Town of Halton Hills

Low-Carbon Transition Strategy

A path toward net-zero by 2030

Town of Halton Hills Lives Green

November 2021

HALTON HILLS

SSG

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Executive Summary

In response to the climate emergency, the Town of Halton Hills set a target to achieve **net-zero greenhouse gas emissions (GHGs) by 2030**. We are the first municipality in Canada to do so, placing Halton Hills on par with global climate leaders like Adelaide, Glasgow, Bristol, and Copenhagen.

This Low-Carbon Transition Strategy (LCTS) is our response to the climate emergency. Designed with input from the public and by a committee with representation from across the community (the Multi-Stakeholder Governance Committee or MSGC), the Strategy lays out a plan for how the public, businesses, and the Town can work together to meet Halton Hills' climate goals and improve local quality of life. Together, we can create a more prosperous, equitable, healthy community.

Within a decade the LCTS envisions streets designed to accommodate cyclists, pedestrians, e-buses, and electric vehicles (EVs). Homes, shops, and industrial facilities will be drastically more energy efficient and heated primarily by renewable electricity from solar panels installed throughout Halton Hills. Instead of decomposing in landfills, food and other organic waste will be diverted to a composting facility or used to create renewable natural gas. And there will be 450,000 more trees.

As we make these changes to reduce emissions, our air will become cleaner, we'll have more greenspaces to enjoy, and we'll reduce our energy bills. Our economy will also grow as investments in green construction, renewable energy, and sustainable transportation create local jobs.

We are a small community with big ambition. The LCTS is our data-based and community-informed pathway toward our target.

Why Net Zero by 2030?

Halton Hills' commitment is aligned with the current science on the climate crisis: the most recent report released by the UN Intergovernmental Panel on Climate Change (IPCC) in August 2021 provides an update on the physical science. The state of global warming is worse than it was expected to be when the last report was released eight years ago. We have now surpassed 1°C of global warming. This means that the target of net zero by 2050 and a 45% reduction from 2005 levels by 2030, which was outlined in the 2018 UN Special Report on Global Warming of 1.5°C, is no longer sufficient to decrease the likelihood of catastrophic climate change. The IPCC will be releasing a new report in early 2022 identifying appropriate mitigation pathways.

The Town's target is also **aligned with international UN principles** of equal but differentiated responsibility, meaning that those who are responsible for more GHGs per capita—currently and historically—and have more resources per capita than others, have a responsibility to rapidly address a larger share of the global carbon budget.

The LCTS is an opportunity. By most indicators, the energy system is in transition away from fossil fuels. Halton Hills' commitment to decarbonize ahead of the curve will enable us to **capitalize on new economic opportunities**, avoid projected financial losses, and ensure sustainable economic growth.

Growing Sustainably

The Town of Halton Hills is planning for a 45% increase in population between 2016 and 2030. The Town will ensure this growth supports a sustainable transition to a low-carbon economy. Anything our community builds today is likely to still be in place in 2030 and beyond. The LCTS outlines how new homes, businesses, and transportation infrastructure can be developed in alignment with a net-zero-by-2030 future. Starting as soon as possible, all new buildings need to be heated with renewable electricity and residents will need to have access to EV chargers, shared e-mobility services, and cycling paths.

The LCTS is also a community investment plan. Its implementation is projected to create local jobs, reduce household energy bills by nearly 50%, and develop local energy projects, all of which will help bring and keep money in the community. This investment plan will attract new businesses and residents and ensure Halton Hills is not just resilient to the economic transition, but thrives in it.

Community Driven

Council passed the Town's ambitious target unanimously in May 2019, acknowledging the strong support for bold action in the community. Since then, the community has been deeply engaged in developing the LCTS.

The Town brought together a diverse group of stakeholders to form the LCTS Multi-Stakeholder Governance Committee (MSGC) via an open-call for applicants. The 24-member group included residents, academics, utilities, youth, industry, environmental groups, and Town staff. The MSGC attended multiple workshops to learn about the Town's energy use and emissions profile and climate action best practices. They then provided input on what kinds of climate actions would be appropriate for Halton Hills. They also provided insight on a systematic implementation program to ensure the Strategy's success.

The LCTS was informed, and will continue to be overseen, by the community.

The Net-Zero Pathway

By implementing an aggressive set of actions across the buildings, transportation, waste, and land use sectors, the analysis completed for the LCTS shows our community can reduce our emissions by nearly 75% by 2030. Because of significant projected population growth, this reduction is much more significant on a per person basis: about an 82% decrease. Halton Hills is a small place in the global context. But this effort is an important symbol. The community has committed to do its part, and in doing so will position itself as a climate leader.

In less than a decade, a Halton Hills resident can reduce their average annual GHG emissions from 7.2 tonnes to 1.3 tonnes of carbon dioxide equivalent (CO_2e). Community-wide, this means 457 kilotonnes (kt) in 2016 to 120 kt in 2030.

The remaining emissions in 2030 are primarily from combustion engine vehicles purchased today and in the near future. They are expected to be phased out as they naturally reach their end of life by around 2040. It is difficult to stop these remaining emissions without removing vehicles from the road before their end of life or introducing policies to prevent residents from owning combustion engine vehicles, which the LCTS does not contemplate. To reduce these remaining 120 kt CO_2e in 2030, and achieve net-zero, the LCTS includes the purchase of offsets. As new technologies and options become available, additional carbon reduction solutions can be incorporated into future iterations of the Strategy, reducing the need for offsets.

The Town's pathway to net zero is made up of four main action areas:

1. **Low-carbon mobility:** Enabling travelling by foot, bicycle, emissions-free transit, or electric vehicles.
2. **Energy efficiency and green development**: New and existing buildings are significantly more energy efficient and are powered by renewable energy, including solar panels on roofs and geothermal heating systems for sufficiently dense new developments;
3. **Local renewable energy:** Replace fossil fuel energy with local renewable electricity and renewable natural gas; and
4. **Natural assets:** Protect and expand the town's natural carbon sinks, greenspaces and healthy soil, to offset some of the remaining emissions.

These actions attract new investments, create jobs, and save money. They also result in social and environmental co-benefits, most notably: reduced air pollution, more active residents, increased biodiversity, and increased resilience to extreme weather events. The result is a better quality of life for the people of Halton Hills.

Turning To Action

Achieving net zero by 2030 will require acting immediately, with a nimble and ambitious approach that includes learning from mistakes while moving forward. This is something the Town and the Multi-Stakeholder Governance Committee (MSGC) have already begun to do.

Achieving net zero by 2030 will also require action from the entire community. The behavioural change needed to accomplish this will be significant, and will be accomplished through a combination of smart program design and a public education campaign.

The LCTS will be guided by the following principles:

- Collaboration and innovation,
- Equity, and
- Community oversight.

These principles have been developed based on a combination of input from the Town and stakeholders as well as best practices. They are expanded upon in Part III of the report.

To learn more and get involved, visit *haltonhills.ca/climatechange*.

Acronyms

ASHP	air source heat pump
BAU	business as usual
CO_2e	carbon dioxide equivalent
EUI	energy use intensity
EV	electric vehicle
GHG	greenhouse gas
GJ	gigajoule
kt	kilotonnes
IPCC	Intergovernmental Panel on Climate Change
LCTS	Low-Carbon Transition Strategy
MAC	marginal abatement cost
MW	mega watt
MSGC	Multi-Stakeholder Governance Committee
PV	photovoltaic
RNG	renewable natural gas
t	tonnes
UN	United Nations
VKT	vehicle kilometres travelled

Land Acknowledgment

The Town of Halton Hills is located on the Treaty Lands and Territory of the Mississaugas of the Credit.

Acknowledgements

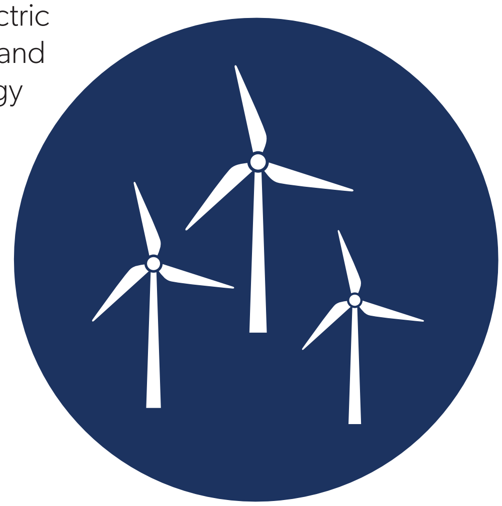
Table 1. Members of the LCTS Multi-Stakeholder Governance Committee (MSGC).

MEMBERS OF THE LCTS MULTI-STAKEHOLDER GOVERNANCE COMMITTEE BY SECTOR			
RESIDENTS-AT-LARGE	Evelyn Lundhill Jean Leckie Colin Royce Daniel Poirier Roscoe Petkovic	**LOCAL UTILITIES**	Carol Suter/ Brian Lennie, Enbridge Chris Hale, Halton Hills Hydro
LOCAL CONSERVATION AUTHORITY	Jason Igras, Credit Valley Conservation	**AGRICULTURE/ ACADEMIA**	Ralph Martin, retired professor, University of Guelph
LOCAL BUSINESS AND INDUSTRY	Dino Degliannis, Chamber of Commerce Robert Maxim Florent Leffevre-Schlick Mike Carter, Renewable Energy Developer	**TOWN OF HALTON HILLS**	Dharmen Dhaliah, Climate Change and Asset Management Mike Dean, Climate Change and Asset Management Ivan Drewnitski, Transportation Rob Stribbell, Planning Graham Lowe, Economic Development Meagan Cooper, Communications
LOCAL ENVIRONMENTAL GROUPS	Dr. Monika Caemmerer, Halton Hills Climate Action Lisa Kohler, Halton Environmental Network	**YOUTH**	Faisal Shahbaz
LOCAL INSTITUTIONS	Suzanne Burwell, Halton District School Board	**BUILDING/ DEVELOPMENT INDUSTRY**	Marina Huissoon, Green Propeller

Halton Hills Climate Emergency Delegates

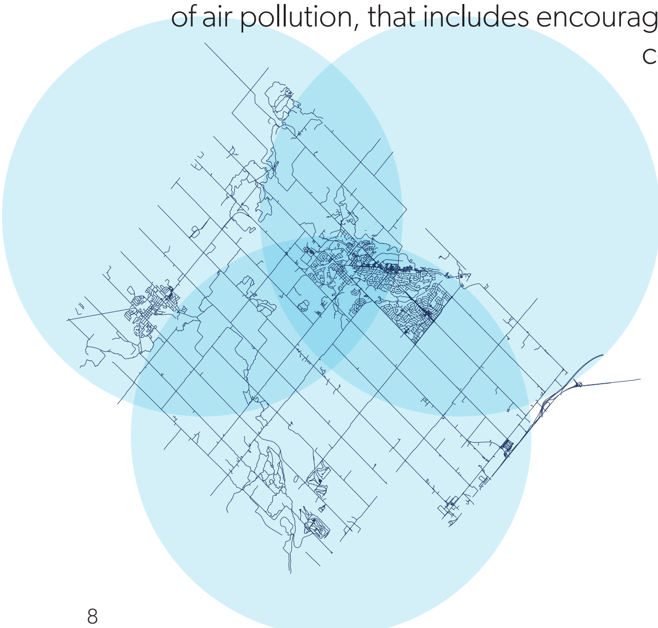
Several delegates spoke in support of the May 6, 2019 motion to declare a climate emergency and set a target of net zero by 2030. The motion then passed unanimously. The following are some highlights from those speeches:

"I want to ask our leaders a serious question: Do I deserve a future? When you were my age, did you think you deserve the life you enjoy now? [...] I believe that we can slow and then stop climate change. [...] We have electric cars, we have buses, we have wind turbines, we have more and more people walking [...] we have smart homes saving energy and smart people helping us. In the future I want to see green forests, clean lakes, comfortable summers and winters [...] I want a future in which there is food for people and animals. [...] I want a future where we live within our environmental limits. We have the power to make a difference [...] All we have to do is make the difference."



Spencer Lippa
12 years old, youngest member of the Green Party of Canada

"[...] If we don't have healthy communities, we really don't have a lot. We know that climate change will affect the health of our communities in various ways. One of the top ways it affects it is with air pollution. We need concrete action on reduction of air pollution, that includes encouraging people to walk, making our communities walkable, encouraging people to bike, making safe separated bike lanes throughout the community so that people feel safe while they are biking, and encouraging the use of things like electric cars. And I think all of these things can be addressed through good policy."



Dr. Lesley Barron, general surgeon, Georgetown

“[...] We know we need action. Our climate is changing, it's fast-paced, it's causing widespread profound consequences for all living organisms. [...] The number one health concern for Canadians is climate change. The number one concern. So, every day I hear from our community, the urgency, the challenge, the need for change. We all do need to lean in. We have no planet B. This is Halton Hills’ opportunity. It's your opportunity to declare an emergency, have dialogue, have tangible actions that will really lead to transformative change. [...]”

Lisa Kohler, Executive Director Halton Environmental Network

“Friday’s climate action rally here in Georgetown was a big success. We asked people to write on these ribbons what they love and hope never to lose to climate chaos. Some of the things they wrote: songbirds, butterflies, the crops that sustain us, coral reefs, the sounds, sights, and smells in our woods, white pines, loon calls, frozen ponds and backyard rinks. My grandchildren's future, my future. All of these are in peril. [...] We can stave off climate chaos with a rapid switch to green energy and many other initiatives. I support this resolution and all the recommended actions within it.”

Janet Duval, Halton Hills Climate Action Rally

Letter from the Mayor

October 2021

Dear Halton Hills residents:

I am proud to introduce this Low-Carbon Transition Strategy: a pathway towards our ambitious target of net-zero greenhouse gas (GHG) emissions by 2030. This strategy stands alongside our Climate Change Adaptation Plan to form our community's response to the climate emergency.

This decarbonization strategy represents a major transition for our community, one that will help make all our residents and businesses healthier, happier, and more prosperous—all while maintaining our small-town feel. This pathway puts us on the leading edge of the global net-zero transition.

Over a year in the making, the following pages contain a decarbonization strategy that leverages our Town's strengths to address the greatest local GHG emissions sources: our dependence on gasoline and diesel guzzling cars and trucks; our energy inefficient homes and businesses; and our reliance on natural gas for heating. It addresses these challenges with our greatest strengths: our local skilled labour and businesses; our abundant renewable energy sources and natural spaces; and our passionate and engaged community. The result is a community investment plan that will create local jobs in green home construction, renewable energy, transit and active transportation infrastructure, and electric vehicles. This strategy will also help keep money in residents' pockets by lowering household energy bills.

Many individuals contributed to develop this strategy, from Town staff, consultants, local utilities, residents (young and old), environmental groups, institutions, and businesses. We made our best efforts to meaningfully engage with these folks, educating them about the challenges we are facing, and listening to their concerns and suggestions.

The release of this strategy is just the beginning. Now it is time for action. From the Town to the broader community, we will act, we will monitor, we will report, and we will improve.

You wanted our community to do its part to respond to the climate emergency, by working towards an ambitious net-zero by 2030 target—this strategy sets a pathway to deliver.

Sincerely,

Rick Bonnette
Mayor, Town of Halton Hills

1 Halton Hills Drive, Georgetown, L7G 5G2
905-873-2601 | 1-877-712-2205 | haltonhills.ca

How to Read This Report

This report summarizes the Town's Low-Carbon Transition Strategy (LCTS).

Part I sets the scene, including information on the 2030 target, the Strategy's overall projected economic impacts, and the process that was used to develop the Strategy.

Part II lays out the net-zero pathway, including the overall energy and emissions shift from business-as-usual to net zero, and a closer look at each of the Strategy's four main actions—related to transportation, buildings, renewable energy, and natural carbon sequestration—their costs and benefits, and key implementation strategies.

Part III turns to LCTS implementation. It includes a discussion of the types of collaboration and innovation that will be needed to bring its big moves to life, as well as the oversight that will be needed to keep it on track and ensure accountability. This section highlights the need for equitable program design to ensure the significant investments are deployed in a manner that benefits the entire community.

The **appendices** contain the technical analysis that underpins the LCTS. These are referenced throughout Parts I-III.

Part I: Setting the Scene

An Ambitious Target

The climate crisis demands bold and swift action to protect our environment and the people, animals, plants, and economy that rely on it. By declaring a climate crisis in 2019, the Town of Halton Hills committed to both addressing the challenge and seizing the opportunity of climate change. The Town set an ambitious target: net-zero greenhouse gas (GHG) emissions by 2030. This target means that, starting as soon as possible, the Town will ensure its investments are aligned with the global shift to net-zero emissions.

By setting a target of net zero by 2030, Halton Hills joins the ranks of a leading group of communities including Copenhagen, Bristol, Ithaca (New York), and Glasgow. This target goes beyond the Federal target of net-zero by 2050, which, until quite recently, was considered the minimum global average reduction needed to avoid catastrophic climate change.[1]

> **It is a prescient target;** one that acknowledges how quickly climate science is evolving. Indeed, in August 2021, the UN IPCC released new science that indicates the climate crisis is more dire and the global carbon budget is smaller than previously understood.[2] Each new projection is consistently worse than the last.
>
> **It is an equitable target** based on the idea that communities that have relatively more resources and emit more per person, have a responsibility to reduce their emissions faster than the global average.
>
> **It is an optimistic target.** It reflects a community that is confident in its growth and wants to harness this new money to invest in a sustainable and profitable future.

The Low-Carbon Transition Strategy (LCTS) sets a course for Halton Hills to work towards its ambitious target and decarbonize. It complements the Town's efforts to improve the community's physical resilience to increasingly extreme weather conditions (via the Town's Climate Change Adaptation Plan). Together, these climate mitigation and adaptation plans form the Town's Low-Carbon Resilience Framework (see Figure 1).

[1] IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

[2] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [MassonDelmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press.

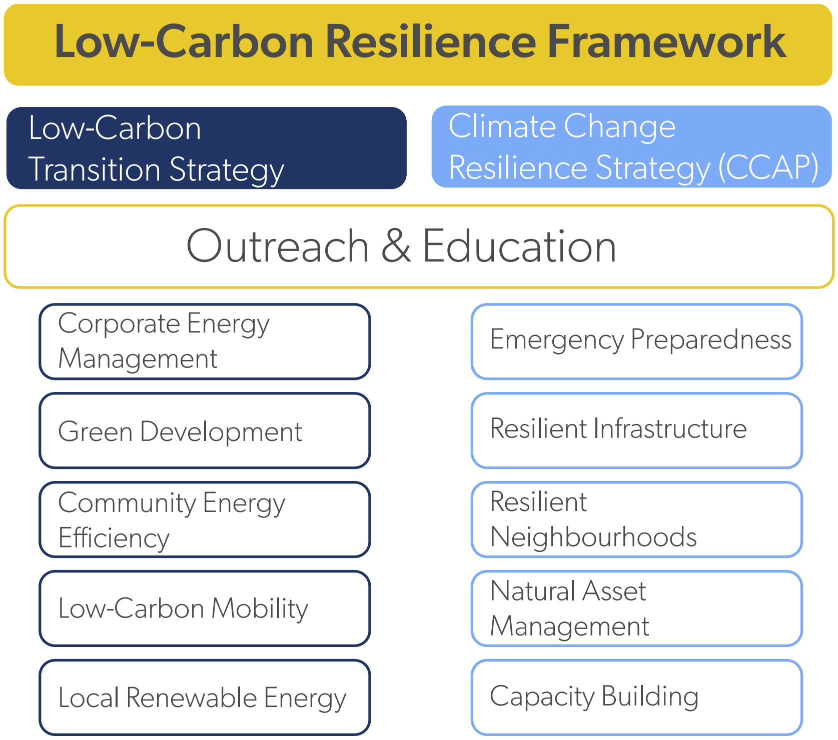


Figure 1. The structure of the Town's Low-Carbon Resilience Framework.

A Science and Equity-Based Target

Halton Hills' commitment is **aligned with current science**: the most recent report released by the UN Intergovernmental Panel on Climate Change (IPCC) in August 2021 provides an update on the physical science. The state of global warming is worse than it was expected to be when the last report was released 8 years ago. We have now surpassed 1°C of global warming. This means that the target of net zero by 2050 and a 45% reduction from 2005 levels by 2030, which was outlined in the 2018 UN Special Report on Global Warming of 1.5°C, is no longer sufficient to decrease the likelihood of catastrophic climate change. The IPCC will be releasing a new report in early 2022 identifying new mitigation pathways.

The Town's target is also **aligned with international UN principles** of equal but differentiated responsibility, meaning that those who are responsible for more GHGs per capita—currently and historically—and have more resources per capita than others, have a responsibility to rapidly address a larger share of the global carbon budget. Halton Hills' commitment to decarbonize ahead of the curve will enable the community to **capitalize on new economic opportunities**, avoid projected financial losses, and ensure sustainable economic growth.

Co-Benefits: Economic, Social, and Environmental

The LCTS is a plan that will enable the Town to capture many co-benefits: positive economic, social, and environmental benefits of actions that reduce GHG emissions. Some of the countless associated co-benefits are outlined below.

ECONOMIC BENEFITS

The Strategy will enable us to participate in the emerging and growing net-zero economy. The financial and economic analysis of the LCTS versus business-as-usual demonstrates that decarbonization has significant financial benefits: our community will spend less on energy, pay lower federal carbon taxes, and see hundreds of new job opportunities.

For example, the proposed mass deep residential and commercial retrofit program—to increase energy efficiency and reduce related emissions—is projected to produce about 1,000 jobs (9,000 person years of employment between 2022 and 2030) while the proposed solar energy developments are projected to produce nearly 350 jobs (3,150 person years of employment between 2022 and 2030).

Nearly $2 billion dollars in investment—or about $218 million a year over 9 years—is required to implement the Strategy. This investment has an estimated net present value of just over $850 million, or a 43% return on investment. To put this into perspective, the LCTS contemplates an annual investment program equivalent to approximately 10% of the Town's 2020 gross domestic product.[3] It is not just the Town that is expected to make investments (and receive the benefits); local businesses, residents, and other levels of government will all have important roles. For example, local businesses can invest in retrofits and develop solar projects. Residents will be able to participate in retrofit programs and choose to walk, cycle, take transit, or drive EVs to reduce their transportation emissions. Other levels of government will need to fund key programs and establish supportive policies.

Investing in the LCTS

Decarbonising Halton Hills requires major investments, by a variety of players. In total, nearly $2 billion over 9 years. When broken down by action and entity, this large number is much easier to swallow. Each electric vehicle purchased today represents at least $10,000 of this investment (the incremental cost over a gasoline car). If 2,000 cars are purchased by households, for example, that represents $20 million of investment. These are investments that can often pay for themselves through fuel and maintenance savings over their lifetimes. Each household that is retrofitted represents an investment of $60,000 (the estimated incremental cost over typical spending on energy efficiency). If 500 homes are retrofitted, the investment totals an estimated $30 million over the baseline. Again, these investments can potentially pay for themselves through energy savings and then through property value increases. These investments will be taken by a wide range of actors and most will generate returns. While the Town will lead some of these investments, in other areas, it will primarily work to remove barriers and build capacity.

[3] In 2020, the gross domestic product of the Town of Halton Hills was $2.24 billion. (View the 2021 Halton Hills Budget and Business Plan, Online at: www.haltonhills.ca/en/your-government/budgets.aspx.)

The investments outlined in the LCTS will create more jobs and attract new investments, while reducing household energy bills by nearly 50%. The proposed community-wide investments in local renewable energy will build on existing experience and expertise; for example, the Town's successful 2017-2018 rooftop solar installations at 3 facilities that together generate over 1 MW a year (enough to power between 150-200 homes per year). Additional community-wide investments in renewable energy will help attract new investment and retain money in the local economy. Currently almost all energy consumed in the Town of Halton Hills is produced and owned well beyond the Town boundary. This plan will attract new businesses and residents, and ensure the community is resilient and prepared to thrive in the coming economic transition.

IMPROVED PUBLIC HEALTH

The social benefits of the LCTS include improved public health. Residents will breathe cleaner air as tailpipe emissions decrease and more trees are planted. The public will also become more physically active as walking and cycling infrastructure improves and more people walk and bike, instead of drive, to their destinations.

Improvements in fuel-efficiency, increased use of public transport, fewer diesel engines, and electrification of transport will all contribute to improved air quality and better health outcomes. Traffic-related air pollution at relatively low concentrations in Ontario was associated with increased mortality from cardiovascular disease,[4] and, more generally, with the increased prevalence of asthma and allergic diseases.[5] An assessment for Toronto found that living near major roadways and highways increased the risk of heart disease.[6] Children living near major highways are at higher risk of developing asthma and reduced lung function.[7]

Studies in Copenhagen[8] and Shanghai[9] have shown that mortality rates are 30-40% lower among those who cycle compared to those who do not use active transport or get equivalent amounts of leisure time exercise. A 19% reduction in mortality risk is shown to occur with 30 minutes of daily moderate-intensity activity, 5 days per week. Children who walk or bike to school are fitter than those who travel by car or bus, with 30% improvements in boys, and seven times in girls.[10]

GREATER EQUITY

Although the Town of Halton Hills is more affluent than the national average, the Town still has some low-income and under-employed residents. As a part of the LCTS, the Town commits to improving social equity by ensuring climate action implementation is designed in a manner

[4] Chen, H., Goldberg, M. S., Burnett, R. T., Jerrett, M., Wheeler, A. J., & Villeneuve, P. J. (2013). Long-term exposure to traffic-related air pollution and cardiovascular mortality. Epidemiology, 24(1), 35–43.

[5] Bowatte, G., Lodge, C.,et al. (2015). The influence of childhood traffic-related air pollution exposure on asthma, allergy and sensitization: a systematic review and a meta-analysis of birth cohort studies. Allergy, 70(3), 245–256.

[6] Beckerman, B. S., Jerrett, M., Finkelstein, M., Kanaroglou, P., Brook, J. R., Arain, M. A., … Chapman, K. (2012). The association between chronic exposure to traffic-related air pollution and ischemic heart disease. Journal of Toxicology and Environmental Health. Part A, 75(7), 402–411.

[7] Brugge, D., Durant, J. L., & Rioux, C. (2007). Near-highway pollutants in motor vehicle exhaust: A review of epidemiologic evidence of cardiac and pulmonary health risks. Environmental Health, 6, 23.

[8] Andersen, L. B., Schnohr, P., Schroll, M., & Hein, H. O. (2000). All-cause mortality associated with physical activity during leisure time, work, sports, and cycling to work. Archives of Internal Medicine, 160(11), 1621–1628.

[9] Matthews, C. E., Jurj, A. L., Shu, X.-O., Li, H.-L., Yang, G., Li, Q., … Zheng, W. (2007). Influence of exercise, walking, cycling, and overall nonexercise physical activity on mortality in Chinese women. American Journal of Epidemiology, 165(12), 1343–1350. https://doi.org/10.1093/aje/kwm088

[10] Voss, C., & Sandercock, G. (2010). Aerobic fitness and mode of travel to school in English schoolchildren. Medicine and Science in Sports and Exercise, 42(2), 281–287. https://doi.org/10.1249/MSS.0b013e3181b11bdc

that ensures the entire community has opportunities to participate in reducing emissions. For example, the LCTS includes a commitment to enable low-income residents to retrofit their homes, which tend to be older and inefficient, to decrease their energy consumption and their energy bills.

ECOLOGICAL HEALTH AND RESILIENCE

Finally, in terms of environmental benefits, more trees and healthier soil, will all contribute to increased biodiversity and resilience to extreme weather events in the Town.

More natural space provides habitat for animals, insects, and plants. All of which are necessary for a healthy, stable ecosystem. These green spaces also provide numerous valuable ecological services to communities. For example, natural places provide stormwater management services, which helps minimize costly and dangerous flooding as well as the energy-intensity of local wastewater treatment systems. Green spaces also help moderate extreme heat events, contributing to greater comfort for creatures and residents in outdoor spaces, and for home and building occupants.

For additional financial and economic analysis results of the LCTS, including key assumptions, see Appendix E.

The LCTS Development Process

The Town developed the LCTS over more than a year between 2020 and 2021 with the help of consultants at Sustainability Solutions Group, who designed and led interrelated community engagement and technical modelling processes (see Figure 2). The interaction between these two processes helped ensure that the plan is achievable and evidence-based while being rooted in the local context and responding to community concerns.

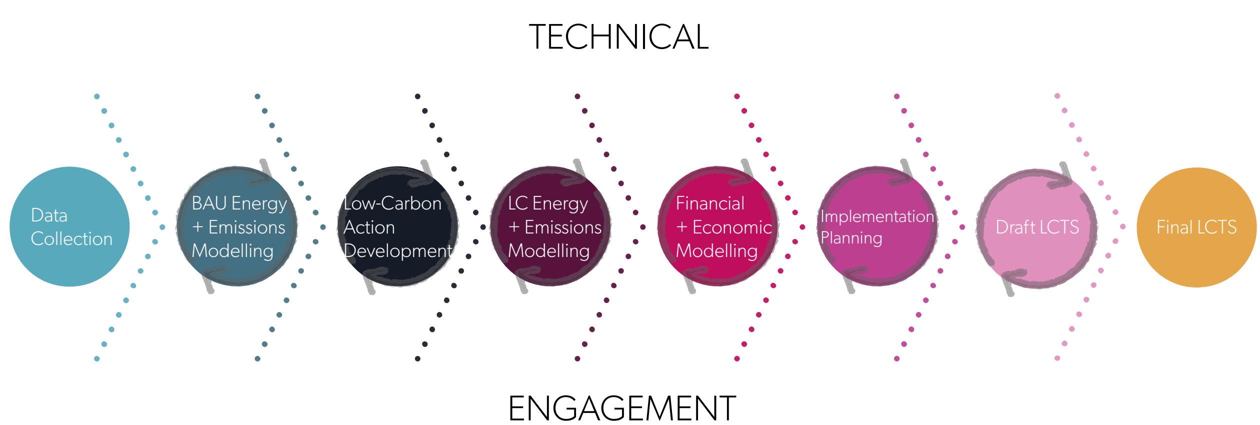


Figure 2. An overview of the LCTS development process.

The technical modelling process began with extensive data gathering, which informed the energy and emissions model for the Town.

The engagement process began with research on community preferences for engagement styles, followed by the formation of a diverse stakeholder advisory committee (the MSGC). A timeline of key engagement events is provided in Figure 3.

The 24-member MSGC was selected by the Town from an open call for applicants, based on the need for diverse stakeholder representation and relevant experience. Its membership consisted of Town residents, youth, utility representatives, Town staff, the business community, local institutions, and environmental non-profits (a full list is provided in Table 1). Their mandate was to provide advice on the LCTS development process; the ultimate decision-maker was and is Council.

The MSGC and its data and implementation/governance subcommittees were key sources of oversight and input into the LCTS. Members participated in nearly a dozen hours of meetings, in which they learned about the Town's energy and GHG emissions in a business-as-usual scenario, as well as the scale of action that would be needed to decarbonize. During these meetings, members had an opportunity to hear from experts, ask questions, share their experiences, and participate in brainstorming sessions. In addition, members were asked to prepare for meetings. The MSGC helped shape the focus of the LCTS, the scale and depth of its actions, and the content of its Implementation Framework.

Drawing on input from the MSGC, combined with research on best practices, the Town and consulting team identified a range of actions Halton Hills could take to reduce its emissions. These low-carbon actions were then evaluated in a financial model to compare the level of investment required for the net-zero scenario versus business-as-usual. These draft technical results were presented to the MSGC who helped refine them with more context-specific data, for example information from their:

- organizations (e.g., current and projected energy costs, fleet decarbonization program),
- research (e.g., soil management best practices), and
- individual household experience (e.g., costs to install heat pumps and EV chargers).

The general public were also provided with opportunities to learn about the plan and provide input early on via: a dedicated LCTS page on the Town's website, social media, a Let's Talk Halton Hills public engagement portal, a virtual Town Hall, and a survey.

The MSGC and the public provided critical input on potential local partners, potential expansion or development of policies and programs, and sources of investment. Answers from an implementation focused public survey are featured throughout this report. This helped inform the LCTS' near-term implementation strategy.

The feedback received through community engagement sessions was critical to shaping this Strategy.

June-July 2020

Pre-Engagement

10 interviews of a cross-section of stakeholder groups to help design an engagement plan that meets the needs of the community

November 2020

Multi-Stakeholder Governance Committee (MSGC) Kick -Off Meeting

An introduction to energy and emissions modelling, the Town's base year and business-as-usual modelling results. Including a consultation on key low-carbon actions.

December 2020

Public Virtual Open House

Session recorded and posted on the Town website-- FAQs developed based on public questions, also posted on the Town website.

January 2021

MSGC Implementation Governance and Data Subcommittee inaugural meetings

Review of climate projects underway by the Town and discussion of proposed additional projects.

Consultation on additional low-carbon actions. Initial feedback on relevant data sources, and potential data issues for the reference and low-carbon scenario

March 2021

MSGC Net-Zero Modelling Results & Intro to Implementation

A review of the initial net-zero energy and emissions modelling results and an introduction to implementation planning. An initial consultation on implementation planning for key net-zero actions.

March-May 2021

MSGC Implementation Governance and Data Subcommittee meetings 2 and 3

Background education on implementation governance, including guest speakers from neighbouring Oakville and Guelph. Consulted on the implementation administration body.

Consulted on key data challenges, including the need: for a sensitivity analysis about future energy prices, to discuss who pays upfront, and a clear and simple communication style.

May 2021

MSGC Net-Zero Financial Results & Implementation Part 2

A review of the net-zero financial and economic modelling results and further consultation on implementation planning for key low-carbon actions.

May-June 2021

Public Survey

Seeking feedback from residents about their priorities for LCTS implementation.

July 2021

MSGC Draft Implementation Framework

Review and feedback provided and incorporated into the final Implementation Framework.

Figure 3. Timeline of key LCTS engagement events.

