stocks and flows that underlie the energy and emissions in the community. All buildings and transportation activities are tracked within a discrete number of geographic zones, specific to the city. 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 points in the study horizon. CityInSight outputs can be integrated with city mapping and GIS systems. This is the feature that allows CityInSight to support the assessment of a variety of urban climate mitigation strategies that are out of reach of more aggregate representations of the energy system. Some examples include district energy, microgrids, combined heat and power, distributed energy, personal mobility (the number, length and mode choice of trips), local supply chains, and EV infrastructure.

For stationary energy use, the foundation for the spatial representation consists of land use, zoning and property assessment databases routinely maintained by municipal governments. These databases have been geocoded in recent years and contain detailed information about the built environment that is useful for energy analysis.

For transportation energy use and emissions, urban transportation survey data characterizes personal mobility by origin, destination, trip time, and trip purpose. This in turn supports the spatial mapping of personal transportation energy use and greenhouse gas emissions by origin or destination.

Modelling Process

CityInSight is designed to support the process of developing a municipal strategy for greenhouse gas mitigation. Usually the model is engaged to identify a pathway for a community to meet a greenhouse gas emissions target by a certain year, or to stay within a cumulative carbon budget over a specified period.

Data Collection, Calibration and Baseline

A typical CityInSight engagement begins with an intensive data collection and calibration exercise in which the model is systematically populated with data on a wide range of stocks and flows in the community that affect greenhouse gas emissions. A picture literally emerges from this data that begins to identify where opportunities for climate change mitigation are likely to be found in the community being modeled. The calibration and inventory exercise helps establish a common understanding among community stakeholders about how the greenhouse gas emissions in their community are connected to the way they live, work and play. Relevant data are collected for variables that drive energy and emissions—such as characteristics of buildings and transportation technologies—and those datasets are reconciled with observed data from utilities and other databases. The surface area of buildings is modeled in order to most accurately estimate energy performance by end-use. Each building is tracked by vintage, structure and location, and a similar process is used for transportation stocks. Additional analysis at this stage includes local energy generation, district energy and the provincial electricity grid. The primary outcome of this process is an energy and GHG inventory for the baseline year, with corresponding visualizations.

The Base Year and Reference Projection

Once the baseline is completed, a reference projection to the target year or the horizon year of the scenario exercise is developed. The reference projection is based on a suite of input assumptions into the model that reflect the future conditions. This is often based on: existing municipal projections, for buildings and population; historical trends in stocks that can be determined during model calibration. In particular, future population and employment and allocating the population and employment to building types and space. In the process the model is calibrated against historical data, providing a technology stock as well as an historical trend for the model variables. This process ensures that the demographics are consistent, that the stocks of buildings and their energy consumption are consistent with observed data from natural gas and electricity utilities, and that the spatial/zonal system is consistent with the municipality's GIS and transportation modelling.

The projection typically includes approved developments and official plans in combination with simulation of committed energy infrastructure to be built, existing regulations and standards (for example renewable energy and fuel efficiency) and communicated policies. The projection incorporates conventional assumptions about the future development of the electrical grid, uptake of electric vehicles, building code revisions, changes in climatic conditions and other factors. The resulting projection serves as a reference line against which the impact and costs of GHG mitigation measures can be measured. Sensitivity analysis and data visualizations are used to identify the key factors and points of leverage within the reference projection.

Low-Carbon Scenario and Action Plan

The low-carbon scenario uses a new set of input assumptions to explore the impacts of emissions reduction actions on the emissions profile. Often this begins with developing a list of candidate measures for climate mitigation in the community, supplemented by additional measures and strategies that are identified through stakeholder engagement. For many actions, CityInSight draws on an in-house database that specifies the performance and cost of technologies and measures for greenhouse gas abatement. The low carbon scenario is analyzed relative to the reference projection. The actions in the low carbon scenario are together to ensure that there is no double counting and that interactive effects of the proposed measures are captured in the analysis.

Addressing Uncertainty

There is extensive discussion of the uncertainty in models and modelling results. The assumptions underlying a model can be from other locations or large data sets and do not reflect local conditions or behaviours, and even if they did accurately reflect local conditions, it is exceptionally difficult to predict how those conditions and behaviours will respond to broader societal changes and what those broader societal changes will be (the “unknown unknowns”).

The modelling approach identifies four strategies for managing uncertainty applicable to community energy and emissions modelling:

6. Sensitivity analysis: From a methodological perspective, one of the most basic ways of studying complex models is sensitivity analysis, quantifying uncertainty in a model’s output. To perform this assessment, each of the model’s input parameters is described as being drawn from a statistical distribution in order to capture the uncertainty in the parameter’s true value (Keirstead, Jennings, & Sivakumar, 2012).
    - Approach: Each of the variables will be increased by 10-20% to illustrate the impact that an error of that magnitude has on the overall total.
7. Calibration: One way to challenge the untested assumptions is the use of ‘back-casting’ to ensure the model can ‘forecast’ the past accurately. The model can then be calibrated to generate historical outcomes, which usually refers to "parameter adjustments" that "force" the model to better replicate observed data.
    - Approach: Variables for which there are two independent sources of data are calibrated in the model. For example, the model calibrates building energy use (derived from buildings data) against electricity data from the electricity distributor.
8. Scenario analysis: Scenarios are used to demonstrate that a range of future outcomes are possible given the current conditions that no one scenario is more likely than another.
    - Approach: The model will develop a reference scenario.
9. Transparency: The provision of detailed sources for all assumptions is critical to enabling policy-makers to understand the uncertainty intrinsic in a model.
    - Approach: The assumptions and inputs are presented in this document.

