Schedule B to Staff Report 2021-0121

RESILIENT CALEDON

Community Climate Change Action Plan

TECHNICAL REPORT

TOWN OF CALEDON

SSG

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1. INTRODUCTION

About This Document

This report was developed as a technical resource to support and inform the T own of Caledon's Community Climate Change Action Plan, Resilient Caledon. The primary purpose of the technical work undertaken was to identify an emissions reduction pathway for Caledon, as well as priority actions for the town to increase its resilience to climate change impacts. This report details the analyses, their results, and the actions identified for inclusion in the Resilient Caledon Community Climate Change Action Plan.

Climate Change

Climate change is an urgent crisis with impacts that reach all corners of the globe. It is a particularly complex problem because it occurs over a long timescale, making it difficult for decision-makers to prioritize, and it requires rapid and radical change to our society and economic systems. This Plan identifies how the Town of Caledon intends to respond to the climate crisis and build a more resilient future.

The world's leading scientific body on climate change has identified that we must limit average global temperatures to 1.5°C above those that were seen before the industrial revolution in order to significantly reduce our risk of experiencing catastrophic impacts to human and natural systems. They have also estimated that human activities have already caused around 1.0°C of global warming, and that limiting warming to 1.5°C requires reaching net zero carbon dioxide (CO_2) emissions globally by around 2050.[1]

Municipal governments are crucial to the effort to get to net zero emissions, since their decisions directly or indirectly influence approximately 50% of GHG emissions in Canada.[2]

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[1] 2018: Technical Summary. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. https://www.ipcc.ch/sr15/technical-summary

[2] "Greenhouse Gas Reductions." Federation of Canadian Municipalities, https://fcm.ca/en/programs/municipalities-climate-innovation-program/greenhouse-gas-reductions.

CLIMATE IMPACTS IN CALEDON

While climate change is a global issue, Caledon is already feeling the impacts locally. If no action is taken, Caledon will see higher risks from:

- damage to roads, bridges, and homes from flooding and other extreme weather,
- increased health impacts from heat stress and disease
- poor air quality,
- damage to crops and livestock.

95% of survey respondents said they were concerned about climate change and its impacts on Caledon.[3]

CALEDON'S GHG EMISSIONS

More than half of Caledon's emissions in 2016 were from transportation, including commuters travelling out of the town for work, and commercial vehicles and trucks. Residential and commercial buildings were responsible for nearly 30% of the town's emissions, arising primarily from the use of natural gas for space and water heating. The remainder of the town's emissions came from agricultural and industrial activities, waste disposal and wastewater treatment, and fugitive[4] sources.

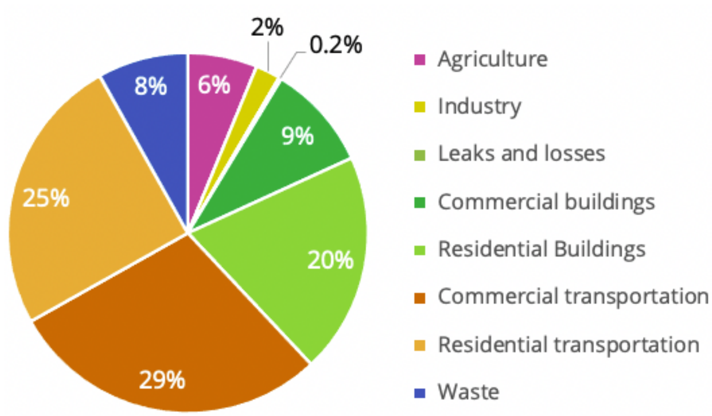

Figure 1. GHG emissions in Caledon, 2016.

[3] Based on an online climate change survey conducted by the Town in 2019.
[4] Fugitive emissions are those attributable to leaks or losses in energy delivery (e.g. natural gas escape). It is estimated that these numbers could be much higher due to underestimates of upstream emissions, and if distribution emissions were added on top of production emissions.
Liggio, J., Li, S., Staebler, R.M. et al. Measured Canadian oil sands CO2 emissions are higher than estimates made using internationally recommended methods. Nat Commun 10, 1863 (2019). https://doi.org/10.1038/s41467-019-09714-9

The figure below shows that under the Business-as-Planned (BAP) scenario (which takes into account existing local, Regional, and Federal plans for development, densification, carbon taxes, technology improvements, and the anticipated doubling of Caledon's population from 2016 to 2050),[5] the Town's GHG emissions are estimated to increase by 119% from 2016 to 2050. This growth reflects the urgency for Caledon to take action, and the opportunity to direct investments into options that will, for example, improve energy efficiency and pay back in cost savings, support the local economy, and build a more resilient, livable Town.

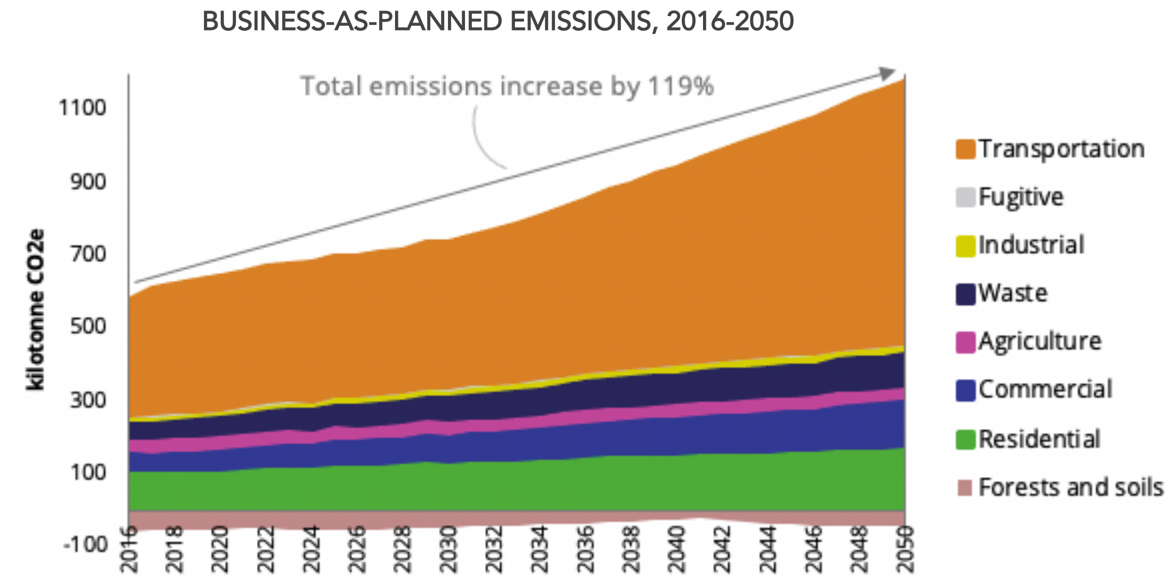

Figure 2. Business-as-Planned GHG emissions in Caledon, 2016-2050.

Caledon's Climate Response

The Town of Caledon has prided itself for its proactive and pioneering approach to action on climate change, having been dubbed the 'Greenest Town in Ontario' as far back as 2003. Accomplishments that have included: integration of climate considerations in land use bylaws and Official Plan, early adoption of a Green Development Program for commercial and industrial buildings, and being amongst the first Canadian municipalities to sign on to the Partners for Climate Protection Program and to complete its fifth and final milestone.

The Town's first iteration of its Community Climate Change Action Plan (CCCAP) was in 2010, which included a GHG emissions inventory and a GHG reduction target of 17% below 2006 levels by 2021. To further their efforts, the Town signed on to the Global Covenant of Mayors for Climate and Energy in 2017, which has become the global standard in municipal climate action.

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[5] These projections extrapolate the growth from the Region of Peel's 2041 projections for the Town of Caledon forward to the year 2050

Resilient Caledon is the Town's updated Community Climate Change Action Plan that builds upon this work. It will help the community reach a target of net zero greenhouse gas emissions by 2050, and adapt to the impacts of climate change.

The **VISION** for the Resilient Caledon Community Climate Change Action Plan is that the Town will be a net zero carbon community, that is resilient and well prepared to adapt to the impacts of climate change.

The **GOALS** for the Resilient Caledon CCAP are to:

1) Reduce GHG emissions to reach net zero by 2050, following a carbon budget that aligns with 1.5C warming.

2) Increase the Town's resiliency to impacts from current and future climate conditions, including residents, businesses, and natural and built systems.

Resilient Caledon is a community plan to address climate change. It has been developed with input from Caledon residents, businesses, farmers, youth, and expert stakeholders. We heard from more than 800 residents, and their priorities were clear: preserving green space and agriculture land, maintaining Caledon's rural character as the Town grows, and a focus on saving energy.

Caledon's Climate Change Action Plan

The Resilient Caledon CCAP contains actions to achieve the Plan's vision and goals, in five key sections: Smart Growth, Sustainable Communities, Agriculture and Natural Systems, Low Carbon Transportation, and Resilient Infrastructure and Energy.

ACTIONS

- Smart growth - Caledon's new communities and buildings are low carbon, resilient to climate impacts, and prioritize energy efficiency, walkability, and the well-being of all residents

  Key actions: Establish a sustainable development standard for new buildings to be net zero and climate resilient; prioritize compact, mixed-use community design in land use planning

- Sustainable communities - Caledon residents and businesses are prepared for climate impacts and have the capacity to reduce their own carbon footprint

  Key actions: Support home and business retrofits; enhance emergency preparedness and response

- Agriculture and natural systems - Caledon's natural and agricultural systems are protected and enhanced to maximize carbon sequestration and build resilience to climate impacts

  Key actions: develop a local food and agriculture strategy for Caledon; create an Open Space strategy to expand parks and green spaces; increase tree planting and other restoration initiatives

- Low carbon transportation - cycling, walking and transit options become accessible to more Caledon residents; electric vehicles are adopted by more residents and businesses

  Key Actions: increase active transportation and public transit infrastructure; expand Caledon's electric vehicle charging network

- Resilient infrastructure and energy - Caledon's energy infrastructure is diversified and resilient, and core infrastructure assets are able to withstand climate impacts like flooding

  Key actions: support the development of more renewable and distributed energy sources; enhance the resilience of roads, bridges and stormwater infrastructure to major climate impacts

COMMUNITY CO-BENEFITS

Taking action on climate change is not only about reducing GHG emissions. The Plan will result in many co-benefits across the community including:

- New jobs and investments in the local economy
- Lower energy bills and avoided costs from climate impacts like flooding
- Healthier habitat and biodiversity
- Improved public health from increased walking/cycling and cleaner air
- Equitable outcomes through diverse and more affordable housing options, accessible child/age friendly infrastructure, reducing climate impacts on vulnerable populations
- Enhanced public safety in the face of increased climate impacts like flooding

2. CALEDON'S RISK AND VULNERABILITY ASSESSMENT

Methodology and Results

In 2018, Caledon completed a Risk and Vulnerability Assessment (RVA) to better understand how the local climate may change in Caledon, and what impacts that could have for the Town and its residents. The Town worked with ICLEI Canada to develop the RVA using the Building Adaptive and Resilient Communities (BARC) process. Key stakeholders from the Town, Conservation Authorities, agriculture, and other sectors were convened on several occasions and provided important insights throughout the process. Below is a summary of the key findings for Caledon's future climate conditions, major impacts, and vulnerability and risk assessments.

Future Conditions Weather Model

An ensemble of climate models from the Climate Model Intercomparison Project Phase 5 (CMIP5) GCMs was used in this study, driven by moderate and business-as-usual greenhouse gas (GHG) emissions scenarios. These CMIP5 models represent the latest generation of global climate models and are the basis of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report. The climate change signals for a variety of indicators (e.g. temperature, growing season, average and extreme precipitation, humidity, and wind) for each decade to 2090 were developed. The changes for each of the indicators were determined based on a comparison of baseline climate signals between 1981 and 2010. The full climate science report can be retrieved by request to the Town of Caledon.

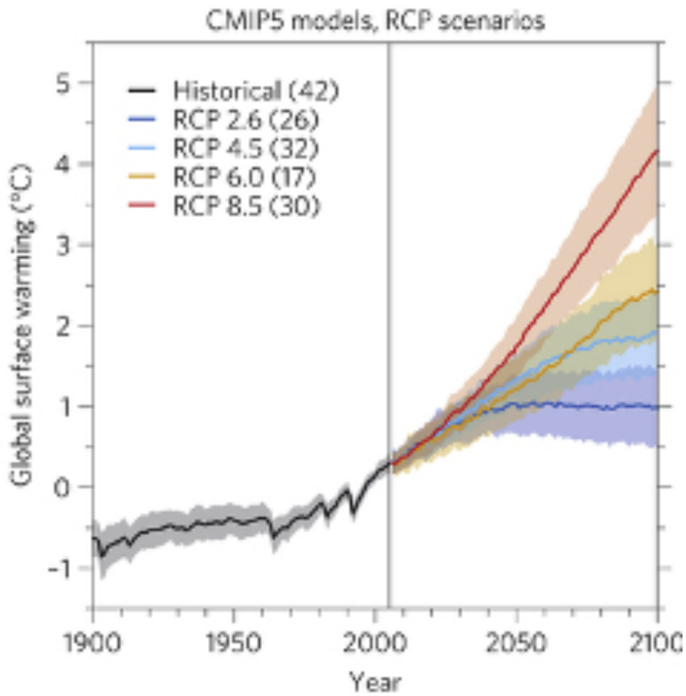

Figure 3. Greenhouse Gas (GHG) Emissions Scenarios - Representative Concentration Pathways (RCPs) Developed and Used by IPCC.

Table 1. RCP Scenario Descriptions.

Scenario	Description
RCP 2.6	Lowest projected GHG concentrations, resulting from dramatic climate change mitigation measures implemented globally. It represents an increase of 2.6 W/m^2 in radiative forcing to the climate system.
RCP 4.5	Moderate projected GHG concentrations, resulting from substantial climate change mitigation measures. It represents an increase of 4.5 W/m^2 in radiative forcing to the climate system.
RCP 6.0	Moderate projected GHG concentrations, resulting from some climate change mitigation measures. It represents an increase of 6.0 W/m^2 in radiative forcing to the climate system.
RCP 8.5	Highest projected GHG concentrations, resulting from business-as-usual emissions. It represents an increase of 8.5 W/m^2 in radiative forcing to the climate system.

Some of the more significant findings from Caledon's future weather model is an increase in temperatures in all seasons, as shown in Figure 4, and significant increase in the number of hot days above 30°C in the summer, as shown in Figure 5. Precipitation is expected to increase in every season, except summer, which will likely become somewhat drier (Figure 6).

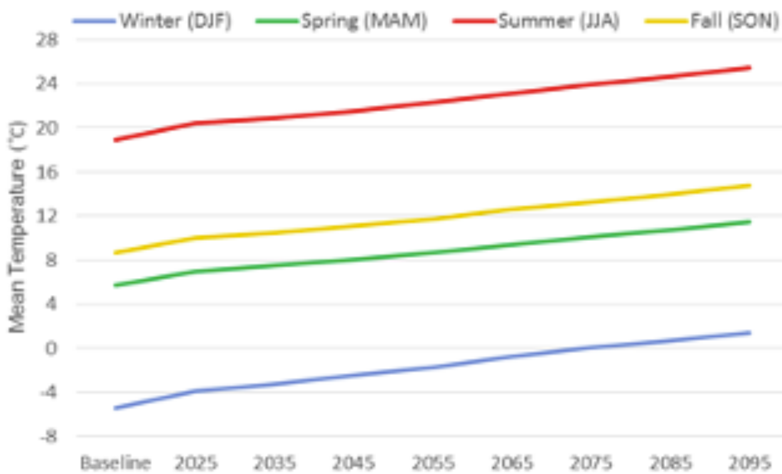

Figure 4. Projected Mean Seasonal Temperatures (°C) (RCP 8.5).

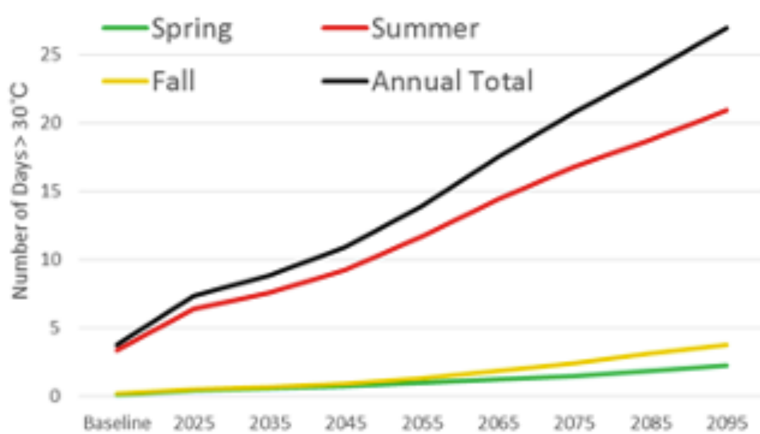

Figure 5. Projected Number of Days Exceeding 30°C (RCP 8.5).

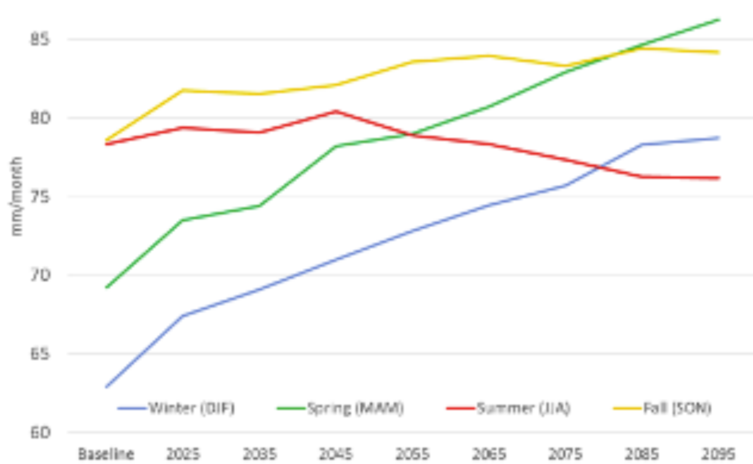

Figure 6. Projected Monthly Precipitation Accumulation (mm/month) (RCP 8.5).

Table 2 summarizes the future climatic conditions projected for the Town of Caledon out to 2090, based on a worst case GHG emissions scenario.

Table 2. Summary of Future Climate Conditions in Caledon.

Climatic Variable	Indicator of Change (RCP 8.5)	Description
Temperature	Annual mean temperatures	Baseline annual mean temperature is 7.0°C and increases to 13.3°C by the end of the century. Temperature will increase across all seasons.
	Hot days above 35°C	Annual baseline hot days above 35°C is currently 0.1 days (without humidex) and increases to 8.9 days by the end of the century.
	Cold days below 0°C	Annual baseline cold days below 0°C is currently 48.86 and decreases to 21.44 days by the end of the century.
	Freeze-Thaw Cycles	Annual baseline is currently 88.7 freeze-thaw days and is expected to decrease to 47.4 days by the end of the century.
	Growing Season Length	Growing season is projected to start earlier and end later. Baseline length is currently 163.3 days and is expected to increase to 224.3 days.
Precipitation	Annual Total Precipitation (mm)	Annual baseline precipitation is currently 867.4 mm/year and is expected to increase to 975.9 mm/year by the end of the century. Similar increases in total precipitation are seen in winter, spring, and fall, with a slight decrease in the summer.
	Annual Number of Dry Days	Annual baseline is currently 227.7 days and is expected to decrease to 222 days by the end of the century.

Climatic Variable	Indicator of Change (RCP 8.5)	Description
	Maximum One-Day Precipitation (mm)	Annual baseline is currently 37 mm and is expected to increase to 44.1 mm by the end of the century.
	95-th Percentile Wettest Days Precipitation (mm)	Annual baseline is currently 228.9 mm and is expected to increase to 313 mm by the end of the century.
	Freezing Rain Days	Annual baseline is currently 2.9 days and is expected to decrease slightly to 2.3 days.

IMPACT STATEMENT DEVELOPMENT

Impact statements are the foundation of the risk and vulnerability assessments and must be tailored to each municipality's context. They are intended to be concise sentences that outline what climatic changes may be occurring and how they will affect the community.

Impact statements address the following considerations:

- What are the climatic threats we are concerned about?
- What are the outcomes of these changes?
- What are the consequences associated with these outcomes?

Caledon's RVA focused on impacts to the Town's infrastructure, natural, and socioeconomic systems. Stakeholders were presented the results of the weather model and tasked with developing a series of impact statements in December 2017. Approximately 87 impact statements were developed reflecting the perceived exposure of the community to climatic changes and subsequent consequences.

Impact statements were consolidated, edited, and peer reviewed to ensure accuracy. The result was 22 socioeconomic impacts (social and economic were merged due to interrelatedness of impacts), 18 natural systems impacts, and 17 infrastructure systems impacts.