PLANNING WHILE DOING

The MSGC also applied a "planning while doing" philosophy. Mindful that there is no time to waste, they set to work on climate mitigation initiatives, including:

- Identifying locations and utility processes for developing local large-scale solar installations;
- Planning an e-bike sharing pilot to help residents tackle the Town's namesake hills;
- Setting up the Town's first EV Day to help educate residents and the local automotive industry about EV options;
- Working with local academic institutions to provide training and guidance to local businesses on reducing energy consumption and GHG emissions; and
- Designing an LCTS oversight and implementation body.

Residents, local businesses, utilities, and Town staff are working hand-in-hand to develop and implement these projects.

MODELLING AS A PLANNING TOOL

Along with the critical engagement input described above, the LCTS was informed by an analysis of Halton Hills' current and projected energy use and emissions in a business-as-usual or "reference" scenario. This scenario was modelled using the CityInSight energy, emissions, and finances model.

The CityInSight Energy, Emissions, and Finances Model

CityInSight is an energy, GHG emissions, and finance model developed by Sustainability Solutions Group and whatIf? Technologies. The model enables detailed bottom-up accounting of a community's energy use and GHG emissions. This means that the model accounts not just for overall energy use and GHG emissions totals, but also ensures these totals are driven by actual cars and buildings in space.

From the stocks of vehicles and buildings, CityInSight traces the flows and transformations of energy from sources through energy currencies (e.g., gasoline, electricity) to end uses (e.g., personal vehicle use, space heating) to energy costs and to GHG emissions. A more limited analysis is undertaken for the stock of organic waste produced per person, with an emissions factor applied based on the applicable waste management system. These flows evolve on the basis of current and projected population, land use, and/or technologies.

This modelling process not only allows the model to capture interactions between different actions, it also allows for consideration of the impact of land-use patterns and urban form on energy use and emissions production.

Finally, CityInSight incorporates a full financial analysis of costs related to energy (expenditures on energy) and emissions (carbon pricing), as well as operating and capital costs for policies, strategies and actions. It allows for the generation of marginal abatement curves to illustrate the cost and/or savings of policies, strategies, and actions.

Drawing on data about local demographics, buildings, transportation, land use, industry, water and wastewater, and waste, the analysis team used the model to create a picture of the Town's energy use and GHG emissions in space from stocks (e.g., cars, furnaces, waste), which change over time (based on changes in population, jobs, and land-use patterns). This reference scenario was critical to understanding the type and scale of actions necessary for the town to decarbonize.

Emissions reduction actions were input into the model to test their impact on energy use and emissions relative to the reference scenario and identify when and in what order in which actions could be implemented to minimize costs and maximize benefits. Through this process, the consulting team developed a net-zero scenario consisting of an optimal bundle of actions—selected based on technical analysis and community input—that informed the LCTS.

The model also helped assess the financial impacts of the net-zero scenario relative to the reference scenario, including the costs of and returns on investments, maintenance of equipment, household and business energy bills, and how much employment would be created by climate actions.

Critically, the scenarios generated by the model are not a prediction, but plausible evidence-based projections on how the future may evolve based on data and assumptions about the key drivers of emissions and critical trends (e.g., rate of technological change, energy prices). Though imperfect, modelling is an important tool to help communities understand the type and scale of action necessary to drive major emissions reductions. In this case, the model helped the Town and MSGC identify the big moves that are necessary for a net-zero transition.

The LCTS is intended to be refined every five years based on updated modelling, annual program reporting on key performance metrics, lessons learned from implementation, updated GHG inventories, best practices, and new technologies. This 5-year review and updating process should not prevent interim piloting of new GHG mitigation policies that may improve LCTS program implementation or address the remaining carbon gap. Any interim piloting will also be included in the 5-year review process. This formal review and updating process will be subject to stakeholder consultation and will be transparent.

For additional information on the technical modeling process, its inputs, and assumptions, please review Appendix F.

Part II: The Plan

From BAU to Net-Zero

In 2016, Halton Hills generated 457 kt CO_2e of greenhouse gas emissions. This translates to about 7.2 tCO_2e per person. Almost half of these emissions are due to personal and commercial vehicles, followed by residential and commercial buildings, and then industrial processes. Despite many positive regulations and market trends, it is projected that in a business-as-usual (BAU) scenario (also referred to as the 'reference scenario'), without further actions to mitigate climate change, the Town's emissions will increase, largely due to population growth. From the base year of 2016, emissions are projected to increase 7% from 457 to 489 $ktCO_2e$, making decarbonization more of a challenge (see Figure 4).

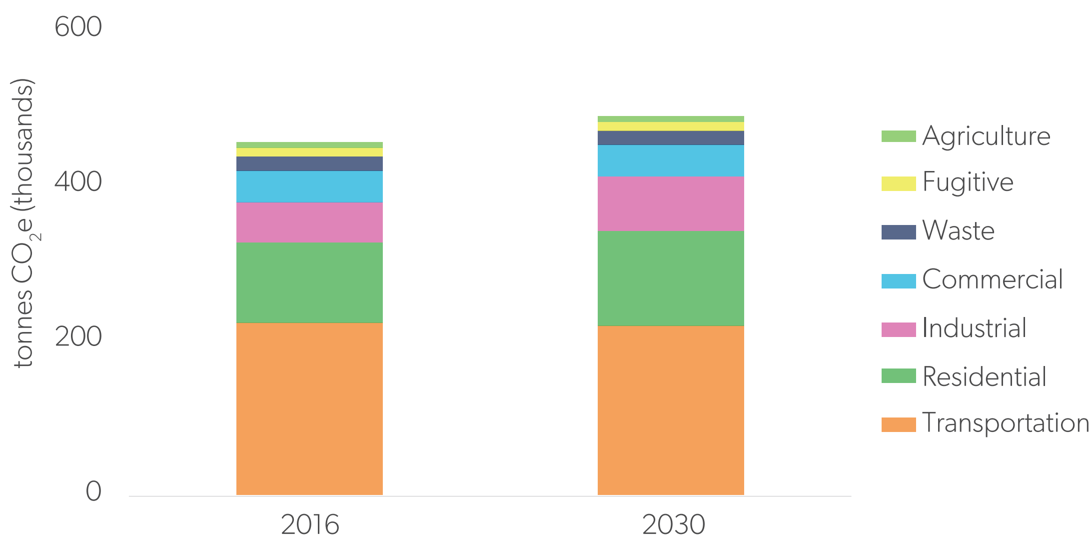


Figure 4. Town of Halton Hills projected emissions in a business-as-usual or 'reference' scenario, by sector, 2016-2030.

To move from business-as-usual to a net-zero future, Halton Hills must address its major sources of emissions which are projected in 2030 to be:

- 44% from cars and trucks (49% in 2016);
- 33% from commercial and residential buildings (32% in 2016);
- 14% from industry (11% in 2016);
- 4% from waste (same as 2016);
- 2% from fugitive emissions from natural gas distribution (same as 2016); and
- 2% from agriculture (same as 2016).[11]

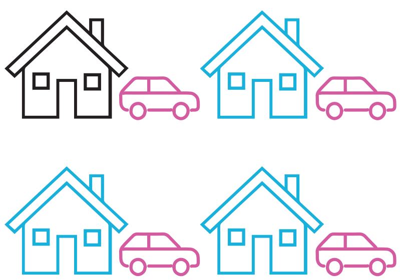
[11] Percentages add up to 99% due to rounding.

Efficiency First

In order to address these emissions, the LCTS adopts an efficiency-first approach (see Figure 5). This means that energy-related GHG emissions (i.e., transportation, buildings, industry, and fugitive) are first lowered via more efficient energy use where possible (e.g., increasing home insulation or working from home instead of driving to an office). Then, the remaining energy consumption is switched from fossil fuels to renewable energy. Improving energy efficiency first helps minimize the need for additional electricity capacity, thereby avoiding associated environmental impacts and financial costs.

For waste-related emissions, primarily from the decomposition of organic waste at the Region's landfill, efficiency first means minimizing the organic waste that goes to landfill, such as with a composting program.

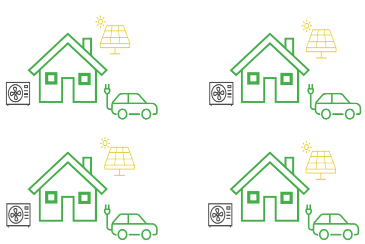
EFFICIENCY FIRST



4 homes: 1 electric baseboard heated,
3 efficient natural gas boiler heated,
Each with a combustion engine vehicle.

Total Energy: 500 GJ

Total GHGs: 40 tonnes*



4 homes: 40% more efficient due to retrofits,
Heated by efficient electric heat pumps,
Each with an electric car,
50% solar panels added.

Total Energy: 200 GJ

Total GHGs: Net Zero*

*assuming carbon-free electricity

Figure 5. An infographic depicting the benefits of introducing efficiency first in a decarbonization strategy.

The Four Main Action Areas

The Town's pathway to net-zero (see Figure 6) is made up of four main action areas:

1. **Low-carbon mobility:** Enable travel by foot, bicycle, emissions-free transit, or electric vehicles;
2. **Energy efficiency and green development:** New and existing buildings are more energy efficient and are powered by renewable energy;
3. **Local renewable energy:** Replace fossil fuel energy with local renewable electricity and renewable natural gas; and
4. **Natural assets:** Protect and expand the town's natural carbon sinks, greenspaces and healthy soil, to offset some of the remaining emissions.

These four action areas are described in more detail below.

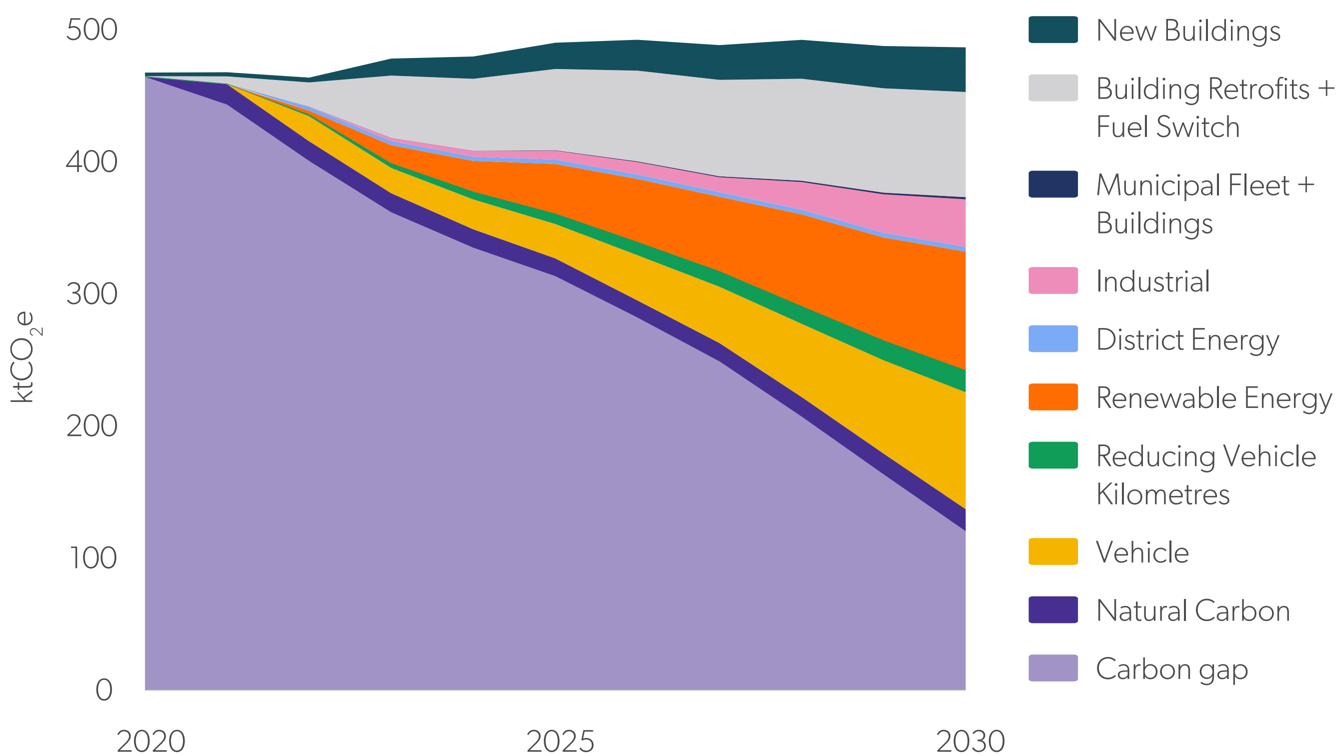


Figure 6. Net-zero scenario emissions reductions by sector (tCO_2e), 2020-2030.(Note: Each wedge is a cumulative reduction from the business-as-usual scenario modelled for the Town.)

As for waste, the Town will collaborate with Halton Region, which currently manages the Town's waste collection and disposal, to tackle emissions. The LCTS recommends maximizing diversion of organic waste away from the landfill and exploring the potential to divert it to an anaerobic digester to produce local renewable natural gas.

Together, these four main action areas have the potential to reduce Halton Hills' emissions by 74% by 2030, even as the population and economy grow significantly. Remaining emissions (see Figure 7) in 2030 will be primarily due to:

- combustion engine vehicles purchased now and in the near future (63%);
- the local share of air and rail travel (20%); and
- organic waste from residents and businesses decaying in the Region's landfill (13%).

These will need to be offset or, ideally, addressed in future LCTS iterations with new policies or technologies.

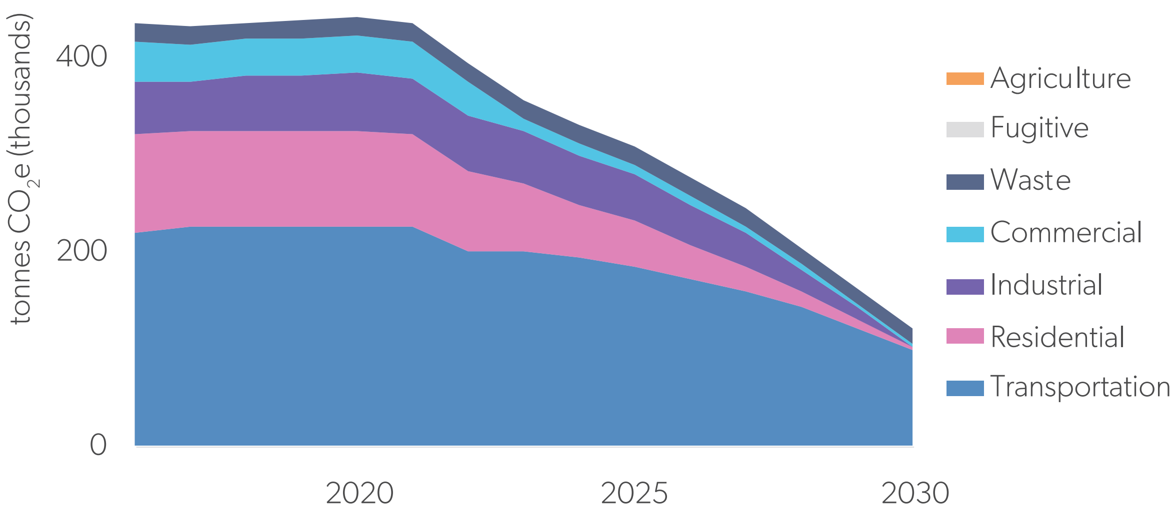


Figure 7. Town of Halton Hills LCTS emissions, by sector 2016-2030.

The Stickiness of the Transportation System

In Figure 7, vehicles are the primary source of remaining emissions. Phasing out emissions from vehicles by 2030 is challenging. The primary pathway to decarbonize transportation is to electrify vehicles. Electric vehicles can then be powered by renewable electricity. A typical vehicle in Canada will last for 10-12 years, so electrifying the fleet by 2030 would require that only electric vehicles are purchased by 2018-2020, which didn't happen. Currently the Government of Canada has indicated that their target for 100% of EV sales is 2035, more than 15 years too late.[12] In order to achieve its target, the Town has to encourage people to purchase electric vehicles as fast as possible through the various policies at its disposal, including early retirement of gasoline vehicles. It will also need to encourage people to get out of cars and use other zero emissions transportation modes such as walking, cycling, and transit as soon as possible.

Other than purchasing offsets, which will come from outside of the community, all of the LCTS actions involve significant local co-benefits, such as:

- improving resident health and wellbeing,
- protecting local biodiversity and ecosystems,
- creating local jobs,
- improving resilience to extreme weather,
- improving economic resilience, and
- lowering household energy bills.

These co-benefits will be discussed throughout this report.

For additional information on the reference scenario and net-zero scenario model results, see Appendix B and C.

1. Low-Carbon Mobility

The LCTS is a vision for a community with fresher air and more convenient options for walking, cycling, and public transit than exist today. By 2030, residents of Halton Hills will breathe in less air pollution as residents use their cars less and more people drive EVs. In addition, workers will commute less often with more flexibility to work from home—a shift that drives down emissions while improving well-being.

Who will benefit?

- People with chronic obstructive pulmonary disease or other respiratory ailments
- People who can't access cars (youth, elderly)
- Households under financial stress

[12] Government of Canada, news release, 'Building a green economy: Government of Canada to require 100% of car and passenger truck sales be zero-emission by 2035 in Canada' (June 29, 2021).

- Construction companies (transit and active transportation infrastructure)
- People with home businesses

EMISSIONS PROFILE AND LOW-CARBON ACTIONS

In 2016, vehicles accounted for 49% of Halton Hills' emissions, primarily due to burning gasoline, and to a lesser extent diesel. With no new action, personal-use vehicles are expected to drive an additional 200 million kilometres a year by 2030.

In contrast, in the net-zero scenario transportation emissions drop by 55% and annual vehicle kilometres travelled (VKT) decrease by 125 million by 2030. This decrease in emissions is driven by a shift from internal combustion engine vehicles to electric vehicles (EVs) powered by renewable electricity. The associated cost to reduce each tonne of GHG associated with the transition to EVs represents savings for the community, especially the proposed EV car-sharing program, which would see many households avoiding the need to purchase a first or second personal use vehicle (see the table below and the textbox: What is a Marginal Abatement Cost?). The decrease in VKT is due to an increase in walking and cycling infrastructure, as well as improvements in public transit.

The actions modelled to achieve the transportation energy efficiency improvements and emissions reductions in the LCTS are detailed in the following table.

What is a Marginal Abatement Cost?

The Marginal Abatement Cost (MAC) is the incremental cost of one tonne of GHG reductions. The lower the cost, the more affordable the action, and in some cases, the action can be profitable. It is calculated by summing the net present value of capital costs and operating costs over the lifetime of the investments divided by the tonnes of GHGs reduced.

By providing individual costs for actions, MACs can imply that the actions are a menu from which individual actions can be selected. In fact, many of the actions are dependent on each other, for example, energy costs increase without retrofits. Another important message is that in order to achieve the Town's target, all the actions need to be undertaken as soon as possible.

MAC do provide useful insights that guide implementation planning:

- Can high cost and high savings actions be bundled to achieve greater GHG emissions reductions?
- How can the Town help reduce the costs of the high cost actions by supporting innovation or by providing subsidies?
- Which actions both save money and reduce the most GHG emissions?
- Which actions are likely to be of interest to the private sector, assuming barriers can be removed or supporting policies introduced?

Table 2. Summary of net-zero scenario (NZS) actions in the transportation sector, including associated GHG reduction and marginal abatement cost.

		GHG REDUCTION NZS VS REFERENCE CUMULATIVE	MARGINAL ABATEMENT COST $ / $TC0_2E$ REDUCED (BRACKETS) = SAVINGS
Transit >15 km	Transit mode share to reach 15% for long-distance trips (>15km).	10 $ktCO_2e$	($1,973)
Transit <15 km	Local electric bus route established by 2030. Transit mode share for short-distance trips increases to 15% by 2030.	15 $ktCO_2e$	($448)
Car share	Starting in 2024, an autonomous EV car share is introduced in the Town. By 2030, the system will serve 10% of trips.	24 $ktCO_2e$	($6,343)
Active transportation	Active mode share accounts for 20% of trips under 5km by 2030.	2 $ktCO_2e$	n/a
Work from home	30% of people telework by the year 2030. By 2030, trips will decline by 15%.	71 $KtCO_2e$	($1,477)
Municipal fleets	Starting immediately, electrify 100% of new administrative vehicles at the time of replacement. At time of replacement, heavy vehicle classes are transitioned to RNG, where electric options exist they should be opted for.	2 $ktCO_2e$	(2,008)
Personal vehicles	At time of replacement, 100% of new vehicles will be EVs by 2030, assuming an average combustion engine vehicle life cycle of 7 years (to be shortened from typical 11 years via policies/programs).	219 $ktCO_2e$	($906)
Commercial vehicles	At time of replacement, 100% of new medium vehicles will be EVs by 2030, 50% of new heavy vehicles will be electric by 2030, and 50% of new heavy vehicles will be fuelled by RNG by 2030.	78 $ktCO_2e$	($739)
Off-road vehicles	50% of new off-road vehicles are electric by 2030.	56 $ktCO_2e$	n/a

CO-BENEFITS

The low-carbon actions have positive economic and health benefits. The number of kilometres walked by residents will increase by 10%, while the number of kilometres cycled will increase tenfold by 2030. These changes will contribute to improved public health: as residents become more active, individual health will improve, and streets will become quieter and safer with fewer cars on the road. In addition, switching from internal combustion engine vehicles to EVs will improve public health by decreasing air pollution. Locals who live or spend time near a major arterial road or controlled access highway will see the biggest benefits as exhaust emissions decrease.[13]

Improving access to walking, cycling, and transit infrastructure can also enhance equity by making it cost-effective and convenient for residents who don't have, cannot drive, or cannot afford vehicles to move around.

KEY IMPLEMENTATION ACTIONS

A number of actions in the short-term (now through 2025) will help increase the uptake of EVs and increase active transport mode share.

- » **Expand EV charging infrastructure:** The Town, working with key partners like Halton Hills Hydro, will expand EV charging infrastructure through a combination of government funding, partner resources, and Town budget. It will begin by assessing the current EV charging infrastructure and identifying priority gaps in the system.
- » **EV info days:** The Town will work with partners such as Halton Hills Hydro, local businesses, and Plug & Drive to host recurring EV info days where residents can learn about and test drive EVs.
- » **Establish a commercial fleet decarbonization working group:** The Town will support the development of a working group of local commercial fleet owners to support education, knowledge sharing, and encourage the adoption of fleet decarbonization targets.
- » **Offer a bike share program:** The Town will complete a feasibility study and pilot a bike-share program. Based on the pilot's outcome, the Town will explore opportunities for further expansion, such as incorporating more bikes, e-bikes, or e-scooters.
- » **Deploy a local e-bus:** The Town will conduct a study to identify the optimal local e-bus routes between population and employment hubs, as well as connections to active transportation and regional transit networks. This will include an assessment of the local Activan fleet which currently serves community seniors and people with disabilities. The Activan fleet will begin the process of electrification no later than 2024. The Town will consult key stakeholders and solicit federal funding for the system.
- » **Expand walking and biking trails:** The Town will prioritize improvement and expansion of walking and biking infrastructure in line with its Active Transportation Plan. In particular, road budgets will be reallocated to active transportation where possible.

[13] Public Health Ontario, Traffic-Related Air Pollution: Avoiding the TRAP zone (2016) online: www.publichealthontario.ca/-/media/documents/O/2016/ohp-trap.pdf?la=en.

2. Energy Efficiency and Green Development

The LCTS is a pathway to a community in 2030 with more comfortable buildings, lower energy bills, and greener industry. New buildings will be constructed to more stringent energy efficient building standards and existing buildings will be retrofitted to improve efficiency. The vast majority of buildings will be heated and cooled by local renewable electricity. Industry will reduce its reliance on fossil fuels and improve industrial process efficiency, lowering its energy bills.

EMISSIONS PROFILE AND LOW-CARBON ACTIONS

Space heating and industrial processes are Halton Hill's largest source of emissions. In 2016, residential buildings represented 31% and commercial/industrial buildings accounted for 33% of the town's energy consumption and about 21% and 22% respectively of its GHG emissions. Natural gas for heating and industrial processes was the largest contributor to these emissions. Heating oil was the second leading source of emissions, primarily from industrial uses.

In the net-zero scenario, energy consumption from all buildings and industrial processes drops by a quarter by 2030 as a result of new energy performance requirements, deep energy retrofits, and the incorporation of energy-efficient heat pumps for space and water heating. These changes drive down energy demand while reducing reliance on fossil fuels. Fuel switching remaining emissions to renewable electricity and renewable natural gas results in a 98% decrease in buildings and industry emissions.

The actions modelled to achieve the building and industry energy efficiency improvements and emissions reductions in the LCTS are detailed in the following table.

Who will benefit?

- Homeowners
- Building owners
- Construction workers and companies
- Private contractors
- Heating, ventilation, and air conditioning installers and manufacturers
- Building component manufacturers (windows, doors, insulation)
- Solar installation companies

Table 3. Summary of net-zero scenario (NZS) actions in the buildings sector, including their associated GHG reduction and marginal abatement cost.

		GHG REDUCTION NZS VS REFERENCE CUMULATIVE	MARGINAL ABATEMENT COST $ / TCO_2E REDUCED (BRACKETS) = SAVINGS
New Buildings			
Residential	New residential buildings to be constructed to increasingly stringent energy use standards. As of 2023, all new buildings to be net-zero ready (i.e., any GHG emissions are offset by community- or building-level renewable energy installations).	133 $ktCO_2e$	$458
Commercial and industrial	New commercial and industrial buildings to be constructed to increasingly stringent energy use standards. As of 2023, all new retail and office buildings to be net-zero ready.	71 $ktCO_2e$	($711)
Municipal	New commercial and industrial buildings to be constructed to increasingly stringent energy use standards. As of 2023, all new buildings to be net-zero ready.	4 $ktCO_2e$	$2,432
Existing Buildings			
Homes built prior to 1980	Retrofit 65% of buildings by 2030 (6% of buildings per year). Most retrofits are deep. (Average energy use intensity (EUI) reduction of 70% across retrofitted building stock.)	217 $ktCO_2e$	$1,896
Homes built after 1980	Retrofit 50% of homes by 2030. Average EUI reduction of 50% across retrofitted building stock.	136 $ktCO_2e$	$1,483
Commercial buildings	Retrofit 50% of commercial building stock. Average EUI reduction of 50% across retrofitted building stock.	92 $ktCO_2e$	$109
Heat pumps	90% of retrofitted buildings receive an air-source heat pump (ASHP). 75% of non-retrofitted buildings receive an ASHP.	118 $ktCO_2e$	$49
Industrial efficiency	Starting in 2022, industrial buildings and processes use 3.75% less energy than in the previous year, resulting in 30% less energy consumed by the year 2030, relative to the 2016 baseline.	98 $ktCO_2e$	$210
Industrial fuel switch	30% of industrial process energy use (prioritizing fuel oil and then natural gas) will be displaced with renewable electricity and renewable natural gas by 2030.	38 $ktCO_2e$	($63)

CO-BENEFITS

As building efficiency increases, energy consumption and associated costs will decrease, creating savings for residents, the Town, and businesses. By 2030, an average Halton Hills household will spend $2,500 on fuel and electricity for household energy and transportation—almost 50% less than they would have in the reference scenario. Between 2022 and 2030, these add up to savings of over $12,400 for the average household. A community survey run during the course of the LCTS development gives a sense of the importance of energy bill savings to community residents (see Figure 8). At the same time, energy efficiency upgrades can improve ventilation, thermal comfort, and other characteristics of buildings, which leads to improved comfort, health, and productivity.

The industrial sector will benefit from greater energy efficiency and access to renewable energy. Shifting away from fossil fuels will create a net benefit, saving industry $63 in energy costs for every tonne of CO_2e reduced. In addition, the shift to low-carbon buildings will contribute to the growth of the green construction sector by creating over 1,300 jobs (or 11,100 person years of employment between 2022 and 2030).

What is most important to you in a community climate change initiative?

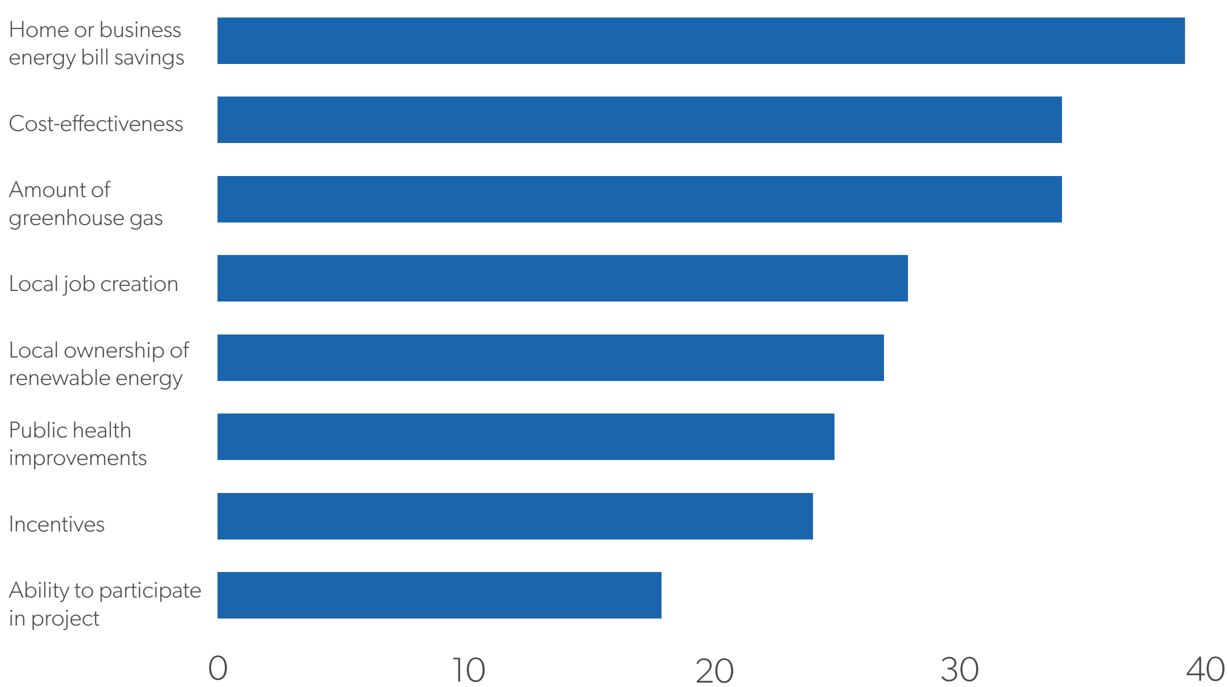


Figure 8. This community survey featured on the Town's Let's Talk Halton Hills site during May-June 2021 asked residents to "check all options that apply."

KEY IMPLEMENTATION ACTIONS

The Town will take a number of actions in the near-term (now through 2025) to overhaul existing buildings, as well as establish the requirements for new ones. These include:

- **Deploy a residential retrofit program:** The Town will complete a feasibility study and run a pilot retrofit program, including financing and an education campaign for homeowners and landlords. Based on learnings from the pilot, the Town will rapidly expand the program, seeking to cover about 1,500 houses a year as soon as a viable program has been demonstrated.
- **Deploy a commercial retrofit program:** The Town will consult small- and medium-sized businesses, map out the business ecosystem to identify relevant resources, and undertake a pilot commercial retrofit program, including financing and an education campaign. Based on learnings from the pilot, the Town will expand the program.
- **Deploy an industrial retrofit program:** The Town will work with small- and medium-sized businesses to outline concrete actions and map out which businesses can provide services for the retrofit program. The Town will then undertake a pilot industrial retrofit program, including financing and an education campaign for industrial business owners and energy managers. Based on learnings from the program, the Town will expand the pilot.
- **Enhance the GHG performance of new construction:** The Town will continue to implement and strengthen its Green Development Standards to ensure new developments align with its net-zero by 2030 target.
- **Ensure Vision Georgetown is a net-zero emissions community:** The Town will seek to implement the recommendations of the Low-Carbon Energy Supply Study for Vision Georgetown.

3. Local Renewable Energy

LCTS imagines a Halton Hills where buildings and vehicles are mostly powered by renewable energy generated by the sun. By 2030, residents will spend less on energy, generate power with solar panels on their homes, and receive returns from the local renewable energy co-operative. Natural gas use that remains will be replaced by renewable natural gas generated from organic waste while a geothermal district energy system will heat buildings in Vision Georgetown.

Halton Hills Hydro and Halton Hills Community Energy Corporation will be key implementation partners for this vision, which they helped shape as members of the MSGC.

Who will benefit?

- Homeowners
- Building owners
- Electricians
- Private contractors
- Solar companies
- Investors

EMISSIONS PROFILE AND LOW-CARBON ACTIONS

Despite major improvements in efficiency across all sectors and a mass fuel-switching program from fossil fuels to low-carbon electricity, the Town will still have some remaining fossil fuel emissions in 2030 if no further action is taken. Those emissions related to natural gas use can be minimized through greater use of renewable natural gas. Those emissions related to central grid electricity consumption can be minimized by increasing local renewable electricity generation.

The local economic benefits of these actions can be maximized if energy is produced locally. For the purposes of the LCTS, solar is considered the primary source of local renewable electricity generation within Town boundaries. This is because of local sun exposure, as well as rooftop and available land area for panels. Wind potential would need to be the subject of further study. Because waste is managed by the Region, it was assumed that any RNG would be procured from outside Town boundaries. However, there is significant potential for a centralized and/or smaller scale anaerobic digesters (e.g., on farms) where organic waste is diverted from landfill and used for energy.

The local renewable energy generation actions in the LCTS are detailed in the following table.

Table 4. Summary of local renewable energy generation net-zero scenario (NZS) actions, including their associated GHG reduction and marginal abatement cost.