Business-as-Planned Scenario Assumptions

CATEGORY	ASSUMPTION	SOURCE
DEMOGRAPHICS		
Population & employment		
Population	2.6% growth from 1996-2016, convert to annual growth rate	2016 Statistics Canada Census for 2016 population Growth rate from historical Census data
Employment	2001-2016 has 1.26% growth in employment, carry this trend forward	Employment by sector from NAICS data for Colchester
Households	Based on current development agreements, there is approximately 300 units being developed in the next 2 years. Number of households tracks on number of dwelling units.	2016 Statistic Canada Census, and Municipality of the County of Colchester
Vehicles	Vehicle stock grows with population. Number of vehicles per household is kept constant.	CANSIM and Natural Resources Canada's Demand and Policy Analysis Division.
LAND USE		
Spatial distribution	Continue current development trajectories. Zones specified for both residential and commercial growth.	Municipality of the County of Colchester
Dwelling size	Baseline dwelling sizes maintained.	Dwelling size and type from PVSC and from Colchester
Building type mix	New buildings type mix ratios reflect baseline building mixes.	Dwelling size and type from PVSC and from Colchester
BUILDINGS		
New buildings energy performance		
Residential	2% improvement to EUI every 5 years for all building types in res and nonRes sectors	Comparison with other jurisdictions in Nova Scotia
Multi-residential		
Commercial & Institutional		
Industrial		
Municipal		
Existing buildings energy performance		
Residential	Existing building stock efficiency remains constant	Pembina, Pathway Study on Existing Residential Buildings in Ottawa, 2019 (at 22).

CATEGORY	ASSUMPTION	SOURCE
Multi-residential		
Commercial & Institutional		
Industrial		
Municipal		
End use		
Space heating	Current instances of heat pump use is extrapolated.	*http://www.caness.ca*
Water heating	Current instances of water heater technology use is extrapolated.	
Space cooling	Current space cooling technology use is extrapolated	
Projected climate impacts		
Heating & cooling degree days	Heating Degree days are expected to decrease, and cooling degree days will increase	*Climateatlas.ca*, RCP 8.5
ENERGY GENERATION		
Low- or zero-carbon energy generation (community scale)		
Rooftop Solar PV	Current instances of solar PV use held constant. Current instance (2016): 0.02 MW Capacity added 2017: 0.04 MW 2018: 0.05 MW 2019 0.3 0MW 2020 and forward: 0.25 MW/year	Nova Scotia Power
Ground mount solar	No new capacity added	Nova Scotia Power
Biomass	None	N/A
District Energy Generation	Dalhousie Agricultural Campus	Details of facility provided by Dalhousie University
Wind	Current instances of wind generation held constant. Current instance (2016): 0.03 MW	Nova Scotia Power
Energy procurement		
Renewable Electricity Procurement	No additional beyond what is already grid-supplied.	N/A
TRANSPORTATION		
Transit		

CATEGORY	ASSUMPTION	SOURCE
Expanded transit	Current Colchester Transportation Cooperative Limited use and capacity held constant	Colchester Transportation Cooperative Limited fuel use data used to calculate emissions and energy use
Electrify transit system	No electrification	Decision made by project team
Active		
Mode share	active mode share held constant from base year 0.10 of 0 - 2 km trips are walking 0.10 of 2 - 5 km trips are biking	Decision made by project team
Private/personal use		
Electrify municipal fleet	No electrification	Municipal fleet data provided by Colchester
Electrify personal vehicles	14% new sales by 2029	Axsen, J., Wolinetz, M. (2018). Reaching 30% plug-in vehicle sales by 2030: Modeling incentive and sales mandate strategies in Canada. Transportation Research Part D: Transport and Environment Volume 65, Pages 596-617
Electrify commercial vehicles	14% new sales by 2029	Axsen, J., Wolinetz, M. (2018). Reaching 30% plug-in vehicle sales by 2030: Modeling incentive and sales mandate strategies in Canada. Transportation Research Part D: Transport and Environment Volume 65, Pages 596-617

CATEGORY	ASSUMPTION	SOURCE
Vehicle fuel efficiencies / tailpipe emission standards	CAFE Fuel standards: 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. ------ Light duty: 2015: 200gCO_2e/km 2025: 119 gCO_2e/km 2030: 105gCO_2e/km Heavy Duty: 20% reduction in emissions intensity by 2025, relative to 2015, 24% reduction in emissions intensity in 2030 relative to 2015	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* *SOR/2010-201*. Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations. Available from: *http://laws-lois.justice.gc.ca* *SOR/2018-98*. Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations and other Regulations Made Under the Canadian Environmental Protection Act, 1999. Available from: *https://pollution-waste.canada.ca*
Vehicle stock	Personal and commercial vehicle stock share in base year to hold constant to 2050, growing with population and employment to 2050.	CANSIM and Natural Resources Canada's Demand and Policy *Analysis Division.*
MARINE, RAIL, & AVIATION		
Marine	No change in fuel use	Statistics Canada Table: 25-10-0029-01 (formerly CANSIM 128-0016) Geography: Nova Scotia Final demand sectors: Railways Provincial data will be allocated to region on the basis of population by default
Rail	No change in fuel use	Statistics Canada Table: 25-10-0029-01 (formerly CANSIM 128-0016) Geography: Nova Scotia Final demand sectors: Railways Provincial data will be allocated to region on the basis of population by default