Assessment of Future Conditions and Vulnerabilities

METHODOLOGY

Vulnerability refers to the susceptibility of the community to harm arising from climate change impacts. Vulnerability is assessed through two factors:

1. **Sensitivity**: Refers to the degree to which the community's *functionality* (ability to provide/perform services) will be affected when exposed to a climate-related impact. Sensitivity is evaluated on a scale of 1-5, with low sensitivity (S1) meaning functionality of the community would stay the same, and high sensitivity (S5) indicating that functionality could worsen or become unmanageable. Sensitivity is impacted by factors such as the severity of the impact, the systems it would affect in the community, and whether those systems are under any existing stress (such as aging roads, ecologically sensitive areas, or vulnerable populations).

2. **Adaptive Capacity**: Determines whether the community can adjust to the climate impact in a manner that considers recovery costs, time and resources to return to status quo. High adaptive capacity means that the community can adjust to the impact with minimal cost and disruption, where low adaptive capacity means that substantial costs and/or intervention would be required if the impact were to occur.

Each impact statement identified was assigned both a Sensitivity and Adaptive Capacity score, which formulates a vulnerability score using a ranking outlined in Table 3 below. Impact statements with a low score mean that the community has a high adaptive capacity (able to cope) and low sensitivity (community can still function) if an impact was to occur. Alternatively, if an impact statement is given a high vulnerability score, this means that the community has a low adaptive capacity and high sensitivity.

The final vulnerability rankings are based on an average of two rankings given, rounded up to the higher vulnerability in cases where decimal scores occurred. Following the workshop, the vulnerability scores were peer reviewed by the consulting team and subject matter experts to ensure accuracy in the process.

Table 3. Vulnerability Matrix.

		Sensitivity: Low → High				
		S1	S2	S3	S4	S5
Adaptive Capacity Low ↓ High	AC1	V2	V2	V4	V5	V5
	AC2	V2	V2	V3	V4	V5
	AC3	V2	V2	V3	V4	V4
	AC4	V1	V2	V2	V3	V3
	AC5	V1	V1	V2	V3	V3

GENERAL OBSERVATIONS FROM THE VULNERABILITY ASSESSMENT

Infrastructure Impacts

Impacts on built infrastructure ranked particularly high due to the sensitivity of the Town of Caledon's infrastructure system. The climatic threats driving these impacts relate to both changes in temperature and precipitation. Increased intensity and frequency of rainfall can cause damage and wear on built infrastructure. There are several flood damage centers in Caledon (e.g. Alton), and with increasing intensity and duration of precipitation, flood risk may be higher in known vulnerable areas. Additionally, rapid freeze-thaw cycles (coupled with precipitation) can cause infrastructure to age faster than expected due to gradual wear and tear such as potholes and cracks.

While the Town has regional roads under the jurisdiction of the Region of Peel, other important local roadways that connect Caledon's various communities are subject to aging, poor maintenance, and are often under stress during heavy precipitation. The Town has begun to see more frequent rainfall events with high intensity rainfall (for example July 2013, May 2017, and February 2018 rainfall events) meaning infrastructure is likely under more stress than was anticipated during its design. In addition to damage of Town property, the increase in rainfall events has also caused a loss in outdoor field use and the associated revenue (in 2017, outdoor field revenue loss was approximately $20,000).

Climate-related impacts on infrastructure tended to result in lower adaptive capacity scores. While the Town has the knowledge and tools to provide proper maintenance and repairs to damaged infrastructure, it would require significant costs and resources to do so.

Natural Impacts

The highest vulnerability impacts for natural systems were temperature-based. While natural systems are generally very adaptable and flexible to environmental changes, ecosystems and species can still be affected by increasing temperatures. Many species can be sensitive to small increases in temperature and precipitation, and some pests and diseases can spread faster and survive through warmer winter months. Warmer temperatures and/or dry conditions in wetlands can cause a hydrological shift in the ecosystem, threatening species that rely on wetland conditions to survive. In Caledon, warmer water temperatures can lead to inhospitable environments for Brook Trout, a species that needs high-quality cold water habitat to survive. With increasing stream temperatures, Brook Trout distribution will be reduced to areas with appropriate groundwater resources that keep the stream network cold.

Socioeconomic Impacts

Social and economic systems were grouped together as many of the impacts were closely interconnected. Most of the high vulnerability socioeconomic impacts related to extreme precipitation and flooding. As has been seen throughout Ontario, urban flooding can have a significant impact on residents in the form of property damage as well as physical and emotional stress. Areas such as Alton, Bolton, and Caledon East are particularly sensitive to flooding. These areas could see more frequent flooding that could range in severity with as little as a one-day inconvenience to longer-term evacuation if the flooding were severe. In addition, power lines and power interruptions can result from extreme weather relating to climate change. This has a significant impact on the entire community, particularly businesses or vulnerable communities who may need assistance in the event of a power outage.

Moving Forward

Impacts with a vulnerability ranking of V3 (medium) and higher were advanced to the risk assessment phase. Low vulnerability impacts were temporarily removed from the process under the assumption that since the Town of Caledon has a low sensitivity and/or a high adaptive capacity to the impact, the associated risks would be manageable.

Risk Assessment

METHODOLOGY

Risk is the combination of the probability of an event and its negative consequences. It can be expressed as a function where:

Risk = likelihood x consequence

"Likelihood" refers to the probability of a projected impact occurring. Each impact statement was assigned a likelihood rating which was determined in consultation with agency stakeholders and Town staff. This rating was assigned based on the criteria outlined in Table 4 below:

Table 4. Likelihood Matrix.

LIKELIHOOD RATING	RECURRENT IMPACT	SINGLE EVENT
Almost Certain (5)	Could occur several times per year	More likely than not – probability greater than 50%
Likely (4)	May arise about once per year	As likely as not – 50/50 chance
Possible (3)	May arise once in 10 years	Less likely than not but still appreciable – probability less than 50% but still quite high
Unlikely (2)	May arise once in 10 years to 25 years	Unlikely not but not negligible – probability low but noticeably greater than zero
Rare (1)	Unlikely during the next 25 years	Negligible – probability very small, closer to zero

"Consequence" refers to the known or estimated outcomes of a climate change impact. Participants reviewed 12 consequence criteria – which were divided into social, economic, and environmental categories using an assessment tool. Participants were asked to assign a consequence rating to each impact statement that considered the 12 categories, representing the severity of outcomes associated with the climatic impact. This process also considered existing community stressors and mitigating actions in place to adapt to a climatic event.

The total risk score (the sum of each risk category score multiplied by likelihood of the impact) was determined using the spectrum below. The top risk spectrum corresponds with singular consequence categories (social, economic, environmental), and the bottom risk spectrum corresponds with total risk scores across all categories.

Figure 7. Risk Spectrums.

The total risk score represents the combined consequences across environmental, social, and economic systems in the community. With this information, we can understand which impacts will have the greatest effect across the entire community, and which will have significant consequences within certain systems.

GENERAL OBSERVATIONS FROM THE RISK ASSESSMENT

Highest-Ranking Impacts

The highest-ranking impacts received a risk score of Medium-High. While this may seem lower than expected, the impacts captured in Table 5 represent the most significant climate-related risks for the Town of Caledon. Risk scores in this range are incredibly common in Ontario municipalities. This is because Very High and Extreme risks capture catastrophic, irreparable damage that is not typically experienced in developed urban areas in Canada. For example, had the impacts resulted in multiple deaths, irrecoverable loss of natural areas, and collapse of the local economy, more extreme rankings would be warranted. However, given existing plans and policies, technological capabilities, and capacity at the Town, most climate impacts, while potentially dangerous and harmful in a short term, would ultimately not be catastrophic.

The highest risk impacts were related to infrastructure risks due to increased precipitation, warmer temperatures, and flood risk. These impacts also scored medium or higher in the vulnerability assessment, meaning the Town is experiencing an existing sensitivity or a lower adaptive capacity if these events were to occur. This is due to the widespread nature of consequences that can occur when climate and weather cause damage to the Town's built systems. Not only is infrastructure costly and time consuming to repair, there can be critical disruptions to the way that businesses, residents, and emergency services move throughout the Town. Particularly in smaller communities that rely on few major roads, bridges, and highways to reach destinations, this can cause an increase in accidents, emergencies, and economic losses. Disruptions or damage to power infrastructure can leave homes and businesses without electricity for hours or days. Depending on the season and other ongoing weather events (e.g. winter storms or rain during heat wave), this can lead to safety risks and possible isolation of residents. While road disruptions and closures are often seen as inconveniences, more persistent occurrences of infrastructure damage can lead to increased contamination in the Town's natural systems. Agricultural and road runoff caused by heavy precipitation can be exacerbated by infrastructure repair measures leading to higher levels of pollutants and sedimentation in Caledon's streams, creeks, and soil.

Natural Impacts

The highest risk natural system impacts capture a range of climatic changes and their consequences on ecosystems and ecosystem services found within the Town of Caledon. Even if the shift is slight and gradual, warmer annual temperatures can have a significant impact on the natural environment. Native species with specific temperature requirements, such as Brook Trout, can be forced into fragmented habitats supported by cold groundwater inputs. This would result in the loss of a top predator in coldwater streams and change the associated community structure. These losses could also be associated with socioeconomic impacts to tourism and angling. In addition, warmer winter temperatures generate a higher survival rate for pests and other invasive species, leading to increased spread and associated damage to natural areas.

The natural systems (wetlands, tree canopies, creeks) within the Town of Caledon provide countless ecosystem services such as air purification, water filtration, water retention, bank stabilization, and habitats for thousands of species. Damage to or loss of these services due to higher temperatures and increased intensity of precipitation can mean significant economic costs in recovery and improvements. For example, invasive species, while seen as a "natural" problem, are ultimately an economic problem. Environment Canada reported that invasive species found in Canada cost between $13.3– $34.5 billion per year in 2004, amounts which would likely increase as climate change continues to provide more favourable conditions for invasive species to spread.

Infrastructure Impacts

The notable risks relating to infrastructure are generally caused by increases in average annual intensity and duration of precipitation. More rain, falling at a faster rate, can add wear and tear and damage to roads, bridges, culverts, highways, and buildings. Extreme weather events can sometimes exceed the capacity of the infrastructure and cause closures, dangerous conditions, and damage, and over time can cause the built structure to fail. In many cases, impacts on the Town of Caledon's infrastructure ranked high because of the existing condition of critical infrastructure. For one, climate change projections were not incorporated into the design of public infrastructure – a problem not unique to the Town of Caledon. Furthermore, Canadian municipalities face a significant infrastructure deficit which has left built systems outdated and vulnerable to climate impacts.[3] Infrastructure maintenance is incredibly costly, and recent assessments have highlighted aging infrastructure as a concern for the Town.[4] The land and resources available to the Town to update and expand stormwater management facilities are also limited. This was reflected in the risk assessment results, seen in the range of infrastructure-based risks identified by agency stakeholders and Town staff who often work on the ground within the Town's built systems. Overland flooding due to precipitation has already caused infrastructure damage and subsequent disruptions across the community, and this is projected to worsen under changing climatic conditions.

The health, economic, and environmental risks associated with infrastructure damage are also captured by the risk assessment results in Table 5 below. If the capacity of the stormwater management system is exceeded, creeks and rivers can be inundated with sediment and pollutant loading. This issue also occurs if road and agricultural runoff is not adequately filtered by natural and built infrastructure. Increased maintenance on existing infrastructure can also disrupt ecosystems and habitats in the surrounding area. Damaged infrastructure, particularly when combined with extreme weather, also poses health and safety risks as it creates dangerous conditions for drivers, cyclists, and pedestrians. Road and/or maintenance closures can also delay or prevent access for emergency services and disrupt the flow of goods and services through the Town.

Socioeconomic Impacts

Climate change impacts may cause increases in morbidity and mortality. The notable socioeconomic risks identified through this project highlight the variety of ways a changing climate can disproportionately affect vulnerable populations. Income, age, social status, education, literacy, gender, culture, and social support networks are strongly correlated with a community's capacity to cope with climate impacts.[5] In the Town of Caledon, the most vulnerable populations include seniors, children and infants, socially and economically disadvantaged populations, those with chronic illnesses, and residents in remote areas. Climate change impacts can cause disproportionate physical, mental, financial, and social stress on these groups by aggravating the existing socioeconomic inequalities that led to their exposure and vulnerability in the first place.[6]

In the Town of Caledon, elderly residents and those who live in more rural, isolated areas are at risk during extreme precipitation, snow buildup, and exceedingly hot or cold temperatures. Emergency response personnel and outdoor workers are also not immune to the effects of these conditions and may experience higher amounts of risk due to heat, rainfall, and an elevated number of calls. Critical systems such as schools, seniors' homes, and hospitals can face stress and disruption. In addition, social services that are typically available to support vulnerable groups may become overloaded and delayed. Power outages, which can occur with strong winds and heavy precipitation, can exacerbate extreme weather conditions, making them even more hazardous.

Health and safety risks resulting from climate change also have notable economic implications for the Town. The above impacts can prevent people from going to work, can cause short or long-term damage to businesses, and can incur costly emergency response efforts. This can be significantly harmful to low income residents who experience property damage, loss of belongings, and high replacement costs for food and household items.

AGRICULTURAL AND NATURAL SYSTEMS RISK ASSESSMENT

Following the Risk and Vulnerability Assessment Project, one key recommendation was to explore additional climate change impacts and consequences on the agricultural and natural systems in the Town of Caledon. In 2019, the Town worked with ICLEI Canada through the Changemakers project to consult with agricultural and natural systems experts and identify any additional climate change impacts that were not fully captured in the original RVA Project.

Local agricultural and natural systems experts were welcomed to a March 6, 2019 workshop to participate in a collaborative risk assessment workshop. Sixteen new agricultural and natural system impacts were validated through an online survey and were then assessed using ICLEI Canada's risk assessment methodology, consistent with the risk assessment conducted through the RVA Project.

The new impact statements and their associated risks were peer reviewed by the Town of Caledon staff and ICLEI Canada and consolidated with those developed during the previous RVA project. This helped to provide a more comprehensive understanding of some of the priority climate-related risks for the community in Caledon.

Table 5 below shows the highest risk impacts from both the original RVA and the reassessed natural and agricultural systems impacts.

Table 5. Highest Ranking Risk Assessment Results

Climate Threat	Impact Statement	Justification from Adaptation Team	Vul.	Likelihood	Social /100	Economic /100	Environment /100	Overall Risk Score /300
Five Highest-Ranked Impacts								
Increase in average annual temperature and shifting precipitation patters leading to increases in freezing rain or freeze-thaw cycles	Increased need for salting of roads resulting in higher salinity levels of streams and waterbodies which can have detrimental impacts on vegetation and wildlife due to contamination	Salt is incredibly harsh on vegetation. Numerous impacts associated with public health and safety (i.e. water pollution), property damage for farmers that are affected, loss of tourism and recreation opportunities like fishing, and loss of health ecosystem function due to impacts on water and soil quality	N/A	5	65	65	90	220
Average annual increases in temperature and changing precipitation patterns over time	Shifting ecological communities' flora and fauna, leading to potential loss of biodiversity	Greater risk of diseases and pests (e.g. lyme disease), property damage including loss of trees and impacts to agriculture land from increased pests, as well as added burden on health services, tree damage and power lines	N/A	4	64	64	72	200
Increase in average annual intensity and duration of precipitation	Increased damage to power infrastructure leading to prolonged outages and disruptions to telecommunication lines.	Isolated but noticeable disruptions to business operations and telecommunications. Possible displacement and community service disruption if power outages were prolonged. Hydro One would be under stress due to high amount of calls.	V4	5	60	65	40	165

Climate Threat	Impact Statement	Justification from Adaptation Team	Vul.	Likelihood	Social /100	Economic /100	Environment /100	Overall Risk Score /300
Increase in average winter temperatures and precipitation, combined with freeze-thaw cycles	Damage to private (e.g. gas, dams, water pipes) and public (roads, sidewalks) infrastructure	Sidewalks and roads would be damaged and see extra wear and tear, causing higher costs to maintain. Road flooding would cause poor driving conditions, potential loss of business for short periods, and could block access to places the community needs to go. This impact has been occurring often in winter 2018. Note that freeze thaw cycles will decrease over time as temperature falls below freezing less frequently.	V5	5	65	65	35	165
Increase in intensity and duration of precipitation and increase in average annual temperatures	Contamination of source water, potentially causing stress on water treatment processes	Potential for property damage, particularly for those on private wells, as well as increased strain on water treatment infrastructure. Also potential for significant impacts on ecosystem function of water, soil and vegetation.	N/A	4	40	72	52	164
Natural Impacts								
Warmer temperatures in the summer and decrease in summer precipitation leading to drier summer months	Potential changes in areal extent, habitat and species diversity of wetlands, threatening survival of sensitive species	Ecosystems would experience loss of services i.e. attenuation, water storage, and biodiversity. Water filtration benefits would also be lost. Long term loss of the ecosystem services provided by wetlands would be costly.	V4	5	55	50	80	185

Climate Threat	Impact Statement	Justification from Adaptation Team	Vul.	Likelihood	Social /100	Economic /100	Environment /100	Overall Risk Score /300
Increase in average annual intensity and duration of precipitation	Damage to tree canopy, increasing the number of hazardous trees and branches	Caledon's abundance of trees means that this risk could cause widespread health and safety concerns as well as costly property damage. Damaged branches and trees can also block waterways, cause contamination in creeks, and effect bank stabilization.	V3	5	50	50	45	145
Increase in average annual temperatures	Increased disturbance in natural ecosystems (due to changes in temperature and precipitation) and decreased minimum winter temperatures, leading to increased survival and spread of invasive species such as Emerald Ash Borer	Tree damage can cause property damage and removal costs. Loss of trees could negatively impact habitats and ecosystems in the Town. May cause overall decrease in multiple ecosystem services (carbon sequestration, pollutant removal, soil formation) due to shifting flora and fauna and increased disturbance in forests and wetlands.	V3	5	35	35	50	120
Increase in average annual temperature and intensity and duration of precipitation	Increase in stream temperature can cause decrease in dissolved oxygen levels, leading to loss of sensitive biota such as the Brook Trout	Loss of colder water can impact fisheries, cause fragmented habitats, and lead to loss of small streams. Not widespread and impact would be in isolated areas.	V4	5	25	30	50	105

Climate Threat	Impact Statement	Justification from Adaptation Team	Vul.	Likelihood	Social /100	Economic /100	Environment /100	Overall Risk Score /300
Infrastructure Impacts								
Longer average annual growing season	Farmers ploughing over (covering up) drainage swales leading to increased flood risk	Road blockage and pooling water can cause driving safety risks. There are administrative consequences when bylaw authorities are unable to access property. Possible water contamination if there is proximity to a stream.	V4	5	60	55	45	160
Increase in average winter and spring temperature	Stress or failure of bridge and culvert infrastructure resulting from ice jams	Bridge collapse causes serious safety risks and high repair costs. Residents could become displaced due to flooding from ice jams or subsequent loss of infrastructure. Important routes through the community could also become blocked.	V5	5	60	65	35	160
Increase in average winter temperatures	Temperatures near the freezing mark, causing increased risk of freezing rain events, leading to a need for salting, damaging infrastructure	Salt causes wear and tear on roads. Infrastructure damage can cause safety risks and incur significant costs if repairs are needed.	V4	5	45	60	50	155

Climate Threat	Impact Statement	Justification from Adaptation Team	Vul.	Likelihood	Social /100	Economic /100	Environment /100	Overall Risk Score /300
Increase in average winter temperatures and variability in winter freeze-thaw cycles	Unpredictable winter conditions, leading to difficulty planning for levels of service in the Town	Town administration would be under pressure due to increased complaints and issues relating to weather-related accidents and emergencies. Water, soil, and vegetation can be severely damaged if not properly adjusted to new climate conditions (e.g. over salting, lack of erosion prevention).	V4	5	45	50	55	150
Increase in average annual intensity and duration of precipitation	More frequent inundation of flood plains, causing higher frequency of flooding in urban areas (Bolton, Caledon East and Caledon Village, Mayfield)	High costs to rebuild in highly populated areas. Could damage natural features of urban areas. Flooding in denser areas also poses serious risks to human health and safety, and can cause temporary economic losses due to road and/or business closures.	V4	4	52	56	36	144
Increase in average annual intensity and duration of precipitation	Stress on municipal buildings, roads, culverts, and bridges leading to infrastructure failure	If this happens to a water facility, runoff could contaminate source water and soil. Town infrastructure failure could also cause dangerous conditions for residents and staff. Replacement and repair costs would be very high.	V4	4	56	56	32	144