		GHG REDUCTION NZS VS REFERENCE CUMULATIVE	MARGINAL ABATEMENT COST $/TCO$_2$E* *(BRACKETS) REPRESENT SAVINGS
Solar PV - rooftop	By 2030, install 30% of feasible rooftop solar PV potential (46 MW based on roof analysis), starting in 2022. This results in an annual installation of 5.6 MW.	20 ktCO_2e	($1,767)
Solar PV ground mount - utility scale	Solar capacity built to meet the Town's remaining central grid electricity demand in 2030, 445 MW of solar capacity (about 13% of available undeveloped settlement land and cropland).	206 ktCO_2e	($4,263)
Renewable natural gas (RNG)	RNG will be procured to replace remaining natural gas demand starting in 2030.	192 ktCO_2e	$56

CO-BENEFITS

Between 2022 and 2030, local solar energy generation will create the equivalent of 340 full time jobs, including for the installation of residential and commercial rooftop solar, as well as large-scale ground mount installations.[14] In addition, the Town is evaluating the potential of establishing a renewable energy co-operative, which could generate returns for community members who join it. Halton Hills households are also expected to save an average of $12,42,000 each on household energy and transportation expenditures between 2022 and 2030, thanks in part to local renewable energy developments that will keep energy dollars within the community.

KEY IMPLEMENTATION ACTIONS

The Town will take a number of actions to increase local renewable energy generation in a way that creates economic benefits for the community. The following have been identified as key near-term actions:

- **Plan a next-generation electricity system:** The Town will hire a consultant to undertake an hourly analysis of how the energy efficiency improvements and electrification included in the LCTS will affect the electricity system and how the demand can be balanced to ensure a stable, reliable grid.

[14] Over 3 thousand person years of employment over the investment period, 2022-2030.

» **Establish a renewable energy co-operative:** The Town will create a public education campaign to raise awareness of the benefits of creating a renewable energy co-operative, which would give Halton Hills residents a chance to own local renewable energy developments. The Town will also work with the LCTS committee to search for potential local groups to establish the co-operative.

» **Develop large-scale solar capacity:** Starting in 2022, the Town will establish criteria for large-scale solar installations and identify locations for solar installations before identifying one or more developers for the project.

» **Evaluate renewable natural gas:** The Town will meet with the Region to discuss how the Region's organic waste management policies can align with the Town's net-zero target. The Town will also work with the Region to undertake a feasibility study and economic analysis to explore the possibility of developing a centralized anaerobic digestion facility and renewable natural gas refining facility.

4. Natural Asset Management

The LCTS envisions a Halton Hills with cleaner air, more trees, and denser neighborhoods with convenient connections to walk, bike, and cycle from place to place. At the same time, farmers will improve their sustainable soil management practices, leading to lower emissions and increased crop productivity.

Who will benefit?

- The community
- Birds and bees
- Farmers
- Foresters

EMISSIONS PROFILE AND LOW-CARBON ACTIONS

Agriculture, primarily from livestock, is estimated to account for 2% of total emissions in Halton Hills in 2016. While agriculture's share of emissions will increase to 7% in the low-carbon scenario, the amount of emissions (8 $ktCO_2e$) is expected to remain constant. At the same time, efforts to protect and enhance green space, including improved soil management practices and tree planting, will reduce emissions by 147 $ktCO_2e$.

Improved green spaces and healthy soil actions in the LCTS are detailed in the following table.

Table 5. Summary of net-zero scenario (NZS) actions related to green spaces and healthy soils, including associated GHG reduction and marginal abatement cost.

		GHG REDUCTION NZS VS REFERENCE CUMULATIVE	MARGINAL ABATEMENT COST $/TCO_2E$* *(BRACKETS) REPRESENT SAVINGS
Tree planting	Starting in 2022, plant 50,000 trees in Halton Hills per year.	37 $ktCO_2e$	$25
Soil management	15% increase in land under sustainable soil management practices by 2030 (i.e., no-till farming).	9 $ktCO_2e$	n/a
Spatial distribution of new buildings	All new developments, apart from Vision Georgetown, are infill (i.e., no greenfield development).	101 $ktCO_2e$	n/a

CO-BENEFITS

In addition to sequestering carbon, the focus on green spaces and healthy soils will create a number of social, health, and economic benefits for the community. Limiting greenfield development will ensure existing green space is preserved, which provides animal habitat and mitigates the heat island effect. Increased tree canopy will improve air quality. Enhanced green spaces will also benefit the wellbeing of community members who use them. Sustainable soil management can increase crop productivity, which can increase farmers' incomes and contribute to better quality of life.

All of these actions also have the potential to improve the community's resilience to extreme weather events. In fact, many of these actions also form part of the Town's Climate Change Adaptation Plan. Ideally, these actions would be implemented in a manner that maximizes both outcomes: carbon sequestration and climate adaptation.

KEY IMPLEMENTATION ACTIONS

The Town will take a number of actions to improve natural carbon sequestration of GHG emissions, these include:

- **Establish a tree canopy management and expansion program:** The Town, with support from local conservation authorities, will develop a tree planting target and associated planting program.
- **Improve soil health:** The Town will work with other levels of government, local conservation authorities, and farming associations to assess the state of soil management programs and related carbon sequestration monitoring. Based on its findings, the Town and local partners will identify ways to build on this work and increase land under sustainable soil management practices.
- **Increase density:** The Town will review policy frameworks to support increased densification, more walkable and bicycle-friendly communities, and the development of active transport and transit networks that enable density—all while maintaining the community's small town feel.

For additional information on the:

- actions modelled in the LCTS, see Appendix A;
- the reference scenario model results, see Appendix B;
- the net-zero scenario model results, see Appendix C;
- the financial and economic analysis results, see Appendix D; and
- the near-term implementation plan, see Appendix E.

Part III: Going Forward

Turning to Action

Many investment decisions made today will last to 2030 and beyond. If the community chooses to build sprawling developments, people in Halton Hills will find it harder to walk and bike to their destinations for years to come. If the community constructs homes with few energy efficiency features, those living in them will be on the hook for higher energy bills, possibly for generations.

Getting to net zero by 2030 requires the entire community to take action as soon as possible. Even as the cost of low-carbon technology continues to decline in many areas, there are many financial benefits to acting now. Ensuring that no new major investments, such as new buildings and vehicles, lock the Town into a fossil-fueled future helps minimize stranded assets (i.e., assets that will need to be retired before their natural end of life). Reducing energy consumption helps reduce energy bills and free up electricity capacity for the many new forms of electricity demand (e.g., EVs and electric heat pumps).

To ensure LCTS investments result in successful outcomes, the following key principles will guide the Strategy's implementation:

- Collaboration and innovation,
- Community participation and oversight, and
- Equitable growth.

These principles are discussed further below.

COLLABORATION AND INNOVATION

The whole community must come together to bring the LCTS to life. Residents, businesses, institutions, and organizations need to:

1. learn about and spread awareness of the LCTS and related initiatives among family members, neighbours, and colleagues;
2. participate in retrofit programs and make low-carbon transportation choices; and
3. partner to deliver programs.

Getting to net zero also requires the **political and financial support of other levels of government:** regional, provincial, and federal. For example, the Province must decarbonize the electricity grid and strengthen its energy efficiency regulations, while the Region must divert as much organic waste as possible from landfills.

Technologies to decarbonize homes and cars exist, but transitioning vehicles and retrofitting buildings at scale and in short order demands **innovation in program delivery and financing**. In order to reach net zero by 2030, the Town will:

- learn from best practices in other communities (for example Bristol UK's City Leap partnering with the private sector to achieve their net-zero by 2030 target,[15] and Europe's mass deep energy retrofit program 'Energiesprong');[16]
- take risks by trying new programs and policies; and
- collaborate with neighbouring communities by sharing resources to achieve more with less.

COMMUNITY PARTICIPATION AND OVERSIGHT

The Town plays a leadership role in the LCTS. It has already committed to decarbonize its assets by 2030; however, Town operations represent a minority of emissions into the community. Getting to net zero requires action from the entire community. Businesses need to set net-zero targets and provide net-zero products and services. Households need to retrofit their homes and make carbon-free transportation choices. Success will depend on whether the community learns about the LCTS and gets involved. The LCTS requires a major public education and marketing campaign.

To ensure the community is held accountable to the LCTS and meeting its net-zero-by-2030 target, regular public GHG emission reporting, by sector, will be necessary, as well as reporting on program-specific metrics. Town Council will need to receive annual reporting, and benefit from direct oversight and input from the community. Incremental LCTS reviews, based on regular reporting will also be critical, this will allow for further refinement and updates to be made.

When it comes to overseeing the LCTS' implementation, what is important to you?

"Show a clear plan, a clear budget and updated results shown to the community"

"Showing how the town of Halton Hills is working with our local municipal partners"

"Making sure public and private sector groups/corps are actually carrying their weight"

"That the Town does what it can to offer financial incentives to help people make the changes they want to make. Subsidizing purchases, etc."

- Select Town survey responses (2021).

[15] See: www.bristol-energy.co.uk/cityleap.

[16] See: energiesprong.org/about/.

EQUITABLE GROWTH

With the LCTS, our community is starting down a path that will enable us to capture economic opportunities arising from decarbonization while increasing the wellbeing of residents.

Although the Town of Halton Hills is more affluent than the national average, the Town still has some low-income and under-employed residents. The transition requires significant movement of capital, which provides an opportunity for equitable redistribution, rather than further entrenching existing inequities. Though the majority of low-carbon actions more than pay for themselves over time, they often have relatively high upfront costs that may exclude low-income groups from participating. For example, retrofits may be too costly for low-income households, and some households may not own their own home. At the same time these low-income households generally have a higher energy burden, paying more for fuel for older inefficient vehicles and spending more on electricity and natural gas to power and heat older, inefficient homes. These are the residents that stand to benefit most from many LCTS programs; however, they may be left behind if programs are not tailored to their financial capacity.

Local suppliers, local expertise, local business, and local labour can all be leveraged to deliver the pathway to net zero by 2030. The Town can help maximize these local opportunities by ensuring local training for LCTS-related jobs is made accessible to members of the community, especially those that are currently under-employed, and that LCTS-related procurement is designed so that local businesses have an opportunity to participate.

Finally, renewable energy, such as large-scale solar can and should be developed in such a way to maximize local benefits. Community ownership structures, such as cooperatives, help local revenue stay in the community and give residents a chance to invest in renewable energy.

What can the Town do to facilitate you getting involved in the LCTS?

"Have a regular sustained public education/information strategy that emphasizes positive aspects of reducing our carbon footprint, using all available media"

"More fast charging stations for electric vehicles"

"Make local transit a priority"

"Community tree plantings"

"Be transparent about plans"

- Select Town survey responses (2021).

Toward a Sustainable, Circular Economy

The LCTS begins to define what sustainable growth looks like for Halton Hills: growth that enables the community to reduce its emissions in line with its net-zero-by-2030 target, while preserving the environment, improving quality of life, and decreasing inequity. The Town is committed to ongoing research and innovation to address the remaining carbon gap presented by this LCTS.

Going forward, the Town will continue to work to define sustainable growth. This is likely to include a more holistic carbon lens that accounts for a broader range of emissions. For example, while this plan accounts for building emissions from the energy required to power and heat buildings; a more holistic lens would consider the emissions from producing the steel and cement used to construct buildings. By starting to consider emissions from “cradle to grave”, the community can place less value on carbon-intensive goods relative to goods produced with renewable energy, increased energy efficiency, and recycled materials. This helps move the community towards a more sustainable, circular economy.[17]

With the LCTS, Halton Hills is starting down an important path to becoming a thriving, more sustainable community, and economy. The LCTS reflects a community that is optimistic about its future, knows it is growing, and is not afraid to innovate and change.

This Strategy for a low-carbon Halton Hills is put forward in the context of what will be one of the great transitions in the story of human civilization: the transition to an ecologically sustainable and healthy economic system that runs on renewable energy and circular flows of materials. It is in its early stages, but it is building momentum from the ground up through thousands of local initiatives like this one. Like a train pulling out of a station, at first progress seems slow and the destination impossibly far away, but it will gain speed quickly. It will require resolve to implement and the ability to embrace the disruption that inevitably accompanies grand transitions. This will be possible if the community is confident that the journey will lead to a healthier and more sustainable economy.

[17] To learn more about the circular economy, check out Doughnut Economics by Kate Raworth.

APPENDICES

APPENDIX A: Table of Reference and Net-Zero Scenario Modelled Assumptions

July 2021

Purpose of this Document

To provide a comprehensive summary of the 32 modelled actions that make up the reference and net-zero scenarios developed to inform the Town of Halton Hills' Low-carbon Transition Strategy. All actions included in the table are future projections related to energy use and greenhouse gas emissions based on research and stakeholder input, a selection of which have been highlighted in the Table. All actions were subject to review by the Town and MSGC. The actions do not constitute future commitments of the Town.

For an analysis of the Town's reference and net-zero scenario energy use and GHG emissions, see Appendices C and D respectively.

Contents

Acronyms

ASHP	air-source heat pump
CaGBC	Canada Green Building Council
CHP	combined heat and power
EUI	energy use intensity
EV	electric vehicle
GDS	Green Development Standard
GHG	greenhouse gas emissions
IESO	Independent Electricity System Operator
MSGC	Multi-Stakeholder Governance Committee
OBC	Ontario Building Code
PV	photovoltaic
NZS	net-zero scenario
REC	renewable energy certificate
RNG	renewable natural gas
TEDI	thermal energy demand intensity
VKT	vehicle kilometres travelled

New Buildings: Buildings Codes and Standards

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
1. Residential energy performance	• By 2030, 25% of all new construction is built to the Town's Green Development Standard (GDS). • From 2016 to 2020, GDS mandated standards 20% better than Ontario Building Code (OBC) 2012 energy performance. • From 2020 to 2026, GDS will mandate standards 15% better than OBC 2020 energy performance. • Once energy performance under OBC is higher than updated GDS, 100% of buildings will be constructed to OBC.	New residential buildings to be constructed to the following energy use intensity (EUI), in kwh/m^2: • 2022: EUI 130 (TEDI 40) • 2026: EUI 100 (TEDI 25) • 2030: EUI 70 (TEDI 15) As of 2023, all new buildings to be net-zero ready (i.e., any GHG emissions need to be offset by community- or building-level renewable energy installations). For the purpose of modelling the NZS, it was assumed that this would be accomplished by using heat pumps for space and water heating.	**Modelling notes:** • The NZS targets are achieved by providing heat and hot water via heat pumps for 100% of new builds, rather than natural gas. • Other technologies could be used however at the time of this report these were the best and most advantageous options. **Best practice:** • Toronto Green Standard-equivalent (i.e., Passive House or net-zero standard) energy efficiency improvements. **Sources:** • Town of Halton Hills. (2014). Green Development Standard. • Town of Halton Hills. (2018). Vision Georgetown Energy Master Plan.

New Buildings: Buildings Codes and Standards

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
2. Commercial and industrial energy performance	• Energy performance under the Building Code improves by 10% every five years.	**Office:** New commercial buildings to be constructed to the following energy use intensity (EUI) and thermal energy demand intensity (TEDI), in kwh/m^2: • 2022: EUI 130 (TEDI 30) • 2026: EUI 100 (TEDI 22) • 2030: EUI 65 (TEDI 15) **Retail:** • 2022: EUI 120 (TEDI 40) • 2026: EUI 90 (TEDI 25) • 2030: EUI 70 (TEDI 15) As of 2023, all new retail and office buildings to be net-zero ready (i.e., any GHG emissions need to be offset by community or building-level renewable energy installations). **Industry:** • 2030: 25% improvement over 2016 EUI (linear).	**Modelling notes:** • These EUI targets are achieved without connections to natural gas by providing heat and hot water via heat pumps for 100% of new builds. **Best practice:** • Toronto Green Standard-equivalent (i.e., Passive House/ Net Zero) energy efficiency improvements. Tiered improvements according to the City of Toronto. (2016). Zero Emissions Building Framework.

New Buildings: Buildings Codes and Standards

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
3. Municipal building performance	• Energy performance improves according to the Town's plans	From 2025 onwards, new municipal buildings to be constructed to the following energy use intensity (EUI) and thermal energy demand intensity (TEDI), in kwh/m^2: EUI 65 (TEDI 15). As of 2023, all new buildings to be carbon neutral (i.e., any GHG emissions need to be offset by community- or building-level renewable energy installations).	**Modelling notes:** • For the purpose of modelling the NZS, it was assumed that this would be accomplished by using heat pumps for space and water heating, and installing rooftop solar PV. **Best practice:** • Toronto Green Standard-equivalent (i.e., Passive House or net-zero standards) energy efficiency improvements. Tiered improvements according to: City of Toronto. (2016). Zero Emissions Building Framework. **Source:** • Halton Hills 2020-2025 Corporate Energy Plan.

Existing Buildings: Retrofitting

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
4. Retrofit homes built prior to 1980	• Currently, 1% of building stock is retrofitted annually. • Existing buildings accounted for nearly 40% of Halton Hills' emissions in 2016.	Retrofit 65% of buildings by 2030 (6% of buildings per year).	**Precedents:** • City of Windsor is considering a City-sponsored retrofit program to cover 80% of Windsor's 60,000 homes by 2041. • Toronto's Home Energy Retrofit Program reached 187 homes between 2014-2019, while the High-rise Retrofit Improvement Support Program reached 2,200 units. • Canada Green Building Council's (CaGBC) Roadmap for retrofits calls for 40% of buildings over 35 years old be retrofitted by 2030 (in moderate carbon grids). **Stakeholder feedback:** • 63% of the stakeholder advisory group respondents thought that the majority of buildings should be retrofitted by 2030. • 22% of the stakeholder advisory group respondents thought that about half of buildings should be retrofitted by 2030. **Sources:** • Statistics Canada, Building permits, by type of structure and type of work, Tabel 34-10-0066-01, 2019

Existing Buildings: Retrofitting

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
5. Retrofit depth	Held constant: • In 2030, existing buildings account for nearly 40% of Halton Hills' emissions, in line with the 2016 base year.	Most retrofits are deep. (Average EUI reduction of 70% across retrofitted building stock.)	**Current status:** • Average EUI for buildings constructed before 1981 is 281 kwh/m^2. Average EUI for buildings constructed after 1981 is about 160kwh/m^2. • Passive House standards limit new buildings to an EUI of 120kwh/m^2. This is effectively an EUI reduction of 33% from buildings constructed after 1981, or an 84% reduction from buildings constructed before 1981. **Research:** • Deep retrofits (40-80%) energy reductions involve air sealing and re-insulation, mechanical ventilation, fuel source conversions. • Moderate retrofits (30-50%) involve reductions involving lighting retrofits, daylighting, controls, and mechanical systems. • Shallow retrofits (10-20%) include recommissioning, fixture replacements, and weatherization. **Stakeholder feedback:** • 77% of the stakeholder advisory group respondents thought that retrofits should target EUI reductions of about 70%. **Source:** • Pembina, Building Energy Retrofit Potential in B.C., 2016, at Table 2.
6. Retrofit homes built after 1980	See actions 4 and 5.	Retrofit 50% of homes by 2030.	See actions 4 and 5.
7. Retrofit depth	See actions 4 and 5.	Average EUI reduction of 50% across retrofitted building stock.	See actions 4 and 5.
8. Retrofits of commercial	No assumed upgrades to existing buildings.	Retrofit 50% of commercial building stock.	See actions 4 and 5.

Existing Buildings: Retrofitting

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
9. Retrofit depth	No assumed upgrades to existing buildings.	Average EUI reduction of 50% across retrofitted building stock.	Research: Lighting upgrades can result in energy reduction of 50% for retail buildings (*NRCan 2017*).
10. Electrification—heat pumps	• No change in electrification assumed because there are no immediate plans to electrify heating in Halton Hills. • About 77% of home heating was provided by natural gas in 2016 in Halton Hills. This proportion is conservatively expected to be held constant through to 2030.	90% of retrofitted buildings receive an air-source heat pump (ASHP). 75% of non-retrofitted buildings receive an ASHP. During implementation, heat pumps should be prioritized for energy efficient homes, as it will maximize their capacity.	**Modelling notes:** • Assuming 2.75% coefficient of performance **Precedents:** • Switching from electric resistance to heat pumps is widely recommended for energy efficiency and cost savings. • Over 700,000 residential heat pumps were installed in Canada in 2018 (*Canada Energy Regulator, 2018*). • CaGBC Roadmap for Retrofits calls for 40% of buildings over the age of 35 be electrified by 2030 (*CaGBC, 2018*). **Stakeholder feedback:** • 59% of respondents said that all buildings that are retrofitted should receive an ASHP. • 41% of respondents said that all non-retrofitted buildings should receive an ASHP. • 18.5% of respondents said that 75% of buildings should receive an ASHP. • 18.5% of respondents said that half of non-retrofitted buildings should receive an ASHP. This feedback was used to inform the assumption that 90% of retrofitted buildings receive an ASHP in the NZS, as it is likely that an ASHP will not be feasible in all cases. For non-retrofitted buildings, survey respondents were split on the extent to which non-retrofitted buildings receive an ASHP. 75% penetration was selected as a middle ground between the most common responses.

Existing Buildings: Retrofitting

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
11. Industrial building and process efficiency	No assumed upgrades to existing buildings.	Starting in 2022, industrial buildings and processes use 3.75% less energy than in the previous year, resulting in 30% less energy consumed by the year 2030, relative to the 2016 baseline.	**Current status:** • Industrial buildings account for 18% of energy consumption in Halton Hills. **Research:** According to the 2019 Achievable Potential Study (for natural gas and electricity conservation) undertaken by the Independent Electricity System Operator and the Ontario Energy Board, the difference between the business-as-usual scenario and technically achievable efficiency potential for the industrial sector is from nearly 30 GWh to just over 100 GWh.
12. Industrial end-use fuel switch	No change.	30% of industrial process energy use (prioritizing fuel oil and then natural gas) will be displaced with renewable electricity and renewable natural gas by 2030.	See action 11.

Energy Generation

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
13. Solar PV (rooftop)	Hold existing solar PV capacity and generation constant, at 4.08MW in IESO contracts.	For all buildings (split between residential and commercial based on total sq/ft roof area): • By 2030, install 30% of feasible rooftop solar PV potential (46 MW based on roof analysis), starting in 2022. This results in an annual installation of 5.6 MW (or 7,849 MWh/yr including a 16% capacity factor).	**Current status:** • There are several solar PV installations in the Town of Halton Hills, including on several municipal buildings. • According to Canada's Energy Regulator, homeowners can generally expect net cost savings by installing rooftop solar PV in Ontario, because of the relative cost of electricity, mature solar PV market in Southern Ontario, and the presence of time-of-use electricity pricing. **Research:** • There is approximately 149MW of technical rooftop solar PV potential in the Halton Hills, based on an analysis of rooftops that factors in pitch, capacity factor, and structure.

Energy Generation

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
14. Solar PV ground mount—utility scale	Maintain existing 0.5 MW of ground-mount solar PV under IESO contracts.	Solar PV rooftop and solar ground mount capacity to be built to meet remaining Town electricity demand, with the condition that solar installations do not cover more than 30% of "suitable land". "Suitable land" is defined as land that is either vacant or agricultural land, and is at least 4 hectares large. By 2030 , install 445 MW of solar capacity or 623,712 MWh in 2030 (applying a 16% capacity factor). Assuming 4 h/ MW, the land required would be 1,780 ha, which is about 13% of available land (undeveloped settlement land and cropland).	**Current status:** • Utility-scale solar is currently limited in Ontario by financial and regulatory barriers, *according to Canada's Energy Regulator* • Delivery models include power purchase agreements, municipal- or utility-owned projects, and co-operative-owned projects. **Precedents:** • Ottawa's Renewable Energy Cooperative (6.45 MW, 750+ members) • Town of Nelson Community Solar Garden (an avg. 65,800 kWh annually) • Municipally-owned Hydro Ottawa's energy generation subsidiary (Portage Power), has 2.3 MW installed solar capacity in Ottawa. **Research:** • Utility-scale solar PV requires a land profile of 4 ha for 1 MW (Calvert, Mapping opportunities for land-based renewable energy generation in Ontario, 2019). **Stakeholder feedback:** • 60% of respondents said that more than 30% of suitable land should be used for renewable energy development. • 20% of respondents said 20% of suitable land should be used for renewable energy development.

Energy Generation

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
15. New Developments—district energy	No district energy applied. While a Natural Gas CHP Unit (<1MW) will be used to provide heat and electricity to a maximum of 2,713 units connected to the district heating system at Vision Georgetown, this system is expected to be installed in 2035 (beyond the model end date).	New developments in Vision Georgetown to be powered by a 4 MW geothermal district energy system by 2030.	**Current status:** • The Town of Halton Hills is considering the development of a district energy system in Vision Georgetown in 2035. The Town was originally looking at a 1 MW system (CHP) using natural gas to heat and power up to 2,713 buildings, but is now considering ground-source heat pump technology. **Precedents:** • There are many examples of geothermal district energy systems for greenfield developments. For example, Drake Landing in Okotoks, Alberta, uses a district energy system that uses solar thermal heating and borehole storage. The Lulu Island Energy Company runs a ground-source heat pump district energy system in Richmond, British Columbia; Markham, Ontario; and Blatchford, Alberta. **Stakeholder feedback:** • 80% of respondents said that all new communities meeting an adequate energy density threshold should be powered by carbon-free district energy.

Transit

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
16. Transit mode share (>15 km)	GO Kitchener line expansion to two-way all-day service complete by 2025: • By 2025, GO trains will make 220 daily trips from Acton to Toronto and 643 daily trips from Georgetown to Toronto. • GO trains remain fuelled by diesel.	Transit mode share to reach 15% for long-distance trips (>15 km).	**Current status:** • In 2016, 9% of all vehicle trips were over 15km. • In 2016, 90% of all trips over 15 km were made by car. **Modelling notes:** • Only to apply to zones that have a minimum density of 50 people or jobs/hectare (per *MTO Transit Supportive Guidelines*). With the exception of the 2 most dense zones: Acton and Vision Georgetown. **Research:** • Kitchener GO Train expansion is already expected to increase ridership at Georgetown and Acton Station by 16% (over 100 new daily riders). **Stakeholder feedback:** • 37.5% of respondents said the Town should aim to increase the transit mode share incrementally (about 10%). • 31.3% of respondents said the Town should aim to increase the transit mode share significantly (20%). • 15% mode share was selected as a mid-point between the two most common responses. **Source:** • *Metrolinx. (2019). Kitchener GO Rail Service Expansion*.

Transit

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
17. Transit mode Share (<15 km)	No change. • Halton Hills currently has a Universal Transit Service, which acts similar to a taxi. • There is a GO bus and rail service between Acton and Georgetown. • In 2016, about 5% of trips under 15 km were made by transit.	Local electric bus route established by 2030 (could include autonomous vehicles); Transit mode share for trips within 5 km-15 km increase to 15% of trips by 2030.	**Precedents:** • Halton Hills has studied the feasibility of implementing a local transit service, where an expansion of the existing Universal Transit Service was recommended for ridership and economic suitability (*Town of Halton Hills 2018*). **Modelling notes:** • The NZS only to apply to zones that have a minimum density of 50 people or jobs/hectare. With the exception of the 2 most dense zones in Acton and the zone that covers Vision Georgetown. **Stakeholder feedback:** • 56.3% of respondents supported establishing a local electric bus service (increasing transit mode share for short trips to 20%); • 25% of respondents supported establishing a local electric bus service (increasing transit mode share for short trips to 10%). 15% mode share was selected as a mid-point between the two most common responses.
18. Autonomous electric vehicle (EV) car share	N/A	Starting in 2024, an autonomous EV car share is introduced in the Town. By 2030, the system will serve 10% of trips.	**Modelling notes:** • Each autonomous EV carshare vehicle replaces 10 personal vehicles **Precedents:** • *First Transit* has 8 shared autonomous vehicle projects across the US • *In Nov. 2020 Loblaws (Toronto)* has started a pilot of 5 autonomous delivery trucks.

Transit

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
19. Active mode share	• Transit share doubles from 2016 to 2030, while vehicle share decreases slightly and other mode shares stayed almost the same. • During the 2016 afternoon peak, personal vehicles accounted for 84% of trips, transit accounted for 2% of trips, active transport accounted for 7% of trips, and school buses accounted for 7% of trips. • Active modeshare stays constant at 7%	Active mode share accounts for 20% of trips under 5 km by 2030.	**Current status:** • In 2016, 8% of trips under 5km were active. This is expected to remain similar through to 2030 under the Reference scenario. • Halton Hills is in the process of completing its Active Transportation Master Plan **Modelling notes:** • Only to apply to zones that have a minimum density of 50 people or jobs/hectare. With the exception of the 2 most dense zones: Acton and Vision Georgetown **Stakeholder feedback:** • 62.5% of respondents wanted a tripling the projected active mode share (22%); • 12% wanted a modest increase (8-12%). **Research:** According to Census Canada in 2016 the highest rate of: • inter-suburban commutes under 5km was Vancouver with 16.% • inter-urban commutes was 47.4% in Toronto
20. Trip generation	No change in trip generation.	• 30% of people telework by the year 2030. • By 2030, a split between long distance (+15 km) and medium distance trips (5-15 km), where long distance trips decline by 15%, and medium distance trips decline by 15%. • Residential electricity consumption increases by 10% for dwellings associated with trip reduction.	**Research:** • 30% of jobs can be done at home (*Pallais 2020*); See also Global Workplace Analytics Covid-19 2021 work from home forecast (25-30%) • A 2010 UK study of 3 towns over a 5-year period, found that travel planning, increasing active transportation, and transportation marketing reduced individual car trips by 9%, and trip length by 6% (*Sloman L, et.al. 2010*). • Residential energy consumption rebound effect is possible (*O'Brien & Aliabadi 2020*).

Private/Personal Use Vehicles

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
21. Electrify municipal fleets	No change to municipal fleets.	Starting immediately, electrify 100% of new administrative vehicles at the time of replacement. At time of replacement, heavy vehicle classes are transitioned to RNG, where electric options exist they should be opted for. (To be modelled as 50% of new heavy vehicles are electric by 2030, and 50% of new heavy vehicles are RNG by 2030.)	**Modelling notes:** • Assuming an average vehicle life cycle of 7 years for combustion engine vehicles. This will need to be ensured through supportive policies. **Precedent:** • Many municipalities and governments are targeting 100% electrification of their fleets, including the Government of Canada (Government of Canada Greening Government Strategy). International cities are aiming for 100% electrification by 2020-2030 (Oslo, Norway: 2020; Amsterdam, Netherlands: 2025; Antelope Valley, California: 2025; Los Angeles, California: 2030)
22. Electrify personal vehicles	EVs make up 14% of new sales by 2030.	At time of replacement, 100% of new vehicles will be EVs by 2030, assuming an average combustion engine vehicle life cycle of 7 years.	**Current status:** • EV Market Trends: EVs made up 5% of new sales in Canada during the first quarter of 2020 (Electric Mobility Canada, 2020). • The average lifespan of an EV is 13 years. **Precedents:** • The Government of Canada has set a nationwide target of EVs making up 10% of new sales by 2025, 30% of sales by 2030, and 100% by 2040 (*NRCan 2020*). • Cities that have high EV uptake typically deploy a comprehensive suite of policies to address EV barriers, including installing charging points, providing prioritized parking, subsidizing capital costs, etc. Local municipal policy needs to be paired with provincial and federal policies to address key barriers. (*International Council of Clean Transportation 2017*) **Research:** • Adoption of EV car or bike share services can further increase electric trips. In municipalities where people have access to electric car or bike shares, at least 28% of all trips up to 10.5 KM were taken by e-Bike, transit trips dropped by 18%, and personal-vehicle trips dropped by 10% (low estimate from study) (Fhyri 2015).

Private/Personal Use Vehicles

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
23. Low-carbon commercial transport activities	No change.	At time of replacement, 100% of new medium vehicles will be EVs by 2030, 50% of new heavy vehicles will be electric by 2030, and 50% of new heavy vehicles will be RNG by 2030. Assuming an average vehicle life cycle of 11 years.	**Current status:** • Ontario's commercial EV industry is nascent. **Precedents:** • EVs are feasible for light-duty commercial transport. 33% growth rate in new commercial EV sales by 2030 (*Guidehouse 2019*). • Heavy-duty electric models are expected to be available in the coming years (*Daimler 2020*). **Research:** • Hydrogen is seen as being the most viable fuel source for heavy haul trucks (*CBC, 2020*). • Currently, most hydrogen is made from natural gas (*IEA 2019*). • As a result, hydrogen is not included in the NZS.
24. Off-road vehicles	No change.	50% of new off-road vehicles are electric by 2030.	Based on data shared from the Multi-Stakeholder Advisory Committee.

Water and Waste

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
25. Waste generation	No change. Waste generation stays constant at 1.07 tonnes/person/year. Overall waste-related emissions grow due to population growth.	Reduce waste generation by 40% by 2030 (to 650 kg/person/year).	**Current status:** Waste generation rates in Halton Hills are just over 1 tonne/person/year. **Precedents:** Nova Scotia has the lowest waste generation rate of all Canadian provinces at 386 kg/person/year. (*Conference Board of Canada 2016*).

Water and Waste

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
26. Waste diversion	The waste diversion rate was 57.4% in 2010 and 65% in 2016. The waste diversion rate is anticipated to increase to 70% by 2025.	Reach 80% organic waste diversion by 2030.	**Source:** • Future waste diversion rate as planned by Halton Region (Waste Diversion Strategy). **Current status:** • Waste is the responsibility of Halton Region. Several waste diversion streams, including recycling and compost, are available in Halton Hills. **Precedent:** • Halton Region already exceeds Ontario's goal of 50% waste diversion by 2030. The province has set a target of 80% by 2050 (*Government of Ontario*). • Ontario is considering a ban on organic waste from landfills as well as associated resource recovery (see: Food and Organic Waste Framework). **Modelling Note:** • Because waste treatment is under the control of Halton Region, no assumptions for waste treatment are presented (i.e., anaerobic digestion, etc). • The Town should consider lobbying for this from the Region
27. Water efficiency	No change.	Water consumption declines by 10% by 2030.	Current status: Halton Hills has a water/wastewater treatment rate of 150 m3/person/year. Water delivery and wastewater treatment is the responsibility of Halton Region. Precedent: City of Guelph has water-use targets of 11% decline in total water use by community by 2038 (6% decline in L/person/day) (City of Guelph 2016). Halton Region offers several water conservation rebates for toilets and rain barrels.