CATEGORY	ASSUMPTION	SOURCE
Aviation	No change in fuel use	Statistics Canada Table: 25-10-0029-01 (formerly CANSIM 128-0016) Geography: Nova Scotia Final demand sectors: Total Airlines Provincial data will be allocated to region on the basis of population by default
WATER AND WASTEWATER		
Increase pumping efficiency	Current intensity held constant.	Municipality of the County of Colchester
Increase water efficiency	Current intensity held constant.	
Wastewater treatment		
WASTE		
Waste generation	Current waste generation rates held constant	Colchester Solid Waste Management; Municipality of the County of Colchester
Waste diversion	Current waste diversion rates held constant	
Waste treatment	No change to waste treatment	
RNG capture and use	None	N/A
AGRICULTURE		
Agricultural practices	No change from current practices	2016 Census of Agriculture
Off-road fuel use	No change from current practices	Comprehensive Energy Use Database, Office of Energy Efficiency, Natural Resources Canada and Statistics Canada.
Agricultural Industry Fuel Shift	No change from current practices	Comprehensive Energy Use Database, Office of Energy Efficiency, Natural Resources Canada and Statistics Canada. scaled to Colchester using GDP from Statistics Canada. Table 36-10-0402-01 Gross domestic product (GDP) at basic prices, by industry, provinces and territories (x 1,000,000)
INDUSTRY		
Major industry energy use	No change from current practices	NPRI data for Lafarge Cement Plant
Carbon storage	No change from current practices	Decision made by project team
Industrial efficiencies	No change from current practices	Decision made by project team

Low-carbon Scenario Assumptions

CATEGORY	ASSUMPTION	SOURCE
DEMOGRAPHICS		
Population & employment		
Population	Same as BAP assumptions	Decision made by project team to facilitate comparison of scenarios
Employment	Same as BAP assumptions	
Households	Same as BAP assumptions	
Vehicles	Same as BAP assumptions	
LAND USE		
Spatial distribution	80% of residential development in selected development zones, 100% of non-residential development in selected development zones	Development zones for modelling purposes were chosen in consultation with the project team. Consultation with the community and broader stakeholders would be undertaken before development zones would be officially selected for planning purposes.
Dwelling size	Current dwelling size mix held constant	PVSC and Colchester
Building type mix	Decrease the share of new buildings that are single family homes to 10% by 2030 in development nodes, 85% in remaining nodes.	Decision made by project team
BUILDINGS		
New buildings energy performance		
Residential	New buildings are net-zero by 2030.	Current model National Building Code and National Energy Building Code 2020 (delayed until at least December 2021) proposes buildings be net-zero ready by 2030. (Net Zero Energy Ready (NZER) is a highly energy efficient building that minimizes energy use such that on-site or community renewables or energy from a clean grid can be used to reach NZE.) NZER is achieved using a mandatory step code, starting in 2022.
Multi-residential		
Commercial & Institutional		

CATEGORY	ASSUMPTION	SOURCE
Industrial		
Municipal		
Existing buildings energy performance		
Residential	Achieve 50% thermal savings and 50% electrical savings in 80% of all existing dwellings by 2040.	Studies undertaken by the US National Renewable Energy Laboratory and the Rocky Mountain Institute indicate that retrofits achieving far more than 50% in energy savings are possible, and that the deeper and more systemic the retrofits, the more affordable they become.
Multi-residential		
Commercial & Institutional		
Industrial		
Municipal	100% of all existing municipal buildings achieve net zero by 2035.	
End use		
Space heating	100% of buildings' space heating needs are met by electric systems by 2040.	To ensure net-zero by 2050, no fossil-fuelled heating systems can be purchased that might still be in use by 2050. In addition, air source heat pumps offer the most efficient use of energy for cooling and heating.
Water heating	100% of buildings' water heating needs are met by electric systems by 2040.	
Space cooling	100% of buildings' space cooling needs are met by electric systems by 2040.	
Projected climate impacts		
Heating & cooling degree days	Held constant with BAP assumptions	*Climateatlas.ca*, RCP 8.5
ENERGY GENERATION		
Low- or zero-carbon energy generation (community scale)		
Rooftop Solar PV	90% of new buildings have solar PV installed by 2050, supplying 50% of the buildings' electric load. By 2050 all retrofitted buildings have solar PV installed, supplying 50% of the buildings electric load	Municipality of the County of Colchester and project team
Ground mount solar	10MW installed capacity from 2030 to 2045	Municipality of the County of Colchester and project team