Climate Threat	Impact Statement	Justification from Adaptation Team	Vul.	Likelihood	Social /100	Economic /100	Environment /100	Overall Risk Score /300
Increase in average winter temperatures and precipitation, combined with freeze-thaw cycles	Increased potential for rain on frozen ground events causing flooding and associated damage	Injury in homes or displacement from homes can be exacerbated by winter conditions. Flood damage can be very costly for residents depending on their level of preparedness.	V5	4	48	52	40	140
Increase in average annual intensity and duration of precipitation	Ice storms causing damage of public and private infrastructure (i.e. buildings and transit network), and energy systems.	Ice storms and damaged infrastructure can cause fatalities. Temporary economic impact would result from inability to get to work or closures of roads and businesses. Property damage can be major, and costly, but there is more administrative preparedness since the 2013 ice storm.	V4	4	48	52	36	136
Increase in average annual intensity and duration of precipitation	Stress on stormwater management infrastructure leading to facility/system failure	Possible flooding could damage property. Can cause water safety concerns if the sanitary system is affected, e.g. parts of Downtown Bolton have combined sewers. Stormwater pond overflow can cause the pond to have trouble filtering out sediment and phosphorus, which can cause contamination in creeks and soil.	V5	4	40	52	40	132

Climate Threat	Impact Statement	Justification from Adaptation Team	Vul.	Likelihood	Social /100	Economic /100	Environment /100	Overall Risk Score /300
Increase in average annual intensity and duration of precipitation	Increase in instances of overland flooding, causing road closures that block access for emergency services	Flooding on Charleston Rd. in the past caused 5 critical closures. Isolated incidences of property damage and temporary disruption of business and services due to flooding and blocked access. Health implications if emergency services cannot reach people in need during a flood.	V4	5	50	50	25	125
Socioeconomic Impacts								
Increase in average annual temperature and intensity and duration of precipitation	Increased risk of damage to and/or flooding of septic systems, resulting in localized contamination of wells and natural features		N/A	4	52	52	60	164
Increase in average annual intensity and duration of precipitation	More instances of overland flooding, causing evacuation of vulnerable populations and displacement of residents from homes	Possible fatalities and serious injuries during severe flood events. Other consequences include economic losses, mental stress, and high demand on emergency response systems. Property damage and recovery would also be time consuming and costly.	V4	4	52	52	37	140

Climate Threat	Impact Statement	Justification from Adaptation Team	Vul.	Likelihood	Social /100	Economic /100	Environment /100	Overall Risk Score /300
Increase in average summer temperatures and moisture holding capacity of the atmosphere	Increasing demand for water and water shortages, especially impacting rural areas that rely on wells	High impact to those on agricultural property and the agricultural community. There would be costs to purchase water and impact on crop production. Rural areas on private wells may experience water shortages	V4	4	48	52	36	136
Increase in average annual hot days over 30°C	Increase in number of heat and poor air quality days resulting in health issues for vulnerable populations and outdoor workers	Health impacts include respiratory issues, heat stroke. Cooling centers and public water stations would be under stress. Some people would not be able to do regular activities, meaning loss of livelihood and economic losses. Air pollution and smog can exacerbate these impacts.	V3	5	45	40	45	130
Increase in average winter temperature with increase in intensity and duration of precipitation	More rain during winter months, sometimes accumulating mixed with snow or as wet snow, making snow heavier and more challenging to remove	Health risks such as injury, heart attack, slips and falls for elderly. Roof collapses can cause displacement and high repair costs. Snow accumulation can also limit movement through the community and block access for important services.	V4	4	60	40	24	124

Climate Threat	Impact Statement	Justification from Adaptation Team	Vul.	Likelihood	Social /100	Economic /100	Environment /100	Overall Risk Score /300
Increase in intensity and duration of precipitation	Increased pressure on basement sump pumps and shallow works (pipes) casing increased lot-level flood risk	Risk of property damage due to flooding as well as insurance challenges, potential health implications due to vector-borne diseases (from excess water pooling) and mould.	N/A	5	45	50	25	120
Increase in average summer temperatures and decrease in summer precipitation leading to drier conditions in summer	Increased and potentially significant pressures on overall water supply, jeopardizing water availability for farming	Drier conditions could significantly impact the farming community, particularly hay producers, and could lead to greater soil erosion and potentially increased fire risk. Ecosystem functions in aquatic systems would also be severely impacted	N/A	5	30	30	55	115
Increase in average annual intensity and duration of precipitation, particularly during the spring	Water logging of fields (especially in low lying areas), washing out of important soil nutrients, delay in farming activities and lower crop yields	Delays in getting crops in the ground likely only a few weeks, but could still impact many farmers. A heavy spring washout, however, could cause a major impact	N/A	5	25	35	50	110

Action Planning

With a final list of climate impacts, the next step was to identify adaptation actions that the community could implement to address priority risks. Effective adaptation actions are those that address climate change risks and improve the adaptive capacity of people, assets, and services. Adaptation actions identified for the adaptation component of the Town of Caledon's CCCAP were developed to meet three key criteria:

- Must be implementable in the Town of Caledon (i.e. local)
- Must address priority impacts of climate change or extreme weather
- Must include non-municipal partners in planning and implementation

The community was engaged in the action identification process through an open house, community action-setting workshop, community pop-up events, and an online survey. The Town also hosted a stakeholder workshop in September 2019 to review and refine the list of adaptation actions with experts in areas such as stormwater management, road engineering, public health, ecologists, and planners.

Adaptation actions were assessed alongside mitigation actions to leverage the many synergies and co-benefits between the two. The final Resilient Caledon plan includes action areas that respond to both mitigation and adaptation in order to support more holistic, integrated implementation of the overall plan.

3. GHG EMISSIONS MODELLING METHODOLOGY

GETTING TO ZERO EMISSIONS

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

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

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

Modelling Approach

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

MODELLING STEPS

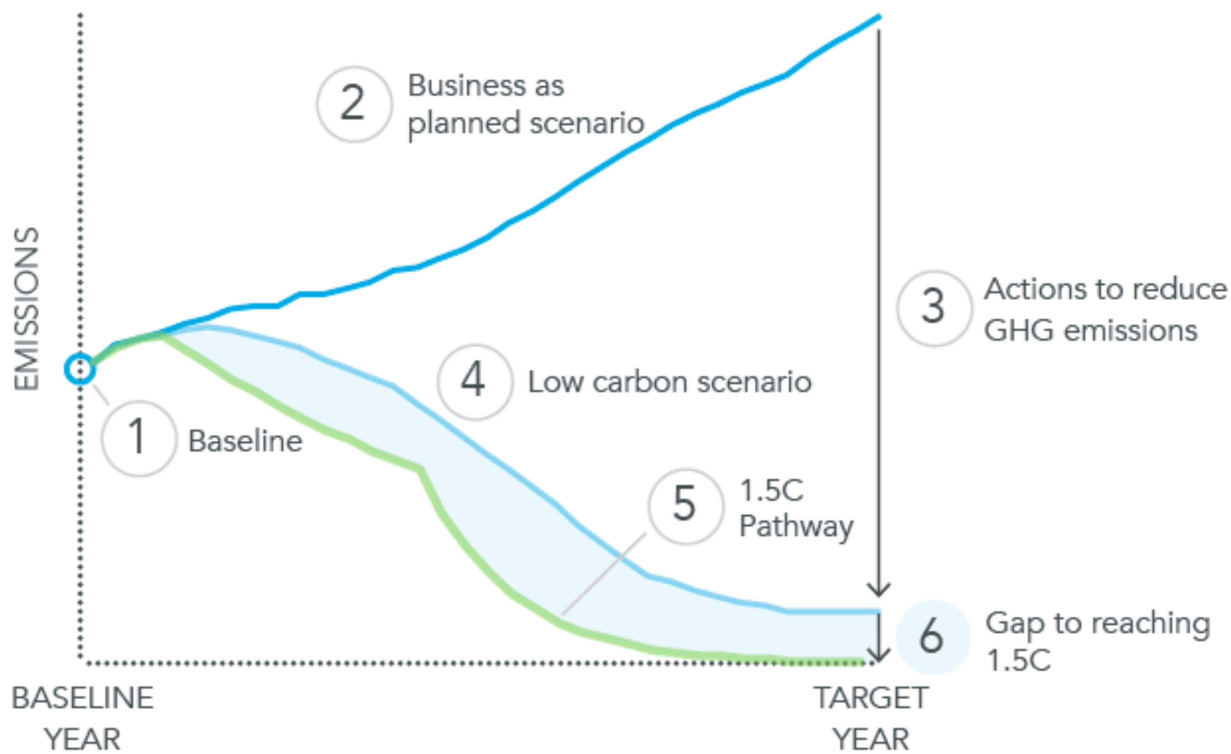

Figure 8. Modelling steps taken to develop the Low-Carbon Pathway.

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

2) Business-as-Planned (BAP) Scenario: A BAP scenario was developed that accounts for anticipated changes in Caledon until 2050 including its increasing population and employment, new homes and workplaces, and evolving transportation patterns that would likely result in an increase in GHG emissions. It also took into account existing climate actions at various levels of government including, federal fuel efficiency standards, the national carbon levy, the impact of climate change on heating and cooling requirements in buildings, and other factors that would help to mitigate GHG emissions over the same time period. The result is an estimate of what Caledon's GHG emissions will look like by the year 2050 if no new action is taken at any level of government.

3) Actions to Reduce GHG Emissions: Actions including switching to renewable energy sources, increasing energy efficiency, and reducing or altering emissions-producing activities were identified, and their energy, emissions, and cost impacts were compared to the BAP Scenario.

4) Low Carbon Scenario: The GHG emissions that would result from the above actions being implemented out to 2050, relative to the BAP scenario. The low carbon scenario allows the Town to achieve approximately 77% reduction in its GHG emissions below the 2016 baseline.

5) 1.5°C Pathway: The maximum emissions allowed for the Town to support a global target of 1.5°C warming, and equivalent to the Town's target of net zero emissions by 2050.

6) Gap to Reaching 1.5°C: These emissions, often referred to as the Town's carbon liability, would need to be offset through the purchase of carbon credits or other measures to keep the Town within its carbon budget and eventually to reach its net zero target.

4. MODELLING RESULTS

Business-As-Planned Results

POPULATION AND DEMOGRAPHICS

Demographics provide important information in establishing a community's energy and emissions baseline. Population trends, rate of employment, and expected number of households are important elements to consider in documenting current—and estimating future—energy use and emissions production. The 2016 National Census (performed every 5 years) provides this information for past years. For future years, Region of Peel growth projections to 2041 were used, and then carried forward to 2050 using the same rate of growth as expected from 2016 and 2041. Based on these assumptions, Caledon's population is expected to more than double from 2016 to 2050, increasing by 130,934 people. Households are expected to scale with population growth, with 44,852 added by 2050. A total of 86,858 jobs are expected to be added between 2016 and 2050, slightly increasing per-capita employment over the time period from 0.37 to 0.56 jobs per resident.

Table 6. Key demographics in 2016 and 2050.[6]

	2016	2050	Difference 2016-2050	% Difference 2016-2050
Population	68,820	199,754	130,933	190%
Employment	25,807	112,665	86,858	337%
Dwelling units	22,120	66,972	44,852	203%

PROJECTED TOTAL ENERGY USE

Total and Per Capita Energy Use

Figure 9 shows the total community energy use in 2016, and the energy use projection to 2050. Energy use is expected to more than double, increasing by approximately 12 million GJ, 224% of 2016 emissions. Despite the overall increase, per capita energy use decreases over the time period by about 23,000 GJ/person. The population is increasing, however there is a simultaneous improvement to space

[6] 2016 to 2041 Population, employment and dwelling units are from: Peel 2041 Growth Allocation and Growth Management- Regional Official Plan Amendment – Request to Proceed with Consultation on Draft Amendment. Oct 12, 2017.Forecasts to 2050 are estimated by carrying forward the same rate of growth from prior years.

heating/cooling and water heating demands, due in part to smaller homes and also increased energy efficiency resulting from upper-level of government regulations on appliances and the building code.

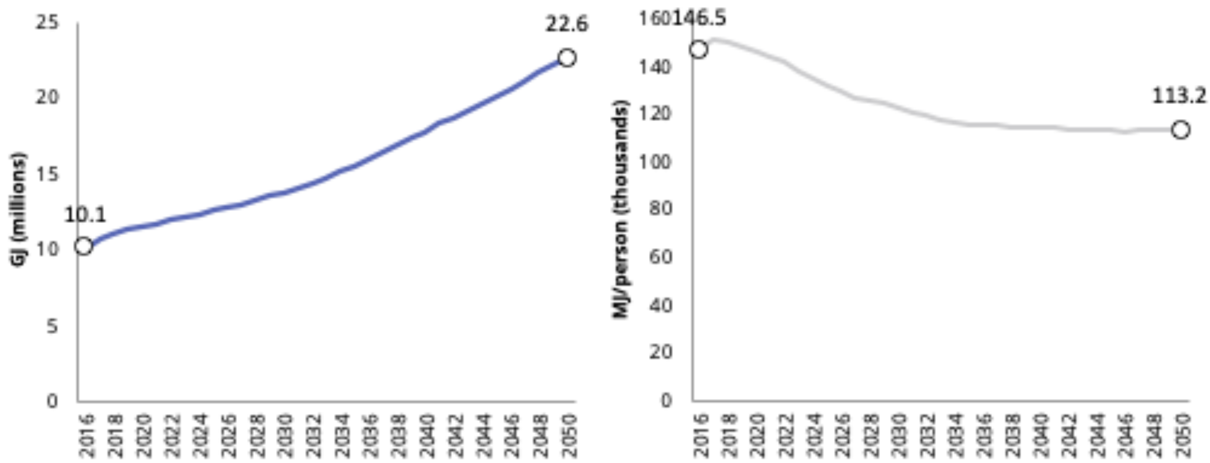

Figure 9. Projected yearly total (left) and per-capita (right) community energy use, 2016-2050.

Total Energy Use by Sector

Transportation accounts for nearly half of Caledon's energy use, both in 2016 and in 2050. Half of the increase in energy use is projected to come from commercial and residential buildings to accommodate the Town's growing population and workforce. The other half of this increase is projected to result from transportation.

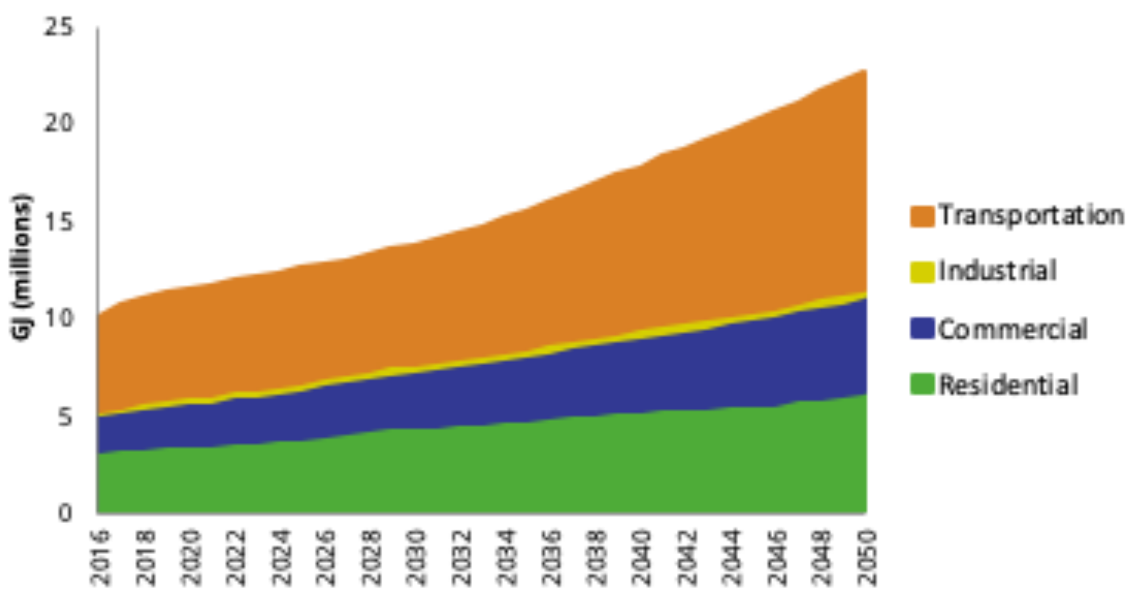

Figure 10. Projected community energy use by sector, 2016-2050.

Table 7. Business-as-Planned Scenario energy consumption (GJ) by sector, 2016 and 2050.

	2016 (GJ)	Share of total 2016	2050 (GJ)	Share of total 2050	% change 2016-2050
Total (GJ) >	10,079,467	100%	22,607,064	100%	124%
Commercial	1,825,781	18%	4,919,683	22%	169%
Industrial	289,198	3%	429,414	2%	48%
Residential	3,236,330	32%	6,192,495	27%	91%
Transportation	4,728,158	47%	11,065,473	49%	134%

Total Energy Use by Fuel Type

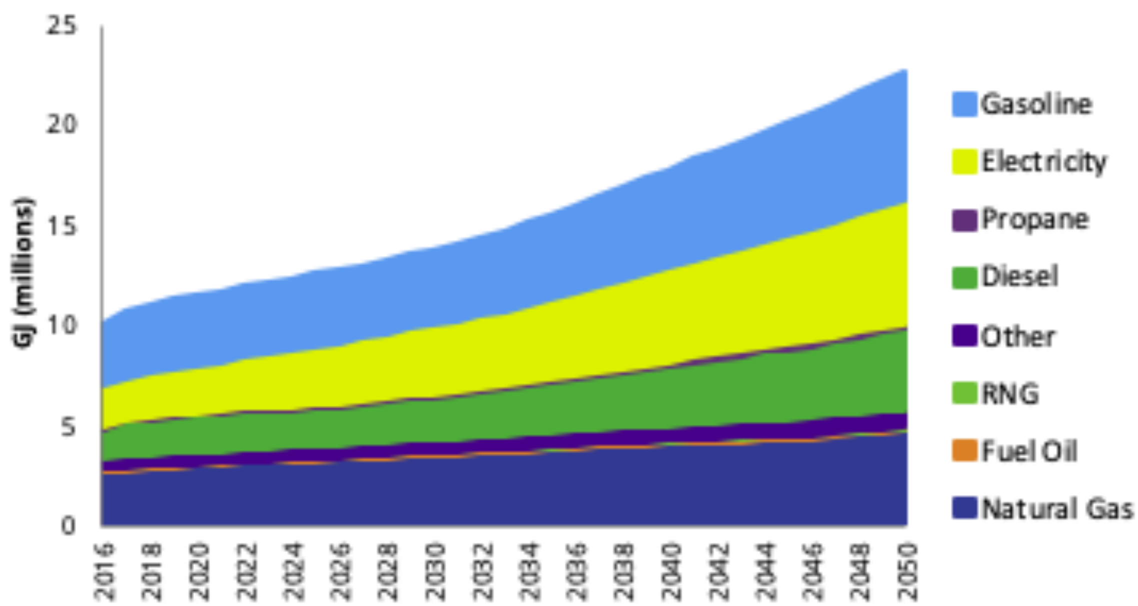

Figure 11. Projected community energy use by end use, 2016-2050.

Table 8. Business-as-Planned Scenario energy consumption (GJ) by fuel source, 2016 and 2050.

	2016 (GJ)	Share of total 2016	2050 (GJ)	Share of total 2050	% change 2016-2050
Total (GJ) >	10,079,467	100%	22,607,064	100%	124%
Diesel	1,461,129	14%	4,038,792	18%	176%
Electricity	1,952,946	19%	6,153,352	27%	215%
Fuel Oil	140,038	1%	132,968	1%	-5%
Gasoline	3,109,923	31%	6,374,316	28%	105%
Natural Gas	2,763,041	27%	4,735,270	21%	71%
Other	513,871	5%	905,109	4%	76%
Propane	138,520	1%	202,439	1%	46%
RNG	-	0%	64,817	0.3%	1000%

The greatest increase in energy use is from electricity, by over 4 million GJ, indicating that additional electricity grid capacity may be required to meet this increased demand. As the emissions factor for electricity is anticipated to remain relatively constant and relatively low (Figure 12), this increase in electricity use is not projected to drive a significant increase in emissions. Second to this is the increase in diesel, primarily for commercial transportation, by approximately 2.5 million GJ from 2016 to 2050, occurring alongside the growth in jobs, non-residential floorspace, and shipping of goods.