Sequestration and Land Accounting

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
28. Tree planting	No change.	Starting in 2022, plant 50,000 trees in Halton Hills per year.	**Current status:** • No active tree planting initiatives. **Precedent:** • City of Hamilton planted 10,000 trees per year between 2013 and 2018. • Wellington, New Zealand has been planting a tree every five minutes, on average, for the past 15 years—more than 1.5 million in total. About 40% of the city's emissions are now mitigated by land use, land-use change. and forestry activities. **Research:** • Assuming that 500 trees are planted per acre and Halton Hills has a land area of 273 km^2, planting 50,000 trees would roughly cover 1.3% of Halton Hills' land coverage area.
29. Natural areas	No change.	15% increase in land under sustainable soil management practices by 2030 (i.e., no-till farming).	**Precedent:** • Sustainable soil management is advocated by the *Government of Ontario* as an emissions reduction method.
30. Spatial distribution of new buildings	According to Town projections 30,203 additional dwellings will be built in the Town by 2029. (Source: Environics Analytics, 2019. Demo Stats, 2019.)	All new developments, apart from Vision Georgetown, are infill (i.e., no greenfield development).	**Precedent:** • Infill development is currently influenced through the Official Plan, through limits to the Georgetown/Acton Urban Growth Boundary, and by increasing maximum density limits for residential areas. Land-use regulations reduce emissions (*Leibowicz, 2017*). **Note:** • Vision Georgetown makes up the vast majority of planned greenfield development before 2030. The development will have a more significant impact on emissions after 2030.

Renewable energy procurement

ACTION CATEGORY	REFERENCE SCENARIO	NET-ZERO SCENARIO (NZS)	NOTES/SOURCES/KEY STAKEHOLDER INPUT
31. Purchases of renewable electricity certificates (RECs)	None.	Currently, additional solar capacity modelled offsets any central grid demand, and therefore, no RECs are necessary to achieve net-zero. The Town may want to consider the purchase of RECs should solar capacity not meet expected model projections.	**Current status:** • The Town of Halton Hills does not currently purchase RECs. **Precedent:** • Bullfrog Power is one of Ontario's largest REC services, and works with residents, businesses, and governments. **Note:** • Each REC represents the environmental benefits of 1MWh of renewable energy generation. When you purchase RECs, it is guaranteed that renewable energy has been generated on your behalf and sent to the electrical grid, which is the network that delivers electricity from suppliers to consumers. However, once it enters the grid, it is impossible to distinguish where or how that electricity is being delivered.
32. Renewable natural gas (RNG)	None.	Will be procured to replace remaining natural gas demand starting in 2030.	**Current status:** • There are several potential sources of RNG production in Halton Hills, including farm manure and residues, wastewater solids, separated organics, and food waste. • Enbridge is expected to launch its Voluntary RNG Program pilot for customers in *2021*. **Research:** • Ontario Energy Board and Enbridge are actively exploring increased RNG integration. *A 2019 Ontario Biogas and RNG Market Potential* study conservatively projects that RNG energy production in Ontario has the potential to grow five-fold by 2029,with the most important source of supply being organic waste diverted from landfill. Communities in Ontario are increasingly diverting their organic waste to anaerobic digestion facilities.

APPENDIX B: Net-Zero Modelling Results

July 2021

Purpose of this Document

This document reports the energy use and greenhouse gas (GHG) emissions modelling results for the Town of Halton Hills in a net-zero-by-2030 scenario. The series of assumptions that make up the net-zero scenario are outlined in Appendix A.

The modelling results are shown in comparison to the reference scenario energy use and GHG emissions projections, which are detailed in Appendix E.

Disclaimer

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

This analysis includes strategic-level estimates of energy efficiency and greenhouse gas reduction potential represented by the proposed Low-Carbon Transition Strategy (LCTS). The intent of this analysis is to help inform project stakeholders about the potential reductions represented by the LCTS in relation to the modelled reference scenario. It should not be relied upon for other purposes without verification. The authors do not accept responsibility for the use of this analysis for any purpose other than that stated above, and do not accept responsibility to any third party for the use, in whole or in part, of the contents of this document.

This analysis applies to the Town of Halton Hills and cannot be applied to other jurisdictions without further analysis. Any use by the Town of Halton Hills, its sub-consultants, or any third party, or any reliance on or decisions based on this document, are the responsibility of the user or third party.

Contents

ACRONYMS

CDD	cooling degree day
CO_2e	carbon dioxide equivalent
EF	emissions factor
EV	electric vehicle
GHG	greenhouse gas
GJ	gigajoule
GWP	global warming potential
HDD	heating degree day
ICE	internal combustion engine
Kt	kilotonne
Mt	megatonne
NZS	net-zero scenario
PUV	personal-use vehicle
RNG	renewable natural gas

UNITS

GHG emissions

1 $ktCO_2e$ =	1,000 tCO_2e
1 tCO_2e =	1,000 $kgCO_2e$
1 $kgCO_2e$ =	1,000 gCO_2e

Energy

1 MWh =	1,000 kWh
1 MWh =	3.6 GJ
1 GJ =	278 kWh
1 GJ =	1,000,000 J
1 MJ =	0.001 GJ
1 TJ =	1,000 GJ
1 PJ =	1,000,000 GJ

Introduction

This document highlights the key results from the net-zero scenario model. The model was developed using CityInSight, SSG's energy, emissions, land-use, and finance model. The model estimates likely energy use and emissions trends between 2016 and 2030 across the following sectors: buildings, industry, transportation, waste, agriculture, and fugitive emissions.

Whereas the reference scenario, whose results are presented in a separate report, represents a continuation of current trends and policies in these sectors, the net-zero scenario (NZS) includes detailed actions to improve the efficiency of existing buildings and industrial processes, implement higher energy efficiency standards for new buildings, switch from fossil fuels to low-carbon alternatives, increase renewable energy consumption and local generation, enhance transit and active transportation, and increase waste diversion.

The modelling time frame is from 2016 to 2030, with 2016 as a base year. The census of 2016 is a key data source used to establish the base year. Model calibration for the base year uses as much locally observed data as possible.

Method

CityInSight is an energy, emissions, and finance model developed by SSG and whatIf? Technologies. It enables bottom-up accounting for energy supply and demand, including renewable resources, conventional fuels, energy-consuming technology stocks (e.g., vehicles, appliances, dwellings, buildings), and all intermediate energy flows (e.g., electricity and heat). Energy and greenhouse gas (GHG) emissions values are derived from a series of connected stock and flow models, and evolve based on current and future geographic and technology decisions/assumptions (e.g., EV uptake rates). The model accounts for physical flows (e.g., energy use, new vehicles by technology, VKT) as determined by stocks (e.g., buildings, vehicles, heating equipment, etc.).

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

The CityInSight workflow models the actions according to the "Reduce-Improve-Switch" philosophy, where avoiding energy consumption in the first place is the top priority, followed by energy efficiency improvements and, finally, switching to low-carbon energy sources for the remaining demand. The workflow also prioritizes improvements to long-lasting infrastructure that can "lock in" energy consumption patterns for many decades and takes advantage of opportunities to align proposed investments with the natural turnover of infrastructure and buildings.

The model supports the use of scenarios as a mechanism to evaluate potential futures for communities. A scenario is an internally consistent view of what the future might turn out to be—not a forecast, but one possible future outcome. Scenarios must represent serious considerations defined by planning staff and community members. They are generated by identifying population projections into the future, identifying how many additional households are required, and then applying those additional households according to existing land-use plans and/or alternative scenarios.

Additionally, the municipal greenhouse gas inventory baseline development and scenario modelling approach correlate with the Global Protocol for Community-Scale GHG Emissions Inventories (GPC).

For further information on modelling methodology, see the Reference Scenario, Part 2: Data, Methods and Assumptions (Feb. 2021).

Part 1: Net-Zero Scenario Results

NET-ZERO SCENARIO: OVERALL ENERGY AND EMISSIONS OUTCOMES

Energy Reduction, Energy Efficiency, and Fuel Switching

In order to reduce GHG emissions in a manner that reduces overall financial and environmental costs, it is essential to first reduce energy use and then switch remaining fuel consumption from fossil fuels towards clean energy sources. Prioritizing energy efficiency helps reduce the need for additional electricity capacity, renewable natural gas (RNG) feedstock, and the purchase of renewable electricity certificates.

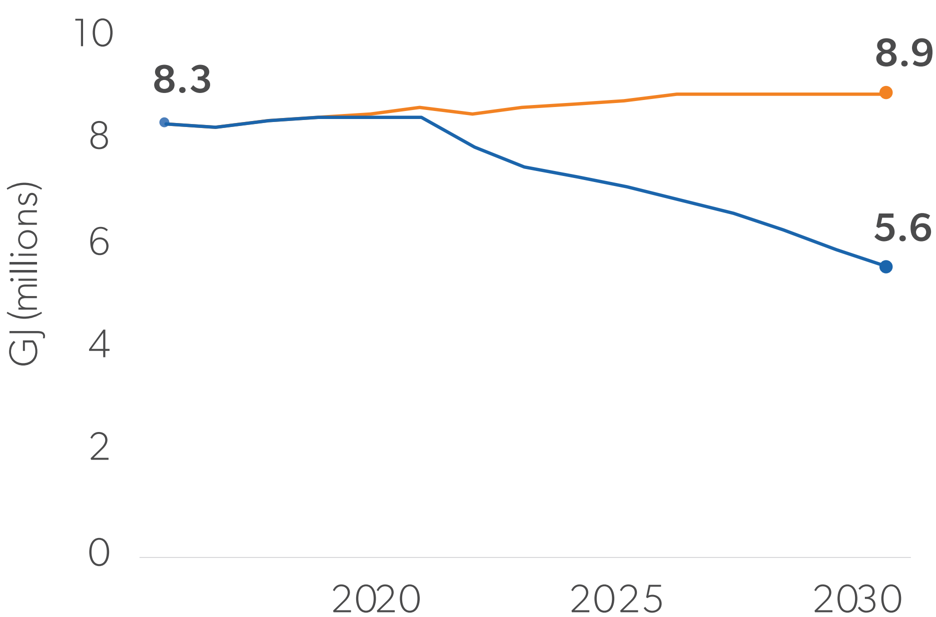


Figure 1. Net-zero scenario (blue) versus the reference scenario (orange), total community energy use, 2016-2030.

The net-zero scenario for Halton Hills provides significant energy efficiency improvements (see Figure 1), reducing the overall energy consumption by 33% compared with 2016, and slightly more in comparison to the 2030 reference scenario.

Along with reducing energy consumption, the shift in the energy sources must be aggressive to meet the 2030 emissions targets. Whereas natural gas in 2016 accounted for more than one third of energy use in the town (37%), by the end of the evaluation period it is completely removed from Halton Hills' energy matrix through efficiency, fuel switching, and replacement with renewable natural gas. On the other hand, gasoline and diesel consumption, which combined account for 34% of total energy consumption in 2016, are only reduced to 20% in 2030. Grid electricity is almost completely replaced with local renewable electricity and renewable energy certificates.

See Table 1 in the Appendix for a more comprehensive set of data.

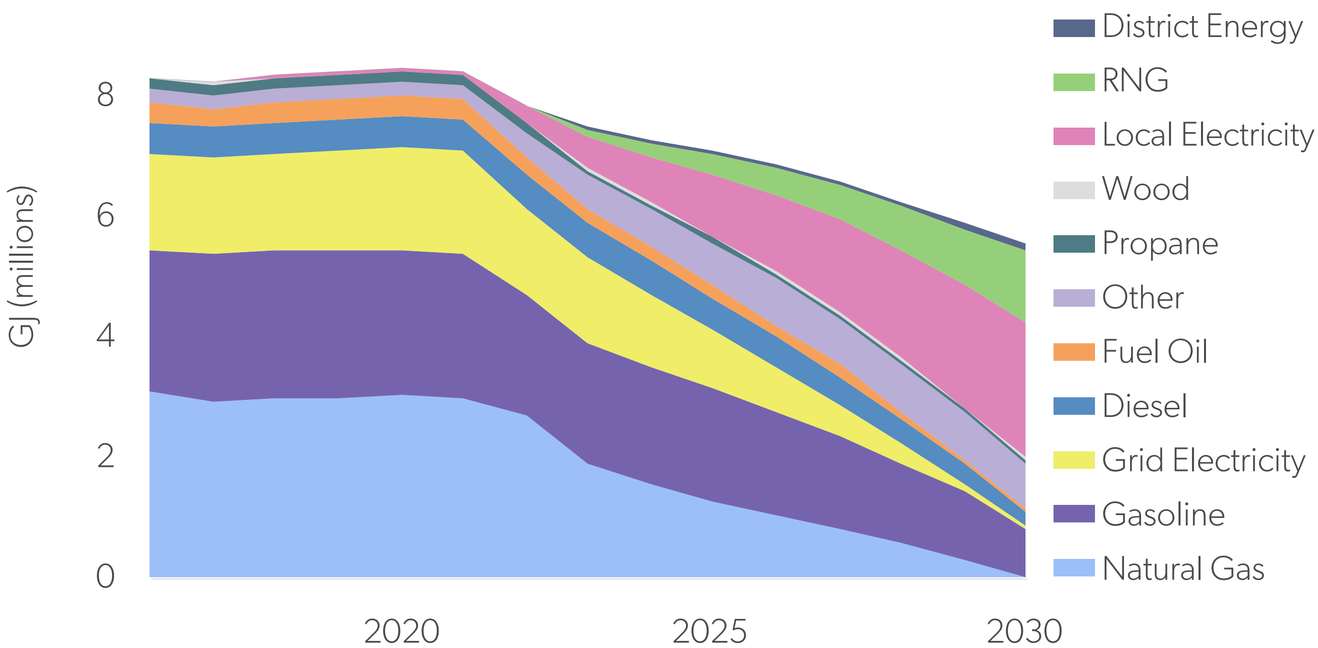


Figure 2. Halton Hills' energy consumption by source in the net-zero scenario (gigajoules), 2016-2030.[1]

Where and How Energy Is Used

The transportation sector reduces its energy demand by 46% by 2030, despite significant population growth (Figure 3). This is mostly due to the transformation of personal vehicles to electric ones and the impressive energy efficiency of electric vehicles (EVs).[2] It is also due to the reduced need for personal vehicles due to an increase in transit use, walking, and cycling, as well as the introduction of an autonomous EV carshare.

On the other hand, residential buildings use 24% less energy in 2030 than in 2016, while commercial buildings use 46% less. The municipal sector accounts for a small proportion of overall energy consumption in 2016 representing 1% of the total, which is reduced to 0% in 2030.

[1] 'Other' includes steam, waste heat, biofuels, and ambient heat for heat pumps.

[2] Electric vehicles convert over 77% of the electrical energy from the grid to power at the wheels, whereas the internal combustion energy vehicles convert about 12%–30%. US Department of Energy (n.d.) All-electric vehicles. Retrieved from: fueleconomy.gov/feg/evtech.shtml.

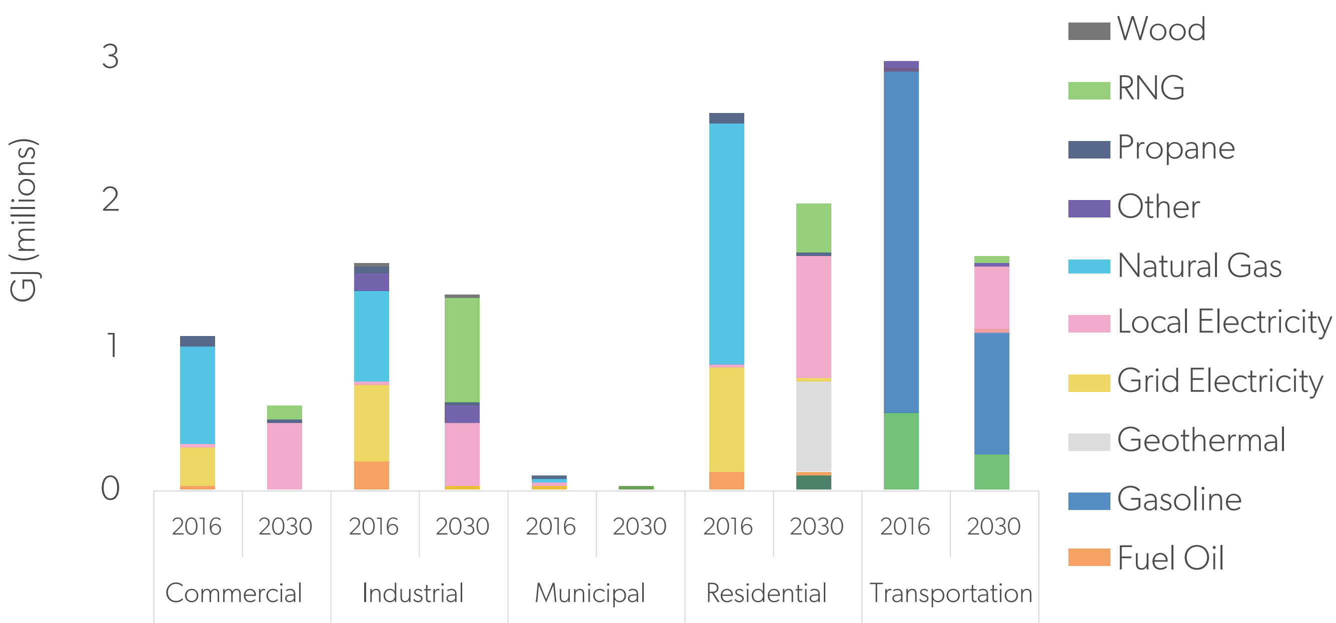


Figure 3. Net-zero scenario community energy use by sector and fuel (gigajoules), 2016-2030.[3]

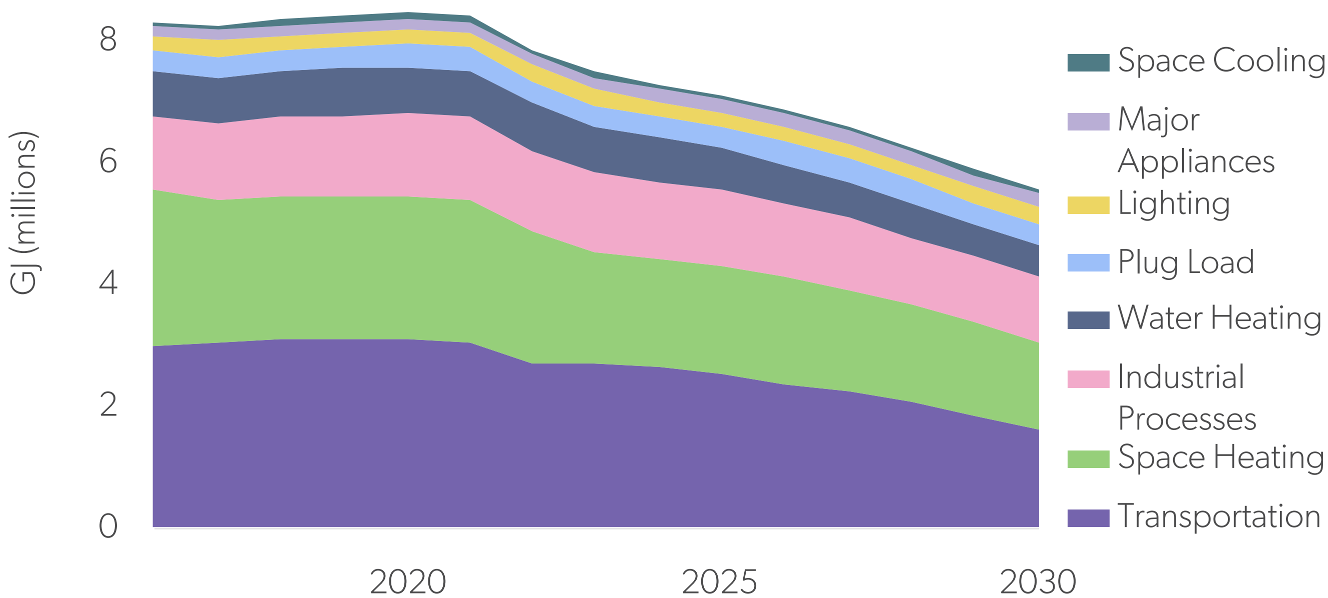


Figure 4. Net-zero scenario community energy use by end use (gigajoules), 2016-2030.

Emissions Reduction

Implementation of the net-zero scenario dramatically alters Halton Hills' emissions compared to 2016 and compared to the 2030 reference scenario, as illustrated in the chart below (Figure 5). By 2030, the net-zero scenario reduces greenhouse gas emissions by 74% compared to 2030

[3] "Other" includes steam, waste heat, biofuels, and ambient heat for heat pumps.

reference scenario levels. This is an impressive outcome over an eight-year period in an energy supply market currently dominated by fossil fuels.

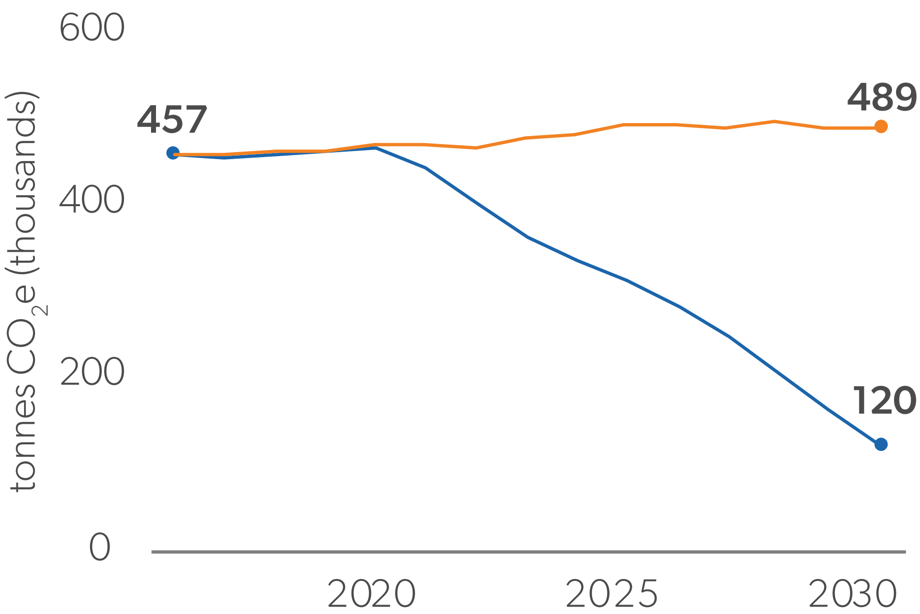


Figure 5. Total community GHG emissions, net-zero scenario (blue) versus the reference scenario (orange) (tCO_2e), 2016-2030.

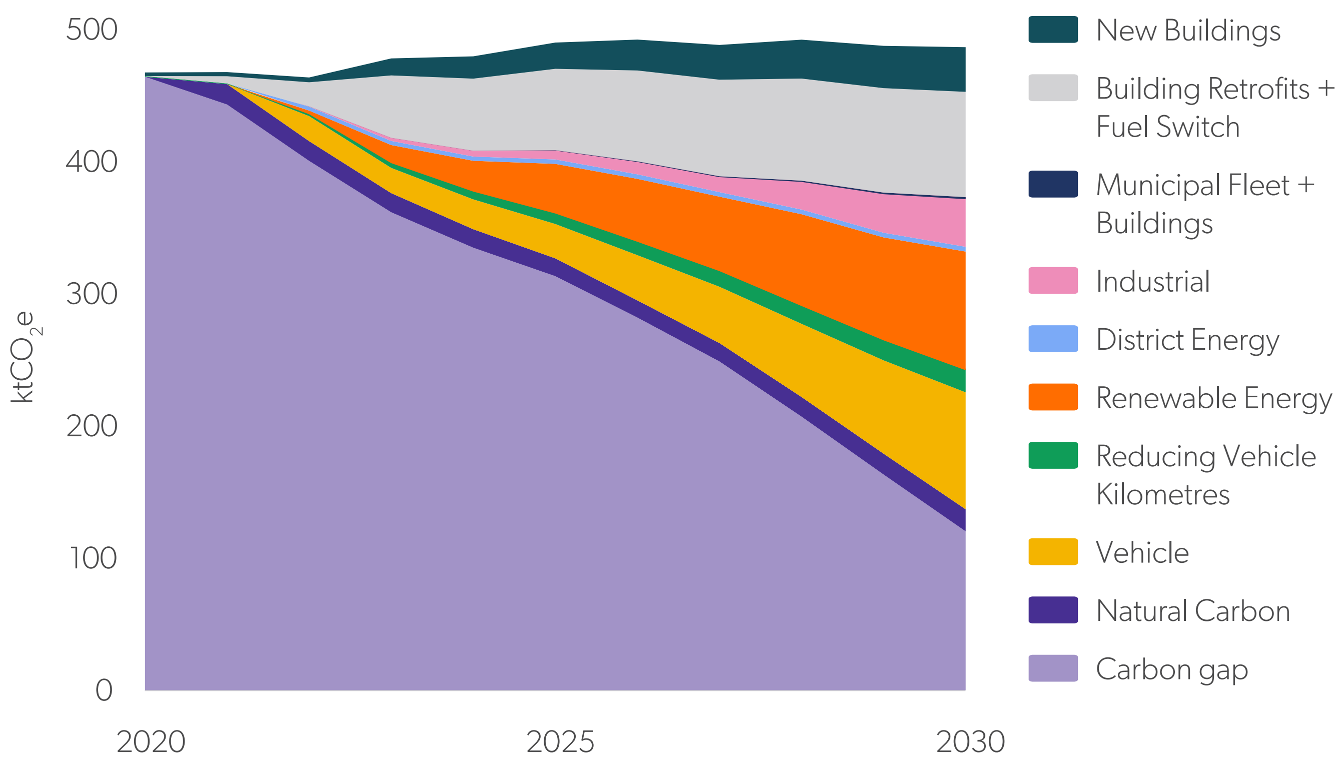


Figure 6. Wedge diagram illustrating the emissions reductions associated with the net-zero scenario actions (some have been aggregated for visual clarity). Note: The emissions reduction of each action is interdependent with the other actions. The wedges diagram shows the emissions reduction effect of implementing all actions considered. Only implementing some will affect the emissions reduction effectiveness of the others.

Residential retrofits account for the biggest GHG reduction in the net-zero scenario, followed by commercial and personal-use vehicle electrification, and then local renewable energy production (ground mount solar and district energy).

These low-carbon actions result in the widespread reduction of fossil fuel consumption—chiefly natural gas in buildings and gasoline in vehicles (see Figure 7). The dramatic expansion of renewable/low-carbon energy use in the community ensures that the remaining energy consumption generates as few emissions as possible. This is consistent with the "Reduce-Improve-Switch" philosophy described in the Method section.

As a result of the trends in energy use, natural gas emissions are reduced completely by 2030, while emissions from gasoline, diesel, and grid electricity are reduced by 64%, 51%, and 98%, respectively, compared with 2016 (see Figure 7). At the same time, the increase in RNG and renewable electricity consumption does not translate into higher emissions for those energy sources as they are low- or net-zero emissions.

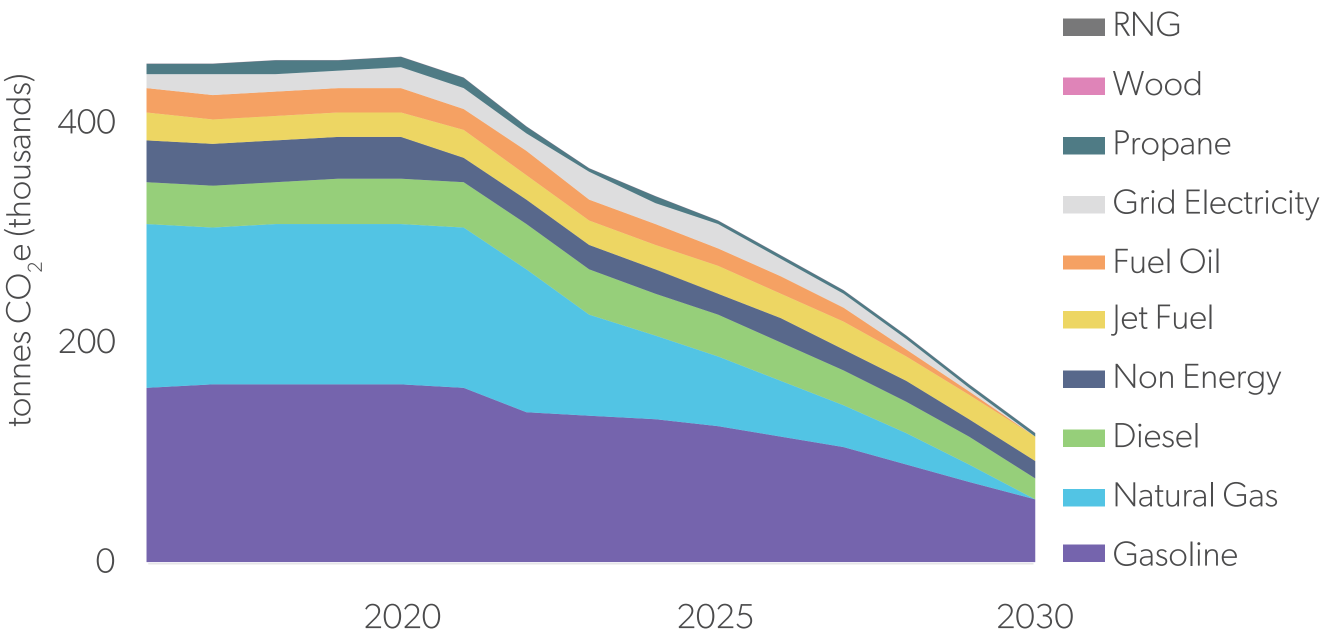


Figure 7. Net-zero scenario emissions by source (ktCO_2e), 2016-2030.

Additionally, the net-zero scenario reduces emissions in all sectors. The greatest decrease in terms of net emissions are obtained in the transportation, residential, industrial, and then commercial sectors with reductions of 1.2, 1, 0.5 and 0.4 MtCO_2e respectively. In 2030, transportation represents the largest source of GHG emissions, resulting in about 1 Mt CO_2e of emissions—55% less emissions compared to 2016. Waste emissions are reduced by 18%.

See Table 3 in the Appendix for more details on community emissions.

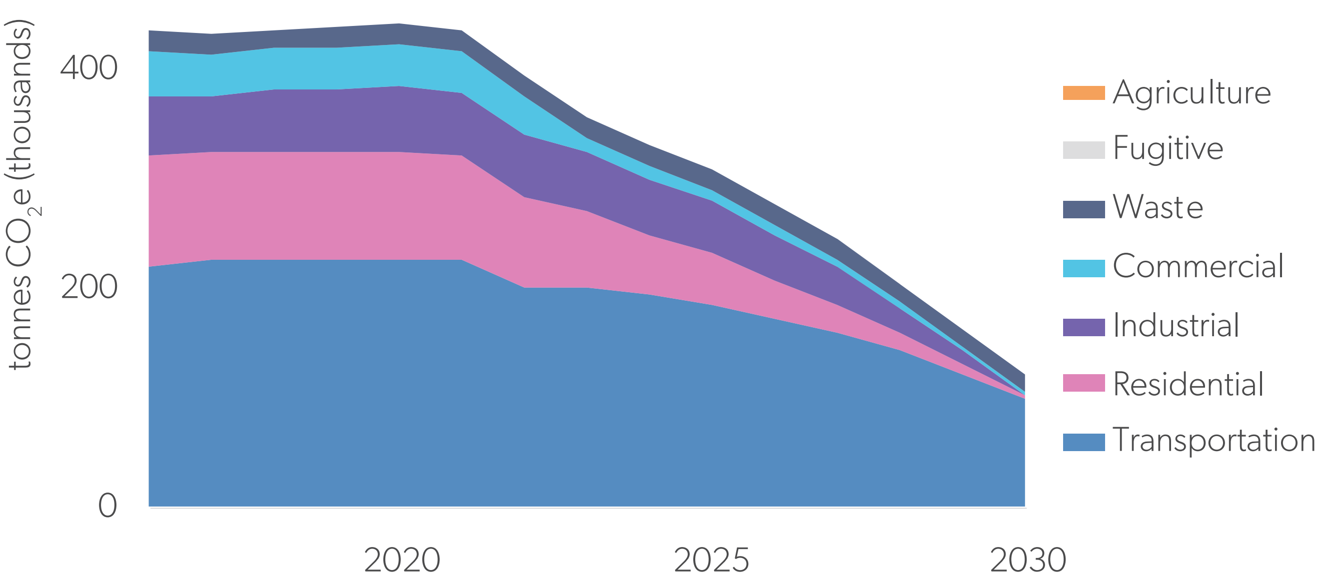


Figure 8. Net-zero scenario emissions by sector (tCO_2e), 2016-2030.

NET-ZERO SCENARIO: SECTOR-BY-SECTOR ENERGY AND EMISSIONS OUTCOMES

Transportation

Though transportation remains the town's largest source of emissions, the transportation sector transforms dramatically over the 2016-2030 time period, resulting in reduced emissions of 55% from 2016 (Figure 9).