CATEGORY	ASSUMPTION	SOURCE
District Energy Generation	Install DE biomass system at the hospital/retirement home and school in Tatamagouche similar to the system at Dalhousie University	Municipality of the County of Colchester and project team
Wind	Install 2 MW/year wind turbines	Municipality of the County of Colchester and project team
Renewable electricity storage	6% performance improvement per year of both wind and solar technologies, this added capacity is handled as storage with a capacity factor of 0.1125	Municipality of the County of Colchester and project team
Energy procurement		
Renewable electricity procurement	Replace 100% of the remaining grid electricity with green electricity by 2050.	Municipality of the County of Colchester and project team
TRANSPORTATION		
Transit		
Expanded transit	shift 10% of the Personal Use Vehicle between designated nodes to transit/car-share	Municipality of the County of Colchester and project team
Electrify transit system	100% of vehicles electric and right-sized fleet by 2035.	Municipality of the County of Colchester and project team
Active		
Mode share	Double walk/bike share from BAP	Municipality of the County of Colchester and project team
Private/personal use		
Electrify municipal fleet	100% electric by 2030.	Municipality of the County of Colchester and project team
Electrify personal vehicles	30% of market share by 2030, 60% by 2035, 100% by 2040.	Municipality of the County of Colchester and project team
Electrify commercial vehicles	30% of market share by 2030, 60% by 2035, 100% by 2040.	Municipality of the County of Colchester and project team

CATEGORY	ASSUMPTION	SOURCE
Vehicle fuel efficiencies / tailpipe emission standards	CAFE Fuel standards: 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. ------ Light duty: 2015: 200gCO_2e/km 2025: 119 gCO_2e/km 2030: 105gCO_2e/km Heavy Duty: 20% reduction in emissions intensity by 2025, relative to 2015, 24% reduction in emissions intensity in 2030 relative to 2015	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* *SOR/2010-201*. Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations. Available from: http://laws-lois.justice.gc.ca SOR/2018-98. Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations and other Regulations Made Under the Canadian Environmental Protection Act, 1999. Available from: *https://pollution-waste.canada.ca*
Vehicle stock	Personal and commercial vehicle stock share in base year to hold constant to 2050, growing with population and employment to 2050.	CANSIM and Natural Resources Canada's Demand and Policy Analysis Division.
MARINE, RAIL, & AVIATION		
Marine	Shift 50% of the diesel fuel use to electric	International Marine Organization commitment, halving emissions by 2050 as compared to a 2008 baseline (S&P Global, 'Your climate change goals may have a maritime shipping problem' at: *https://www.spglobal.com/esg/insights/your-climate-change-goals-may-have-a-maritime-shipping-problem)*
Rail	Shift rail fuel to Hydrogen by 2040	CP piloting hydrogen trains, and rail industry trends are investigating hydrogen for freight transport. *https://www.nrcan.gc.ca/climate-change/hydrogen-opportunities-key-findings/23104*

CATEGORY	ASSUMPTION	SOURCE
Aviation	*100% net zero by 2050 - Air Canada commits*	Air Canada committed to be 100% Net-Zero by 2050; International Civil Aviation Organization has also begun to track net-zero aligned commitments by airlines and airports: *https://www.icao.int/environmental-protection/SAC/Pages/Aviation-net-zero.aspx* (e.g., Jet Blue has set a target of net-zero by 2040)
WATER AND WASTEWATER		
Increase pumping efficiency	Upgrade to high efficiency pumps by 2035 (-50% energy use)	Ontario Achievable Potential Study, Newfoundland Achievable Conservation Potential Study
Increase water efficiency	Decrease water volume use by 1%/year to 2050.	Municipality of the County of Colchester and project team
WASTE		
Waste generation	Reduce generation 30% by 2050	Municipality of the County of Colchester and project team
Waste diversion	100% diversion by 2050, 100% organics to anaerobic digestion	Municipality of the County of Colchester and project team
RNG capture and use	Installation of anaerobic digestion facilities for waste water treatment and biogas capture for use as renewable natural gas in the industry sector. RNG produced will displace propane used for space heating in industrial buildings	Municipality of the County of Colchester and project team
AGRICULTURE		
Agricultural practices	30% decrease in livestock emissions to account for improvement in livestock breeding, feed sources, manure management	McKinsey & Company: Agriculture and Climate Change, reducing emissions through improved farming practices
Off-road fuel use	Switch 70% of the offRoad fossil fuel use to electric by 2040 (off-road vehicles include recreational vehicles, airport and rail maintenance vehicles)	Decision made by project team
Agricultural Industry Fuel Shift	Switch agriculture industrial end uses - motive and process heat - to electricity by 2050. Motive: farming equipment and tractors	Decision made by project team
INDUSTRY		
Major industry energy use	Fuel switch from petroleum coke to tires (50% of the feed) 10% efficiency gain	Fuel Switch: Lafarge Holciem Inc. Efficiency gain: decision made by project team

CATEGORY	ASSUMPTION	SOURCE
Carbon storage	Carbon capture at Lafarge - assuming 100% by 2050	Lafarge Holciem Inc.
Industrial efficiencies	50% efficiency improvement in all industrial processes except cement	Studies undertaken by the US National Renewable Energy Laboratory and the Rocky Mountain Institute indicate that retrofits achieving far more than 50% in energys savings are possible, and that the deeper and more systemic the retrofits, the more affordable they become.