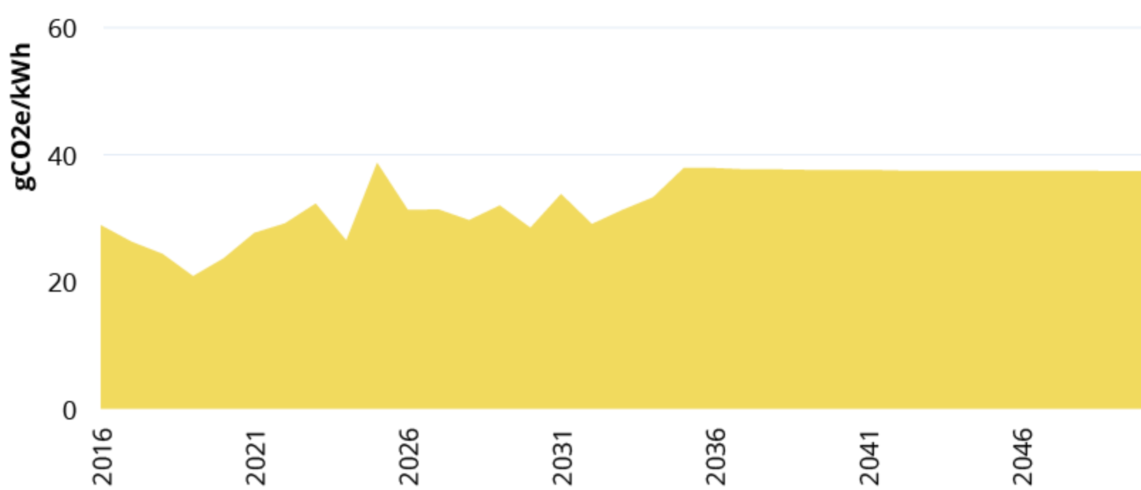

Figure 12. Projected emissions factor for electricity grid, Ontario (2011-2050.)[7]

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[7] National Energy Board. (2016). Canada's energy future 2016. Government of Canada. Retrieved from https://www.cer-rec.gc.ca/nrg/ntgrtd/ftr/2016/2016nrgftr-eng.pdf; IESO (2016) MODULE 4: Supply Outlook. Retrieved from http://ieso.ca/Documents/OPO/MODULE-4-Supply-Outlook-20160901.pptx

Projected changes to the fuel mix for electricity production in Ontario

Examining future emissions for electricity generation, fluctuations occur as Pickering nuclear units are to be decommissioned between 2022 and 2024, and refurbishments of the remaining nuclear facilities mostly occur in the 2020s. Wind, solar and natural gas show increases in capacity from 2016 to 2025, as projected by IESO. From 2015 onwards there is a slight increase in carbon intensity as nuclear loses some of its share. Post 2035, it is assumed that fossil-fuel based electricity generation (natural gas) is maintained at 2035 levels, and all increases in capacity, required due to increases in demand, is non-fossil fuel based. As a result, the carbon intensity post 2035 remains constant.

PROJECTED TOTAL EMISSIONS

Caledon's total emissions for the 2016 baseline year was 0.5 megatonnes of carbon dioxide equivalent (MtCO2e). Total projected emissions rise to 1.1 MtCO2e by 2050 (+119%) (Figure 13). Per capita emissions decrease by 1.9 tCO2e per person between 2016 and 2050 (-20%), largely due to improved efficiencies in buildings from code and technology upgrades.

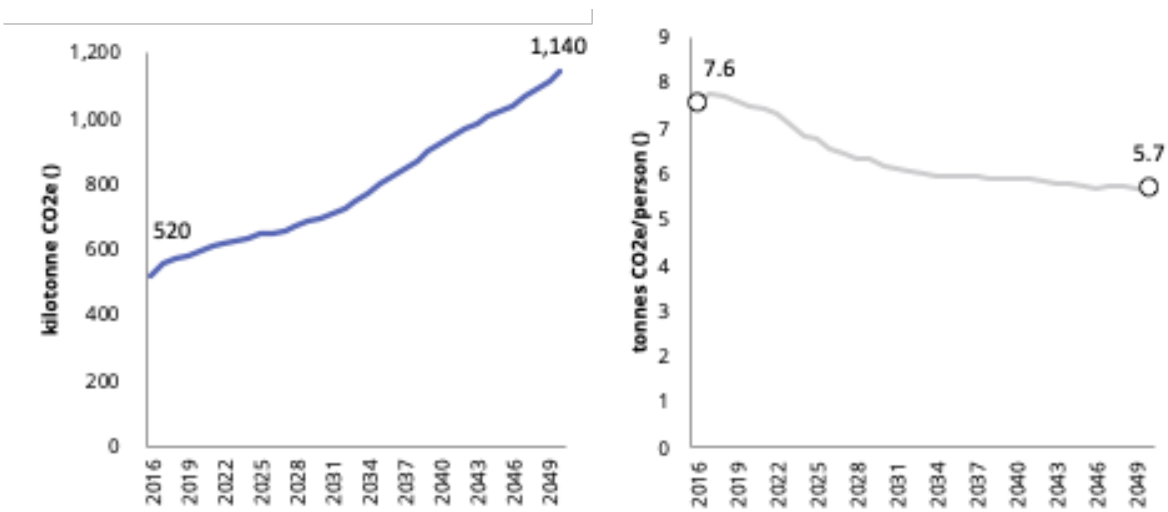

Figure 13. Projected yearly total (left) and per-capita (right) community emissions, 2016-2050.

Total Emissions by Sector

The residential buildings and transportation sectors are responsible for the vast majority of Caledon's emissions in 2016, with 20% and 54% of total 2016 emissions, respectively (Figure 14, Table 9). By 2050, transportation emissions are anticipated to double, with a 130% increase, driven by an increase in population and jobs, and the travel associated with each.

The commercial building sector is projected to experience a 140% increase in emissions (in step with added commercial buildings) while the residential sector will see just a 58% increase (this is much less of an increase due to increased space heating/cooling and water heating efficiency).

With Federal requirements for landfill gas capture, the Region of Peel's targeted improvements in waste diversion and bringing an anaerobic digester online, waste emissions are slated to increase by 55%. Wastewater emissions increase by 213%, making for a total increase in waste and wastewater emissions of 100%. Growth in waste and wastewater emissions are caused by the increase in residents and commercial activities in the Town, and assuming similar per-capita waste generation rates over the projected time period. Sequestration from vegetation and agricultural soils decreases by 33%, due to encroachment of development on agricultural and forest lands from anticipated residential and commercial development.

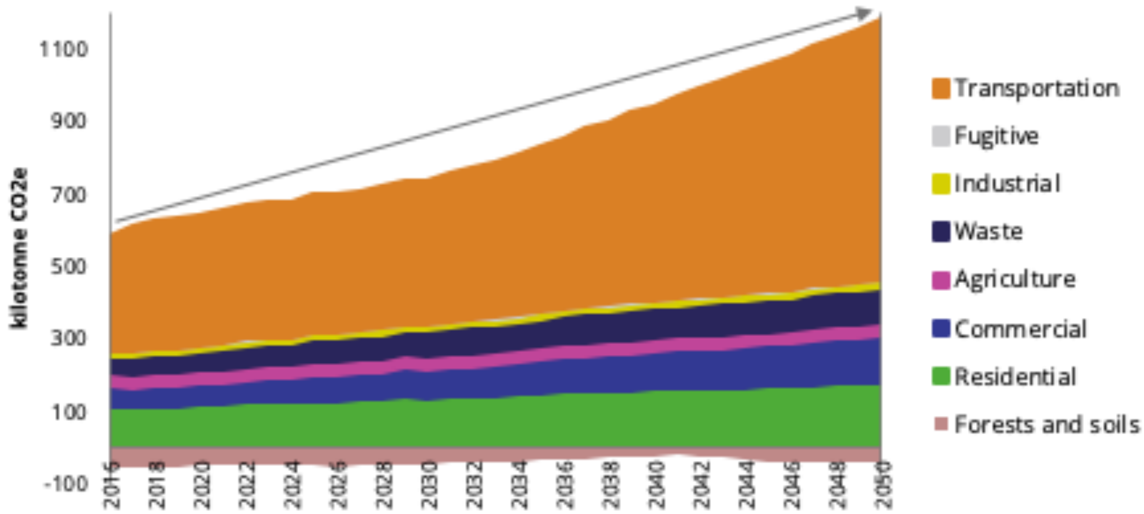

Figure 14. Projected community emissions by sector, 2016-2050.

Table 9. Business-as-Planned Scenario emissions (ktCO2e) by sector, 2016 and 2050.

	2016 ($ktCO_2e$)	Share of total 2016	2050 ($ktCO_2e$)	Share of total 2050	% change 2016-2050
Total (ktCO2e) >	520	100%	1,140	100%	119%
Agriculture	36	6%	36	3%	0%
Sequestration	(58)	-10%	(39)	-3%	-33%
Commercial	55	9%	131	11%	140%
Fugitive	1	0%	2	0%	71%
Industrial	13	2%	19	2%	45%
Residential	115	20%	182	15%	58%
Transportation	311	54%	716	61%	130%
Waste	47	8%	94	8%	100%

Total Emissions by Fuel Source

In 2016, the highest emitter by fuel type was gasoline from transportation, accounting for 36% of total emissions. Natural gas (used in buildings) was responsible for 24% of total 2016 emissions. Together with diesel used in transportation (at 18%), they constitute more than three quarters of total fuel emissions. The shares of emissions from natural gas, gasoline and diesel are expected to remain nearly constant. Emissions associated with electricity production are expected to increase by 235%, primarily due to the increase in electricity use as energy demands grow with population and are increasingly electrified, as well as a slight increase in the emissions factor for electricity over the time period (Figure 15, Table 10).

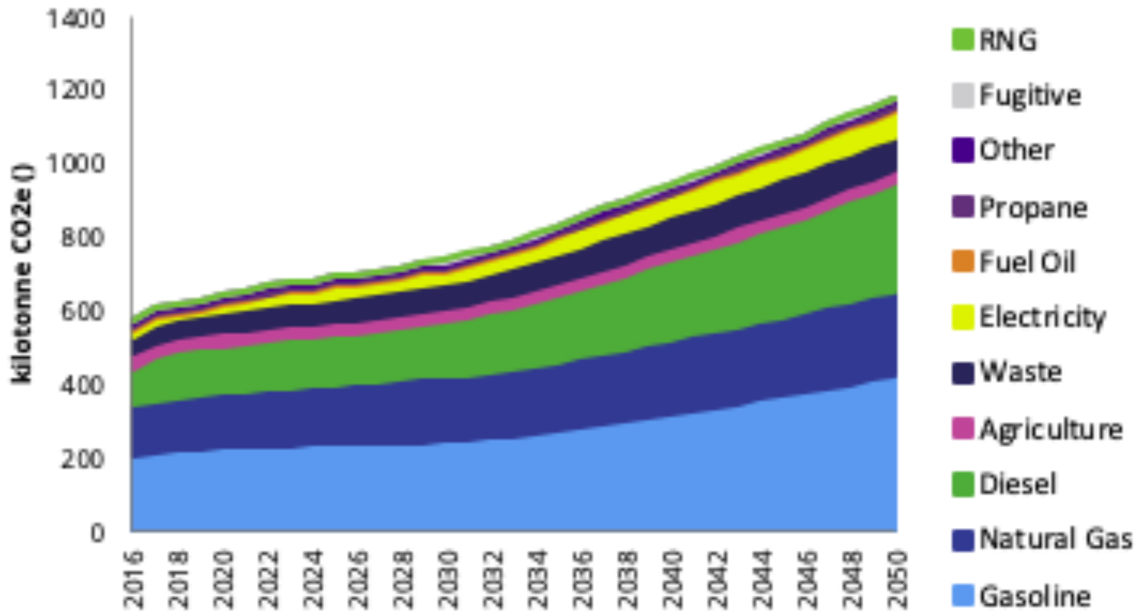

Figure 15. Projected community emissions by fuel source, 2016-2050.

Table 10. Business-as-Planned Scenario emissions (ktCO2e) by fuel source, 2016 and 2050.

	2016 ($ktCO_2e$)	Share of total 2016	2050 ($ktCO_2e$)	Share of total 2050	% change 2016-2050
Total (ktCO2e) >	520	100%	1,140	100%	119%
Agriculture	36	6%	36	3%	0%
LULUCF	(58)	-10%	(39)	-3%	-33%
Diesel	105	18%	290	25%	176%
Electricity	20	4%	68	6%	235%
Fuel Oil	10	2%	9	1%	-5%
Fugitive	1	0%	2	0%	71%
Gasoline	207	36%	424	36%	105%
Natural Gas	137	24%	234	20%	71%
Other	7	1%	10	1%	39%
Propane	8	1%	12	1%	46%
RNG	-	0%	0	0%	>100%

LOW-CARBON SCENARIO RESULTS

Modelled actions and assumptions

Table 11 below summarizes the actions that were modelled for the low carbon scenario, along with their targeted scale, and their contributions to overall GHG emissions reduction. The most significant emissions reductions are likely to come from widespread EV adoption.

Table 11. Low-Carbon Scenario Action Impact Summary.

Sector	Target	GHG Reduction (ktCO2e) relative to 2050 BAP	Contribution to Total Emissions Reductions (do not add to 100% due to rounding)
Electric Vehicles (EVs)	• 100% of vehicles are EV, or zero emissions, by 2050.	677	66%
Buildings	• 100% of existing buildings are retrofit for increased efficiency by 2040. • 100% of new buildings are net zero by 2030. • 100% of buildings use electric heat pumps by 2040.	227	22%
Waste Diversion and Reduction	• 80% of waste diverted by 2050. • Per capita waste generation reduced by 50% from 2016 by 2050.	38	4%
New solar Photovoltaics (PV)	• 100 MW of ground-mount PV are installed by 2030. • All viable rooftops have PV installed by 2040 (394 MW). • All PV systems include battery storage	61	6%
Additional Actions (i.e. active transportation and transit infrastructure; biogas for agriculture waste; water conservation; etc.)	• 1000 kW of on-farm biogas systems are installed by 2050. • Peel Transportation Master Plan (TMP) 2040 targets are exceeded as a result of increased transit services, active transportation infrastructure, and infill/densification. • By 2030, ⅓ of homes have reduced their water consumption by 50%. • Wastewater systems are upgraded, per the Peel Climate Change Action Plan. • Industrial process improvements	10	1%
Protection and	• Increased infill and densification result in the	7	<1%

Restoration of Natural systems	preservation of several hectares of forests, wetlands, and agricultural lands.		
Total		1,012	

Energy

In the Low Carbon scenario, energy consumption decreases by 1% from the 2016 base year level (Figure 16, Table 12). This is less than half of the energy consumption in the BAP scenario, which totals 22.6 million GJ by 2050. From 2016 to 2050, commercial and industrial energy consumption in the Low-Carbon scenario increase by 58% and 35%, respectively, while residential energy decreases by 15% and transportation by 17%.

Energy by Sector

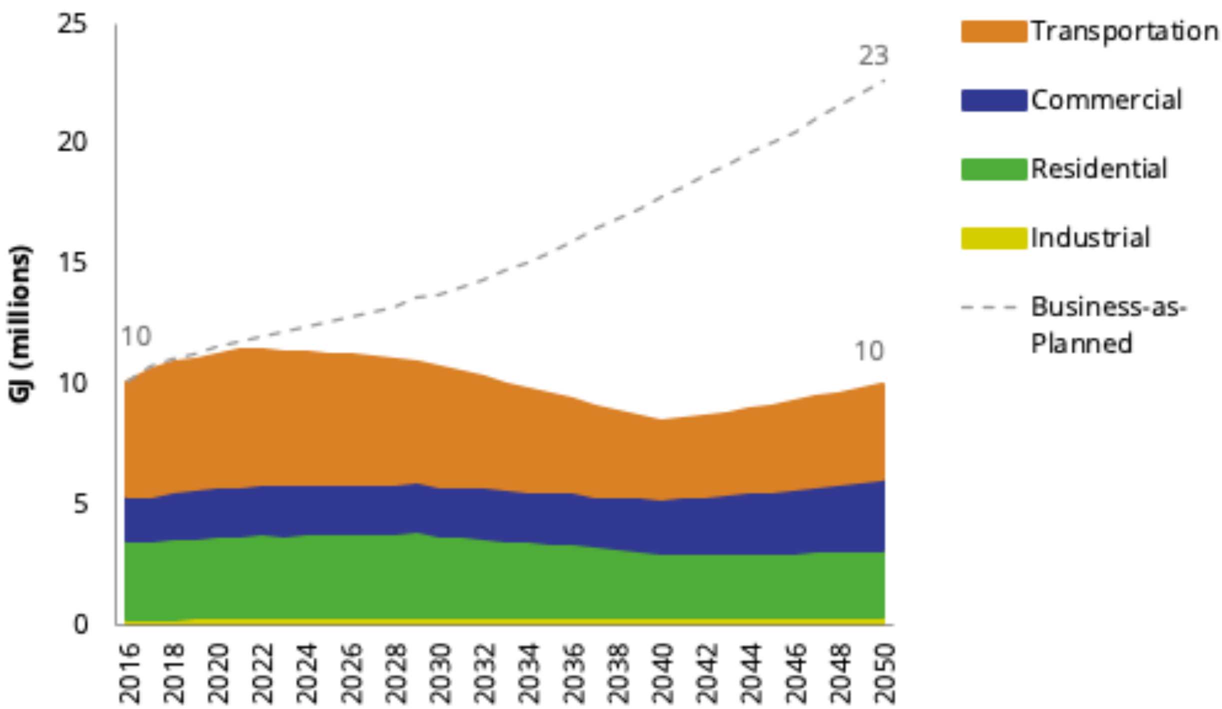

Figure 16. Low-Carbon Scenario energy consumption (GJ) by sector, 2016-2050.

Table 12. Low-Carbon Scenario energy consumption (GJ) by sector, 2016 and 2050.

	2016 (GJ)	Share of total 2016	2050 (GJ)	Share of total 2050	% change 2016-2050
Total (GJ) >	10,079,467	100%	9,970,443	100%	-1%
Commercial	1,825,781	18%	2,891,816	29%	58%
Industrial	289,198	3%	391,223	4%	35%
Residential	3,236,330	32%	2,757,767	28%	-15%
Transportation	4,728,158	47%	3,929,637	39%	-17%

Transportation energy accounts for the greatest amount of energy use in the Low Carbon scenario in 2050 (39%), despite full electrification of the vehicle stock by that time, and the fact that electric vehicles on average use one third of the amount of energy per kilometer travelled compared to gasoline vehicles.[8] There are three primary reasons for the high energy consumption in the transportation sector:

1. **Caledon's population and jobs nearly double from 2016-2050.** Transportation energy use decreases from 2020 to 2040 as vehicles transition to electric and efficiencies increase. After this point, the Town's growing population outpaces these effects, and transportation energy use increases towards 2050.
2. Despite efforts to increase alternative mode shares and reduce trip lengths, Caledonians **primarily travel by personal use vehicles.**
3. Residents in Caledon also commute **long travel distances** that are prohibitive to active travel modes. Similarly, fleet vehicles must also travel relatively long distances to other central business area locations in the GTHA.

Actions to improve energy use from industrial, commercial, and residential buildings in the Low-Carbon Scenario include: deep energy retrofits for residential and non-residential buildings, switching space and water heating systems to electricity, implementing green building standards to improve energy efficiency of new buildings, and improving industrial process energy use. These actions collectively decrease building energy use to 6 million GJ in 2050, 3% below 2016 levels (Figure 17, Table 13).

From 2016 to 2050, energy consumption from commercial and industrial buildings in the Low-Carbon Scenario increases by 58% and 35%, respectively. This growth in energy use occurs due to a significant increase in non-residential floorspace by approximately 3.5 times, which overshadows GHG reductions from building improvements. For residential buildings, the number of households increases by just a factor of 2, and the actions noted above result in an overall decrease in energy consumption by 15%.

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[8] US Department of Energy (2019). Office of Energy Efficiency and Renewable Energy. Fuel Economy.org: 2018-2019 Ford Focus. https://www.fueleconomy.gov/feg/PowerSearch.do?action=noform&path=1&year1=2018&year2=2019&make=Ford&baseModel=Focus&srchtyp=ymm

Energy by fuel

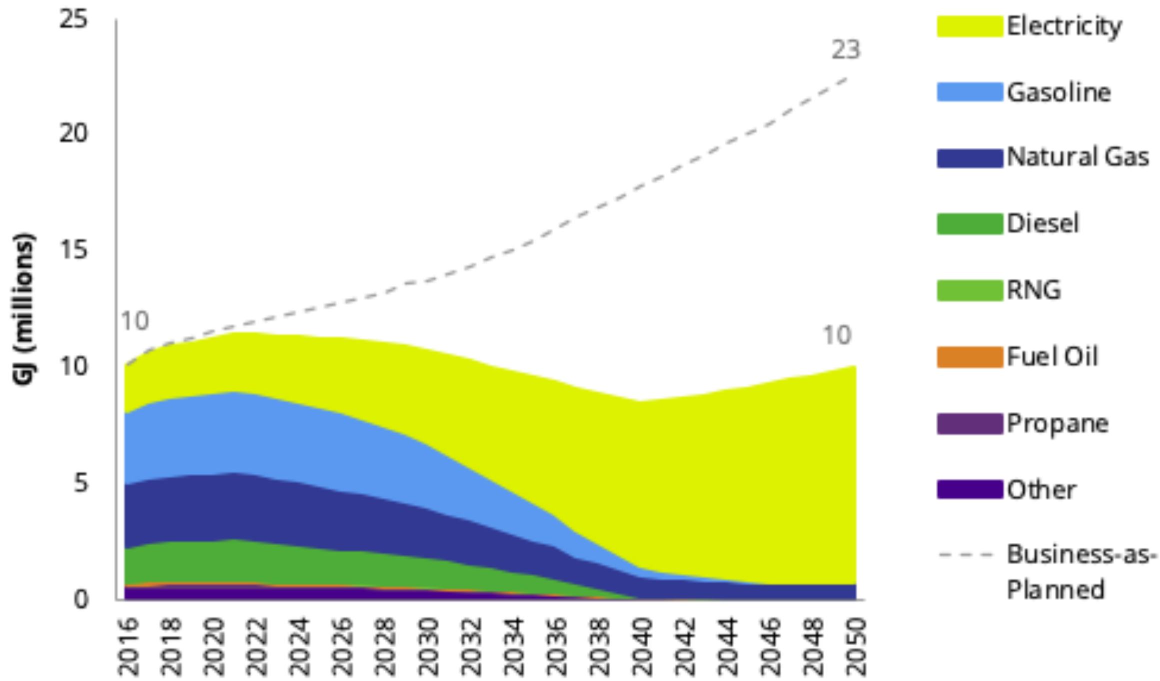


Figure 17. Low-Carbon Scenario energy consumption (GJ) by fuel, 2016-2050.