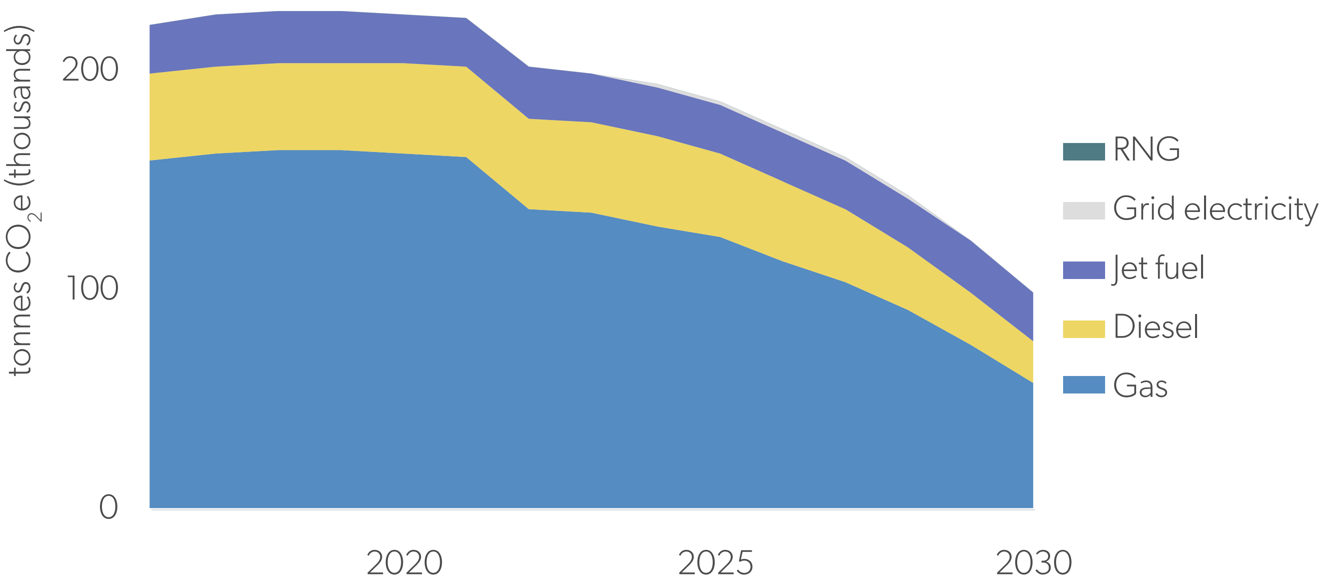


Figure 9. Transportation emissions by fuel type, in 2016 and 2030 in the net-zero scenario ($tC0_2e$).

The main driver of this decrease is the shift from internal combustion engines (ICE) to electric vehicles, especially the electrification of cars and light trucks. While the Ontario grid powers electric transportation to start, this electricity is increasingly replaced by local solar and renewable electricity procured from sources outside the town boundaries.

Additionally, increasing walking and cycling infrastructure as well as increasing local transit options, among other actions, help reduce vehicle trip generation and trip distance. The resulting reduction in vehicle kilometres travelled also helps reduce energy consumption and GHG emissions in Halton Hills.

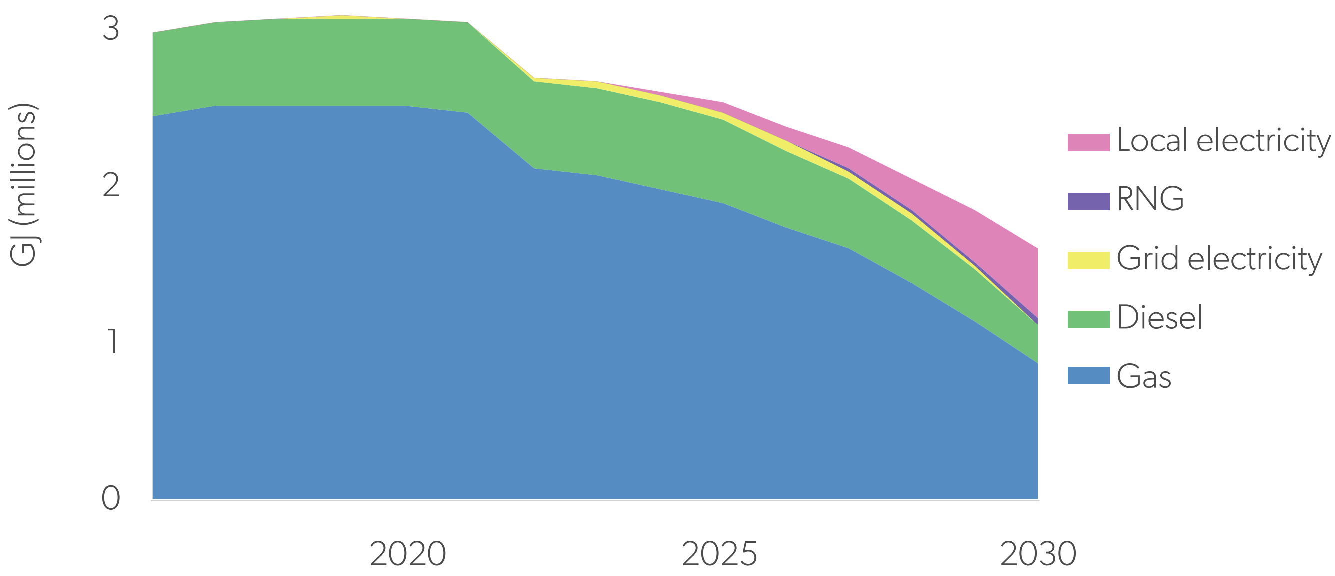


Figure 10. Transportation energy consumption (gigajoules) for the net-zero scenario by fuel type, 2016-2030.

In addition, energy consumption decreases because electric vehicles are much more efficient than their ICE counterparts.

Industry and Buildings

In 2016, residential buildings in Halton Hills accounted for 31% of energy consumption and 22% of GHG emissions, while commercial and industrial buildings accounted for 32% of energy consumption and 20% of GHG emissions. Reduction of energy consumption is the main priority in this sector in the net-zero scenario, with implementation of new building energy performance requirements, deep energy retrofits of existing buildings, and the incorporation of highly energy-efficient heat pumps for space and water heating. These actions combine to reduce energy consumption from buildings by 26% between 2016 and 2030 (see Figure 11).

The transition to low-emissions or zero-emissions fuels is dramatic in the commercial and residential buildings sectors. Whereas in 2016 the dominating energy source is natural gas and the electricity from the Ontario grid, by 2030 renewable electricity and renewable natural gas will become the predominant sources. Given this shift in the energy mix, the sector experiences a 98% reduction in emissions by 2030 compared with 2016 levels (see Figure 12).

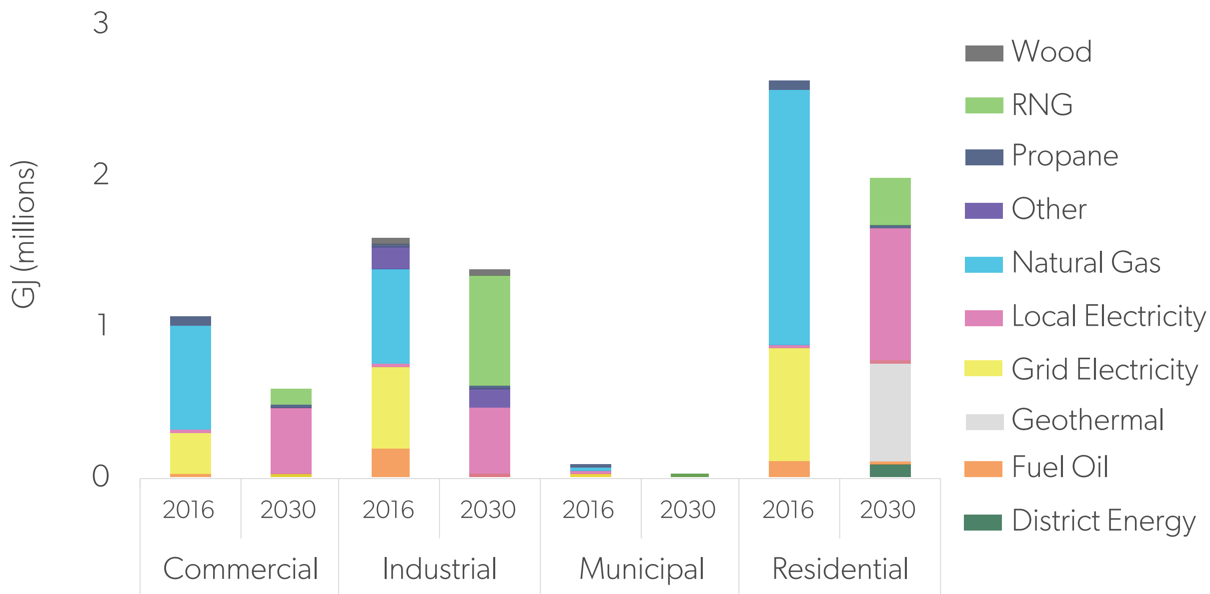


Figure 11. Buildings and industry energy consumption (gigajoules) by sector and fuel type, 2016-2030.4

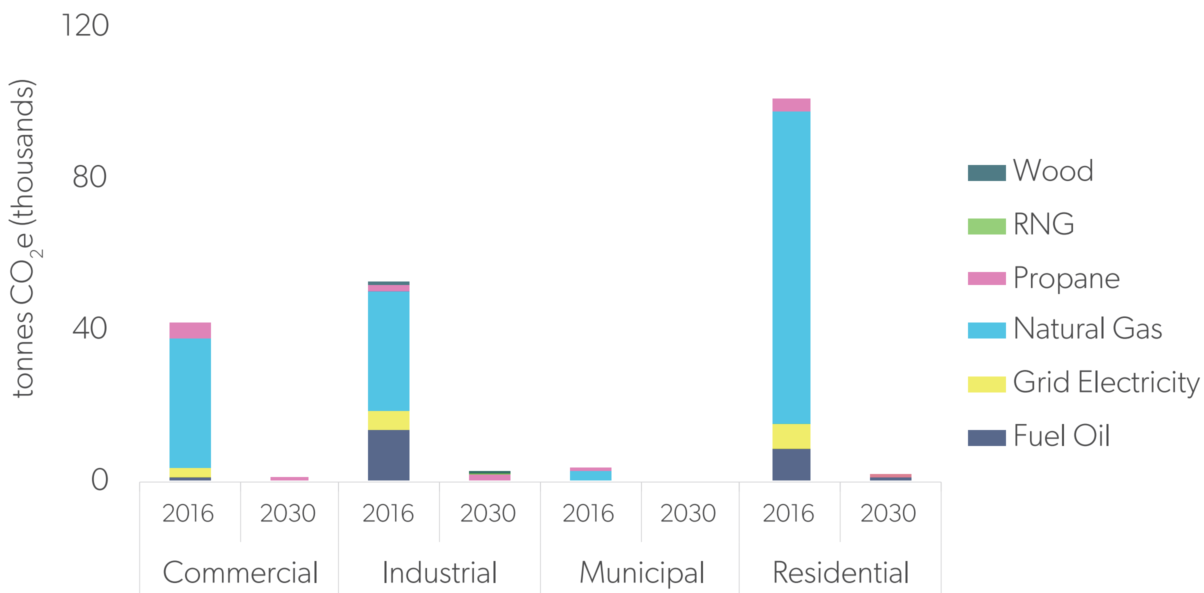


Figure 12. Buildings and industry emissions ($tC0_2e$) by sector and fuel type, 2016-2030.

The residential sector was the main energy consumer and emitter in Halton Hills in 2016. This sector will have to deal with important transformations in the way energy is used.

The Town has prioritized industry energy efficiency process improvement targets, assuming an improvement of 50%. Industrial emissions, in turn, show a more dramatic reduction by 2030

[4] "Other" includes steam, waste heat, biofuels, and ambient heat for heat pumps.

(dropping 97% below 2016 levels). The shift is driven by the decrease in energy consumption, as well as reliance on new energy sources that are zero emissions or low emissions.

Figure 13 shows the three areas where building and industrial energy use are centred in the Town in 2016: Acton, Georgetown, and the commercial hub at the turn off from highway 401. Figure 14 shows the emissions associated with these same energy sources in 2016.

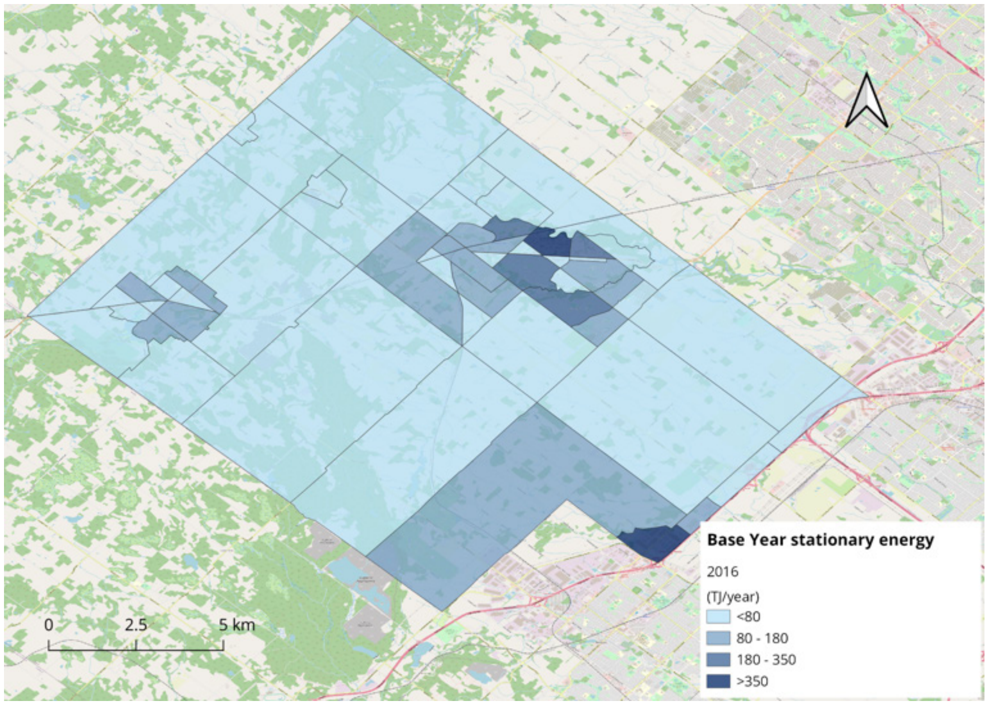


Figure 13. Building and industry energy use ('stationary energy') in 2016.

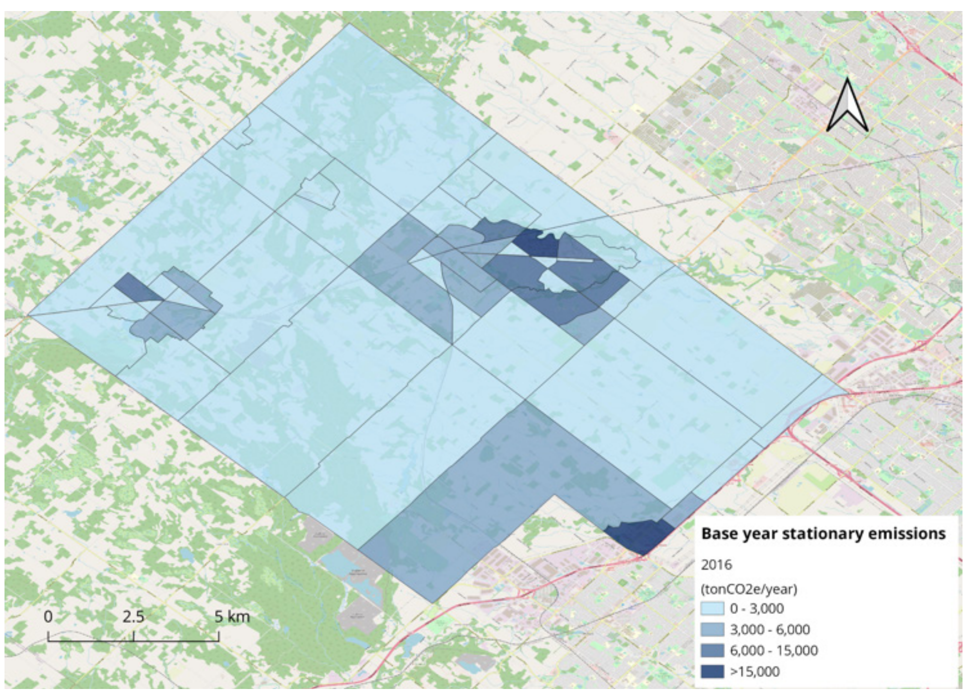


Figure 14. Building and industry emissions ('stationary emissions') in 2016.

Figures 15 and 16 show how the net-zero scenario affects building and industry energy use and emissions in space as a result of energy efficiency and fuel switching measures.

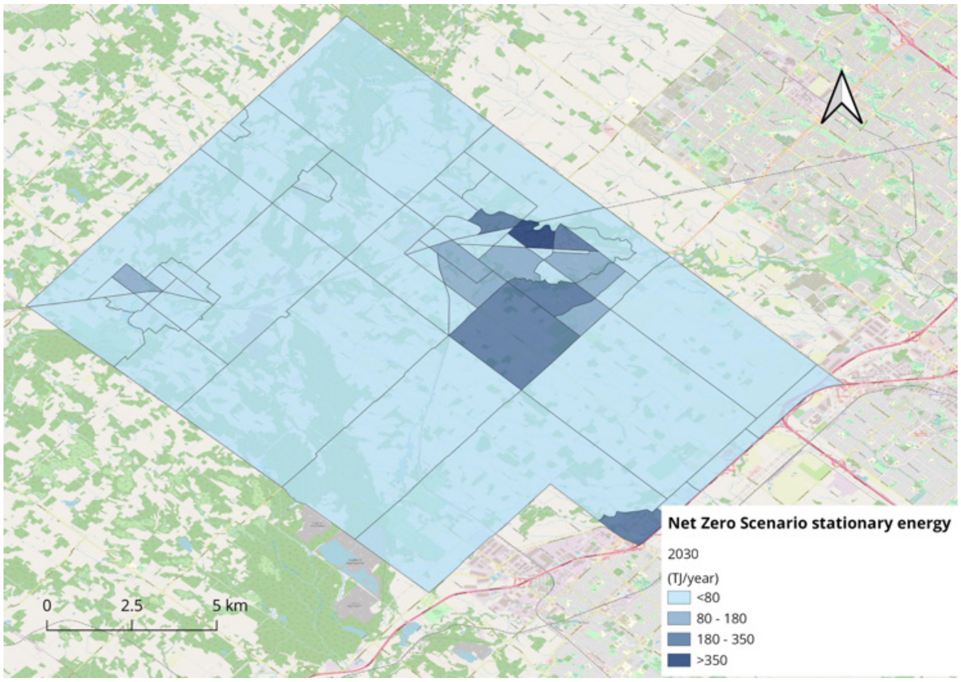


Figure 15. Building and industry energy use ('stationary energy') in 2030.

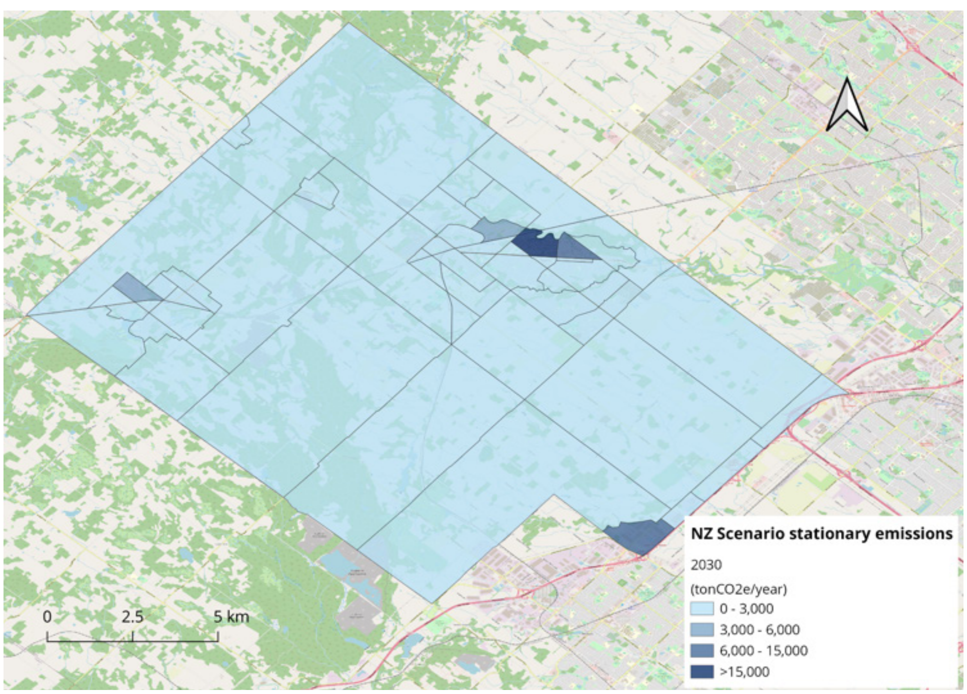


Figure 16. Building and industry emissions ('stationary emissions') in 2030.

SENSITIVITY ANALYSIS

Uncertainty is inherent in modelling future scenarios and the projection of future emissions. A sensitivity analysis was conducted to examine how these uncertainties could affect the overall results.

The following chart shows how changing key parameters in the model will affect the net-zero scenario for Halton Hills.

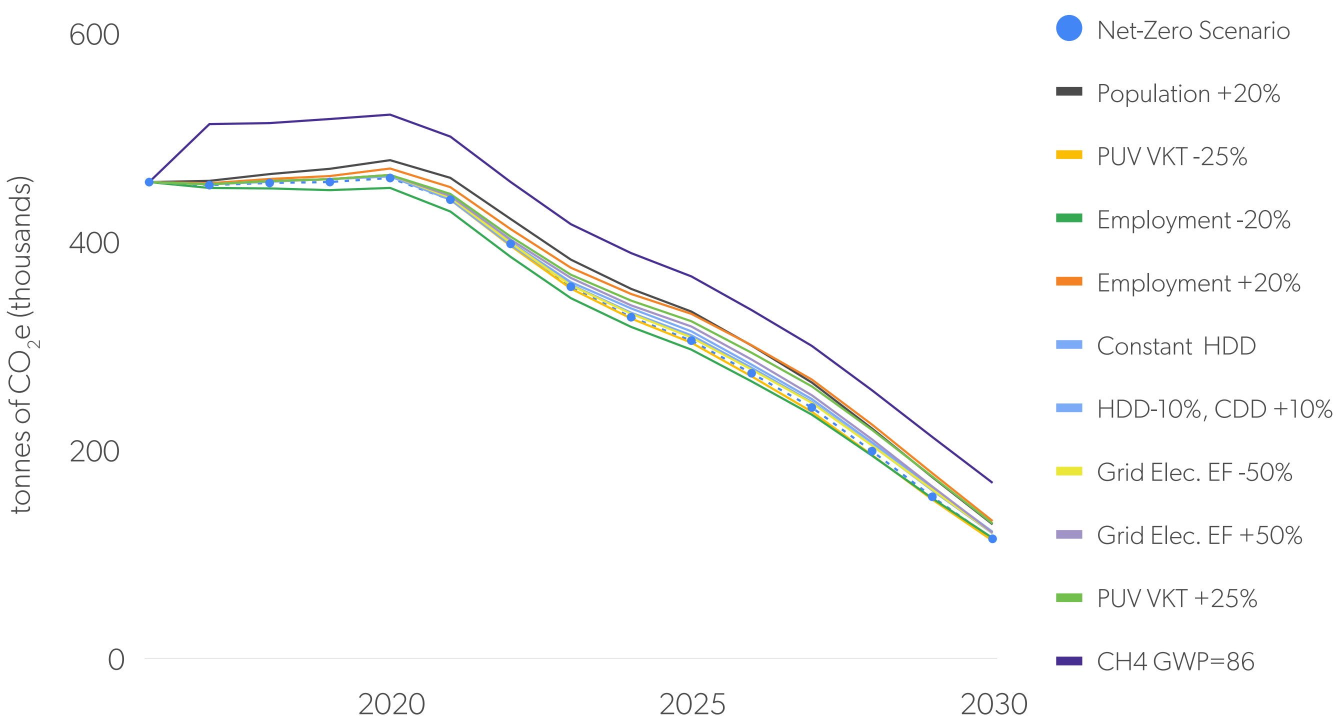


Figure 17. Variations in net-zero scenario emissions due to a sensitivity analysis of eight key assumptions (ktCO_2e), 2016-2030.

This sensitivity analysis shows what happens when you change the inputs of one of several key inputs, namely:

- Population (increasing and decreasing by 20%),
- Employment (increasing and decreasing by 20%),
- Methane (CH4) global warming potential (GWP) (from 34 to 86),
- Heating and cooling degree days (HDD and CDD) (decreasing and increasing by 10%, respectively),
- Provincial electricity grid emissions factor (increasing and decreasing by 50%), and
- Personal-use vehicle (PUV) vehicle kilometre travelled (VKT) (increasing and decreasing by 25%).

All of the above changes are modelled individually in comparison to the net-zero scenario.

The maximum variation in the net-zero scenario in the sensitivity analysis—a 40% increase in emissions—results from adjusting the methane global warming potential from 100 years (the politically accepted accounting methodology) to 20 years (the scientifically accepted accounting methodology). In other words, if the methane GWP were 86 instead of 34, then the NZS would result in an overall emissions reduction of 63% against the base year, whereas it currently reduces emissions by about 74%.

All other variables assessed in the sensitivity analysis result in a less than 10% impact on overall emissions.

The data illustrated in Figure 17 is provided in Table 10 of the Appendix.

Appendix B.1: Data Tables

COMMUNITY ENERGY

Table 1. Community energy consumption tabulated results in the net-zero scenario (NZS), 2016 & 2030.

ENERGY BY SECTOR (GJ)	2016	SHARE 2016	2030 (NZS)	SHARE 2030	% +/ 2016- 2030
Commercial	1,071,601	13%	579,317	10%	-46%
Industrial	1,584,413	19%	1,366,510	25%	-14%
Municipal	72,446	1%	13,077	0%	-82%
Residential	2,620,586	31%	1,983,637	36%	-24%
Transportation	2,992,639	36%	1,618,728	29%	-46%
Total	8,341,685		5,561,269		-33%
Energy by fuel (GJ)	**2016**	**share 2016**	**2030 (NZS)**	**share 2030**	**% +/ 2016-2030**
Diesel	537,183	6%	257,284	5%	-52%
District Energy	0	0%	95,463	2%	100%
Fuel Oil	313,369	4%	19,691	0%	-94%
Gasoline	2,369,554	28%	841,847	15%	-64%
Grid electricity	1,601,633	19%	13,747	0%	-99%
Local electricity	18,058	0%	2,255,677	41%	12391%
Natural Gas	3,081,390	37%	0	0%	-100%
Other	214,901	3%	787,148	14%	266%
Propane	168,676	2%	46,264	1%	-73%
RNG	0	0%	1,211,548	22%	100%
Wood	36,920	0%	32,600	1%	-12%
Total	8,341,685	100%	5,561,269	100%	-33%
Energy per capita (GJ/cap)	132		61		-54%

COMMUNITY EMISSIONS

Table 2. Per capita emissions, 2016 and 2030 (NZS).

EMISSIONS BY SECTOR (TCO_2E)	2016	2030 (NZS)	% +/- 2016-2030
Emissions per capita (tCO_2e/person)	7.2	1.3	-82%

Table 3. Community emissions tabulated results, 2016 & 2030 (NZS).

EMISSIONS BY SECTOR (TCO_2E)	2016	SHARE 2016	2030 (NZS)	SHARE 2030	% +/- (2016-2030)
Agriculture	8,083	2%	8,083	7%	0%
Commercial	41,721	9%	955	1%	-98%
Fugitive	10,754	2%	8,487	7%	-21%
Industrial	51,683	11%	2,176	2%	-96%
Municipal	2,411	1%	21	0%	-99%
Residential	101,151	22%	1,697	1%	-98%
Sequestration	0	0%	-16,671	-14%	100%
Transportation	221,704	49%	99,679	83%	-55%
Waste	19,064	4%	15,544	13%	-18%
Total	456,571	100%	119,970	100%	-74%
EMISSIONS BY FUEL (TCO_2E)	**2016**	**SHARE 2016**	**2030 (NZS)**	**SHARE 2030**	**% +/- (2016-2030)**
Diesel	39,613	9%	19,228	16%	-51%
Fuel Oil	22,291	5%	1,399	1%	-94%
Gasoline	158,853	35%	56,860	47%	-64%
Grid electricity	14,330	3%	290	0%	-98%
Jet Fuel	23,238	5%	23,238	19%	0%
Natural Gas	149,970	33%	0	0%	-100%
Non Energy	37,900	8%	15,443	13%	-59%
Propane	10,317	2%	2,830	2%	-73%
RNG	0	0%	631	1%	100%
Wood	58	0%	51	0%	-13%
Total	456,571	100%	119,970	100%	-74%

BUILDING SECTOR

Table 4. Buildings sector energy tabulated results, 2016 & 2030 (NZS).

BUILDINGS ENERGY (GJ) BY BUILDING TYPE	2016	SHARE 2016	2030 (NZS)	SHARE 2030	% +/- (2016-2030)
Commercial	1,071,601	20%	579,317	15%	-46%
Industrial	1,584,413	30%	1,366,510	35%	-14%
Municipal	72,446	1%	13,077	0%	-82%
Residential	2,620,586	49%	1,983,637	50%	-24%
Total	5,349,046	100%	3,942,541	100%	-26%
BUILDINGS ENERGY (GJ) BY FUEL	**2016**	**SHARE 2016**	**2030 (NZS)**	**SHARE 2030**	**% +/- (2016-2030)**
District Energy	0	0%	95,463	2%	100%
Fuel Oil	313,369	6%	19,691	0%	-94%
Grid electricity	1,601,596	30%	10,705	0%	-99%
Local electricity	18,058	0%	1,798,408	46%	9859%
Natural Gas	3,081,390	58%	0	0%	-100%
Other	129,035	2%	762,440	19%	491%
Propane	168,676	3%	46,264	1%	-73%
RNG	0	0%	1,176,971	30%	100%
Wood	36,920	1%	32,600	1%	-12%
Total	5,349,046	100%	3,942,541	100%	-26%
BUILDINGS ENERGY (GJ) BY END USE	**2016**	**SHARE 2016**	**2030 (NZS)**	**SHARE 2030**	**% +/- (2016-2030)**
Industrial Processes	1,207,854	23%	1,071,268	27%	-11%
Lighting	250,545	5%	256,190	6%	2%
Major Appliances	167,168	3%	228,569	6%	37%
Plug Load	336,133	6%	358,958	9%	7%
Space Cooling	80,262	2%	73,931	2%	-8%
Space Heating	2,562,879	48%	1,450,242	37%	-43%
Water Heating	744,205	14%	503,383	13%	-32%
Total	5,349,046	100%	3,942,541	100%	-26%

Table 5. Buildings sector emissions tabulated results, 2016 & 2030 (NZS).

BUILDINGS EMISSIONS (TCO_2E) BY BUILDING TYPE	2016	SHARE 2016	2030 (NZS)	SHARE 2030	% +/- (2016- 2030)
Commercial	41,721	21%	955	20%	-98%
Industrial	51,683	26%	2,176	45%	-96%
Municipal	2,411	1%	21	0%	-99%
Residential	101,151	51%	1,697	35%	-98%
Total	196,966	100%	4,848	100%	-98%
BUILDINGS EMISSIONS (TCO_2E) BY FUEL	**2016**	**SHARE 2016**	**2030 (NZS)**	**SHARE 2030**	**% +/- (2016- 2030)**
Electricity	14,329	7%	226	0%	-98%
Fuel Oil	22,291	11%	1,399	0%	-94%
Natural Gas	149,970	76%	0	0%	-100%
Propane	10,317	5%	2,830	1%	-73%
RNG	0	0%	342	0%	100%
Wood	58	0%	51	0%	-12%
Total	196,966	100%	4,848	100%	-98%
BUILDINGS EMISSIONS (TCO_2E) BY END USE	**2016**	**SHARE 2016**	**2030 (NZS)**	**SHARE 2030**	**% +/- (2016- 2030)**
Industrial Processes	40,274	20%	1,626	34%	-96%
Lighting	2,217	1%	31	1%	-99%
Major Appliances	2,162	1%	32	1%	-99%
Plug Load	3,475	2%	376	8%	-89%
Space Cooling	1,112	1%	10	0%	-99%
Space Heating	115,818	59%	1,321	27%	-99%
Water Heating	31,907	16%	1,451	30%	-95%
Total	196,966	100%	4,848	100%	-98%

TRANSPORTATION SECTOR

Table 6. Transportation sector energy tabulated results, 2016 & 2030 (NZS).

TRANSPORTATION ENERGY (GJ) BY FUEL	2016	SHARE 2016	2030 (NZS)	SHARE 2030	% +/- (2016-2030)
RNG	0	0%	34,576	2%	100%
Diesel	546,370	18%	260,988	16%	-52%
Gas	2,446,232	82%	862,851	53%	-65%
Grid electricity	37	0%	3,043	0%	8218%
Local electricity	0	0%	457,270	28%	100%
Total	2,992,640	100%	1,618,728	100%	-46%
TRANSPORTATION ENERGY (GJ) BY VEHICLE TYPE	**2016**	**SHARE 2016**	**2030 (NZS)**	**SHARE 2030**	**% +/- (2016-2030)**
Car	1,136,787	38%	410,784	25%	-64%
Heavy truck	204,729	7%	126,078	8%	-38%
Light rail	316	0%	1,580	0%	400%
Light truck	1,030,948	34%	605,540	37%	-41%
Off road	601,473	20%	459,111	28%	-24%
Rail	7,475	0%	7,475	0%	0%
Urban bus	10,911	0%	8,159	1%	-25%
Total	2,992,640	100%	1,618,728	100%	-46%

Table 7. Transportation emissions, tabulated results, 2016 & 2030 (NZS).