Appendix B: Detailed modelling results

Community Energy and Emissions

Table 1. Community energy use, Colchester.

ENERGY BY END USE (GJ)	2016	SHARE 2016	2050 (BAU)	SHARE 2050	2050 LCS	SHARE 2050	% +/- 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Industrial Processes	1,909,406	29%	1,930,445	34%	1,303,565	42%	-32%	-32%
Lighting	146,950	2%	155,449	3%	96,867	3%	-34%	-38%
Major Appliances	123,976	2%	138,147	2%	90,813	3%	-27%	-34%
Plug Load	205,985	3%	213,726	4%	133,242	4%	-35%	-38%
Space Cooling	53,778	1%	85,060	2%	27,025	1%	-50%	-68%
Space Heating	1,544,160	24%	1,210,898	21%	588,682	19%	-62%	-51%
Transportation	2,342,466	36%	1,772,677	31%	811,256	26%	-65%	-54%
Water Heating	161,428	2%	143,145	3%	57,266	2%	-65%	-60%
Total	6,488,150	100%	5,649,549	100%	3,108,716	100%	-52%	-45%
Energy by fuel (GJ)	2016	share 2016	2050 (BAU)	share 2050	2050 LCS	share 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Cement Fuel	952,791	15%	963,263	17%	866,173	28%	-9%	-10%
Diesel	1,347,983	21%	1,271,422	23%	101,338	3%	-92%	-92%
District Energy	22,800	0%	19,794	0%	17,717	1%	-22%	-10%
Electricity Procurement	0	0%			463,956	15%	100%	
Fuel Oil	814,777	13%	544,945	10%	25,306	1%	-97%	-95%

ENERGY BY END USE (GJ)	2016	SHARE 2016	2050 (BAU)	SHARE 2050	2050 LCS	SHARE 2050	% +/- 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Gasoline	1,560,074	24%	1,031,306	18%	102,158	3%	-93%	-90%
Grid Electricity	1,196,836	18%	1,282,110	23%	12	0%	-100%	-100%
Hydrogen	0	0%	0	0%	137,460	4%	100%	
Local Electricity	75,466	1%	112,545	2%	944,956	30%	1152%	740%
Other	0	0%	0	0%	347,818	11%	100%	
Propane	213,518	3%	193,067	3%	3,010	0%	-99%	-98%
RNG	0	0%	0	0%	36,955	1%	100%	
Wood	303,905	5%	231,096	4%	61,856	2%	-80%	-73%
Total	6,488,150	100%	5,649,549	100%	3,108,716	100%	-52%	-45%
Energy by sector (GJ)	2016	share 2016	2050 (BAU)	share 2050	2050 LCS	share 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Agriculture	647,469	10%	653,550	12%	172,444	6%	-73%	-74%
Commercial	677,078	10%	635,378	11%	190,132	6%	-72%	-70%
Industrial	1,372,481	21%	1,389,170	25%	1,200,835	39%	-13%	-14%
Municipal	49,838	1%	50,309	1%	30,227	1%	-39%	-40%
Residential	1,398,817	22%	1,148,464	20%	703,821	23%	-50%	-39%
Transportation	2,342,466	36%	1,772,677	31%	811,256	26%	-65%	-54%
Total	6,488,150	100%	5,649,549	100%	3,108,716	100%	-52%	-45%
Per capita energy (GJ/cap)	172		144		34		-41%	-76%

Table 2. Table B2. Community GHG emissions, Colchester.

EMISSIONS BY SECTOR (TCO_2E)	2016	SHARE 2016	2050 (BAU)	SHARE 2050	2050 LCS	SHARE 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Agriculture	103,089	12%	96,002	16%	33,988	50%	-67%	-65%
Commercial	93,554	0%	50,568	8%	196	0%	-100%	-100%
Energy Production	71	31%	71	0%	89	0%	26%	26%
Industrial	251,837	19%	226,542	37%	6,207	9%	-98%	-97%
Residential	154,692	22%	82,167	13%	286	0%	-100%	-100%
Transportation	174,867	4%	137,312	22%	14,943	22%	-91%	-89%
Waste	33,822	100%	23,717	4%	11,715	17%	-65%	-51%
Total	811,932	0%	616,379	100%	67,425	100%	-92%	-89%
Emissions by source (tCO_2e)	2016	share 2016	2050 (BAU)	share 2050	2050 LCS	share 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Cement Fuel	99,308	12%	100399.7	0	4,418	7%	-96%	-96%
Cement Process	99,314	12%	99,314	16%	85	0%	-100%	-100%
Diesel	59,483	7%	53,611	9%	7,954	12%	-87%	-85%
Fuel Oil	98,265	12%	79,470	13%	1,854	3%	-98%	-98%
Gasoline	104,413	13%	69245.291	0.112342142	6,988	10%	-93%	-90%
Grid Electricity	238,825	29%	115,336	19%	1	0%	-100%	-100%
Jet Fuel	10,966	1%	10,966	2%	0	0%	-100%	-100%
Livestock	48,552	6%	48,552	8%	33,986	50%	-30%	-30%
Propane	13,059	2%	11,808	2%	184	0%	-99%	-98%
RNG	0	0%	0	0%	11	0%	100%	
Waste	33,822	4%	23,717	4%	11,715	17%	-65%	-51%