Table 13. Low-Carbon Scenario energy consumption (GJ) by fuel, 2016 and 2050.

	2016 (GJ)	Share of total 2016	2050 (GJ)	Share of total 2050	% change 2016-2050
Total (GJ) >	10,079,467	100%	9,970,443	100%	-1%
Diesel	1,461,129	14%	5,797	0%	-100%
Electricity	1,952,946	19%	9,253,368	93%	374%
Fuel Oil	140,038	1%	6,299	0%	-96%
Gasoline	3,109,923	31%	2,328	0%	-100%
Natural Gas	2,763,041	27%	664,715	7%	-76%
Other	513,871	5%	5,564	0%	-99%
Propane	138,520	1%	25,953	0%	-81%
RNG	-	0%	6,419	0.1%	1000%

Fuel sources in 2016 are primarily electricity (19%), gasoline (31%), and natural gas (27%). Diesel, fuel oil, propane, and other (wood, petroleum coke) sources make up the remainder.

In the Low-Carbon Scenario, electricity becomes the dominant energy source (93%) as natural gas boilers and furnaces are replaced with electric heat pumps for home heating, and gasoline and diesel vehicles are replaced with electric ones.

Emissions

The Low Carbon Scenario achieves a 77% reduction from 2016 levels in 2050, with 120 kt CO2e of annual emissions remaining in 2050 (Figure 18, Table 14).

Emissions by Sector

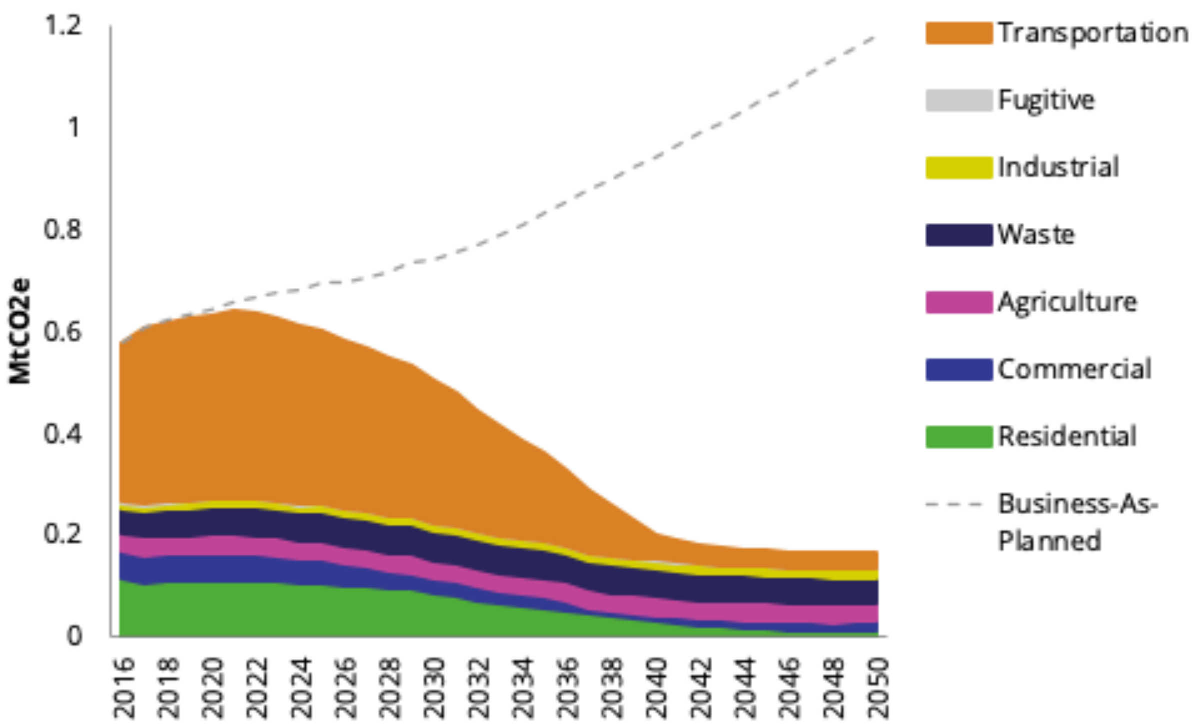


Figure 18. Gross Low-Carbon Scenario emissions by sector, 2016-2050.

Table 14. Low-Carbon Scenario emissions by sector, 2016 and 2050.

	2016 ($ktCO_2e$)	Share of total 2016	2050 ($ktCO_2e$)	Share of total 2050	% change 2016-2050
Total (ktCO2e) >	520	100%	120	100%	-77%
Agriculture	36	6%	36	22%	0%
Sequestration	(58)	-10%	(46)	-28%	-20%
Commercial	55	9%	19	11%	-66%
Fugitive	1	0%	0	0%	-76%
Industrial	13	2%	17	10%	31%
Residential	115	20%	13	8%	-89%
Transportation	311	54%	31	18%	-90%
Waste	47	8%	50	30%	8%

The residential, commercial, and industrial sectors make up nearly 30% of emissions by 2050. These emissions are from natural gas use which remains from building or heating systems that have not yet turned over, and from the emissions that are still being produced from the provincial electricity grid.

Transportation emissions account for 18% of total emissions by 2050. With full electrification of vehicles by 2050, all of these emissions are from the electricity grid.

Agriculture emissions (from manure management and enteric fermentation) remain constant from 2016 to 2050, with no changes in overall agricultural activity. One thousand kW of anaerobic digesters that produce biogas from agricultural waste are brought in, but by 2050 these result in emissions reductions of just 0.3 ktCO2e, compared to the 36 ktCO2e coming from that sector.

Emissions from waste and wastewater increase by 8% from 2016 to 2050. For waste, per capita waste generation is reduced, and diversion rates increased. For wastewater, household water use is reduced, and wastewater treatment systems improved, as planned by Peel Region and outlined in their Climate Change Action Plan. Despite these efforts, population growth results in an overall increase from 47 ktCO2e of GHG emissions in 2016 to 50 ktCO2e by 2050.

Some GHGs are absorbed, or sequestered, from Caledon's forests, wetlands, and agricultural soils. In the Low-Carbon Scenario, these decrease from 58 ktCO2e to 46 ktCO2e of sequestration, as a result of natural and agricultural lands being replaced by residential, commercial, and industrial development.

Emissions by Fuel

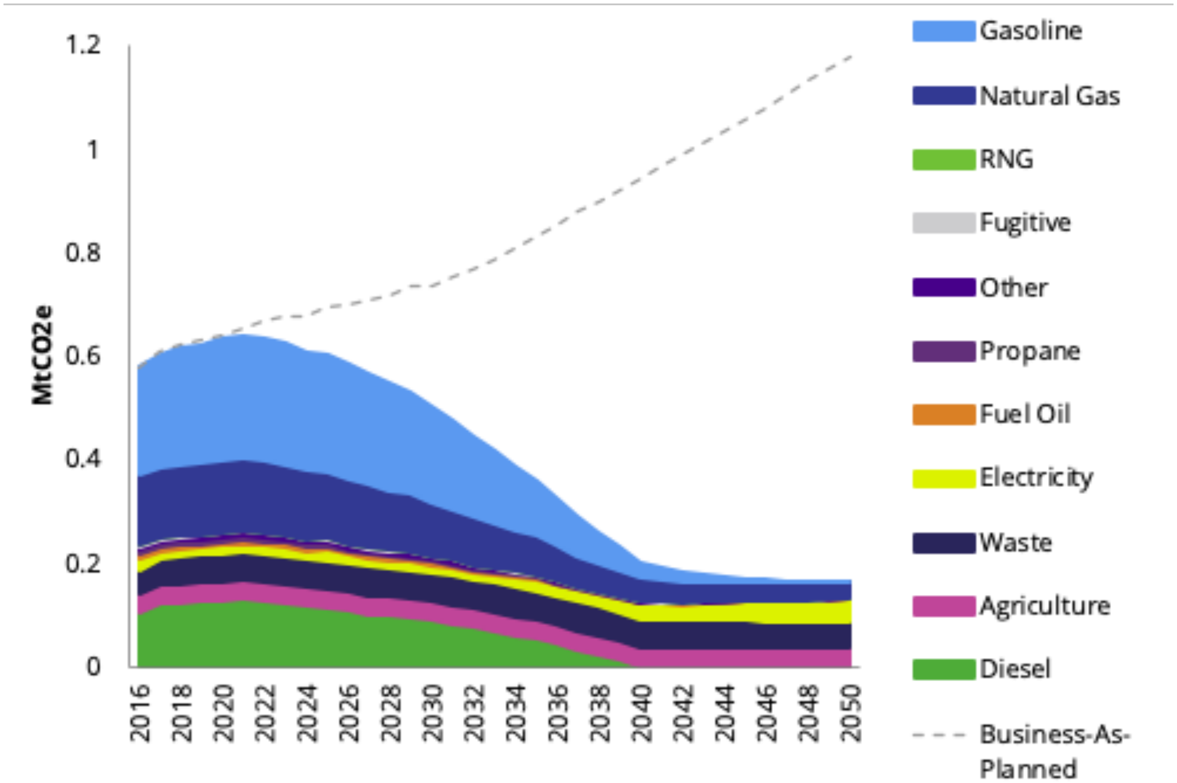


Figure 19. Gross Low-Carbon emissions by fuel source, 2016-2050.

Table 15. Low-Carbon Scenario emissions by fuel source, 2016 and 2050.

	2016 ($ktCO_2e$)	Share of total 2016	2050 ($ktCO_2e$)	Share of total 2050	% change 2016-2050
Total (ktCO2e) >	520	100%	120	100%	-77%
Agriculture	36	7%	36	22%	0%
Sequestration	(58)	-11%	(46)	-28%	-20%
Diesel	105	20%	0	0%	-100%
Electricity	20	4%	44	26%	115%
Fuel Oil	10	2%	0	0%	-95%
Fugitive	1	0%	0	0%	-76%
Gasoline	207	40%	0	0%	-100%
Natural Gas	137	26%	33	20%	-76%
Other	7	1%	0	0%	-99%
Propane	8	2%	2	1%	-81%
Waste	47	100%	50	30%	8%
RNG	-	0%	0	0%	>100%

The Low-Carbon Scenario reduces energy demand by a total of 1%, alongside a major shift to electricity. In 2016, electricity represents 19% of total energy and 4% of emissions. By 2050, electricity represents 93% of total energy and 26% of total emissions. Decarbonization of the provincial electricity grid and increased production of local renewable energy will be necessary to continue to reduce this source of emissions.

The remaining amount of natural gas and propane will need to be phased out through additional efforts to convert building systems to electric forms. The Town will also need to work with the Region on upgrading its waste and wastewater facilities to improve methane capture and use as a fuel source, as well as with the agricultural sector.

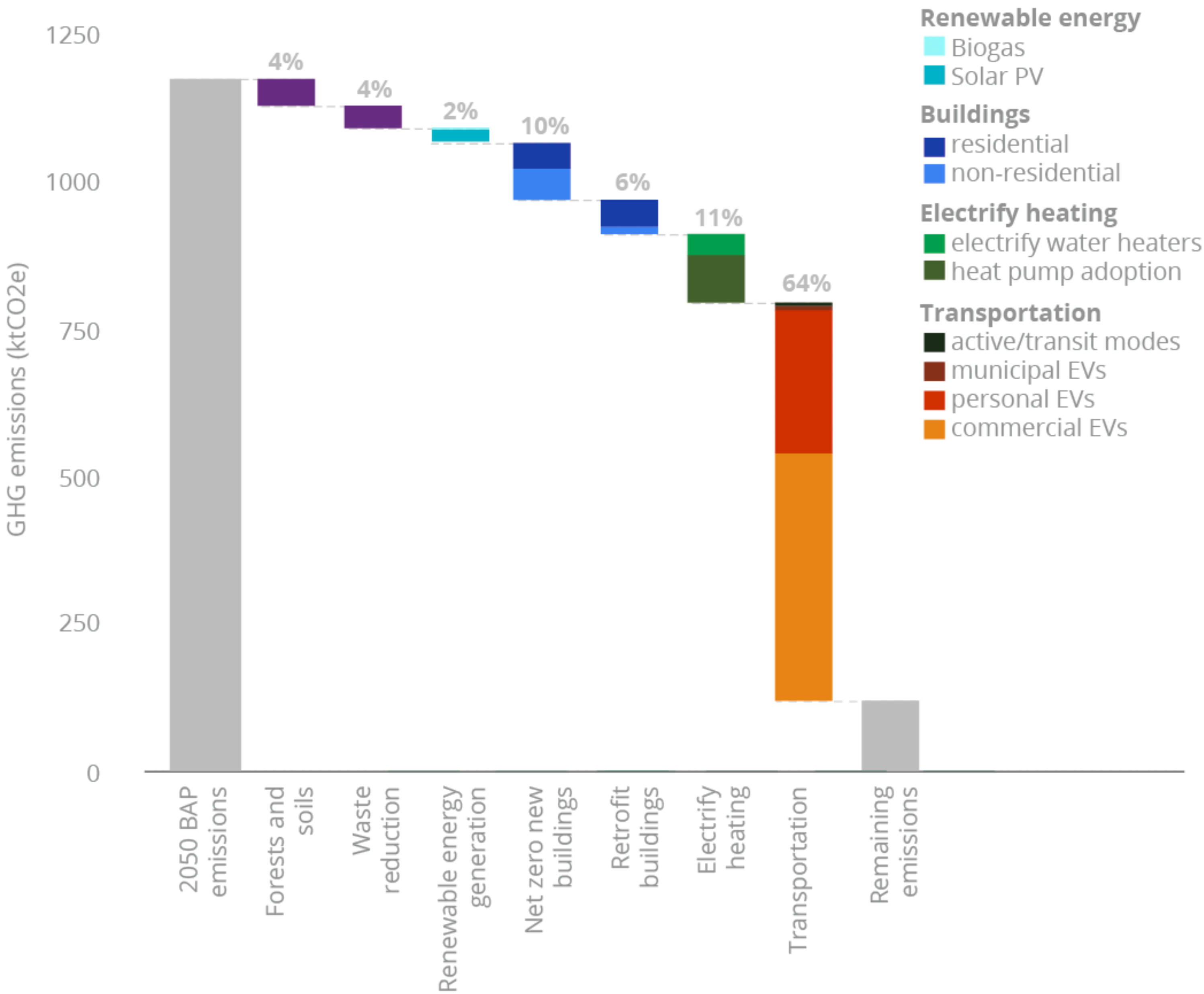


Figure 20. Waterfall diagram showing emissions reductions from Low-Carbon actions over the Business-as-Planned Scenario, 2016-2050.

Financial Analysis

A high-level financial analysis was undertaken to identify the costs, savings, and net present value of the modelled actions. In both the Business-as-Planned and Low-Carbon scenarios, expenditures are made and savings occur. The financial information presented here shows the incremental additional expenditures required and additional savings resulting from the implementation of the Low-Carbon scenario over those that are expected in the Business-as-Planned Scenario.

SUMMARY OF COSTS AND SAVINGS

Modelling of costs and savings considered upfront capital expenditures, operating and maintenance costs (including fuel and electricity), and carbon pricing. The table below summarizes the expenditure types that were evaluated.

Table 16. Categories of expenditures evaluated.

Category	Description
Building construction, retrofits, and equipment	Cost of dwelling construction and retrofitting (incl. equipment); operating and maintenance costs (non-fuel).
Buildings fuel	Energy costs for heating, cooling, and operating buildings, as well as for commercial and industrial production.
Buildings emissions	Costs resulting from a carbon price on GHG emissions from buildings.
Energy production equipment	Cost of the equipment for generating local electricity.
Energy production revenue	Revenue derived from the sale of locally generated electricity.
Personal, commercial & municipal/transit vehicles	Cost of vehicle purchase; operating and maintenance costs (non-fuel).
Vehicle fuel	Energy costs for transportation fuel.
Vehicle emissions	Costs resulting from a carbon price on GHG emissions from transportation.
Transportation infrastructure	Investments in expanding active transportation infrastructure.

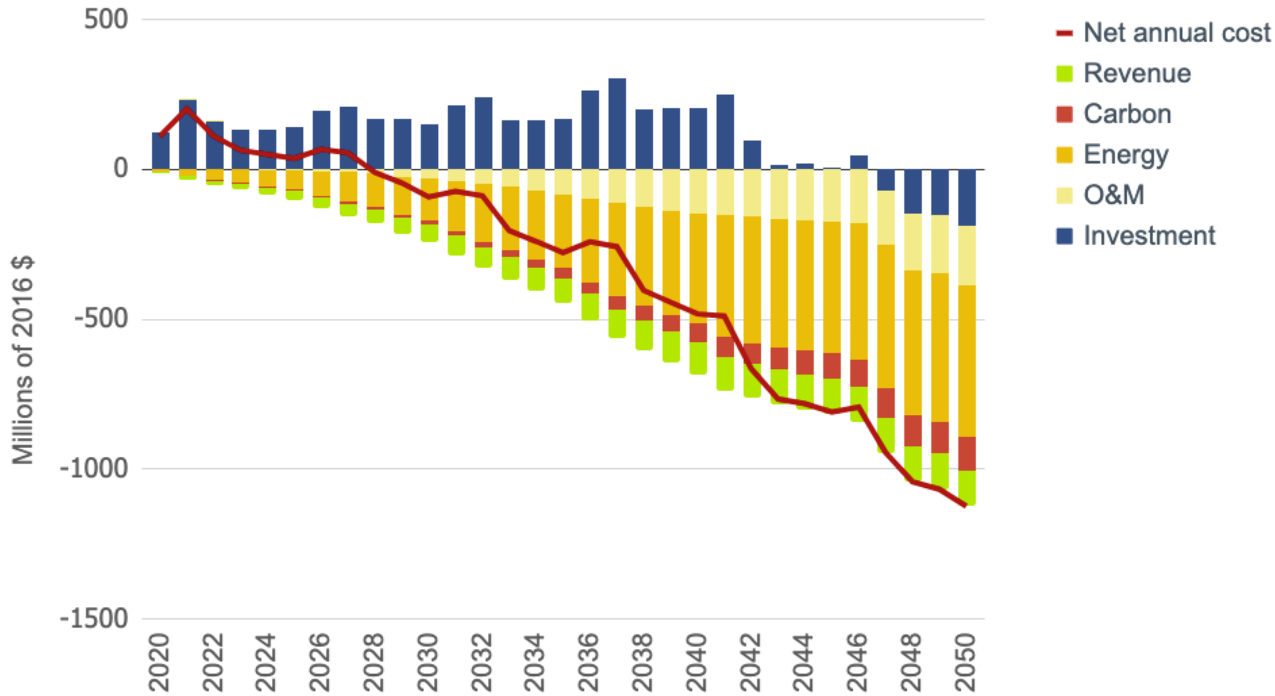


Figure 21. Summary of Low-Carbon Scenario costs (above the x-axis) and savings (below the x-axis) relative to the Business-as-Planned scenario.

The figure above shows costs and savings for Low-Carbon Scenario actions compared to the Business-as-Planned Scenario. The costs, or investments, vary year-over-year, based on the timelines and levels of ambition of the Low-Carbon versus Business-as-Planned actions. The majority of investments are incurred in the first 20 years, in line with the need to take action as soon as possible. Investments actually become 'negative' as of 2047, when Low Carbon technologies become cheaper than conventional ones.

Savings from operations and maintenance grow over the years, as the use of heat pumps over conventional systems require less servicing and replacement. Savings from reduced energy use offer the greatest financial returns over the years, which primarily result from more efficient vehicles and buildings.

Rooftop and ground mount solar PV systems generate revenue, which increases over the years as more systems are brought online.

Fuel and electricity savings also lead to savings from fewer carbon price costs. These savings increase over the years with greater energy savings associated with action implementation, as well as from increases to the carbon price itself over the years. The federal carbon price is currently $30/tonne, which is scheduled to increase to $50/tonne by 2022. Commitments beyond 2022 have not yet been made, but it is estimated that carbon pricing will be at least $100/tonne by 2050.