TRANSPORTATION EMISSIONS (TCO_2E) BY FUEL	2016	SHARE 2016	2030 (NZS)	SHARE 2030	% +/- (2016-2030)
RNG	0	0%	289	0%	100%
Diesel	39,613	18%	19,228	19%	-51%
Gas	158,853	72%	56,860	57%	-64%
Grid electricity	0	0%	64	0%	19503%
Jet fuel	23,238	10%	23,238	23%	0%
Total	221,704	100%	99,680	100%	-55%
TRANSPORTATION EMISSIONS (TCO_2E) BY VEHICLE TYPE	**2016**	**SHARE 2016**	**2030 (NZS)**	**SHARE 2030**	**% +/- (2016-2030)**
Aviation	23,238	10%	23,238	23%	0%
Car	73,354	33%	16,893	17%	-77%
Heavy truck	14,205	6%	5,252	5%	-63%
Light truck	66,541	30%	23,527	24%	-65%
Off road	43,000	19%	29,775	30%	-31%
Rail	601	0%	699	1%	16%
Urban bus	765	0%	295	0%	-61%
Total	221,704	100%	99,680	100%	-55%

WASTE SECTOR

Table 8. Waste Sector Emissions, 2016 & 2030 (NZS).

WASTE EMISSIONS (TCO_2E) BY FUEL	2016	SHARE 2016	2030 (NZS)	SHARE 2030	% +/- (2016-2030)
Biological	1,584	8%	2,247	14%	42%
Landfill	16,648	87%	12,180	78%	-27%
Wastewater	832	4%	1,117	7%	34%
Total	19,064	100%	15,544	100%	-18%

LAND USE

Table 9. Land-Use Change Emissions 2021-2030 (NZS).

	(TCO_2E/YR)		
	2021	2026	2031
1. Forest land: remaining forest land	-93,828	-93,638	-93,504
1. Cropland: remaining cropland	124	-172	-466
1. Settlements: remaining settlements	-19,748	-25,664	-31,674
2.1 Forest land converted to settlements	27,997	6,588	4,666
2.2 Cropland converted to settlements	502	2,920	2,325
Total carbon sequestered	-84,953	-109,966	-118,651

SENSITIVITY ANALYSIS

Table 10. NZS sensitivity analysis results.

	ENERGY IMPACT: RELATIVE TO NZ SCENARIO IN 2030		EMISSIONS IMPACT: RELATIVE TO NZ SCENARIO IN 2030	
	[+/-] GJ	[+/-] %	[+/-] tonnes CO_2e	[+/-] %
DEMOGRAPHICS				
Decrease population -20%	-297,153	-5.3%	-5,769	-4.8%
Increase population 20%	487,200	8.8%	8,139	6.8%
EMPLOYMENT				
Decrease employment -20%	-369,171	-6.6%	-4,963	-4.1%
Increase employment 20%	538,343	9.7%	11,324	9.4%
HEATING DEGREE DAYS (HDD)				
Hold HDD fixed	121,094	2.2%	922	0.8%
Decrease HDD + increase CDD by 10%	-258,239	-4.6%	-548	-0.5%
GRID ELECTRICITY EMISSIONS FACTOR (EF)				
Decrease grid emissions factor 50%	0	0.0%	-145	-0.1%
Increase grid emissions factor 50%	0	0.0%	145	0.1%
VEHICLE KILOMETRES TRAVELLED (VKT)				
Decrease VKT 25% by 2030	-190,198	-3.4%	-7,549	-6.3%
Increase VKT 25% by 2030	190,198	3.4%	8,875	7.4%
METHANE				
Adjust methane global warming potential (GWP) from 100-yr to 20-yr GWP (i.e., 86)	0	0.0%	47,956	40.0%

APPENDIX C: Reference Scenario Modelling Results

July 2021

This document reports the energy use and greenhouse gas (GHG) emissions for the Town of Halton Hills in a reference scenario by 2030 scenario (Part 1). The model results are shown in comparison to the Town's 2016 base year energy use and GHG emissions. The data and series of assumptions that make up the reference scenario, as well as the modelling methods are outlined in Part 2.

Disclaimer

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

This analysis includes strategic-level estimates of emissions that should not be relied upon for design or other purposes without verification. The authors do not accept responsibility for the use of this analysis for any purpose other than that stated above, and do not accept responsibility to any third party for the use, in whole or in part, of the contents of this document. This analysis applies to the Town of Halton Hills and cannot be applied to other jurisdictions without analysis. Any use by the Town of Halton Hills, its sub-consultants or any third party, or any reliance on or decisions based on this document, are the responsibility of the user or third party.

Contents

Glossary

Base Year: the starting year for energy or emissions projections.

Carbon dioxide equivalent (CO_2e): a measure for describing the global warming potential of a greenhouse gas using the equivalent amount or concentration of carbon dioxide (CO_2) as a reference. CO_2e is commonly expressed as million metric tonnes of carbon dioxide equivalent ($MtCO_2e$).

Cooling degree days (CDD): the number of degrees that a day's average temperature is above 18oC, requiring cooling.

District energy: Energy generation within the municipal boundary that serves more than one building.

Emissions: In this report, the term 'emissions' refers exclusively to greenhouse gas emissions, measured in metric tonnes (tCO_2e), unless otherwise indicated.

Electric vehicles (EVs): an umbrella term describing a variety of vehicle types that use electricity as their primary fuel source for propulsion or as a means to improve the efficiency of a conventional internal combustion engine.

Greenhouse gases (GHG): gases that trap heat in the atmosphere by absorbing and emitting solar radiation, causing a greenhouse effect that unnaturally warms the atmosphere. The main GHGs are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

Heating Degrees Days (HDD): number of degrees that a day's average temperature is below 18oC, requiring heating.

Local electricity: Electricity produced within the municipal boundary and sold to the electricity system operator or used behind the meter.

Reference scenario: a scenario illustrating energy use and greenhouse gas emissions which aims to reflect current and planned policies and actions that are likely to be implemented.

Renewable Natural Gas (RNG): Biogas resulting from the decomposition of organic matter under anaerobic conditions that has been upgraded for use in place of fossil natural gas.

Sankey: a diagram illustrating the flow of energy through a system, from its initial sources to points of consumption.

Vehicle kilometres travelled (VKT): distance traveled by vehicles within a defined region over a specified time period.

Units of Measurement:

To compare fuels on an equivalent basis, all energy is reported primarily as petajoules (PJ) or sometimes as gigajoules (GJ) (a PJ is a million GJ). Greenhouse gas emissions are primarily characterized as Kilotonnes or megatonnes of carbon dioxide equivalents ($ktCO_2e$ or $MtCO_2e$) (a Mt is a thousand kt).

- An average house uses about 100GJ of energy in a year
- 100 liters of gasoline produces about 3.5 GJ
- A kilowatt-hour is .0036 GJ
- A terawatt-hour is 3.6 PJ
- Burning 50,000 tonnes of wood produces 1 PJ

A typical passenger vehicle emits about 4.7 metric tons of carbon dioxide per year.*

**Data provided by United States Environmental Protection Agency*

EMISSIONS AND ENERGY UNITS

GHG emissions	Energy
1 $mtCO_2$ = 1,000,000 tCO_2e	1 PJ = 1,000,000,000 J
1 $ktCO_2e$ = 1,000 tCO_2e	1 GJ = 1,000,000 J
1 tCO_2e = 1,000 $kgCO_2e$	1 MJ = 0.001 GJ
1 $kgCO_2e$ = 1,000 gCO_2e	1 TJ = 1,000 GJ
	1 PJ = 1,000,000 GJ

1. Introduction

The Low-Carbon Transition Strategy (LCTS) will chart a course for the Town of Halton Hills to reach net-zero emissions by 2030. The LCTS will be developed by evaluating future emission reduction scenarios using CityInSight, a spatial energy and emissions simulation model developed by SSG and whatIf? Technologies.

Scenario analysis projects alternate stories about how the world could unfold based on possible future pathways. Scenario planning is a technique used to inform decision-making by exploring how combinations of alternate policies, economic mechanisms, and investments could impact society and the economy.

Once we have developed a base year energy and emissions model for the town, two emissions scenarios will be evaluated to develop the LCTS: first, a reference scenario and, then a net-zero scenario.

The reference scenario reflects current activities and trends that generate emissions in the Town of Halton Hills, and projects what emissions could look like over time if little additional action is taken to reduce emissions. The net-zero scenario then explores the energy and emissions implications of a suite of actions to reduce the emissions identified in the reference scenario. The net-zero scenario will then inform the LCTS.

This report summarizes the technical modelling results for the base year and reference scenario. The report gives a brief overview of the modelling process and key assumptions used to develop the reference scenario. It ends with a summary of the reference scenario modelling results from the base year (2016) to 2030.

2. 2016 Base Year

The modelling projections for both the reference and the net-zero scenarios are built on a base year energy and emissions model produced for the Town. The base year model represents energy use and processes that generate emissions in the Town of Halton Hills.

Emissions come from three main sources:

- The consumption of carbon-based fuels for energy, which emit greenhouse gases during their combustion. This includes a range of activities that occur in Halton Hills, including building heating, cooling and plug loads transportation; as well as industrial processes.
- Emissions generated from decomposing organic waste and its treatment, and decomposing organic waste in wastewater treatment.
- The incidental release of emissions (methane) from the natural gas system, referred to as fugitive emissions.

The base year is developed based on observed data in Halton Hills, including census data, energy consumption from utilities and observed transportation studies. The base year is 2016 because the most recent Census data is from 2016. Where more current data is available, it is used to calibrate the model projections between 2016-2019.

2.1 GEOGRAPHIC SCOPE

The GHG accounting framework in CityInSight applies the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC Protocol). The geographic boundary of the Town of Halton Hills is the inventory boundary. Further details on the modelling scope is outlined in Part 2.

3. Reference Scenario Assumptions

The reference scenario represents the Town of Halton Hills' energy and emissions projected to 2030 based on ongoing trends and planned initiatives. This scenario is made up of a suite of assumptions applied to the energy and emissions model for the Town of Halton Hills. The assumptions relate to energy and waste systems that drive emissions and include:

- Population growth
- New building construction
- Transit system expansion and its corresponding fuel type
- Personal use vehicles counts and fuel efficiency
- Waste and waste diversion rates

The activities included in the reference scenario are described below. A full list of assumptions applied in the reference scenario model are described in Part 2 of this report.

3.1 POPULATION AND HOUSEHOLDS

The population of Halton Hills is anticipated to increase by 45% by 2030, from 63,000 in 2016 to nearly 92,000, according to Town projections.[1] This captures the development at Vision Georgetown.

Employment is projected to rise by 20%, with just under 40,000 jobs in the Town by 2030 (up from 33,000 in 2016). The smaller relative employment growth projections is indicative of the fact that many residents are currently and projected to continue to commute to work in neighbouring communities, including Toronto.

Population, households and employment are shown in Figure 1. A growing population and employment base translates to more homes, more commercial floor area and more vehicles—all of which influence emissions.

[1] Environics Analytics. (2019). Demo Stats 2019.

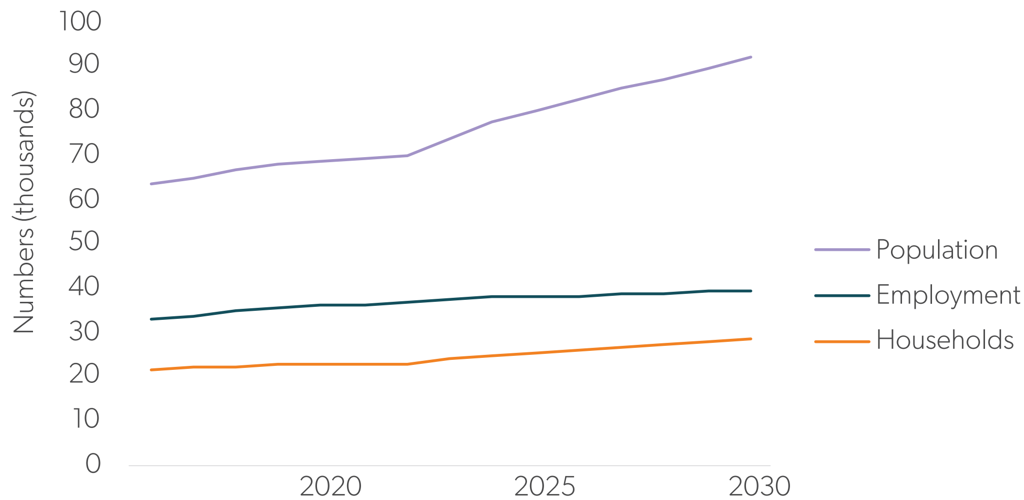


Figure 1. Projected changes in population, vehicles, employment and households, 2016-2030.

3.2 CLIMATE CHANGE

Halton Hills is projected to experience a decline in heating needs and an increase in cooling needs for its buildings as a result of climate change. This is reflected in heating and cooling degree days—the extent to which heating (below 18°C) and cooling (above 18°C) is required. By 2030, heating degree days are projected to decline to 3,573 (from 3,882), and cooling degree days are projected to increase to 405 (from 331).[2]

3.3 BUILDINGS

New Construction

The Halton Hills Green Development Standard (GDS) has been in place since 2014, and uses a point-based system to encourage sustainable design in new construction. Theoretically, GDS energy performance points results in buildings that are 5-20% more efficient than the 2012 Ontario Building Code (OBC).[3] An updated GDS is currently in development, and is expected to advocate for 15% better energy performance than the newest iteration of the OBC (2020).

In the reference scenario, it is assumed that between 2016 and 2030, 25% of new buildings are constructed to meet the GDS Standards applicable at the time of construction. The remaining 75% of new buildings are constructed to meet the OBC standards required at the time of construction. Since OBC 2012, it is assumed that the code is updated every five years to require improved energy performance of 10%.[4]

Existing Buildings

The energy performance of municipal buildings is expected to improve as initiatives in the Town's Corporate Energy Plan are implemented.[5] The energy consumption by facility is anticipated to fall by 43%, averaged across 12 of the Town's facilities.

[2] Climate Atlas of Canada. (n.d.). RCP8.5 BCCAqv2 downscaled climate data from Pacific Climate Impacts Consortium.

[3] Arup. (2017). Vision Georgetown Energy Master Plan.

[4] Environmental Commissioner of Ontario. (2016). Conservation: Let's Get Serious 2015-2016.

[5] Town of Halton Hills. (2019). 2020-2025 Corporate Energy Plan.

The energy performance of non-municipal existing buildings is assumed to remain unchanged, for two reasons:

- There are no targeted retrofit programs for buildings in Halton Hills.
- Any gains from building renovations or heating system replacements that occur may be offset by increasing plug loads.

Across the whole residential building stock (non-municipal new and existing), this translates to about a 12.5% reduction in energy consumption by 2021, 14% reduction by 2026, and a 10% reduction by 2030. For the new non-residential building stock, there is a 10% improvement in energy performance every five years.

3.4 LOCAL ENERGY GENERATION

Existing grid-connected renewable electricity generation is assumed to remain in operation, with contract extensions beyond their current end dates.[6] This includes 4.08 MW of rooftop solar, as well as 0.5 MW of ground mount solar PV.[7] This also includes small solar PV installations on municipal corporate buildings.

While there is a planned district energy system in the Vision Georgetown development, it is not expected to be operational until 2035—beyond the time scope of the reference projection.

3.5 TRANSIT

The reference scenario accounts for an increase in transit trips and transit vehicle kilometres travelled (VKT) from Metrolinx's GO train Kitchener Line expansion. Beginning in 2025, transit trips will increase according to Table 1. Transit VKT is assumed to be five times higher than base year VKT, based on the increasing frequency of transit service.

Table 1. Transit trip increase for GO Train Kitchener expansion.[8]

	2016	2025
Acton	121 daily trips	220 daily trips
Georgetown	618 daily trips	643 daily trips

While the Town is also anticipating an expansion of the local Universal Access Service, this is incorporated into personal vehicle trips because the service closely resembles taxi activities.[9]

Neither the GO expansion, nor the Universal Access Service, is assumed to be electric.

[6] IESO. (March 2020). IESO Active Contracted Generation List (as of March 2020). Retrieved from: www.ieso.ca/Power-Data/Supply-Overview/Transmission-Connected-Generation

[7] It should be noted that the Halton Hills Generating Station, a 641 MW natural gas fired electricity generating station is not included in either the base year or the reference projection. This is because its emissions impact is captured in Ontario's grid emissions factor. For more details, see Part 2 Section 7.

[8] Metrolinx. (2019). Kitchener go expansion initial business case. Retrieved from: www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/2019-11-14-Kitchener-Mid-Term-Service-Expansion-IBC-Update-FINAL.pdf

[9] Town of Halton Hills. (2019). Transit Service Strategy. Prepared by WSP.

3.6 TRANSPORTATION MODE SHARE

The reference scenario assumes that the transit and active mode shares identified in the Town's Transportation Master Plan (TMP) are achieved.[10] In addition, the GO Train expansion is assumed to exceed this transit mode share identified in the TMP. The assumed 2030 modeshare is shown in Table 2.

Table 2. Reference scenario mode share in 2016 (observed) and 2030 (projected).

	2016	2030
Personal use automobiles	88.90%	83.54%
Transit	4.95%	10.77%
School bus	2.29%	2.52%
Walk	3.36%	2.74%
Bike	0.50%	0.43%

3.7 VEHICLES

A portion of personal vehicle stock in Halton Hills is assumed to be replaced with electric vehicles, starting at 0% of new vehicle sales in 2016 and up to 14% of new vehicle sales by 2030.[11] New vehicles are incorporated into the model with new population growth, as well as through replacement at the end of vehicle life. The assumption reflects the underlying increase in EV purchases.

The reference scenario assumes that commercial vehicles are not replaced with an electric counterpart.

New internal combustion engine vehicles are assumed to have the fuel economy of their manufacturing year, according to Canadian regulations.[12] Regulations schedule vehicle efficiency improvements for the upcoming decade.

3.8 MUNICIPAL FLEETS

The reference scenario assumes that there will be no significant changes to municipal fleet vehicles, other than replacements at the end of vehicle life.

3.9 WASTE AND WASTEWATER

Waste generation in Halton Hills is assumed to remain constant at the base year level of 1,250 kg/household/year.[13] The base year waste diversion rate is 57.4%.[14] As a result of Halton Region policies, Halton Hills is expected to reach a 70% waste diversion rate by 2025. After

[10] Town of Halton Hills. (2011). Transportation Master Plan.

[11] Axsen, J., Wolinetz, M. (2018). Reaching 30% plug-in vehicle sales by 2030: Modeling incentive and sales mandate strategies in Canada. Transportation Research Part D: Transport and Environment, 65, 596-617.

[12] SOR/2010-201. Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations. Available from: laws-lois.justice.gc.ca. SOR/2018-98. Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations and other Regulations Made Under the Canadian Environmental Protection Act, 1999. Available from: pollution-waste.canada.ca

[13] Halton Region. (2011). Solid Waste Management Strategy.

[14] Resource Productivity and Recovery Authority. (n.d.). 2016 Residential Waste Diversion Rates by Municipal Program.

2025, the diversion rate stays constant at 70%. Increasing the diversion rate reduces the amount of organic waste sent to landfill.

Currently, waste is landfilled outside the Halton Hills boundary. A landfill gas capture system captures a portion of emissions produced from decomposing organic waste; once captured, some gas is flared, directly releasing carbon dioxide into the atmosphere. The remaining gas is combusted to produce electricity. There are no expected changes to how waste is treated in the reference scenario.[15]

There are two wastewater treatment plants within the Town boundary. Wastewater systems consume various fuels, and also produce emissions from the decomposition of organic waste in sewage. Wastewater emissions are projected to increase with population growth.

3.10 INDUSTRY

The model accounts for energy consumption at industrial facilities. The industrial sector is expected to grow as broader local employment grows between 2016 and 2030.

3.11 AGRICULTURE

Agriculture emissions in the model relate to emissions associated with methane emissions from livestock, not energy use on farms. There are no anticipated changes to agriculture emissions in Halton Hills.

4. Base Year Scenario Results

4.1 BASE YEAR ENERGY, 2016

In 2016, 8.3 PJ of energy were consumed for activities within the Town of Halton Hills. About 80% of energy consumption is from fossil fuels.[16]

The breakdown of fuel uses varies by sector (Figure 2). Building-related sectors (residential, commercial, municipal and industrial) use many of the same fuels, albeit in different proportions. Natural gas is the dominant fuel consumed in residential, commercial, industrial and municipal sectors, mostly for space heating and industrial purposes. Grid electricity is also used in buildings, primarily for cooling and plug loads. A range of other fuels are also used within the Halton Hills boundary, including fuel oil, wood and propane; this is generally in rural areas without access to natural gas for heating, and in industrial processes.

Energy consumption in the transportations sector is made up mostly of gasoline, and to a lesser extent diesel.

[15] Waste treatment occurs outside of Halton Hills' boundaries, and is therefore a scope 3 emission. The electricity produced from the combustion of landfill gas is not included in the Town's inventory as it is under the control of Oakville Hydro. For details on scope, see Part 2 of this report.

[16] This excludes all electrical energy and the combustion of wood biomass for energy.

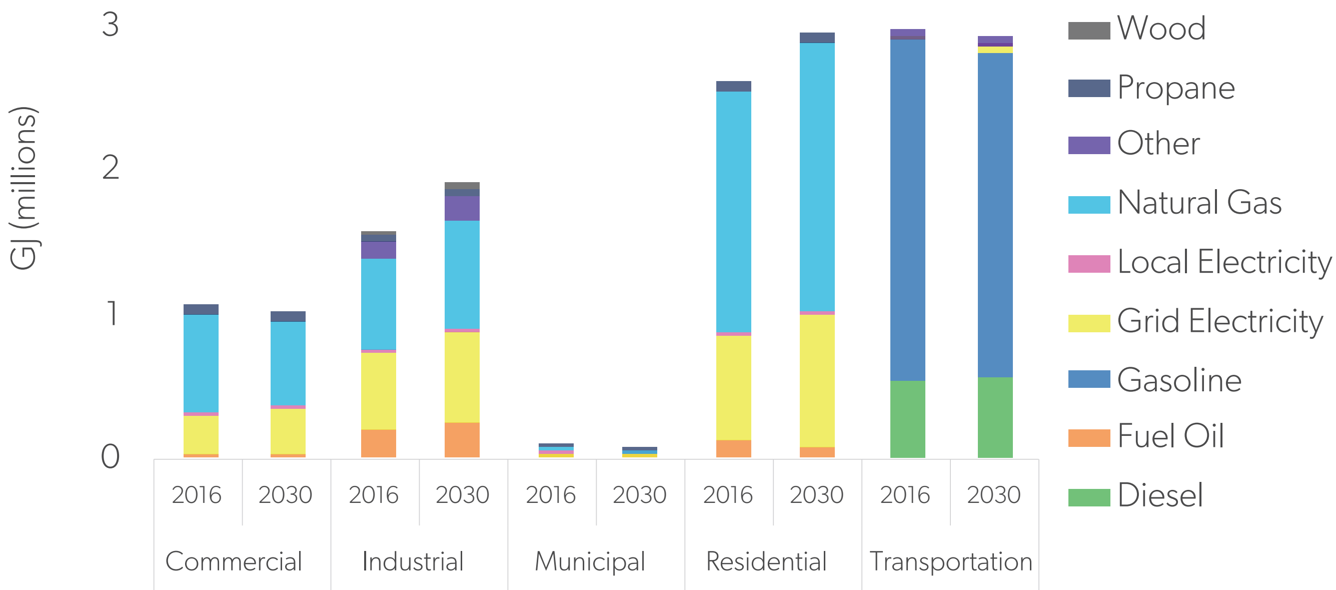


Figure 2. Energy consumption by fuel and by sector in 2016 and in a 2030 reference scenario.

As shown in Figure 3, building energy consumption is highest in areas with dense commercial, residential or industrial activity. This includes Georgetown, followed by zones in Acton, and zones along Highway 401. For transportation energy consumption in particular, zones surrounding the core of Georgetown have the highest VKT (Figure 4). This is likely because these areas have a greater population than the more rural regions, but are not within walking or cycling distance to their end locations.

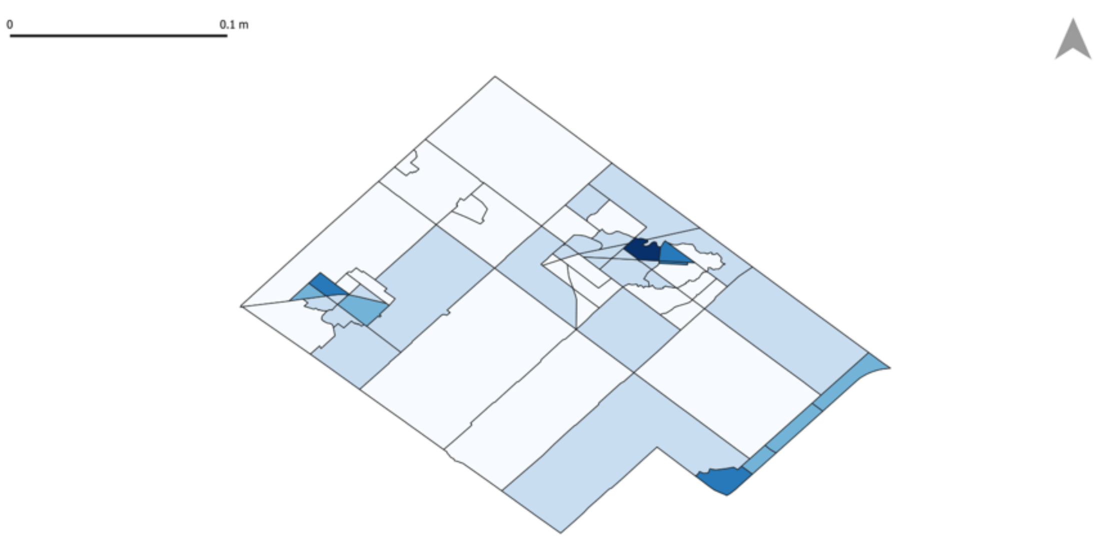


Figure 3. Total building energy consumption by zone, 2016 (GJ).

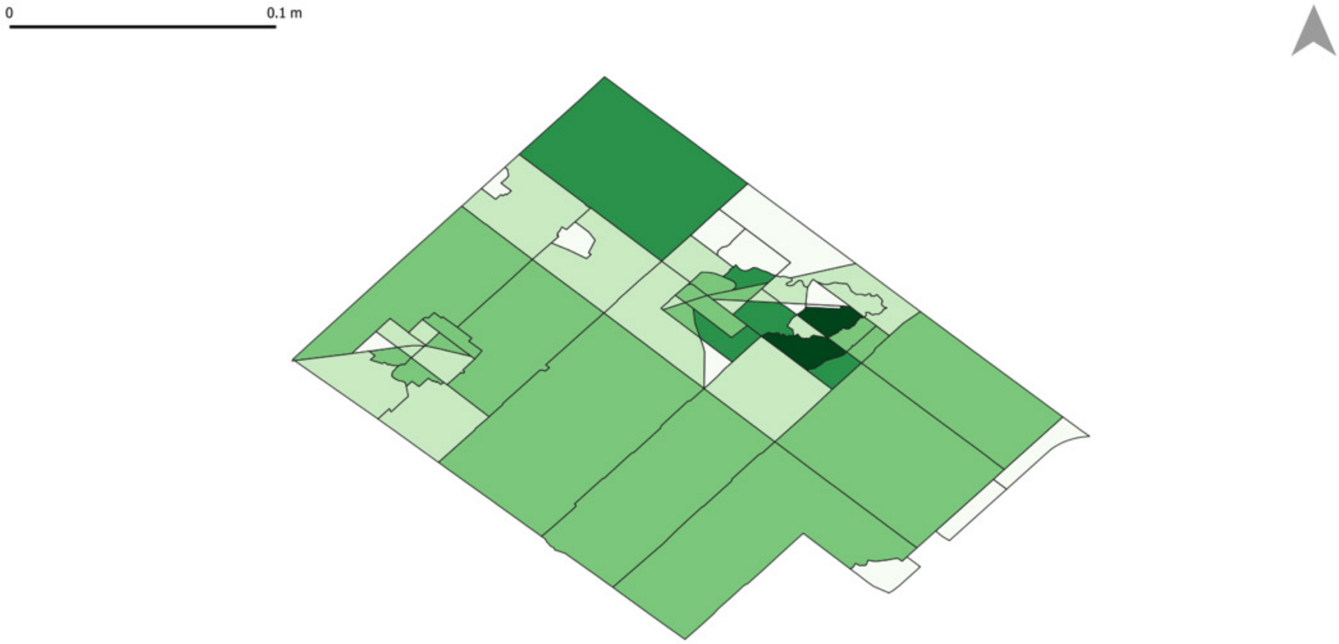


Figure 4. Personal use automobile VKT, 2016. VKT are associated with the zone where the trip originates.

4.2 BASE YEAR EMISSIONS, 2016

The above-noted energy activities—in addition to non-energy related emissions (i.e., waste, agricultural and fugitive emissions)—generate 457 kt CO_2e of greenhouse gas emissions in 2016. This translates to about 7.2 tCO_2e per person, including industrial emissions.

Per capita emissions in Halton Hills are higher than per capita emissions in the Greater Toronto and Hamilton Area as a whole (6.9 tCO_2e/person), with per capita emissions in the City of Toronto at 5.5 tCO_2e/person, and 7.9 tCO_2e/person in the Region of Peel.[17] Compared to other municipalities in Canada with differing energy systems, Halton Hills per capita emissions are somewhere in the middle, with the City of Courtenay, BC emissions at 4.2 tCO_2e/person, and emissions in the Halifax Regional Municipality are 13 tCO_2e/person (this latter is high due to electricity generation from fossil fuels).

Emissions by sector are shown in Figure 5. The transportation sector is the largest energy consumer and makes up the largest share of emissions, at 49% of Halton Hills' total emissions.[18] This greater share of emissions from transportation reflects the greater emissions intensity of transportation fuels over those used in buildings—particularly grid electricity.

The second largest contributor to emissions is the residential sector (at 22% of total emissions). This is mostly from natural gas use, which is the primary source of building space and water heating in the Town of Halton Hills.

[17] The Atmospheric Fund. (2018). Keeping Track: 2015 Carbon Emissions in the Greater Toronto and Hamilton Area. Retrieved from: taf.ca/wp-content/uploads/2018/09/TAF_GTHA_Emissions_Inventory_Report_2018-Final.pdf.

[18] This value includes both on-road and off-road transportation.

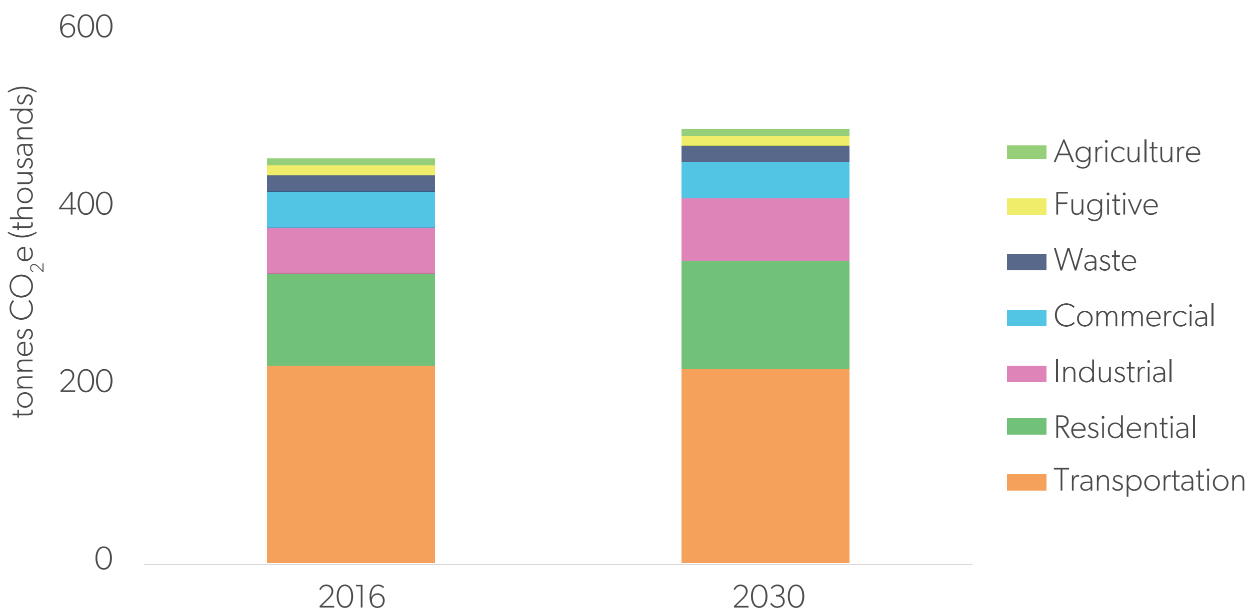


Figure 5. Town of Halton Hills emissions profile by sector in 2016 and in a 2030 reference scenario.

As shown in Figure 6, emissions are the highest in the zone adjacent to Highway 401—an area with concentrated commercial, industrial and warehouse activities. This points to the intensity of emissions generated from industrial activities. Emissions are also generated in both the central and peripheral zones of Georgetown.

Emissions by sector are summarized in Figure 6.