EMISSIONS BY SECTOR (TCO_2E)	2016	SHARE 2016	2050 (BAU)	SHARE 2050	2050 LCS	SHARE 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Wood	5,925	1%	3,959	1%	227	0%	-96%	-94%
Total	811,932	100%	616,379	100%	67,425	100%	-92%	-89%
Per capita emissions (tCO_2eJ/cap)	21		15		1.7		-29%	-89%

Buildings Energy and Emissions

Table 3. Buildings energy use, Colchester

ENERGY BY SECTOR (GJ)	2016	SHARE 2016	2050 (BAU)	SHARE 2050	2050 LCS	SHARE 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Agriculture	647,469	16%	653,550	17%	172,444	8%	-73%	-74%
Commercial	677,078	16%	635,378	16%	190,132	8%	-72%	-70%
Industrial	1,372,481	33%	1,389,170	36%	1,200,835	52%	-13%	-14%
Municipal	49,838	1%	50,309	1%	30,227	1%	-39%	-40%
Residential	1,398,817	34%	1,148,464	30%	703,821	31%	-50%	-39%
Total	4,145,683	100%	3,876,872	100%	2,297,459	100%	-45%	-41%
Energy by end use (GJ)	2016	share 2016	2050 (BAU)	share 2050	2050 LCS	share 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Industrial Processes	1,909,406	46%	1,930,445	50%	1,303,565	57%	-32%	-32%
Lighting	146,950	4%	155,449	4%	96,867	4%	-34%	-38%
Major Appliances	123,976	3%	138,147	4%	90,813	4%	-27%	-34%
Plug Load	205,985	5%	213,726	6%	133,242	6%	-35%	-38%
Space Cooling	53,778	1%	85,060	2%	27,025	1%	-50%	-68%

ENERGY BY SECTOR (GJ)	2016	SHARE 2016	2050 (BAU)	SHARE 2050	2050 LCS	SHARE 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Space Heating	1,544,160	37%	1,210,899	31%	588,682	26%	-62%	-51%
Water Heating	161,428	4%	143,145	4%	57,266	2%	-65%	-60%
Total	4,145,683	100%	3,876,872	100%	2,297,459	100%	-45%	-41%
Energy by fuel (GJ)	2016	share 2016	2050 (BAU)	share 2050	2050 LCS	share 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Cement Fuel	952,791	23%	963,263	25%	866,173	38%	-9%	-10%
Diesel	565,616	14%	570,863	15%	0	0%	-100%	-100%
District Energy	22,800	1%	19,794	1%	17,717	1%	-22%	-10%
Electricity Procurement	0	0%	0	0%	274,777	12%	100%	
Fuel Oil	814,777	20%	544,946	14%	25,306	1%	-97%	-95%
Grid Electricity	1,196,812	29%	1,243,318	32%	7	0%	-100%	-100%
Local Electricity	75,465	2%	110,525	3%	663,840	29%	780%	501%
Other	0	0%	0	0%	347,818	15%	100%	
Propane	213,518	5%	193,067	5%	3,010	0%	-99%	-98%
RNG	0	0%			36,955	2%	100%	
Wood	303,905	7%	231,096	6%	61,856	3%	-80%	-73%
Total	4,145,683	100%	3,876,872	100%	2,297,459	100%	-45%	-41%

Table 4. Buildings GHG emissions, Colchester

EMISSIONS BY END USE (TCO_2E)	2016	SHARE 2016	2050 (BAU)	SHARE 2050	2050 LCS	SHARE 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Industrial Processes	143,850	35%	123,224	46%	6,122	93%	-96%	-95%
Lighting	26,411	6%	12,337	5%	0	0%	-100%	-100%
Major Appliances	23,304	6%	11,361	4%	0	0%	-100%	-100%
Plug Load	38,856	9%	17,901	7%	181	3%	-100%	-99%
Space Cooling	10,322	2%	7,292	3%	0	0%	-100%	-100%
Space Heating	155,438	37%	84,423	32%	255	4%	-100%	-100%
Water Heating	16,845	4%	10,220	4%	33	0%	-100%	-100%
Total	415,026	100%	266,759	100%	6,591	100%	-98%	-98%
Emissions by source (tCO_2e)	2016	share 2016	2050 (BAU)	share 2050	2050 LCS	share 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Cement Fuel	99,308	24%	100,400	38%	4,418	67%	-96%	-96%
Fuel Oil	57,985	14%	38,816	15%	1,839	28%	-97%	-95%
Grid Electricity	238,820	58%	111,846	42%	1	0%	-100%	-100%
Propane	13,059	3%	11,808	4%	184	3%	-99%	-98%
RNG	0	0%	0	0%	11	0%	100%	
Wood	5,854	1%	3,889	1%	138	2%	-98%	-96%
Total	415,026	100%	266,759	100%	6,591	100%	-98%	-98%