By 2050 the cumulative costs to implement the Low-Carbon Scenario actions is $3.82 billion, with a net present value of $2.82 billion (at a discount rate of 3%). Once savings are applied, the result is a net savings of $10.64 billion, with a net present value of $4.9 billion. The figure above shows that net annual costs are incurred until the year 2028, at which point savings, particularly from reduced energy costs outweigh costs.

Table 17. Summary of Low-Carbon scenario financial metrics.

Item	LC (billions of 2018$)	
	Undiscounted	Present value (3%)
Capital investments	3.82	2.82
O&M savings	2.77	1.41
Energy savings	8.01	4.31
Carbon price savings	1.32	0.67
Revenue from local generation	2.36	1.33
Net cost of program	**10.64**	**4.90**

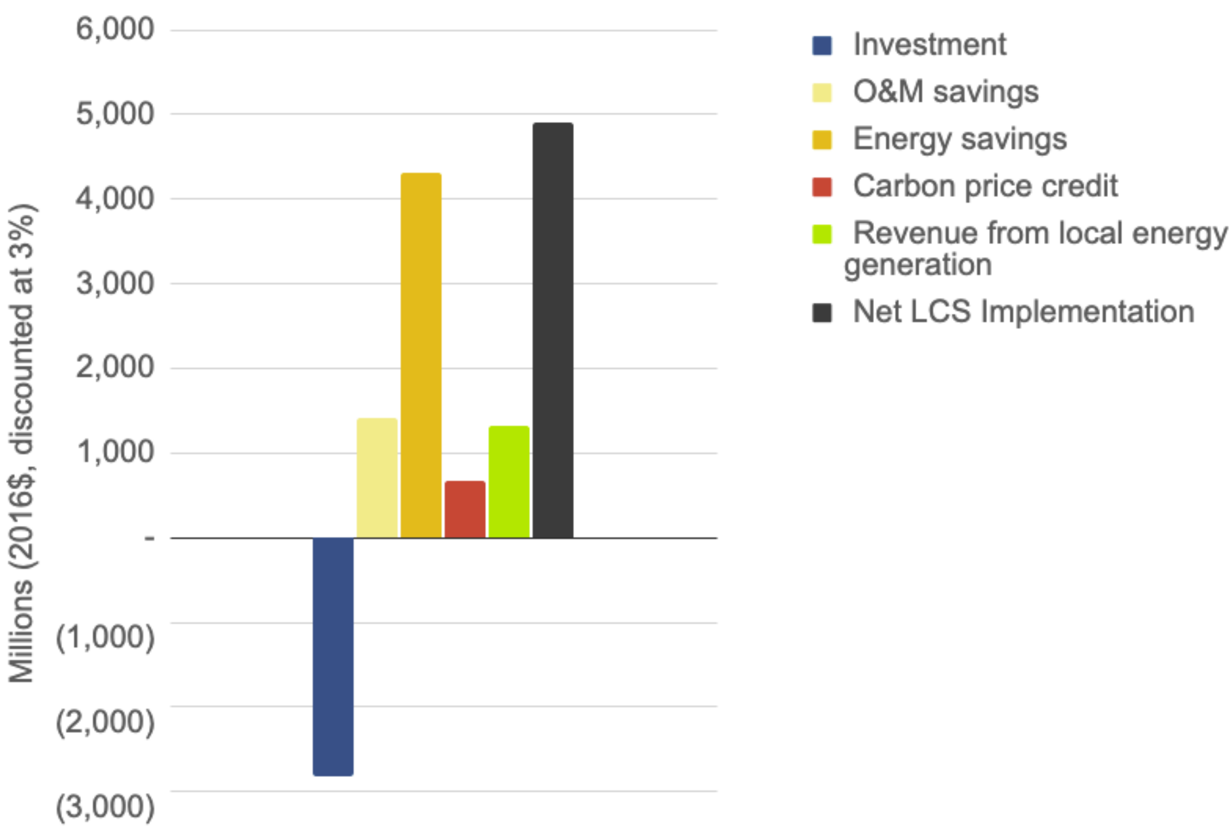


Figure 22. Net present value of costs (negative) and savings (positive) of Low-Carbon over the Business-as-Planned Scenario.

CAPITAL COSTS

Low-Carbon Scenario capital costs are summarized in the figure below.

Retrofits to residential buildings make up the greatest amount of capital expenditures. These expenditures increase until the year 2040, after which all retrofits have been completed.

The next greatest capital expenditure is for local energy generation, primarily rooftop solar PV. These investments are greater in earlier years as both new and existing buildings have solar panels installed.

Personal electric vehicle costs reach a break-even point with conventional vehicles around 2030, after which point electric vehicles become cheaper and net savings begin. For commercial vehicles, this doesn't happen until 2050.

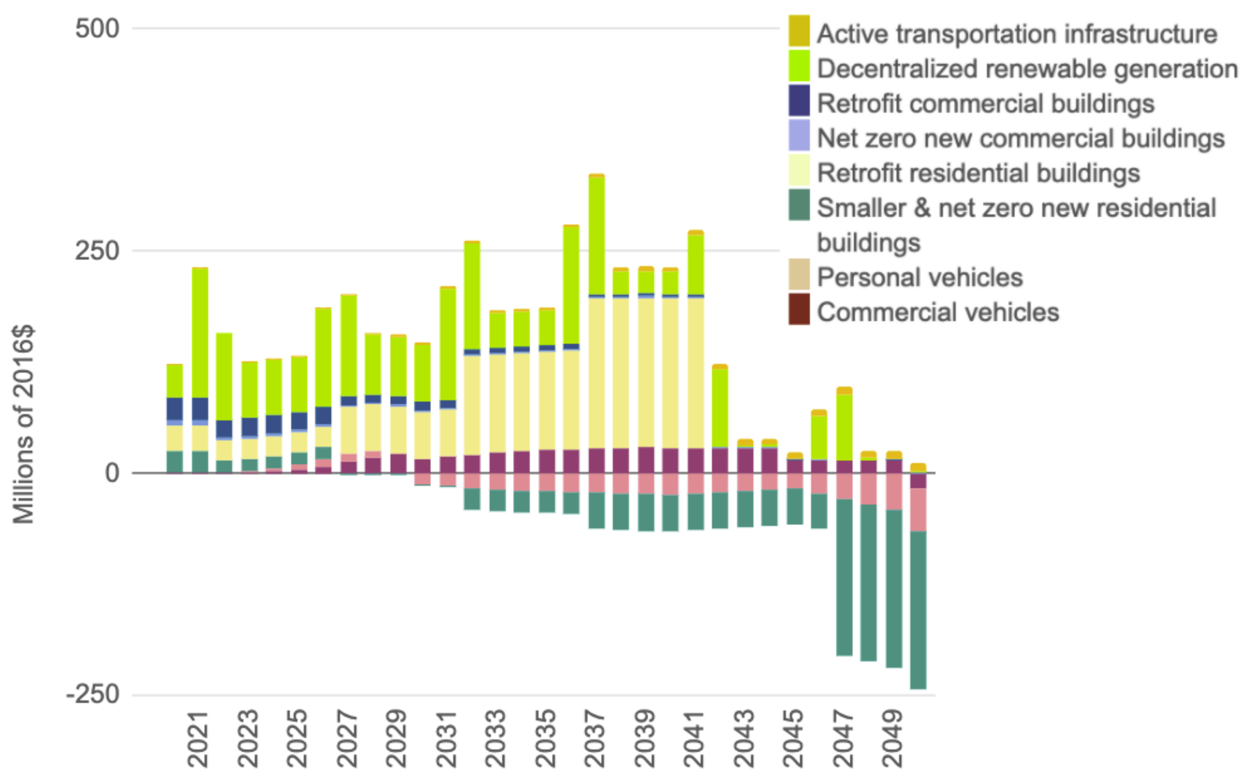


Figure 23. Annual incremental Low-Carbon Scenario capital costs over Business-as-Planned costs.

ENERGY EXPENDITURES

Energy price projections

Energy expenditures were calculated using projected costs for different fuel types. These costs, shown in the figure below, were derived from: the Independent Electricity System Operator's Long-Term Energy Plan (electricity), the US Energy Information Administration (propane), and the National Energy Board (all other fuels).

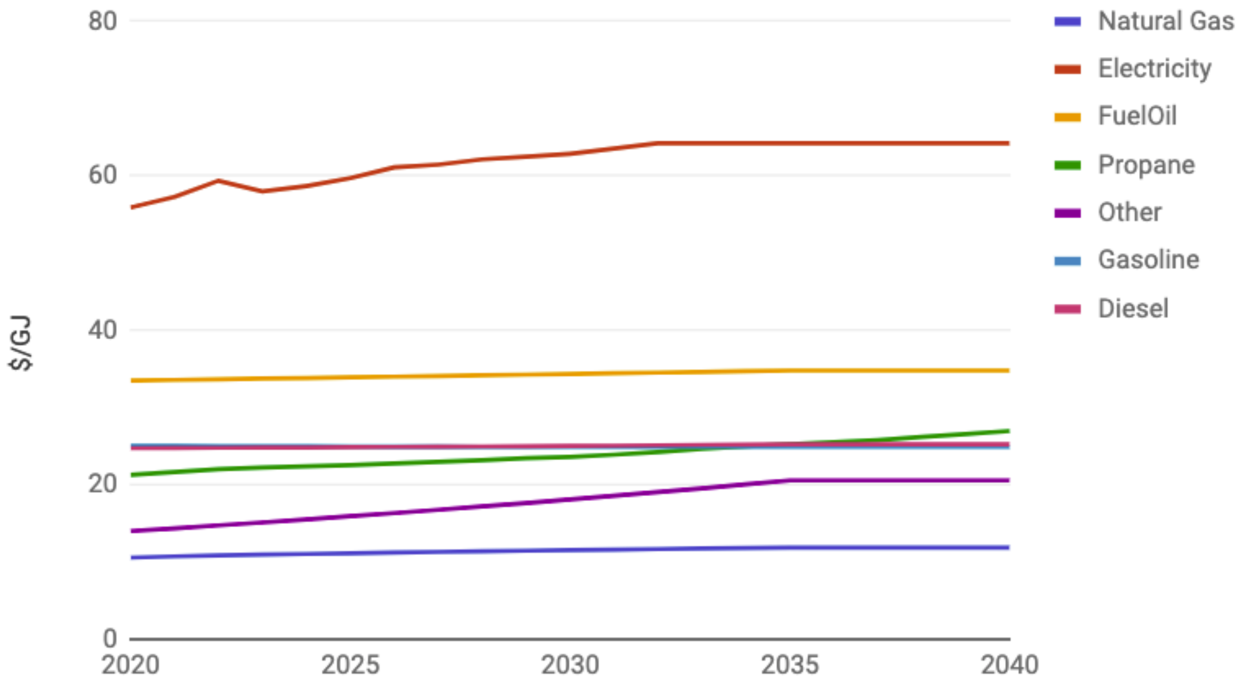


Figure 24. Projected fuel costs.

Energy expenditures

Low-Carbon Scenario costs decrease towards 2040 as building retrofits are undertaken, electric vehicle uptake increases, and solar PV installations are brought in. After this point, most energy efficiency efforts have been achieved and continued population growth in the Town causes energy expenditures to rise.

In 2016, community-wide energy costs totaled approximately $315 million. In the Business-as-Planned Scenario, energy costs increase to $905 million by 2050, whereas in the Low-Carbon Scenario they increase to just $403 million. This represents a 55% decrease in the Low-Carbon Scenario 2050 energy costs compared to those in the Business-as-Planned Scenario. By 2050, households save $3,620 per year on their utility bills in the Low-Carbon Scenario compared to Business-as-Planned.

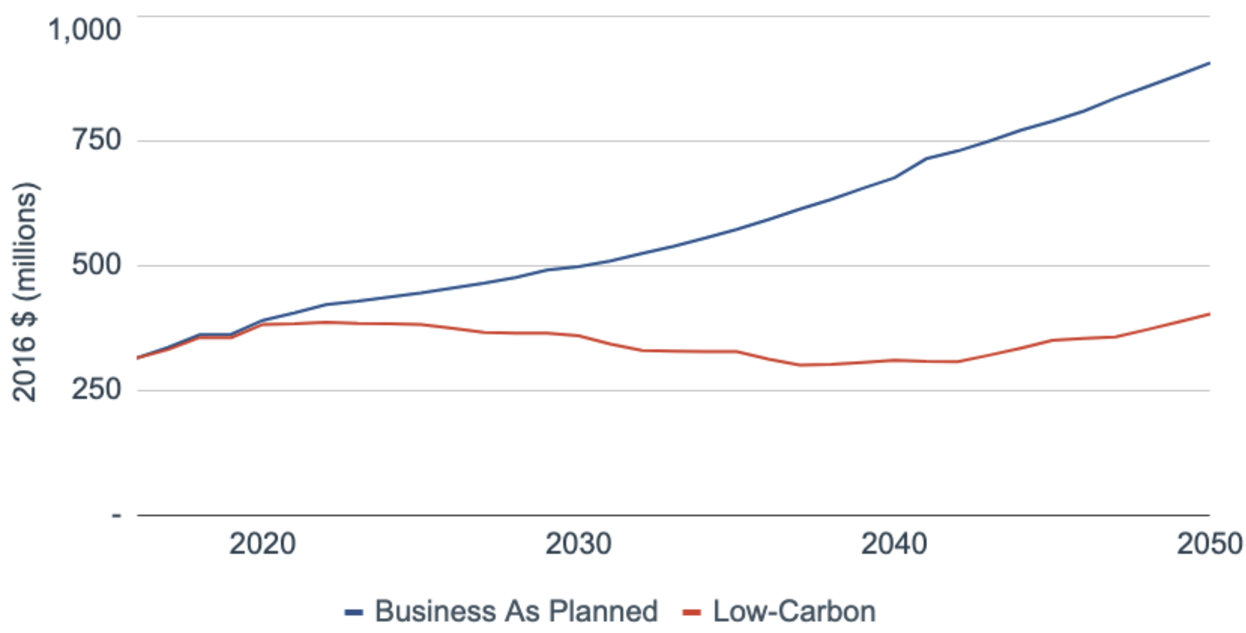


Figure 25. Estimated total annual energy costs for the Business-as-Planned Scenario (blue) and the Low-Carbon Scenario (red).

EMPLOYMENT

The investments in the Low-Carbon Scenario result in increased employment. This includes new opportunities in renewable energy installation, design, and construction of zero-carbon and resilient buildings, and retrofits to existing buildings. Investments made across all sectors create approximately 38,000 person years of employment[9] in Caledon from 2020-2050, an average of just over 1,100 jobs per year. Some jobs will also be lost or will have to transition to other sectors as investments are shifted, resulting in a net of 923 jobs per year being created in the town.

The majority of jobs added are in the building sector, with significant retrofits (including heat pumps and water heating systems) targeted between 2020 and 2040. Local renewable generation jobs are added until 2040 with significant solar PV installs in these years, tapering off after 2040 once most buildings have been fitted with PV systems. Some automotive repair jobs are lost as the requirement for maintenance of electric vehicles is expected to decline.

[9] A person year of employment is equivalent to 1 person working a full-time job for 1 year. Person years of employment were calculated using known numbers of jobs created per dollar invested across different sectors, and applying these to the investments required to implement the actions in the plan.

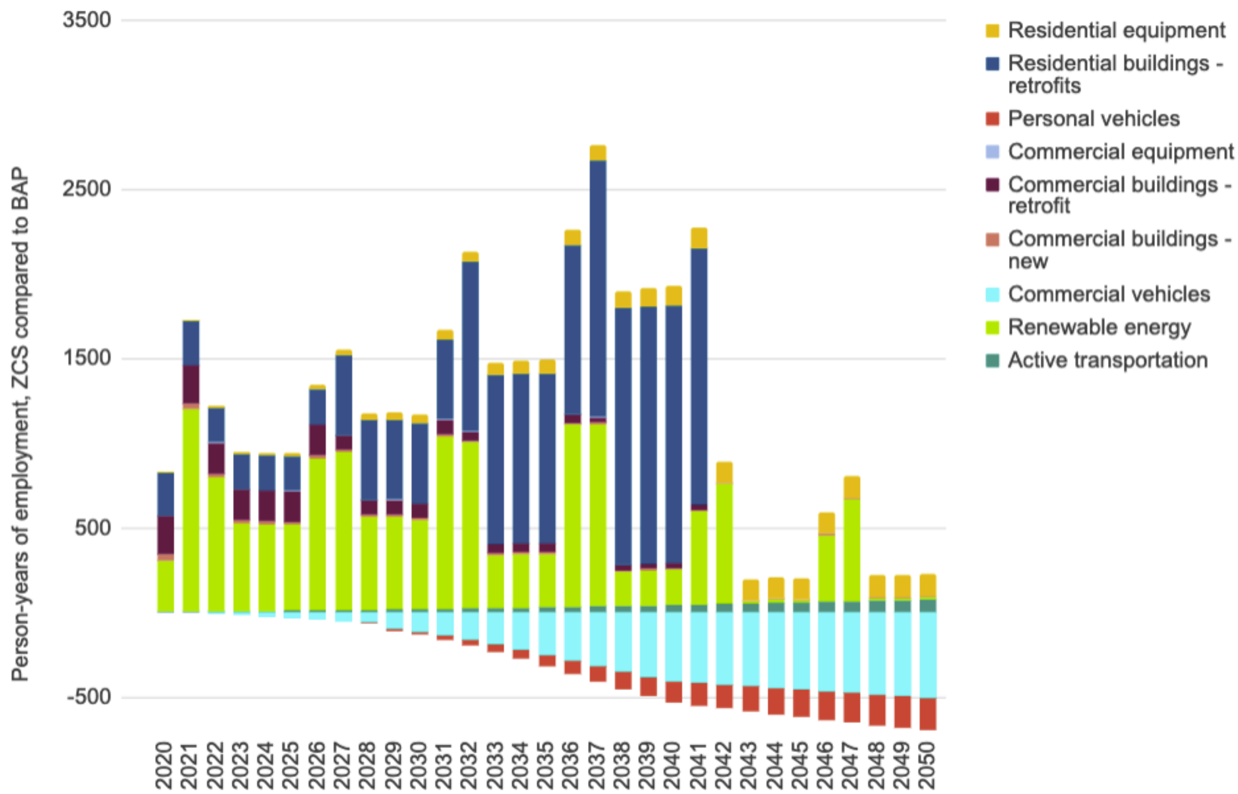


Figure 26. Employment generated by implementation of the Low-Carbon Scenario.

5. BUSINESS-AS-PLANNED SCENARIO - DATA & ASSUMPTIONS

EMISSIONS FACTORS

Table 18. Emissions factors used for GHG calculations.

Category	Description	Comment
Natural gas	49 kg CO2e/GJ	Environment and Climate Change Canada. National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada. Part 2. Tables A6-1 and A6-2, Emission Factors for Natural Gas.
Electricity	2016: CO2: 28.9 g/kWh CH4: 0.007 g/kWh N2O: 0.001 g/kWh 2050: CO2: 37.4 g/kWh CH4: 0.009 g/kWh N2O: 0.001 g/kWh	Projected using CanESS modelling using data from National Energy Board. (2016). Canada's Energy Future 2016. Government of Canada. Retrieved from https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016pt/nrgyftrs_rprt-2016-eng.pdf
Gasoline	g/L CO2: 2316 CH4: 0.32 N2O: 0.66	Environment and Climate Change Canada. National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Diesel	g/L CO2: 2690.00 CH4: 0.07 N2O: 0.21	Environment and Climate Change Canada. National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–12 Emission Factors for Energy Mobile Combustion Sources

Category	Description	Comment
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 1990-2016: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–4 Emission Factors for Refined Petroleum Products
Propane	Transport g/L CO_2: 1515.00 CH_4: 0.64 N_2O: 0.03 Residential g/L CO_2: 1515.00 CH_4: 0.027 N_2O: 0.108 All other sectors g/L CO_2: 1515.00 CH_4: 0.024 N_2O: 0.108	Environment and Climate Change Canada. National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–3 Emission Factors for Natural Gas Liquids Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Waste	Landfill emissions are calculated from first order decay of degradable organic carbon deposited in landfill. Derived emission factor in 2016 = 0.015 kg CH_4/tonne solid waste (assuming 70% recovery of landfill methane); 0.050 kg CH_4/tonne solid	Landfill emissions: IPCC Guidelines Vol 5. Ch 3, Equation 3.1

Category	Description	Comment
	waste not accounting for recovery.	
Wastewater	CH4: 0.48 kg CH4/kg BOD N2O: 3.2 g / (person * year) from advanced treatment 0.005 g /g N from wastewater discharge	CH4 wastewater: IPCC Guidelines Vol 5. Ch 6, Tables 6.2 and 6.3; 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

DATA AND ASSUMPTIONS

Table 19. Baseline and Business-as-Planned data sources and assumptions.