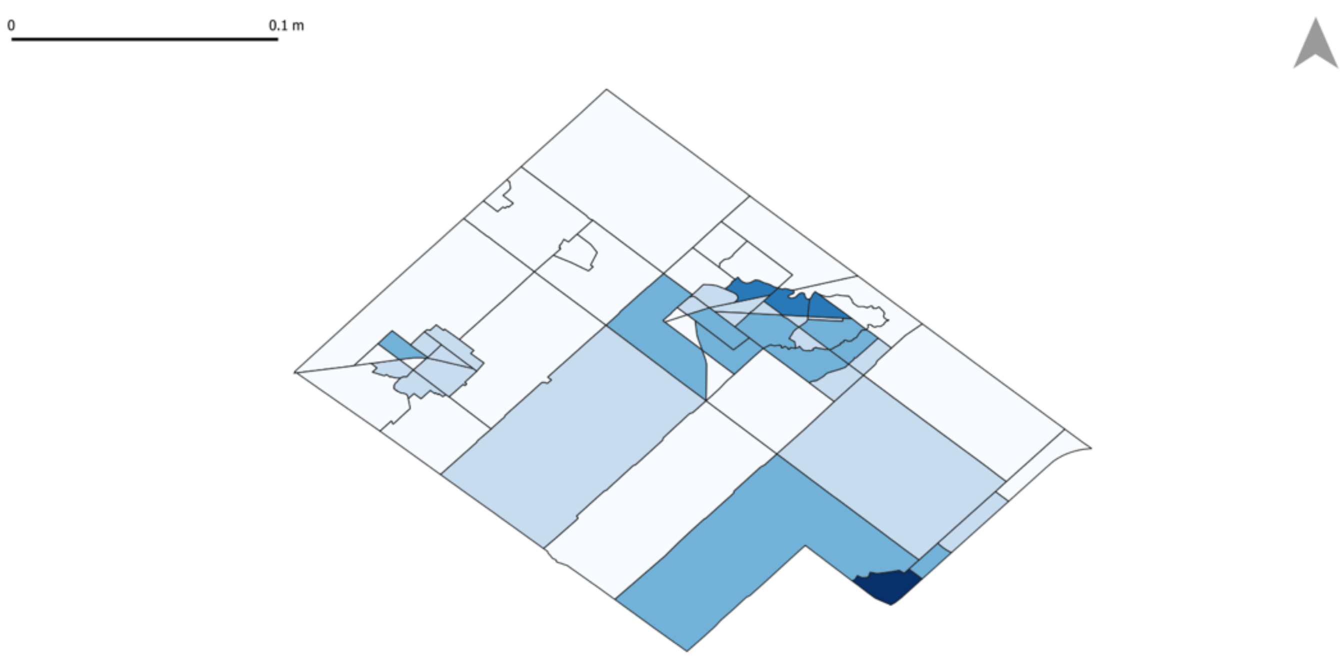


Figure 6. Emissions by zone, 2016 (tco_2e).

5. Reference Scenario Results

5.1 TOTAL ENERGY AND EMISSIONS, 2016-2030

In the reference scenario, total energy consumption increases by 6%, from 8.3 PJ in 2016 to 8.8 PJ in 2030.

The share of fuel consumption remains fairly constant in the Town's reference scenario. Natural gas remains the most consumed fuel in Halton Hills. There is a small decline in gasoline consumption and an increase in electricity from the uptake of electric vehicles.

Although total energy consumption increases slightly through 2030, energy consumption per capita declines by 27%, from 132 GJ per person in 2016 to 97 GJ per person in 2030 (Figure 9). This is because increasing energy consumption related to population growth is being offset by improved vehicle efficiency, reductions in vehicle mode share, and building energy performance improvements.

The resulting emissions pattern is similar, with a 7% increase, from 457 ktCO_2e to 489 ktCO_2e. Per capita emissions also decline from 7.2 tCO_2e per person, to 5.3 tCO_2e.

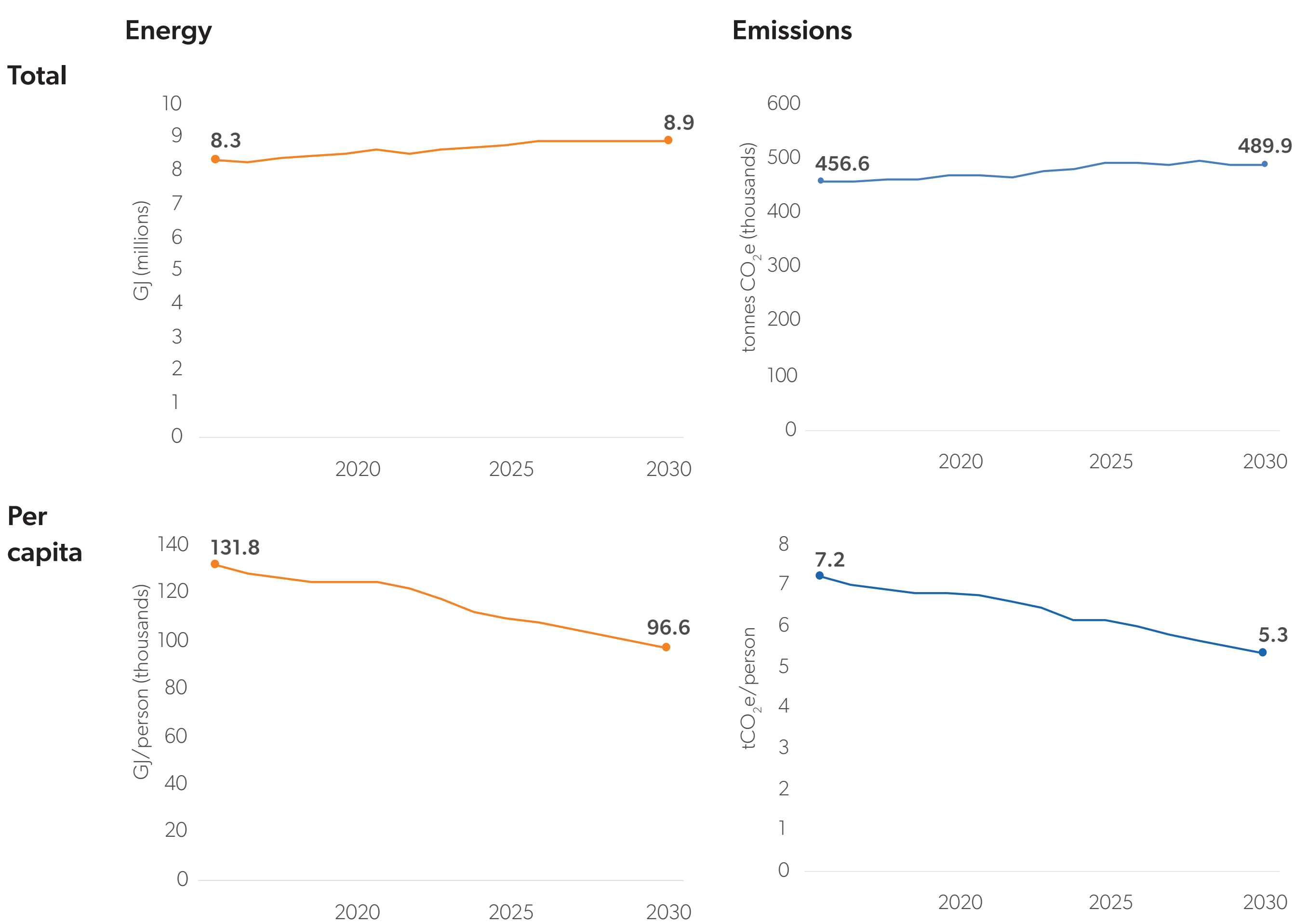


Figure 7. Total and per capita change in energy and emissions, 2016-2030.

The relative share of emissions from each sector varies only slightly from 2016 to 2030 (Figure 8). Sector trends are discussed in more detail below. This emissions growth is driven by population and employment growth projections, which outweigh any projected efficiency improvements and electrification.

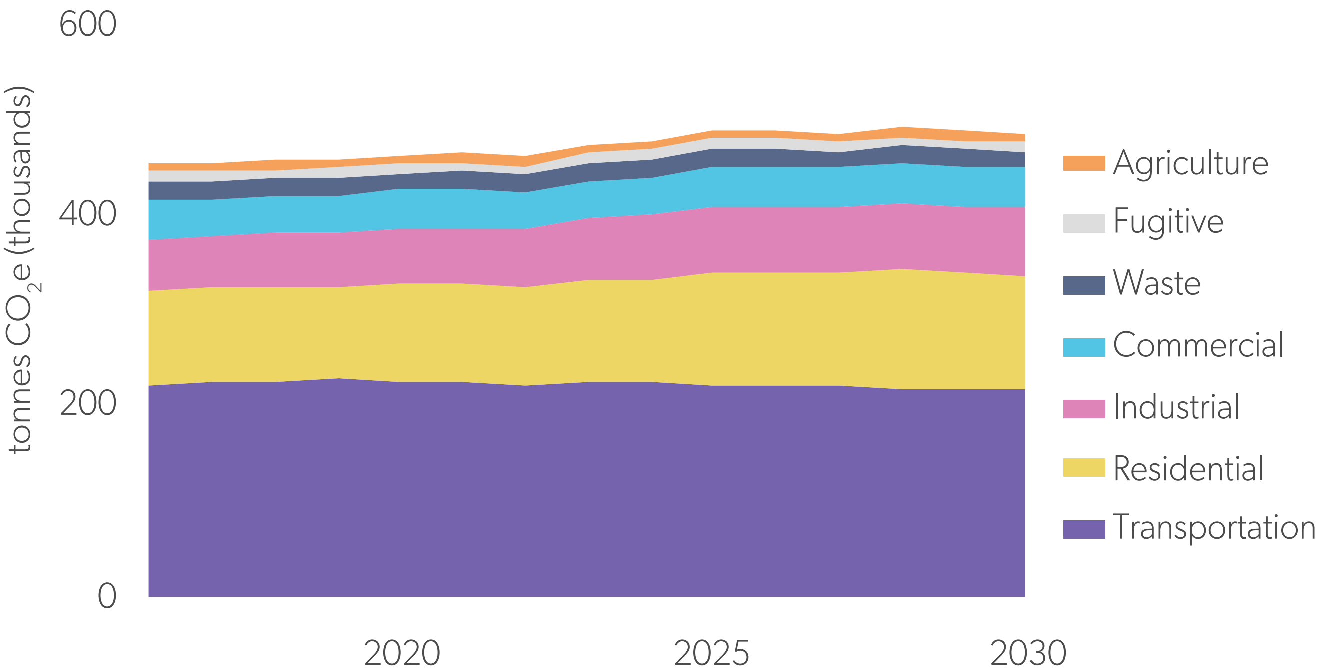


Figure 8. Emissions by sector, 2016-2030.

Similar to the base year, emissions are highest from zones in Georgetown, adjacent to Highway 401, and to a lesser extent in Acton (Figure 9).

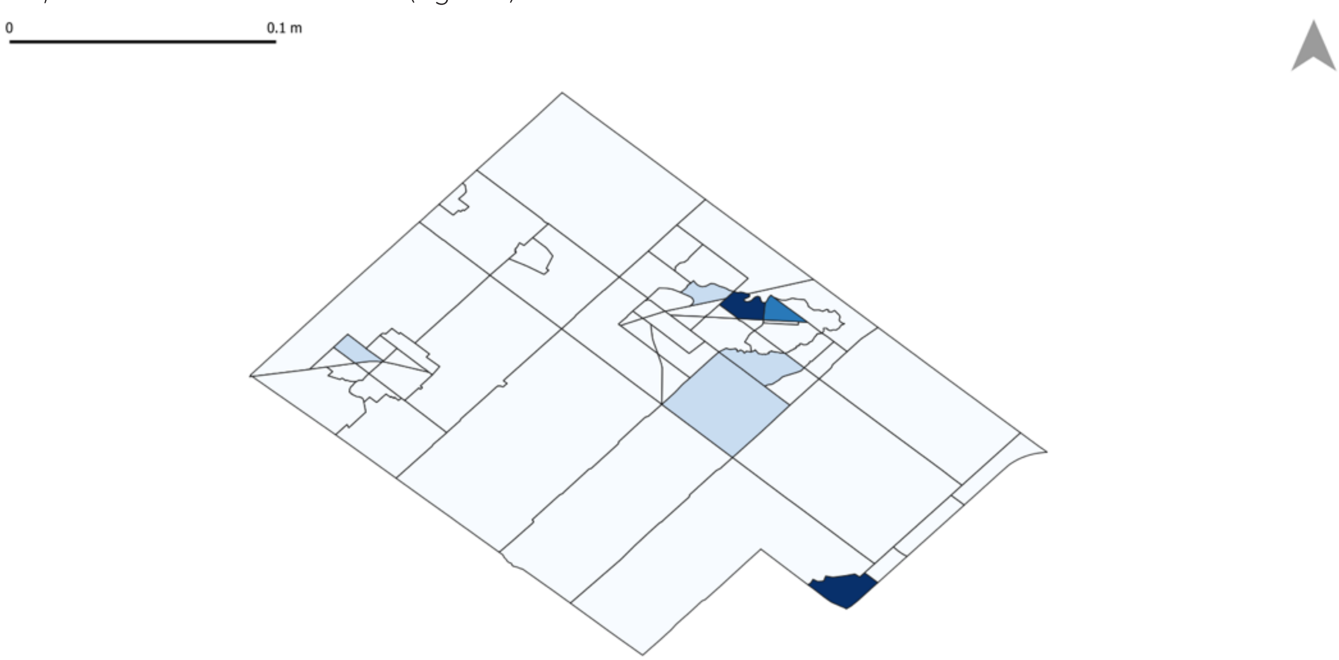


Figure 9. Emissions by zone, 2030.

5.2 ENERGY AND EMISSIONS, 2016-2030

Buildings

Space heating and industrial processes use the most energy, in 2016 and in 2030 (Figure 10). The industrial and residential sectors see increasing energy consumption between 2016 and 2030. The fact that the commercial sector experiences a decline is indicative of the relatively small projected employment growth over the period versus population growth, combined with projected improvements in energy efficiency.

Most of the energy demand is met by natural gas, particularly in the residential sector, but electricity and fuel oil are also used in the residential, commercial and industrial sectors (Figure 11).

Municipal buildings represent the smallest square footage, and in turn use comparatively less total energy than other building sectors. Their projected decline in energy use is due to the Town corporation's energy efficiency targets.

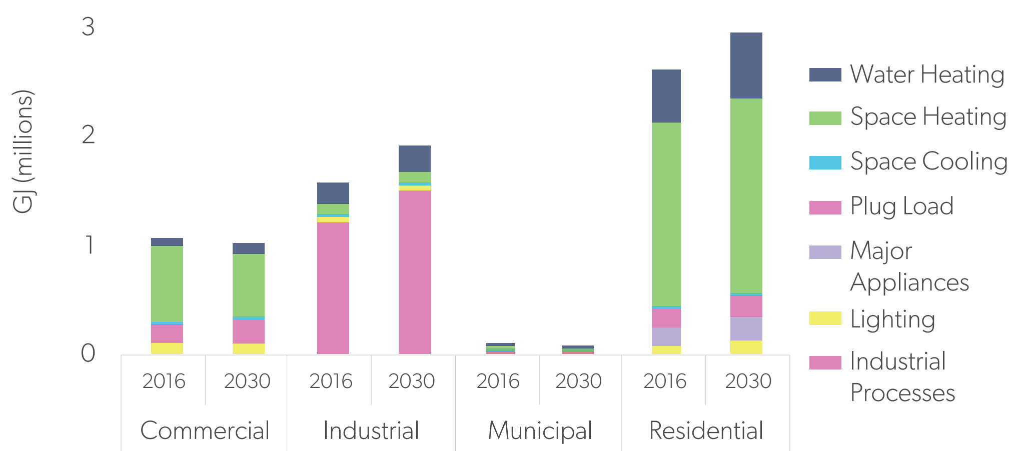


Figure 10. Energy consumption by sector and end use, 2016 and 2030.

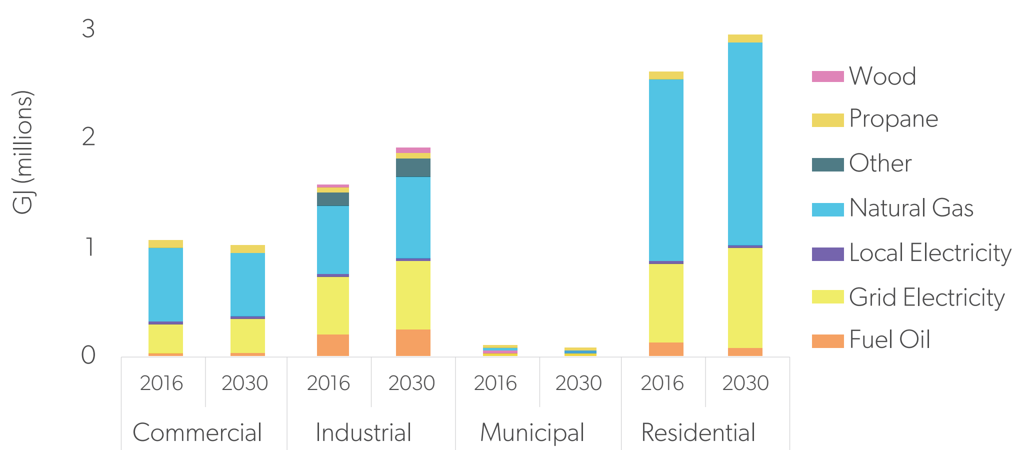


Figure 11. Energy consumption by sector and by fuel, 2016 and 2030.

This energy consumption pattern results in a similar emissions profile in both 2016 and 2030, where space heating and industrial processes are the largest contributors to emissions from buildings (Figure 12). The industrial sector sees the largest growth in emissions by 2030 (+38%), driven in part by sector growth related to employment projections, and its large reliance on carbon-intensive fuel oil. Emissions from the residential sector are also growing (+20%). Emissions from municipal buildings decline by 29%, and emissions from commercial buildings decline by 5% in the reference scenario.

Natural gas is the largest contributor to building emissions in 2016 and 2030 (Figure 13). Fuel oil is responsible for over half of industrial building emissions. Grid-supplied electricity has a lower emissions profile than other fuels, so its relative contribution to Halton Hills' emissions profile is smaller.

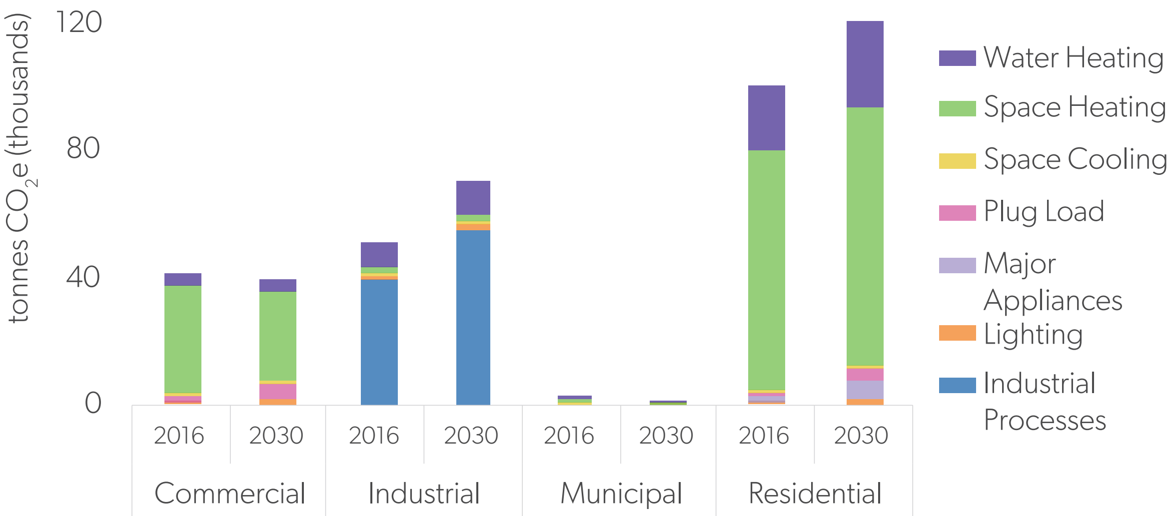


Figure 12. Building emissions by sector and by end use, 2016 and 2030.

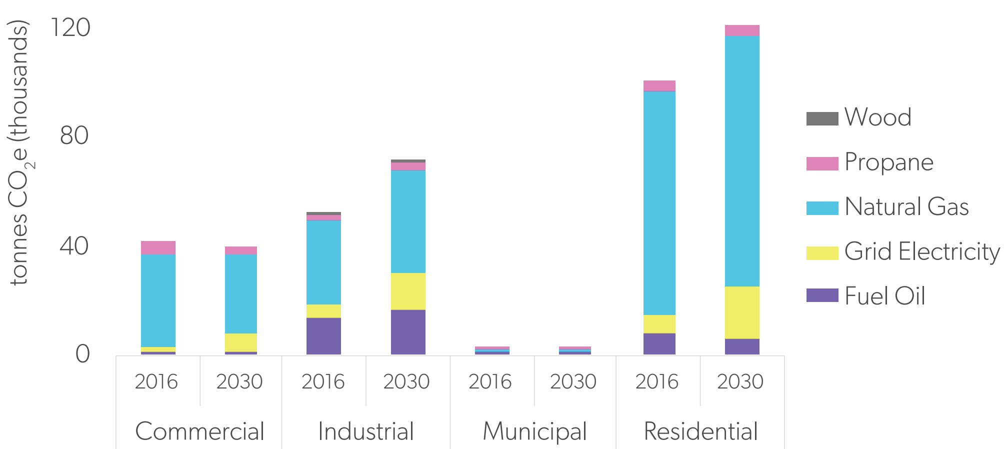


Figure 13. Building emissions by sector and by fuel.

5.3 TRANSPORTATION

Transportation energy consumption remains dominated by personal use vehicles by the year 2030. Annual vehicle kilometres travelled (VKT) by personal use vehicles increases by nearly 0.2 billion between 2016 and 2030, increasing for trips within Halton Hills and for trips that leave or enter the Halton Hills boundary (Figure 14). Much of this growth in VKT is likely due to population increase in the Vision Georgetown development;[19] as shown in Figure 15, the Vision Georgetown zone has the highest VKT in all of Halton Hills in 2030.

This increase in automobile VKT is also accompanied by an increase in trips by other modes, most notably an increase in transit trips (Figure 16). In 2016, transit made up 5% of all trips; in 2030, transit makes up 11% of trips.

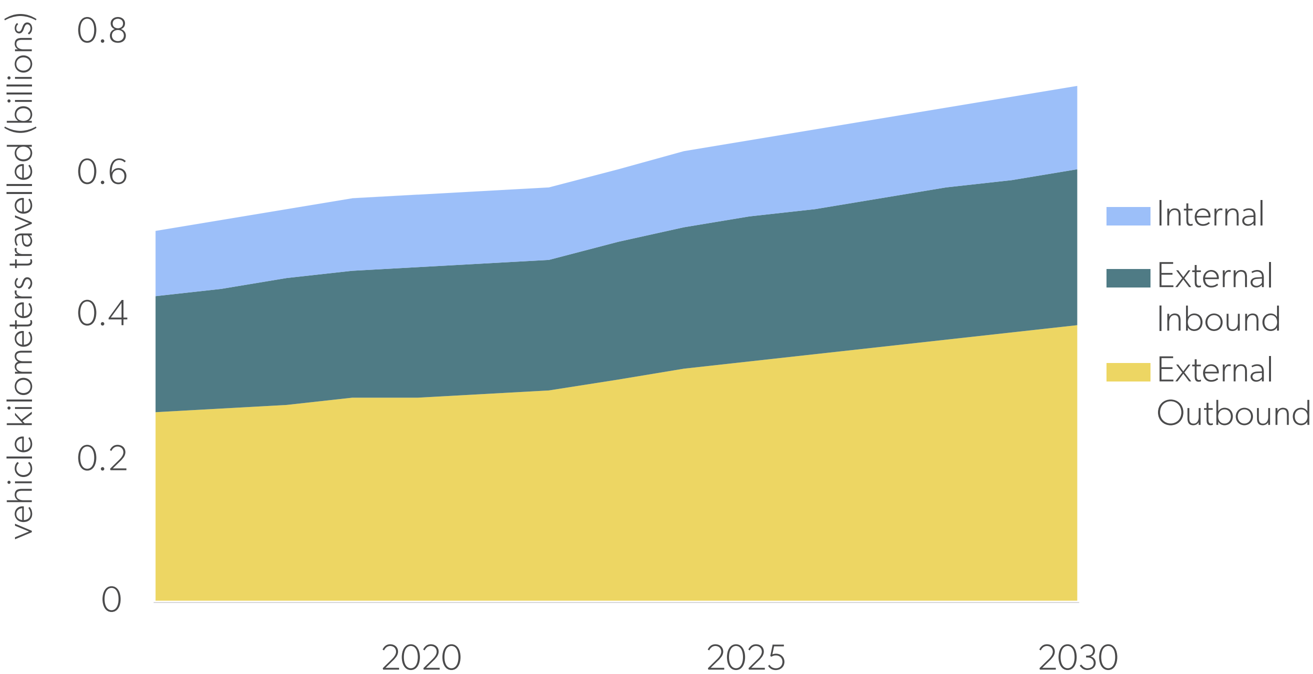


Figure 14. Personal use automobile VKT, 2016-2030.

[19] VKT is allocated to the zone of trip origin.

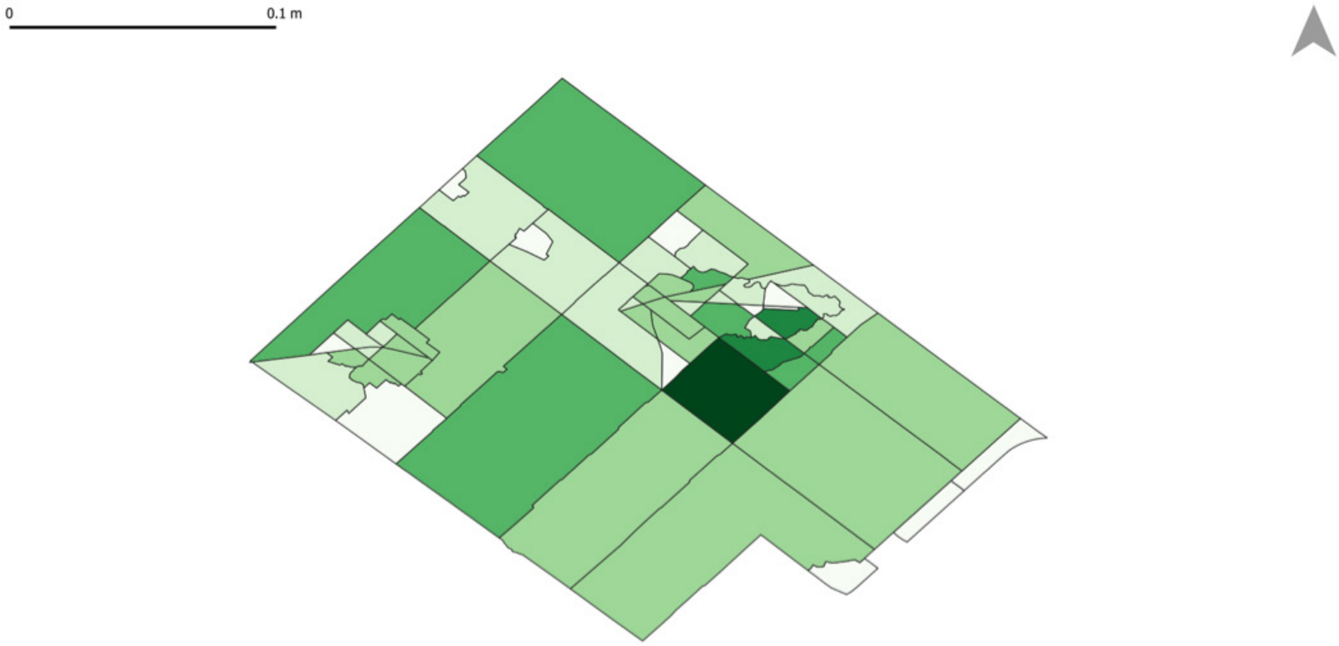


Figure 15. Map of VKT by zone, 2030.

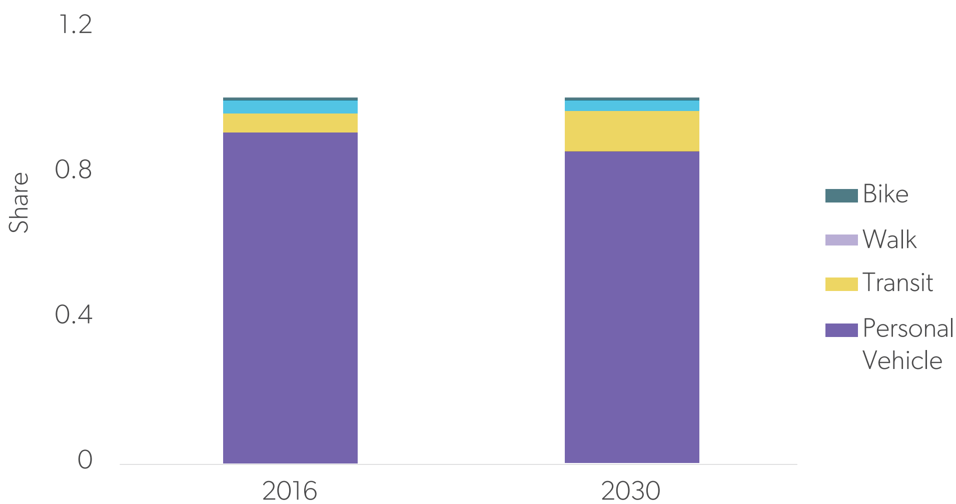


Figure 16. Number of trips by mode, 2016 and 2030.

In the base year, cars make up the largest segment of transportation fuel consumption, using predominantly gasoline (Figure 17). By 2030, light trucks will become the largest fuel consumers in 2030, reflecting trends in increasing truck market share. In 2030, electricity is projected to represent less than 1% of fuels consumed in the car and light truck classes, and is not consumed at all in heavy truck or urban bus classes.

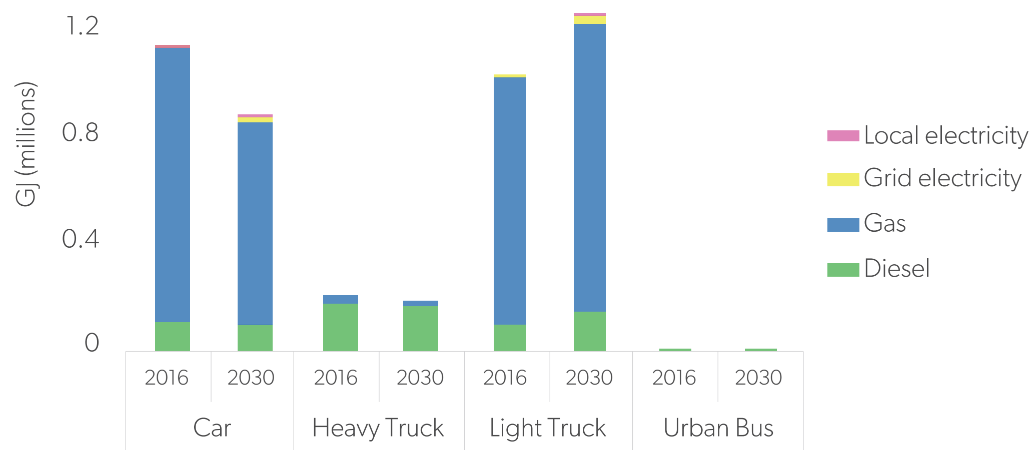


Figure 17. Energy consumption fuel vehicle class and fuel, in 2016 and 2030.

In both 2016 and 2030, emissions are predominantly from gasoline use. Emissions decline slightly by 4 ktCO_2e (Figure 19). The decline is likely due to increasing use of electric vehicles for personal vehicle trips and increasing efficiency of combustion engine vehicles.

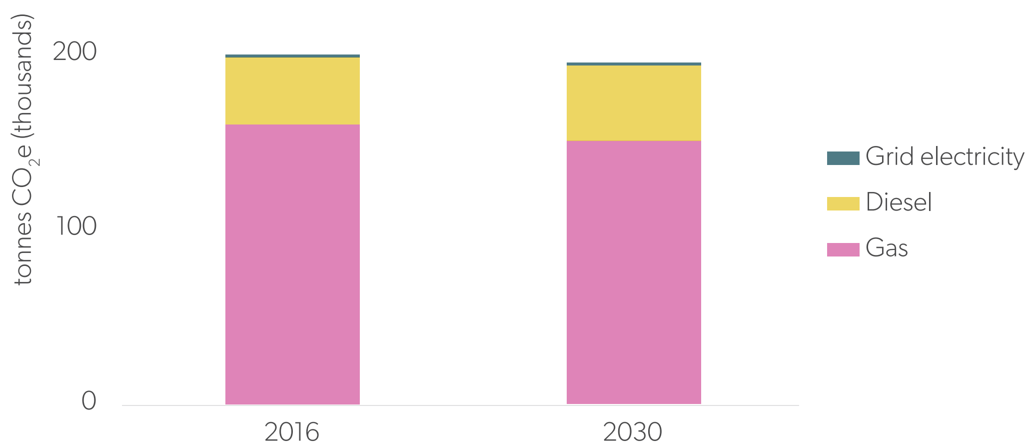


Figure 18. Transportation emissions by fuel, in 2016 and 2030.

5.4 WASTE AND WASTEWATER

Waste emissions decline slightly between 2016 and 2030 (Figure 19). This decline reflects an increasing organic waste diversion rate, which outweighs the projected increase in organic waste generation from a growing population.

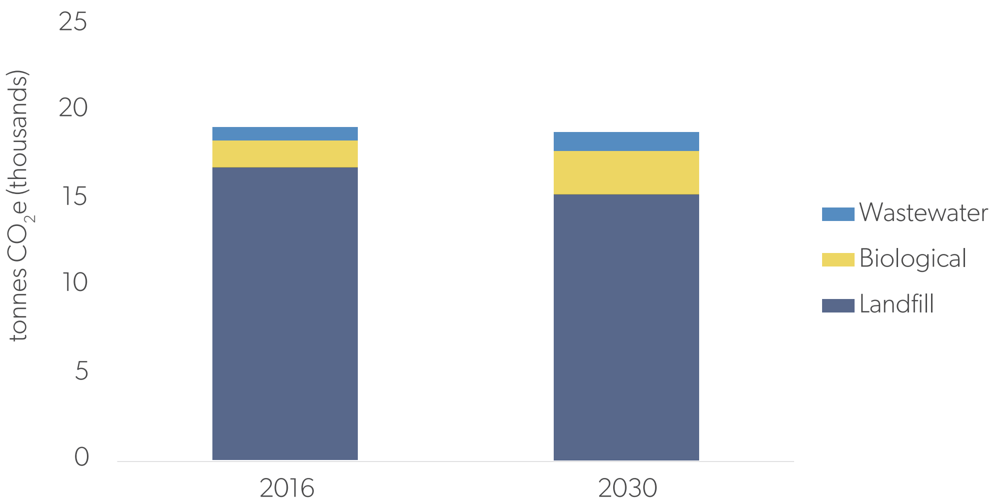


Figure 19. Waste and wastewater emissions, 2016 and 2030.