Table 5. Transportation energy use, Colchester

ENERGY BY FUEL (GJ)	2016	SHARE 2016	2050 (BAU)	SHARE 2050	2050 LCS	SHARE 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Diesel	782,367	33%	700,559	40%	101,338	12%	-87%	-86%
Gas	1,560,074	67%	1,031,306	58%	102,158	13%	-93%	-90%
Grid electricity	24	0%	38,792	2%	189,183	23%	784331%	388%
Hydrogen	0	0%	0	0%	137,460	17%	100%	
Local electricity	1	0%	2,020	0%	281,117	35%	20897994%	13818%
Total	2,342,466	100%	1,772,677	100%	811,256	100%	-65%	-54%
Energy by vehicle (GJ)	2016	share 2016	2050 (BAU)	share 2050	2050 LCS	share 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Car	786,016	34%	437,150	25%	166,655	21%	-79%	-62%
Heavy truck	155,306	7%	113,183	6%	40,957	5%	-74%	-64%
Light truck	696,451	30%	517,651	29%	202,331	25%	-71%	-61%
Marine	134,000	6%	134,000	8%	105,286	13%	-21%	-21%
OffRoad	332,231	14%	332,231	19%	153,732	19%	-54%	-54%
Rail	237,000	10%	237,000	13%	137,460	17%	-42%	-42%
Urban bus	1,462	0%	1,462	0%	4,836	1%	231%	231%
Total	2,342,466	100%	1,772,677	100%	811,256	100%	-65%	-54%

Table 6. Table B6. Transportation GHG emissions, Colchester.

EMISSIONS BY SOURCE (TCO_2E)	2016	SHARE 2016	2050 (BAU)	SHARE 2050	2050 LCS	SHARE 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Diesel	59,483	34%	53,611	39%	7,954	53%	-87%	-85%
Gas	104,413	60%	69,245	50%	6,988	47%	-93%	-90%
Grid electricity	5	0%	3,490	3%	0	0%	-91%	-100%
Jet fuel	10,966	6%	10,966	8%	0	0%	-100%	-100%
Total	174,867	100%	137,312	100%	14,943	100%	-91%	-89%
Emissions by vehicle (tCO_2e)	2016	share 2016	2050 (BAU)	share 2050	2050 LCS	share 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Aviation	10,966	6%	10,966	8%	0	0%	-100%	-100%
Car	52,763	30%	29,779	22%	1,056	7%	-98%	-96%
Heavy truck	11,052	6%	8,054	6%	198	1%	-98%	-98%
Light truck	46,790	27%	35,217	26%	1,229	8%	-97%	-97%
Marine	10,576	6%	10,576	8%	5,288	35%	-50%	-50%
OffRoad	23,909	14%	23,909	17%	7,173	48%	-70%	-70%
Rail	18,706	11%	18,706	14%	0	0%	-100%	-100%
Urban bus	105	0%	105	0%	0	0%	-100%	-100%
Total	174,867	100%	137,312	100%	14,943	100%	-91%	-89%

Table 7. Waste GHG emissions, Colchester.

EMISSIONS BY SOURCE (TCO_2E)	2016	SHARE 2016	2050 (BAU)	SHARE 2050	2050 LCS	SHARE 2050	% +/ 2016-2050 LCS	% +/- 2050 BAU-2050 LCS
Biological	1,855	5%	1,912	8%	0	0%	-100%	-100%
Landfill	23,242	69%	12,801	54%	5,550	47%	-76%	-57%
Wastewater	8,726	26%	9,003	38%	6,165	53%	-29%	-32%
Total	33,822	100%	23,717	100%	11,715	100%	-65%	-51%

Appendix C: GPC tables

This table provides the 2016 base year emissions data, categorized according to the Global Protocol for Community-scale Greenhouse Gas Emission Inventories.1 Using this categorization to update the municipal inventory periodically ensures consistency across inventory years and comparability between global municipal jurisdictions.

Reason for exclusion key

N/A Not applicable; Not included in scope

ID Insufficient data

NR No relevant or limited activities identified

Other Reason provided under Comments

GPC REF NO	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
I		STATIONARY ENERGY SOURCES						
I.1		Residential buildings						
I.1.1	1	Emissions from fuel combustion within the city boundary	Yes		4,993	897	81	5,972
I.1.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes		13,163	19	56	13,239
I.1.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes		956	1	4	962
I.2		Commercial and institutional buildings/facilities						
I.2.1	1	Emissions from fuel combustion within the city boundary	Yes		2,806	1	35	2,843
I.2.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes		18,022	26	77	18,126

[1] The GPC can be found here: https://ghgprotocol.org/sites/default/files/standards/GHGP_GPC_0.pdf

GPC REF NO	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
I.2.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes		1,309	2	6	1,317
I.3		Manufacturing industry and construction						
I.3.1	1	Emissions from fuel combustion within the city boundary	Yes		0	0	0	0
I.3.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes		0	0	0	0
I.3.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes		0	0	0	0
I.4		Energy industries						
I.4.1	1	Emissions from energy used in power plant auxiliary operations within the city boundary	No	NR	7,226	5	37	7,268
I.4.2	2	Emissions from grid-supplied energy consumed in power plant auxiliary operations within the city boundary	No	NR	0	0	0	0
I.4.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption in power plant auxiliary operations	No	NR	0	0	0	0
I.4.4	1	Emissions from energy generation supplied to the grid	No	NR	0	0	0	0