Category	Data/Assumption	Source	Comments/Notes
DEMOGRAPHICS			
Population & employment			
Population & employment	Population: 68,800 (2016) to 160,000 (2041); Region projection for Town to 2041 by zone. Employment: 26,820 (2016) to 80,000 (2041); Region projection for Town to 2041 by zone. 2041-2051: extrapolate 2016-2041 trend for population & employment total to 2051.	All documents provided by Peel Region Planning - Population, employment, and total dwelling units by SGU- aggregated to Transportation zone level per the Region's Request. - Council Resolution.pdf- min. 50% intensification target, and min. 50 people and units per ha for greenfields target - 2-Peel-2041-Growth-Allocation-and-Growth-Management-ROPA.pdf (p61 includes projections for Dwelling Units by type)	-SGU data shows 2016 employment at 1,000 jobs less than other Regional and Town projections - Intensification and density are minimum targets, there is possibility to aim for higher through planning process
BUILDINGS			
New buildings growth			

Category	Data/Assumption	Source	Comments/Notes
Building growth projections	Region projections for the Town to 2041 by zone.	2-Peel-2041-Growth-Allocation-and-Growth-Management-ROPA.pdf (p61 includes projections for dwelling units by type, however, as noted in the document, these are 'market'-based and not Growth Plan-based.	a) Post 2041 projections are not available. Approach is to extrapolate 2016-2041 trend for buildings growth to 2051; and to allocate post 2041 growth to one spatial zone. b) With no breakdown of building sub-sector by type available (eg. residential by > single, semi, row, apartment etc.), we determined existing mix by zone for 2016 (eg. 70% single; 20% semi; 10% row/townhouse) and hold constant to 2051.
New buildings energy performance			
Residential	New construction 15% more efficient every 5 years starting in 2018.	Confirmed with Town staff.	Toronto Green Standard (TGS) analysis by The Atmospheric Fund (TAF) indicates that by 2017, the OBC will be the equivalent of TGS v2 Tier 1. Modelling approach assumes that OBC evolution will follow TGS evolution with a 5-year lag. Based on modelled energy use intensity improvements, the incremental performance improvement for TGS v2 Tier 1 and TGS v3 Tier 1 are 13-15% and 20-40%, respectively. The modelling for all new construction
Multi-residential	New construction 15% more efficient every 5 years starting in 2018.		
Commercial/ Institutional	New construction 15% more efficient every 5 years starting in 2018.		
Industrial	New construction 15% more efficient every 5 years starting in 2018.		

Category	Data/Assumption	Source	Comments/Notes
			assumes a 15% improvement every 5 years.
Existing buildings energy performance			
Residential	Existing building stock unchanged; efficiency held constant from 2016-2050.	Confirmed with Town staff.	
Multi-residential			
Commercial & Institutional			
Industrial			
End use			
Space heating	Use data from Caness (adoption of energy efficient furnaces, etc)	Canadian Energy Systems Simulator	
Water heating			
Space cooling			
Projected climate impacts			
Heating & cooling degree days	Modelled data for Caledon	Climateatlas.ca	
ENERGY GENERATION			
Low or zero carbon energy generation (community scale)			
Solar PV	2016 Solar Capacity Is Held Constant	Confirmed with Town staff.	
Solar PV - ground mount	Not expected in BAP		
Solar heating/hot water	Not expected in BAP		
Energy storage	Not expected in BAP		
Renewable natural gas	Not expected in BAP		
TRANSPORT			
Transit			

Category	Data/Assumption	Source	Comments/Notes
Expansion of GO	No expansion expected.	Confirmed with Town staff.	
Expanded transit	2 new transit lines this year.		
Electrify transit system	No electrification expected.		
Active			
Increase/improve cycling & walking infrastructure	Modal Split expected to stay the same to 2050.	Confirmed with Town staff.	
Private/personal use			
Electrify municipal fleet			
Electrify personal vehicles	5% new personal EVs in personal use vehicle stock by 2040.	EIA Annual Energy Outlook 2016 - https://www.eia.gov/outlooks/aeo/pdf/0383(2016).pdf	
Electrify commercial vehicles	No major change in BAP Scenario.	Confirmed with Town staff.	
Vehicle kilometers travelled	VKT is expected to increase towards 2050	CItyInSight Model Assumptions based on population and job growth within the Town of Caledon.	
Vehicle fuel efficiencies	Vehicle fuel consumption rates reflect the implementation of the U.S. Corporate Average Fuel Economy (CAFE) Fuel Standard for Light-Duty Vehicles, and Phase 1 and Phase 2 of EPA HDV Fuel Standards for Medium- and Heavy-Duty Vehicles.	EPA. (2012). EPA and NHTSA set standards to reduce greenhouse gases and improve fuel economy for model years 2017-2025 cars and light trucks. Retrieved from https://www3.epa.gov/otaq/climate/documents/420f12050.pdf http://www.nhtsa.gov/fuel-economy	

Category	Data/Assumption	Source	Comments/Notes
Vehicle share	Personal vehicle stock share changes between 2016-2050. Commercial vehicle stock unchanged 2016-2050.	CANSIM and Natural Resources Canada's Demand and Policy Analysis Division.	
WATER AND WASTE			
Waste generation	Existing per capita waste generation rates unchanged.	Confirmed with Town staff.	
Waste diversion	Peel Region target of 75% diversion by 2034. https://www.peelregion.ca/strategicplan/20-year-outcomes/waste-diversion-rate.asp	Regional target.	
Waste treatment	Existing waste treatment processes per capita unchanged.	Confirmed with Town staff.	

6. GPC INVENTORY TABLES - 2016

Table 20. GHG Emissions Report, following reporting format from the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories.

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Reason for exclusion (if applicable)	tonnes			
					CO2	CH4	N2O	Total CO2e
I		STATIONARY ENERGY SOURCES						183,527
I.1		Residential buildings						
I.1.1	1	Emissions from fuel combustion within the city boundary	Yes		96,664	257	4	104,387
I.1.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes		9,459	3	0	9,607
I.1.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes		593	0	0	602
I.2		Commercial and institutional buildings/facilities						
I.2.1	1	Emissions from fuel combustion within the city boundary	Yes		44,762	1	1	45,088
I.2.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes		8,986	3	0	9,126
I.2.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes		563	0	0	572
I.3		Manufacturing industry and construction						
I.3.1	1	Emissions from fuel combustion within the city boundary	Yes		12,267	0	0	12,346
I.3.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes		403	0	0	409
I.3.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes		25	0	0	26
I.4		Energy industries						
I.4.1	1	Emissions from energy used in power plant auxiliary operations within the city boundary	No	NR	0	0	0	0

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Reason for exclusion (if applicable)	tonnes			
					CO2	CH4	N2O	Total CO2e
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
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						
I.8.1	1	Emissions from fugitive emissions within the city boundary	Yes		4	54	0	1,363
II		TRANSPORTATION						311,460
II.1		On-road transportation						
II.1.1	1	Emissions from fuel combustion for on-road transportation occurring within the city boundary	Yes		253,943	13	9	256,863
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		54,349	3	1	54,596

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Reason for exclusion (if applicable)	tonnes			
					CO2	CH4	N2O	Total CO2e
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
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
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	Yes	ID	0	0	0	0
II.5.2	2	Emissions from grid-supplied energy consumed within the city boundary for off-road transportation	Yes		0	0	0	0
III		WASTE						46,925

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Reason for exclusion (if applicable)	tonnes			
					CO2	CH4	N2O	Total CO2e
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
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	945	0	23,631
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	211	16	10,012
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
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	184	0	4,649
III.4.2	3	Emissions from wastewater generated within the city boundary but treated outside of the city boundary	No	NR	0	341	0	8,634
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)						0
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)						-22,116

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Reason for exclusion (if applicable)	tonnes			
					CO2	CH4	N2O	Total CO2e
V.1	1	Emissions from livestock within the city boundary	Yes		36,072	0	0	36,072
V.2	1	Emissions from land within the city boundary	No	NR	-58,188	0	0	-58,188
V.3	1	Emissions from aggregate sources and non-CO2 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
2016 TOTAL								519,796

Notation Key

Reasons for exclusion:	
N/A	Not applicable; Not included in scope
ID	Insufficient data
NR	No relevant or limited activities identified
Other	Reason provided under Comments

Table 21. GHG Emissions Summary following the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories reporting levels.

Sector		Total by Scope (tCO2e)				Total	Total by city-induced reporting level (tCO2e)	
		Scope 1	Scope 2	Scope 3	Other Scope 3		BASIC	BASIC+
Stationery Energy	Energy use (all I emissions except I.4.4)	163,184	19,142	1,200		183,527	182,327	183,527
	*Energy generation supplied to the grid (I.4.4) **	0						
Transportation (all II emissions)		256,863	1	54,596		311,460	256,863	311,460
Waste	Generated in the city (all III.X.1 and III.X.2)	4,649		23,631		28,280	28,280	28,280
	Generated outside city (all III.X.3)							
IPPU (all IV emissions)								
AFOLU (all V emissions)								
Total		424,696	19,143	79,427	0	523,266	467,469	523,266
		(All territorial emissions)					*(All BASIC emissions)*	*(All BASIC & BASIC+ emissions)*

Key for cell colour coding

Sources required for BASIC reporting	
Sources required for BASIC+ reporting (green & blue)	
Sources included in Other Scope 3	
Sources required for territorial but not for BASIC/BASIC+ reporting	
Non-applicable emissions	

7. FINANCIAL DATA TABLES

Table 1: New Dwelling Building Construction

Average of values for GTA ($/m2)	
Single	1,722
Double/Row	1,372
Apartment 1-4 storey	2,476
Apartment 5-14 storey	2,664
Apartment > 15 storeys	2,718

source: *Altus Group Cost Guide - 2018*

Table 2: Dwelling Operations & Maintenance Costs

Household spending intensity	
$/m2/year	3.18

source: *Statistics Canada. Table 11-10-0222-01 Household spending, Canada, regions and provinces*
Repairs and maintenance for owned living quarters

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

$/vehicle	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
gas	56,912	57,239	57,566	57,893	58,083	58,274	58,464	58,655	58,845	59,924	59,924	62,595
diesel	61,279	61,772	62,266	62,759	63,055	63,351	63,648	63,944	64,240	64,718	64,718	65,540
electric	93,410	93,383	93,355	93,328	88,101	82,875	77,648	72,422	70,058	58,240	58,240	58,240

source for gas and diesel: *https://about.bnef.com/blog/battery-pack-prices-fall-as-market-ramps-up-with-market-average-at-156-kwh-in-2019/*
source for electric: *same as personal use vehicles assuming light trucks*
with these factor applied:- car to light truck factor: 1.75- manufacturing to retail cost factor: 1.5- USD to CAD exchange rate: 1.3

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

$/vehicle	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
gas	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500
diesel	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500	84,500
electric	132,762	125,840	118,917	111,994	108,517	105,040	101,564	98,087	94,610	97,431	97,431	84,500

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

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

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

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

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

$/vehicle/year	2017	2021	2026	2031	2036	2041	2046	2051
gas/diesel	8,600	8,600	8,600	8,600	8,600	8,600	8,600	8,600
electric	6,592	6,592	6,592	6,592	6,592	6,592	6,592	6,592

source: *Lion refrigerated truck model provided by Matthew Elgin*

Table 7: Transit Bus Capital Costs

$/vehicle	2021	2026	2031	2036	2041	2046	2051
dieselBioDieselMix	701,880	701,880	701,880	701,880	701,880	701,880	701,880
electricity	1,146,639	940,832	797,502	701,880	701,880	701,880	701,880

source: *Calcuation for capital costs from internal sources; electric includes charging station and building infrastructure costs*
Assumes 50% of cost of EV bus is related to batteries and cost declines from 161 $/kWh in 2020 to 100 in 2026 to 61 in 2031 as per BNEF projections

Table 8: Transit Bus Maintenance Costs

$/vehicle/5-year	2021	2026	2031	2036	2041	2046	2051
diesel	$ 38,719	$ 38,719	$ 38,719	$ 38,719	$ 38,719	$ 38,719	$ 38,719
electricity	$ 27,000	$ 27,000	$ 27,000	$ 27,000	$ 27,000	$ 27,000	$ 27,000

source: Calcuation for bus maintenance from internal sources

Table 10: Active Mode Infrastructure Costs

$/year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
Total expenditures	0	0	0	$574,485	$709,343	$857,523	$1,015,349	$1,181,884	$1,358,934	$2,389,341	$5,470,782	$9,465,156

source: Assumes cycling infrastructure climbs to be in the range of European cities on a per capita basis
http://www.copenhagenize.com/2016_04_01_archive.html

Table 11: Residential Heat Pump Capital Costs, Installed

$/heat pump	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
Air source	6,435	6,435	6,435	6,435	6,435	6,435	6,435	6,435	6,435	6,435	6,435	6,435
Geothermal	25,545	25,545	25,545	25,545	25,545	25,545	25,545	25,545	25,545	25,545	25,545	25,545

source: US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018
assume USD to CAD exchange rate of 1.3

Table 13: Residential Heat Pump Operations & Maintenance Costs

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
Air source	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5
Geothermal	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5

source: US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018
assume USD to CAD exchange rate of 1.3

Table 15: Residential Water Heater Capital Costs, Installed

$ / unit	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
30 Gallon natural gas	1,820	1,820	1,820	1,820	1,820	1,820	1,820	1,820	1,820	1,820	1,820	1,820
40 Gallon	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300
Solar 40 Gallon	9,230	9,230	9,230	9,230	9,230	9,230	9,230	9,230	9,230	9,230	9,230	9,230
On Demand Electric	3,500	3,501	3,502	3,503	3,504	3,505	3,506	3,507	3,508	3,513	3,523	3,533
Heat Pump	3,120	3,120	3,120	3,120	3,120	3,120	3,120	3,120	3,120	3,120	3,120	3,120
District energy	900	901	902	903	904	905	906	907	908	913	923	933

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

Table 16: Residential Water Heater Maintenance Costs

$/unit/year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
Solar 40 Gallon	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5
On Demand Electric	85	86	87	88	89	90	91	92	93	98	108	118
Heat Pump	26	26	26	26	26	26	26	26	26	26	26	26
District energy	85	86	87	88	89	90	91	92	93	98	108	118

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

Table 17: Non Residential Heat Pump Capital Costs

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

source: *US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018*
assume USD to CAD exchange rate of 1.3

Table 18: Non Residential Heat Pump O&M Costs

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

source: *US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018*
assume USD to CAD exchange rate of 1.3

Table 19: Non Residential Water Heater Capital Costs

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

source: *US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018*
assume USD to CAD exchange rate of 1.3

Table 20: Non Residential Water Heater O&M Costs

$/water heater/year	
electric	65
natural gas	351

source: *US EIA Updated buildings sector appliances and equipment costs and efficiencies, June 2018*
assume USD to CAD exchange rate of 1.3

Table 19: Commercial Energy Savings Capital Costs

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

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

Table 20: Residential Energy Savings Capital Costs

$/GJ of energy saved	2015	2020	2025	2030	2040	2050
Space heating	124	118	112	106	96	87
Lighting	33	31	30	28	25	23
Major appliances	142	135	128	122	110	99
Water heater	81	77	74	70	63	57
Plug load	48	46	44	41	37	34

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

Table 21: Electricity Production Capacity Capital Costs

$/kW	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
Rooftop solar PV	2,414	2,353	2,239	2,110	2,080	2,032	1,984	1,936	1,888	1,647	1,492	1,318

Groundmount solar PV	2,016	2,018	2,019	2,020	2,021	2,023	2,024	2,025	2,027	2,033	2,046	2,059
Wind	2,093	2,057	2,022	1,986	1,950	1,914	1,878	1,843	1,807	1,628	1,487	1,336
Electricity storage	1,930	1,799	1,669	1,587	1,505	1,422	1,340	1,258	1,217	1,040	909	790
Hydropower	5,229	5,229	5,229	5,229	5,229	5,229	5,229	5,229	5,229	5,229	5,229	5,229
Digester ICE	2,610	2,567	2,523	2,480	2,455	2,430	2,406	2,381	2,356	2,233	2,124	2,016
Biogas CHP	1,450	1,426	1,402	1,378	1,370	1,363	1,356	1,349	1,341	1,305	1,269	1,233

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

Table 22: Electricity Production Operations & Maintenance Costs

$/kW/year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
Rooftop solar PV	23	22	22	21	21	20	20	19	19	16	15	13
Groundmount solar PV	26	18	17	17	16	16	16	15	15	13	12	11
Wind	57	56	56	55	55	54	54	53	53	51	47	43
Electricity storage	48	45	42	40	38	36	34	31	30	26	23	20
Hydropower	55	55	55	55	55	55	55	55	55	55	55	55
Digester ICE	0.3	0.3	0.3	0.3	0	0	0	0	0	0	0	0
Biogas CHP	15	14	14	14	14	14	14	14	14	13	13	12

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

Table 23: Personal Use Vehicles Capital Costs

$/vehicle	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
Car - gas	32,522	32,708	32,895	33,082	33,191	33,300	33,408	33,517	33,626	34,242	34,242	35,769
Car - gas hybrid	37,074	37,125	37,177	37,229	37,174	37,119	37,064	37,009	36,954	36,808	36,808	36,426
Car - diesel	35,017	35,298	35,580	35,862	36,031	36,201	36,370	36,540	36,709	36,982	36,982	37,452
Car - plug-in electric gas hybrid	41,207	40,608	40,009	39,410	39,366	39,322	39,277	39,233	39,189	40,379	40,379	35,774
Car - electric	53,378	53,362	53,347	53,330	50,344	47,357	44,371	41,384	40,033	33,280	33,280	33,280
Light truck - gas	56,912	57,239	57,566	57,893	58,083	58,274	58,464	58,655	58,845	59,924	59,924	62,595
Light truck - gas hybrid	64,879	64,970	65,060	65,151	65,055	64,959	64,862	64,766	64,670	64,414	64,414	63,746
Light truck - diesel	61,279	61,772	62,266	62,759	63,055	63,351	63,648	63,944	64,240	64,718	64,718	65,540
Light truck - plug-in electric gas l	72,112	71,063	70,015	68,967	68,890	68,813	68,735	68,658	68,581	70,663	70,663	62,605
Light truck - electric	93,410	93,383	93,355	93,328	88,101	82,875	77,648	72,422	70,058	58,240	58,240	58,240

source: *Assessment of Vehicle Sizing, Energy Consumption, and Cost Through Large-scale Simulation of Advanced Vehicle Technologies, Argonne National Laboratory, March 2016*
BNEF Battery Projections
with these factor applied:- manufacturing to retail cost factor: 1.5- USD to CAD exchange rate: 1.3

Table 24: Personal Use Vehicles Maintenance Costs

$/vehicle/km	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
Car - gas	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Car - gas hybrid	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Car - diesel	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Car - plug-in electric gas hybrid	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Car - electric	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

Light truck - gas	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Light truck - gas hybrid	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Light truck - diesel	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Light truck - plug-in electric gas l	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Light truck - electric	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

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

Fuel Cost Intensities

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

Linear extrapolation applied after 2040

Table 27: Transportation Fuels

$/GJ	2016	2017	2018	2019	2020	2021	2022	2023	2024	2029	2039	2049	2050
Gasoline	31.80	37.38	40.14	38.6	41.21	41.92	42.41	42.12	41.87	41.32	39.43	38.73	38.63
Diesel	27.42	29.79	32.54	31.09	33.75	34.5	35.05	34.79	34.57	34.15	32.47	31.97	31.89

source: *Ontario Ministry of Energy, Motor Fuel Prices - Ottawa*

Table 28: Electricity

$/GJ	2016	2017	2018	2019	2020	2021	2022	2023	2024	2029	2039	2049	2050
Residential	58.26	59.40	59.90	60.41	60.91	61.42	61.94	62.46	62.98	65.67	71.39	76.84	77.40
Commercial	41.81	42.63	43.12	43.62	44.12	44.63	45.15	45.67	46.20	48.93	54.89	60.46	61.04
Industrial	38.55	39.30	39.73	40.16	40.59	41.03	41.48	41.93	42.38	44.73	49.81	54.58	55.08

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

Table 29: Natural Gas

$/GJ	2016	2017	2018	2019	2020	2021	2022	2023	2024	2029	2039	2049	2050
Residential	9.40	11.79	11.22	11.27	12.50	13.07	13.58	13.60	13.71	14.26	14.46	15.51	15.58
Commercial	6.14	8.79	8.21	8.27	9.50	10.07	10.58	10.60	10.68	11.13	11.26	12.20	12.26
Industrial	5.50	7.84	7.25	7.31	8.57	9.14	9.66	9.67	9.75	10.20	10.32	11.25	11.31

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

Table 30: Fuel Oil

$/GJ	2016	2017	2018	2019	2020	2021	2022	2023	2024	2029	2039	2049	2050
Residential	26.89	32.46	35.29	33.94	36.82	37.76	38.53	38.4	38.31	38.5	37.78	38.56	38.60
Commercial	23.74	28.8	31.24	30.05	32.75	33.66	34.4	34.28	34.19	34.32	33.61	34.30	34.33
Industrial	18.37	21.43	23.35	22.01	24.82	25.74	26.46	26.28	26.14	26.02	24.9	25.08	25.06

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

Table 31: Biogas

$/GJ	2016	2017	2018	2019	2020	2021	2022	2023	2024	2029	2039	2049	2050
	$18.80	$13.10	$12.70	$12.30	$12.20	$12.20	$12.20	$12.20	$12.20	$12.10	$12.05	10.77	10.69
$/m3	*$0.71*	*$0.50*	*$0.48*	*$0.47*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*$0.46*	*0.41*	*0.41*

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

Table 32: Carbon Price

$/tonne CO2eq	2019	2020	2021	2022	2023	2024	2025	2026	2027	2032	2042
reference	20	30	40	50	52	53	55	56	58	67	90

source: *Calculated internally post 2022*

Table 33: Electricity Revenue Rate

$/MWh	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2040	2050
Rooftop solar	214	216	217	219	221	223	225	227	229	238	259	279
Groundmount solar	141	143	145	146	148	149	151	153	154	163	181	198
Wind	125	125	125	125	125	125	125	125	125	125	125	125
Hydro	100	100	100	100	100	100	100	100	100	100	100	100
RNG	108	108	108	108	108	108	108	108	108	108	108	108

source: Assumes net metering for rooftop solar and groundmount solar (industrial rate)
IESO 2017 FIT Price Schedule, assumes differentiated revenues by technology
RNG assumes $30/GJ

Table 34: Commercial Vehicle Capital Costs, 15 tonnes and over

$/vehicle	
gas	300,000
diesel	300,000
electric	502,000

source: Analysis of garbage truck costs diesel vs. electric provided by Lion Electric

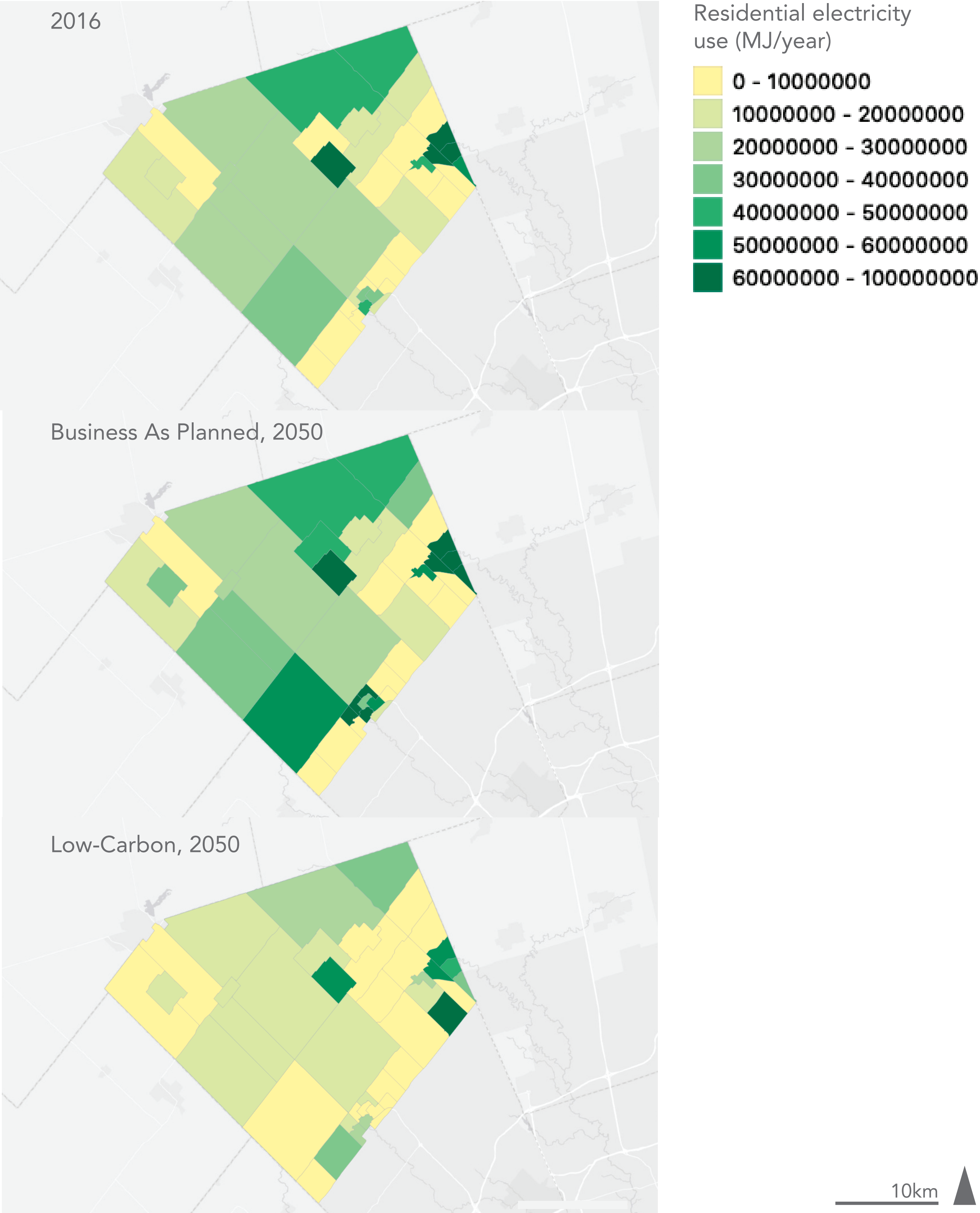
Table 35: Commercial Vehicle Operations & Maintenance Costs, 15 tonnes and over

$/vehicle/year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2033	2043
gas/diesel	17,688	19,173	21,242	23,603	26,300	29,001	32,037	35,454	39,299	#######	#######
electric	12,128	13,022	14,252	15,652	17,247	18,845	20,638	22,651	24,913	27,454	27,454

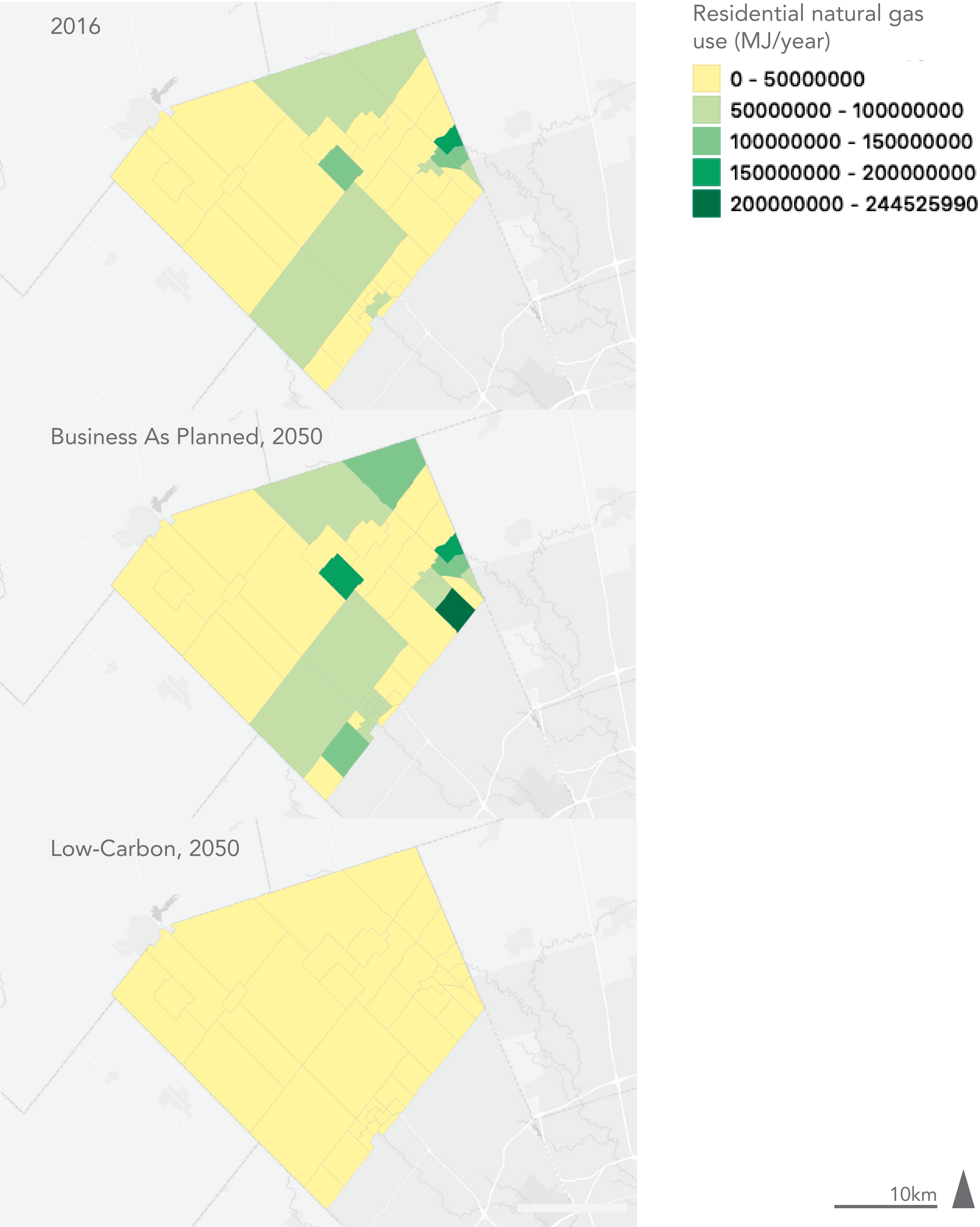
source: Analysis of garbage truck costs diesel vs. electric provided by Lion Electric, assume Year 0 is 2020

8. MAPS

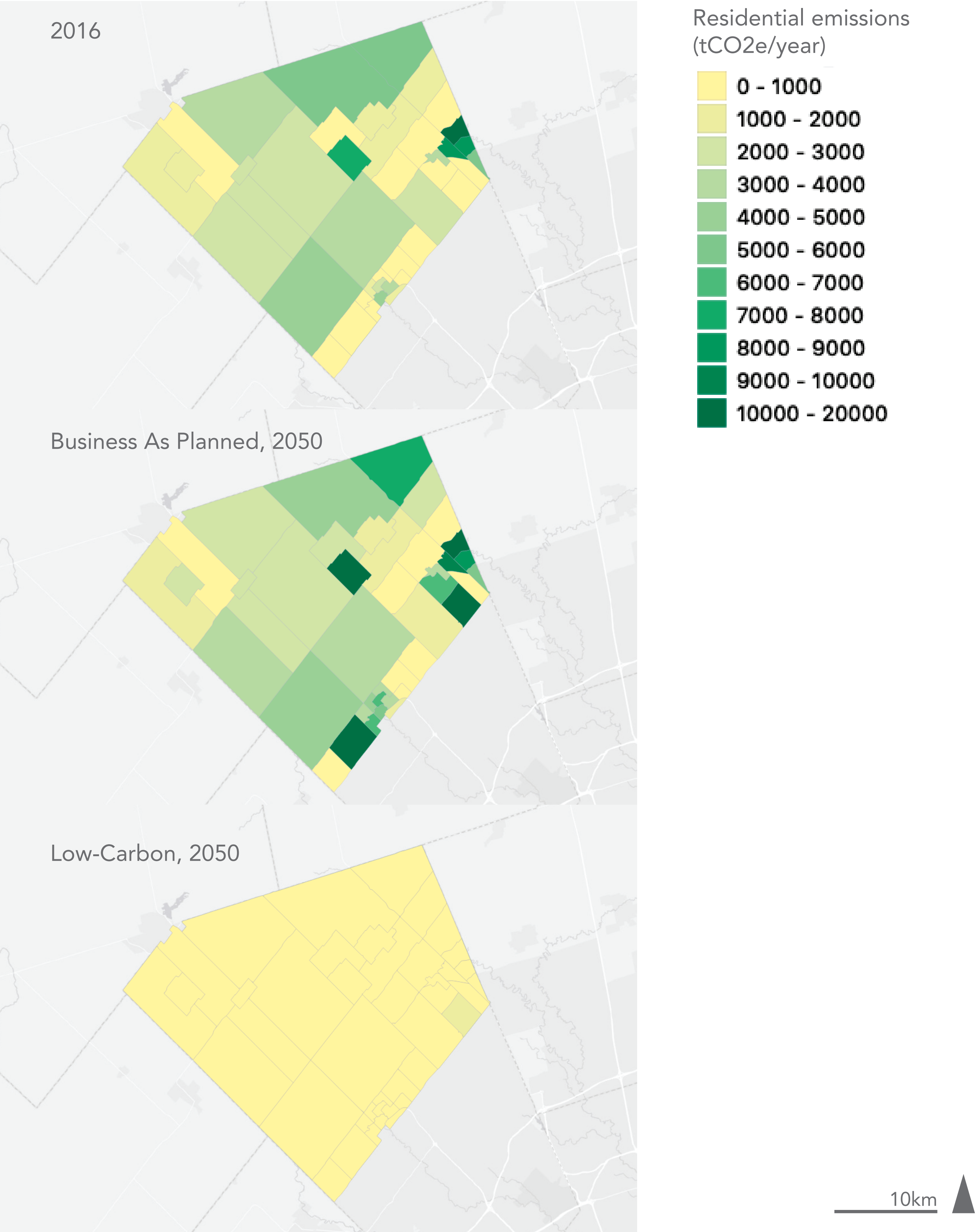
Residential buildings electricity use



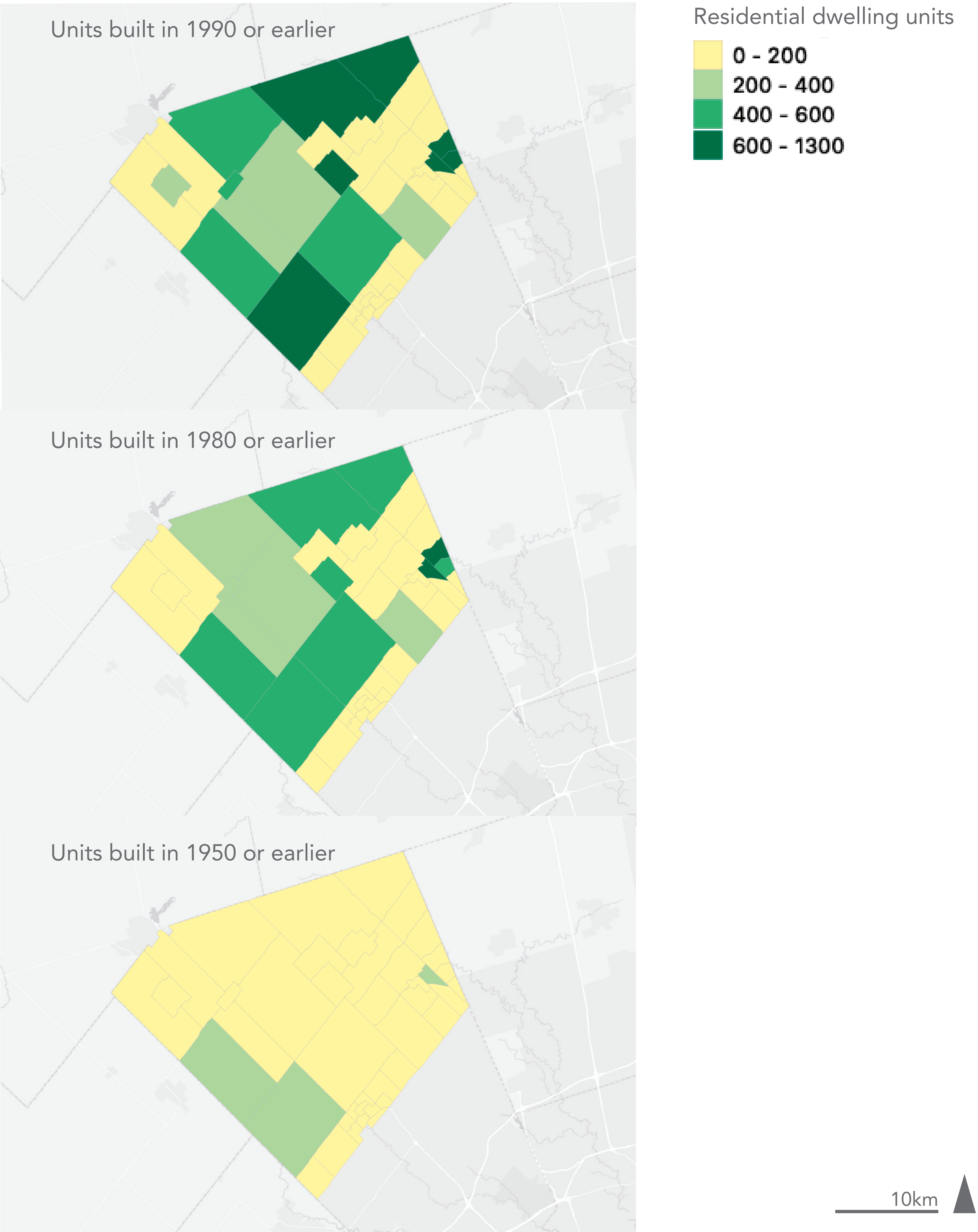
Residential buildings natural gas use



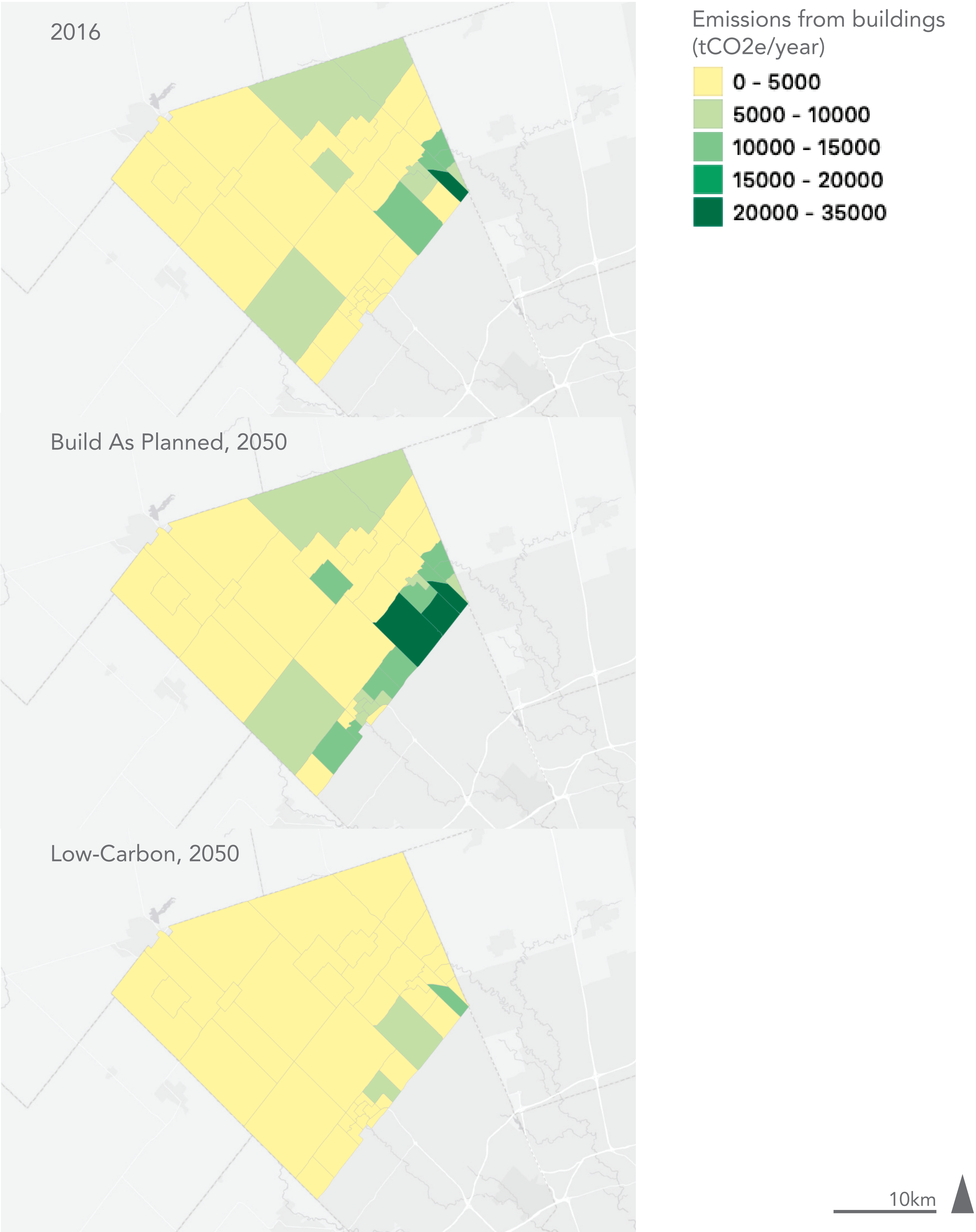
Residential buildings emissions



Residential dwelling units in 2016



Buildings emissions



Buildings energy use