GPC REF NO	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
I.5		Agriculture, forestry and fishing activities						
I.5.1	1	Emissions from fuel combustion within the city boundary	No	NR	0	0	0	0
I.5.2	2	Emissions from grid-supplied energy consumed within the city boundary	No	NR	0	0	0	0
I.5.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	No	NR	0	0	0	0
I.6		Non-specified sources						
I.6.1	1	Emissions from fuel combustion within the city boundary	No	NR	0	0	0	0
I.6.2	2	Emissions from grid-supplied energy consumed within the city boundary	No	NR	0	0	0	0
I.6.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	No	NR	0	0	0	0
I.7		Fugitive emissions from mining, processing, storage, and transportation of coal						
I.7.1	1	Emissions from fugitive emissions within the city boundary	No	NR	0	0	0	0
I.8		Fugitive emissions from oil and natural gas systems						

GPC REF NO	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
I.8.1	1	Emissions from fugitive emissions within the city boundary	Yes		0	888	0	888
II		TRANSPORTATION						
II.1		On-road transportation						
II.1.1	1	Emissions from fuel combustion for on-road transportation occurring within the city boundary	Yes		8,069	15	53	8,137
II.1.2	2	Emissions from grid-supplied energy consumed within the city boundary for on-road transportation	Yes		1	0	0	1
II.1.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	Yes		5,469	11	19	5,499
II.2		Railways						
II.2.1	1	Emissions from fuel combustion for railway transportation occurring within the city boundary	No	NR	0	0	0	0
II.2.2	2	Emissions from grid-supplied energy consumed within the city boundary for railways	No	NR	0	0	0	0

GPC REF NO	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
II.2.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	No	NR	0	0	0	0
II.3		Water-borne navigation						
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring within the city boundary	No	N/A	0	0	0	0
II.3.2	2	Emissions from grid-supplied energy consumed within the city boundary for waterborne navigation	No	N/A	0	0	0	0
II.3.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	No	N/A	0	0	0	0
II.4		Aviation						
II.4.1	1	Emissions from fuel combustion for aviation occurring within the city boundary	No	N/A	0	0	0	0

GPC REF NO	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
II.4.2	2	Emissions from grid-supplied energy consumed within the city boundary for aviation	No	N/A	0	0	0	0
II.4.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	No	N/A	0	0	0	0
II.5		Off-road						
II.5.1	1	Emissions from fuel combustion for off-road transportation occurring within the city boundary	No	NR	0	0	0	0
II.5.2	2	Emissions from grid-supplied energy consumed within the city boundary for off-road transportation	No	NR	0	0	0	0
III		WASTE						
III.1		Solid waste disposal						
III.1.1	1	Emissions from solid waste generated within the city boundary and disposed in landfills or open dumps within the city boundary	Yes		0	0	0	0

GPC REF NO	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
III.1.2	3	Emissions from solid waste generated within the city boundary but disposed in landfills or open dumps outside the city boundary	Yes		0	901	0	901
III.1.3	1	Emissions from waste generated outside the city boundary and disposed in landfills or open dumps within the city boundary	No	N/A	0	0	0	0
III.2		Biological treatment of waste						
III.2.1	1	Emissions from solid waste generated within the city boundary that is treated biologically within the city boundary	Yes		0	0	0	0
III.2.2	3	Emissions from solid waste generated within the city boundary but treated biologically outside of the city boundary	No	N/A	0	0	0	0
III.2.3	1	Emissions from waste generated outside the city boundary but treated biologically within the city boundary	No	N/A	0	0	0	0
III.3		Incineration and open burning						
III.3.1	1	Emissions from solid waste generated and treated within the city boundary	No	N/A	0	0	0	0

GPC REF NO	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
III.3.2	3	Emissions from solid waste generated within the city boundary but treated outside of the city boundary	No	N/A	0	0	0	0
III.3.3	1	Emissions from waste generated outside the city boundary but treated within the city boundary	No	N/A	0	0	0	0
III.4		Wastewater treatment and discharge						
III.4.1	1	Emissions from wastewater generated and treated within the city boundary	Yes		0	188	11	198
III.4.2	3	Emissions from wastewater generated within the city boundary but treated outside of the city boundary	No	NR	0	0	0	0
III.4.3	1	Emissions from wastewater generated outside the city boundary	No	N/A	0	0	0	0
IV		INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)						
IV.1	1	Emissions from industrial processes occurring within the city boundary	No	ID	0	0	0	0
IV.2	1	Emissions from product use occurring within the city boundary	No	ID	0	0	0	0
V		AGRICULTURE, FORESTRY AND LAND USE (AFOLU)						

GPC REF NO	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
V.1	1	Emissions from livestock within the city boundary	No	NR	0	0	0	0
V.2	1	Emissions from land within the city boundary	No	NR	5	0	0	5
V.3	1	Emissions from aggregate sources and non-CO_2 emission sources on land within the city boundary	No	NR	0	0	0	0
VI		OTHER SCOPE 3						
VI.1	3	Other Scope 3	No	N/A	0	0	0	0