5.5 OTHER

The Reference Scenario also accounts for methane emissions from agricultural livestock. Agriculture makes up 2% of total emissions in Halton Hills. These emissions are expected to remain constant between 2016 and 2030.

6. Conclusions and Next Steps

Total emissions in the Town of Halton Hills are projected to marginally increase if no additional interventions are made. In the reference scenario, emissions from residential and industrial buildings increase, while all other sectors see small declines in emissions. Generally, total emissions increase is the result of its projected population growth, although per capita emissions do decline consistently between 2016 and 2030 from small gains in energy and waste efficiency. If no further action is taken, the Town is estimated to be 489 ktCO_2e over its net-zero emissions target in the year 2030.

Ambitious action will be needed to reach its emissions reduction target. As transportation and residential buildings are the largest contributors to emissions, these sectors should be the focus of action, although emissions will need to be addressed in all sectors to achieve net zero emissions by 2030. These ambitious actions to reduce emissions will be modelled in the net-zero scenario.

Reference Scenario Results Summary Tables

Table 3. Energy by Sector (GJ).

SECTOR	2016	%	2030	%
Commercial	1,071,601	13%	1,011,348	11%
Industrial	1,584,413	19%	1,909,620	22%
Municipal	72,446	1%	48,324	1%
Residential	2,620,586	31%	2,953,881	33%
Transportation	2,992,639	36%	2,950,082	33%
Total	8,341,685	100%	8,873,255	100%

Table 4. Energy consumption by fuel (GJ).

FUEL	2016	%	2030	%
Diesel	537,183	6%	572,641	6%
Fuel Oil	313,369	4%	330,815	4%
Gasoline	2,369,554	28%	2,244,737	25%
Grid Electricity	1,601,633	19%	1,955,460	22%
Local Electricity	18,058	0%	24,283	0%
Natural Gas	3,081,390	37%	3,296,448	37%
Other	214,901	3%	242,000	3%
Propane	168,676	2%	160,996	2%
Wood	36,920	0%	45,874	1%
Total	8,341,685	100%	8,873,255	100%

Table 5. Energy by end-use (GJ).

END USE	2016	%	2030	%
Industrial Processes	1,207,854	14%	1,503,644	17%
Lighting	250,545	3%	284,616	3%
Major Appliances	167,168	2%	227,029	3%
Plug Load	336,133	4%	409,628	5%
Space Cooling	80,262	1%	101,118	1%
Space Heating	2,562,879	31%	2,470,512	28%
Transportation	2,992,639	36%	2,950,082	33%
Water Heating	744,205	9%	926,626	10%
Total	8,341,685	100%	8,873,255	100%

Table 6. Energy by sector and fuel (GJ).

SECTOR	YEAR	DIESEL	FUEL OIL	GASOLINE	GRID ELEC.	LOCAL ELEC.	NATURAL GAS	OTHER	PROPANE	WOOD
Commercial	2016	0	9,819	0	287,343	3,240	697,954	0	73,246	0
	2030	0	8,880	0	345,546	4,291	594,114	0	58,516	0
Industrial	2016	0	188,430	0	547,351	6,171	645,006	129,035	31,499	36,920
	2030	0	234,356	0	634,603	7,881	787,522	160,328	39,057	45,874
Municipal	2016	0	340	0	28,775	324	40,101	0	2,906	0
	2030	0	288	0	23,551	292	22,623	0	1,571	0
Residential	2016	0	114,780	0	738,128	8,322	1,698,330	0	61,025	0
	2030	0	87,290	0	901,356	11,193	1,892,189	0	61,852	0
Transpor tat ion	2016	537,183	0	2,369,554	37	0	0	85,865	0	0
	2030	572,641	0	2,244,737	50,405	626	0	81,673	0	0

Table 7. Fuel by on-road vehicle class (GJ).

VEHICLE	YEAR	DIESEL	GAS	GRID ELECTRICITY	LOCAL ELECTRICITY
Car	2016	107,235	1,029,532	20	0
	2030	102,205	756,560	18,230	226
Heavy truck	2016	179,821	24,908	0	0
	2030	168,806	23,417	0	0
Light truck	2016	316	0	0	0
	2030	1,580	0	0	0
Urban bus	2016	99,887	931,044	17	0
	2030	150,947	1,075,676	32,175	400

Table 8. Emissions by sector (tCO_2e).

SECTOR	2016	%	2030	%
Agriculture	8,083	2%	8,083	2%
Commercial	41,721	9%	40,414	8%
Fugitive	10,754	2%	11,014	2%
Industrial	51,683	11%	70,846	14%
Municipal	2,411	1%	1,714	0%
Residential	101,151	22%	121,085	25%
Transportation	221,704	49%	217,032	44%
Waste	19,064	4%	18,667	4%
Total	456,571	100%	488,856	100%

Table 9. Emissions by fuel (tCO_2e).

FUEL	2016	%	2030	%
Diesel	39,613	9%	42,180	9%
Fuel Oil	22,291	5%	23,538	5%
Gasoline	158,853	35%	150,551	31%
Grid Electricity	14,330	3%	41,230	8%
Jet Fuel	23,238	5%	23,238	5%
Natural Gas	149,970	33%	160,436	33%
Non Energy	37,900	8%	37,764	8%
Propane	10,317	2%	9,847	2%
Wood	58	0%	72	0%
Total	456,571	100%	488,856	100%

APPENDIX D: Financial Analysis

July 2021

Purpose of this Document

This document provides a summary of the projected costs, revenues, and savings represented by the Town of Halton Hills Low-Carbon Transition Strategy (LCTS). The pathway's financial impacts are assessed as a whole and on an action-by-action basis.

A detailed analysis of the net-zero scenario modelled as the basis of the LCTS is provided in Appendix C.

Contents

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

This analysis includes strategic-level estimates of capital investments and related revenues, energy savings, and avoided costs of carbon represented by the proposed Low-Carbon Transition Strategy (LCTS). The intent of this analysis is to help inform project stakeholders about the potential costs and savings represented by the LCTS in relation to the modelled reference scenario. It should not be relied upon for other purposes without verification. The authors do not accept responsibility for the use of this analysis for any purpose other than that stated above and do not accept responsibility to any third party for the use, in whole or in part, of the contents of this document.

This analysis applies to the Town of Halton Hills and cannot be applied to other jurisdictions without further analysis. Any use by the Town of Halton Hills, its sub-consultants or any third party, or any reliance on or decisions based on this document, is the responsibility of the user or third party.

ACRONYMS

AV	autonomous vehicle
BAP	business-as-planned
GHG	greenhouse gas
LCTS	Low-Carbon Transition Strategy
NPV	net present value
MAC	marginal abatement cost
MACC	marginal abatement cost curve
PV	photovoltaic
RNG	renewable natural gas

Overview

The following table highlights the key findings from the financial analysis of the net-zero scenario modelled for the Town of Halton Hill's Low-Carbon Transition Strategy (LCTS). Further details about what is captured in each financial estimate are provided in the body of the report, as indicated in the right-hand column.

Table 1. Summary of high-level financial analysis of Halton Hills' LCTS.

FINANCIAL ESTIMATE	KEY RESULTS	WHERE TO FIND FURTHER DETAILS
The net benefit of the LCTS investments, 2021-2069	≈ $854 million, NPV.	NPV, Figure 4
Total incremental capital investment, 2021-2030	≈ $1,966 million NPV.	NPV and MAC Values
Total savings (avoided energy maintenance and carbon costs), 2021-2069[1]	≈ $1,397 million, NPV.	Cash Flow Analysis
Total revenue, 2021-2069	≈ $1,423 million, NPV.	Cash Flow Analysis
Average cost to reduce each tonne of GHG	≈ $448 in savings, NPV.	Table 3
Most cost-effective GHG-reduction action ($/ tonne CO_2e)	Ground mount solar: ≈ $4,000 in savings Municipal fleet electrification: ≈ $2,000 in savings Residential and commercial rooftop solar PV: ≈ $1,300-2,100 in savings Personal use vehicle electrification: ≈ $900 in savings	Table 3
Household savings on energy, 2021-2030 (annual)	≈ $1,380 on average	Pt. 2, Cost Savings for Households

WHAT IS AND IS NOT INCLUDED

The following five categories of costs and savings are included in this financial analysis:

- capital costs,
- maintenance costs,
- revenues,
- energy costs/savings, and

[1] While the capital investments in the LCTS all occur by 2030, the savings and revenue from many of those investments continue well beyond 2030 and are tracked in this analysis to the year 2069.

- carbon cost savings.

Operating costs associated with actions (e.g., administration, education, or marketing costs) are not included in this analysis.

Where defensible cost and savings are not identified for particular actions, they are excluded from the financial analysis. As a result, the following LCTS actions are not included in this financial analysis:

- district energy,
- electricity distribution system costs,
- active transportation (a detailed study would be required to provide an estimate of the capital costs required),
- sustainable soil management (a detailed study required to determine what programs are needed and what they would cost), and
- off-road vehicle electrification (missing data on current fleet vehicle share type).

An exception was made in the case of long-distance transit, which was included despite lack of data for capital costs, as these costs are likely to be spent by higher levels of government, and the benefits are likely to be experienced locally.

Part 1. Key Financial Analysis Concepts

The direct financial impacts of Halton Hills' Low-Carbon Transition Strategy (LCTS) provide important context for local decision-makers. However, it is important to note that the direct financial impacts are a secondary motivation for undertaking actions that reduce greenhouse gas (GHG) emissions. First and foremost, GHG reductions are a critical response to the global climate emergency. In addition, most measures included in the LCTS provide social goods to the community, such as net job creation and positive health outcomes. These benefits are only marginally captured in this financial analysis via the cost of carbon.

Key concepts that are used to analyze the financial impacts of the LCTS are summarized below.

COSTS ARE RELATIVE TO THE BAP

This financial analysis tracks projected costs and savings associated with net-zero measures that are above and beyond the assumed "reference" costs under a business-as-planned (BAP) scenario, which is a projection of current plans and policies.

DISCOUNT RATE

The discount rate is the baseline growth value an investor places on their investment dollar. A project is considered financially beneficial by an investor if it generates a real rate of return equal to or greater than their discount rate.

An investor's discount rate varies with the type of project, the duration of investment, risk, and the scarcity of capital.

The social discount rate is the discount rate applied for comparing the value to society of investments made for the common good. As such, it is inherently uncertain and difficult to determine. Some argue that in the evaluation of climate change mitigation investments a very low or even zero discount rate should be applied. In this project, we evaluate investments in a net-zero future with a 3% discount rate.[2]

NET PRESENT VALUE

The net present value (NPV) of an investment is the difference between the present value (PV) of the future stream of savings and revenue generated by the investment and the capital investment.

NPV= (PV savings + PV revenue) - PV capital investment

Five aggregate categories are used to track the financial performance of the net-zero actions in this analysis: capital expenditures, energy savings (or additional costs), carbon cost savings (assuming the carbon price reaches $170/tonne CO_2e in 2030 and is held constant thereafter), operation and maintenance savings, and revenue generation (associated with renewable energy production facilities and some transit actions).

What is NOT included are administrative costs associated with implementing programs, as well as any energy system infrastructure upgrades that may be required. Similarly, the broader social costs that are avoided from mitigating climate change are not included in the financial analysis.

ABATEMENT COST

The abatement cost of an action is the estimated cost for that action to reduce one tonne of greenhouse gas emissions (GHG) and is calculated by dividing the action's net present value (NPV) by the total GHG emissions it reduces (tCO_2e) over its lifetime. For example, if a project has a NPV of $1,000 and generates 10 t$CO_2$e of savings, its abatement cost is $100 per t$CO_2$e reduced.

AMORTIZATION

The costs of major capital investments are typically spread over a period of time (e.g., a mortgage on a house commonly has a 25-year mortgage period). Amortization refers to the process of paying off capital expenditures (debt) through regular principal and interest payments over time. In this analysis, we have applied a 25-year amortization rate to all investments. This period has been selected as it is the average amortization period for home mortgages in Canada, and the majority of the investments included in the plan are similar infrastructure investments.

ENERGY AND CARBON COST PROJECTIONS

The energy cost projections (not including the federal cost of carbon or the fixed cost of delivery for natural gas and electricity) displayed in Figure 1 underlie the financial analysis. These

[2] 3% is the social discount rate recommended by the Treasury Board of Canada (Treasury Board of Canada Secretariat, Canadian Cost-Benefit Analysis Guide Regulatory Proposals, 2007, at 38). A social discount rate is recommended for instances where: regulatory proposal primarily affects private consumption of goods and services regulatory proposal's impacts occur over the long term (50 years or more) (Treasury Board of Canada, 'Policy on Cost-Benefit Analysis', policy effective as of September 2018, online: www.canada.ca/en/government/system/laws/developing-improving-federal-regulations/requirements-developing-managing-reviewing-regulations/guidelines-tools/policy-cost-benefit-analysis.html).

projections were derived from:

Halton Hills Hydro, the Ontario Energy Board, and the Canada Energy Regulator (electricity);

- Enbridge (natural gas);
- the US Energy Information Administration (propane); and
- the Canadian Energy Regulator (formerly National Energy Board) for all other fuels.

The financial analysis is sensitive to electricity and natural gas costs. Electricity costs are projected to increase more rapidly than natural gas; if natural gas costs increase more rapidly, then the financial benefit of many of the actions increases. The impact of increasing or decreasing energy costs are outlined in the sensitivity analysis at the end of this report.

An escalating cost of carbon, based on federal regulation, was applied out to 2030.

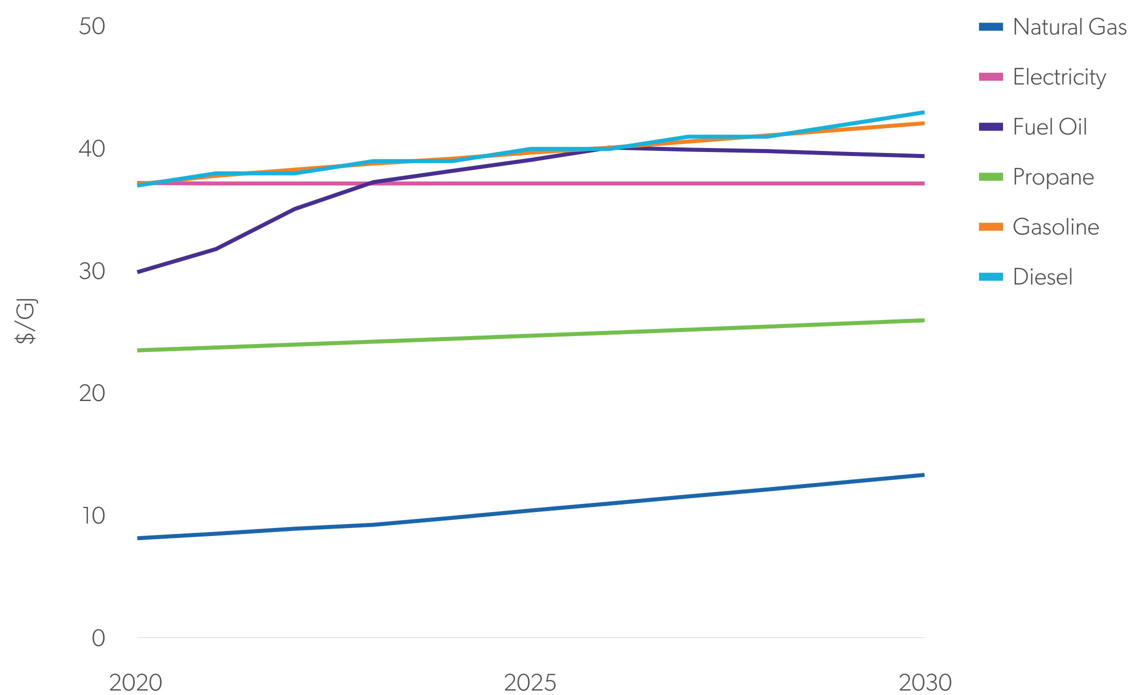


Figure 1. Projected energy costs (not including the federal cost of carbon).

Part 2. Town of Halton Hills LCTS Financial Analysis Results

ABATEMENT COSTS

As outlined in Table 2 (below), the investments included in the LCTS presented here actually yield a negative cost of carbon; that is, the net savings and revenues they generate yield a positive financial return that translates to a weighted average benefit of $448/tonne of CO_2e reduced.[3] The values for the individual measures are included in Table 2; all measures that have a positive abatement cost (i.e., greater costs than benefits) are highlighted in red, all measures with a negative abatement cost (i.e., greater benefits than costs) are highlighted in green.

The most expensive actions are municipal retrofits, at $2,432 per tonne of CO_2e avoided. The municipality, in its leadership role, has set an ambitious target of retrofitting all of its buildings to net zero by 2030. This retrofit action is followed closely by residential retrofits for older homes, at $1,896 per tonne of CO_2e avoided, and for newer homes, at $1,483 per tonne of CO_2e avoided. Though not quite as ambitious as the municipality's retrofit program, the LCTS has set ambitious energy efficiency targets for the rest of the Town's buildings. However, the marginal abatement cost for these retrofit actions does not capture the savings from avoided increased energy generation infrastructure (i.e., new nuclear or other large-scale electricity generation facilities), which can be significant.

The autonomous vehicle car share (shift to AV) and local solar power generation have the lowest cost per tonne of GHG reduction. An autonomous electric vehicle car share program is expected to provide a net benefit of $6,343 per tonne of $C0_2$e avoided, primarily because it is expected to reduce the need for personal-use vehicles. Ground mount solar is estimated to provide $4,263 of fuel savings and revenue per tonne of avoided GHG emissions; followed by rooftop residential and commercial rooftop solar, at $2,126 and $1,338, respectively. Rooftop solar provides fewer benefits as there is no revenue associated with it; however, it does save fuel.

As mentioned at the outset of this report, no capital costs were modelled for long-distance transit, which explains why it is shown so positively in this analysis at $1,973 of benefits per tonne of GHG reduced. We decided to keep this action within this analysis, despite the missing data, as the costs are likely to be covered by higher-levels of government while the benefits are likely to be experienced locally.

Reviewing the following table action-by-action requires understanding the action's sequencing in the model (i.e., what the action is offsetting), which is not provided here as it would require a complex and lengthy model description. For this reason, what is most important when looking at the following table is the abatement cost for the entire plan, as well as identifying which actions are considered to have a positive versus negative abatement cost. Measures with a positive net present value (i.e., where the investment has a positive return of at least 3%) will therefore have a negative abatement cost (i.e., they would be worth doing even without consideration of the carbon benefits), whereas measures with a negative net present value will have a positive abatement cost (i.e., these are measures with returns less than 3%).

[3] This average is weighted in terms of actions that reduce more tonnes of GHGs influence the average more than actions that reduce less tonnes of GHGs, The net present value of the measures includes credit for the avoided costs of carbon ($170/tonne CO_2e by 2030); if that credit were excluded, the net savings per tonne of GHG mitigated would be correspondingly lower.

Table 6. Net present value and marginal abatement costs by action.

ACTION **(SEE APPENDIX A FOR ADDITIONAL DETAILS ON THE ACTIONS LISTED BELOW)**	CUMULATIVE EMISSIONS REDUCTION (KT CO_2EQ)	NET PRESENT VALUE	MARGINAL ABATEMENT COST ($ / T CO_2 EQ)
New residential buildings	133	$60,842,457	$458
Residential retrofits, pre-1980	217	$411,565,409	$1,896
Residential retrofits, post-1980	136	$202,395,768	$1,483
Residential heat pumps - non-retrofits	62	$8,646,493	$140
New non-residential buildings	71	-$50,341,935	-$711
Municipal buildings	4	$8,872,602	$2,432
Non-residential retrofits	92	$10,013,414	$109
Commercial heat pumps - non-retrofits	56	-$14,458,954	-$257
Industrial efficiency	98	$20,440,398	$210
Industrial switch to RNG	38	-$2,413,037	-$63
Residential rooftop solar PV	11	-$22,916,494	-$2,126
Commercial rooftop solar PV	9	-$12,074,066	-$1,338
Long-distance transit	15	-$29,485,258	-$1,973
Medium-distance transit	10	-$4,387,294	-$448
Work from home	71	-$105,136,142	-$1,477
Municipal fleet electrification	2	-$3,368,164	-$2,008
Commercial vehicle electrification	78	-$57,926,389	-$739
Tree planting	37	$917,394	$25
Electrify PUV	219	-$198,569,230	-$906
Shift to AV	24	-$153,069,082	-$6,343
Ground mount solar	206	-$878,128,964	-$4,263
RNG procurement	192	$10,790,711	$56
TOTAL	1,780.87	-$797,790,362	-$448

Marginal Abatement Cost Curve

Figure 3 shows the marginal abatement cost curve (MACC) for measures included in the Town of Halton Hills' LCTS.

While a MACC illustrates the financial profile of the suite of actions, it is an imperfect indicator. The presentation of the MACC implies that the actions are a menu from which individual actions can be selected. In fact, many of the actions are dependent on each other. For example, the energy use costs increase without retrofits. In addition, in order to achieve the Town's target all the actions need to be undertaken, as soon as possible. Delaying action for any reason, including waiting for technological improvements, will reduce the savings that can be achieved for households and businesses, and the new employment opportunities created.

The MACC provides useful insights that guide implementation planning. It helps answer critical questions, such as:

- Can high-cost and high-savings actions be bundled to achieve greater GHG emissions reductions?
- How can the Town help reduce the costs of the high-cost actions by supporting innovation or by providing subsidies?
- Which actions both save money and reduce the most GHG emissions? These can be considered "big" moves.
- Which actions are likely to be of interest to the private sector, assuming barriers can be removed or supporting policies introduced?

Such insights are illustrated in Figure 2.

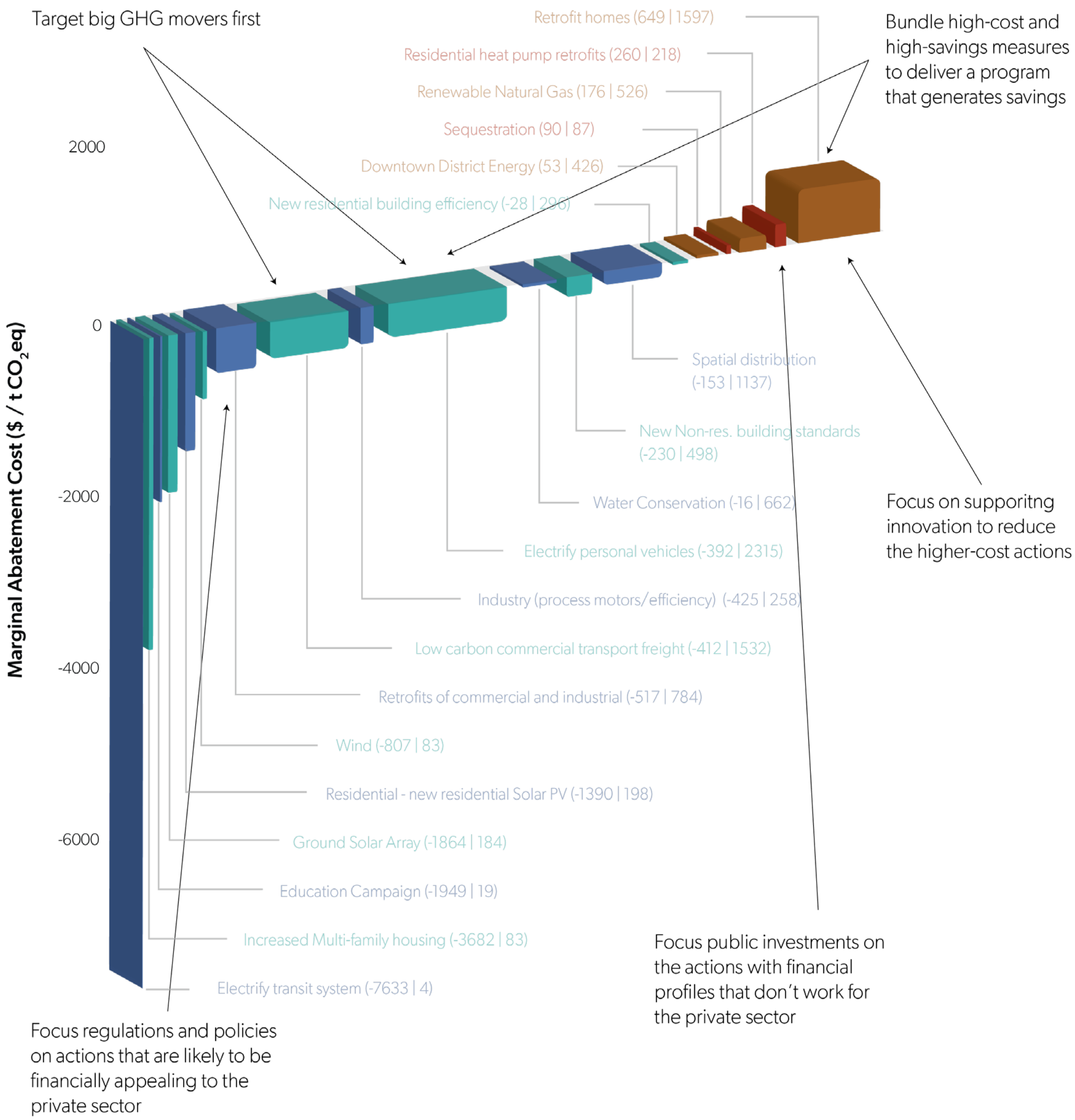


Figure 2. *Examples of the strategic uses of a marginal abatement cost curve analysis.*

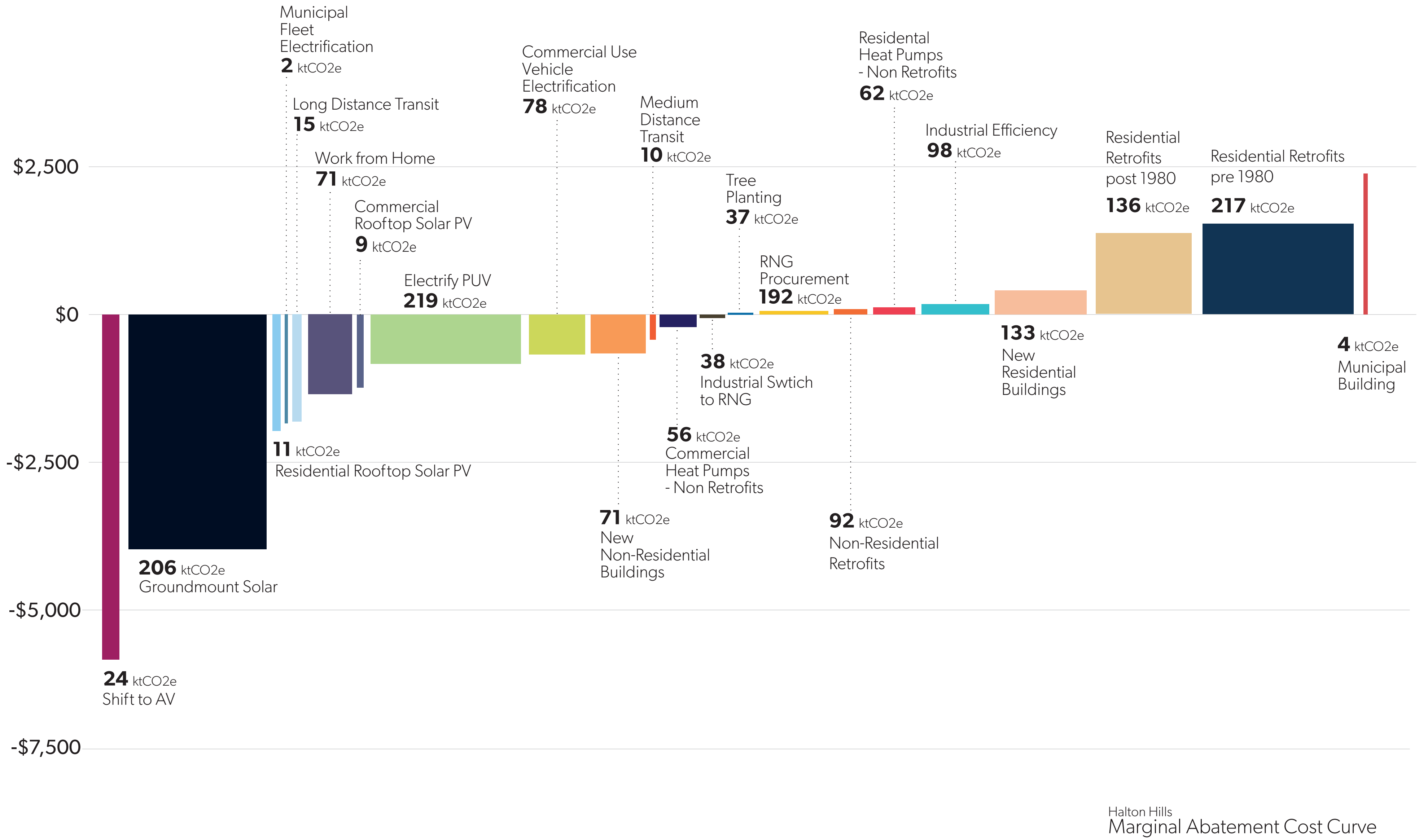


Figure 3. The Marginal Abatement Cost Curve (MACC) for the actions included in the LCTS.

Present and Net Present Values

As noted in the previous section, most of the actions in the net-zero scenario have positive net present values, as does the program of investments as a whole. Figure 4 shows the present value of the major components of the LCTS: investments, operations and maintenance savings, fuel and electricity savings, avoided costs of carbon, and revenue from transit and local energy generation. After discounting at 3%, the investments in the program have a present value of almost $2 billion and the savings and revenue have a present value of $1.4 billion. The NPV of the whole scenario is $854 million.

Even though capital investment for the plan ends in 2030, the NPV includes the energy, maintenance, carbon costs savings and projected revenue over the full life of the measures, which, in some cases, extends as far as 2069.

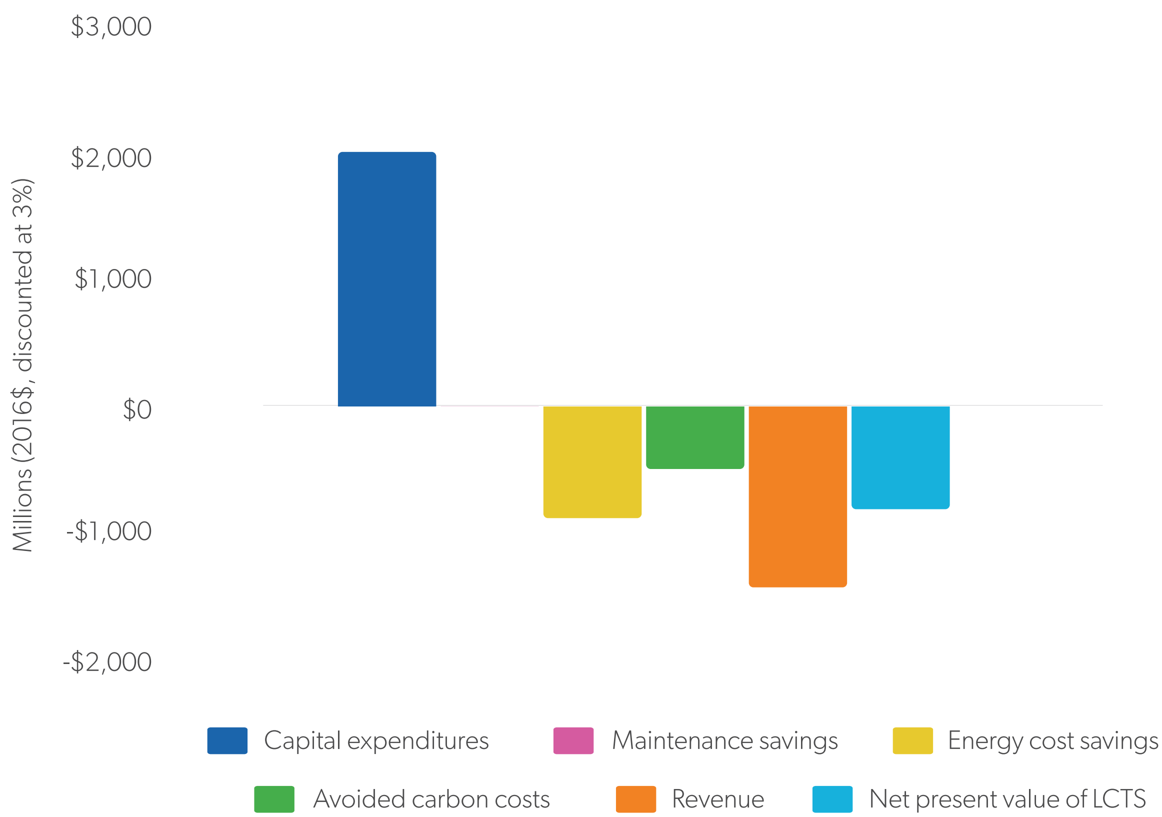


Figure 4. Present values of net-zero scenario costs, and savings, and net present value of the scenario. (Costs are positive in this convention, revenues and savings are negative)

Cash Flow Analysis

The annual costs, savings, and revenue associated with fully implementing the actions in the LCTS are shown in detail in Figure 5, with capital expenditures shown in full in the years in which they are incurred. (Please review the section 'What Is and Is Not Included', above.)

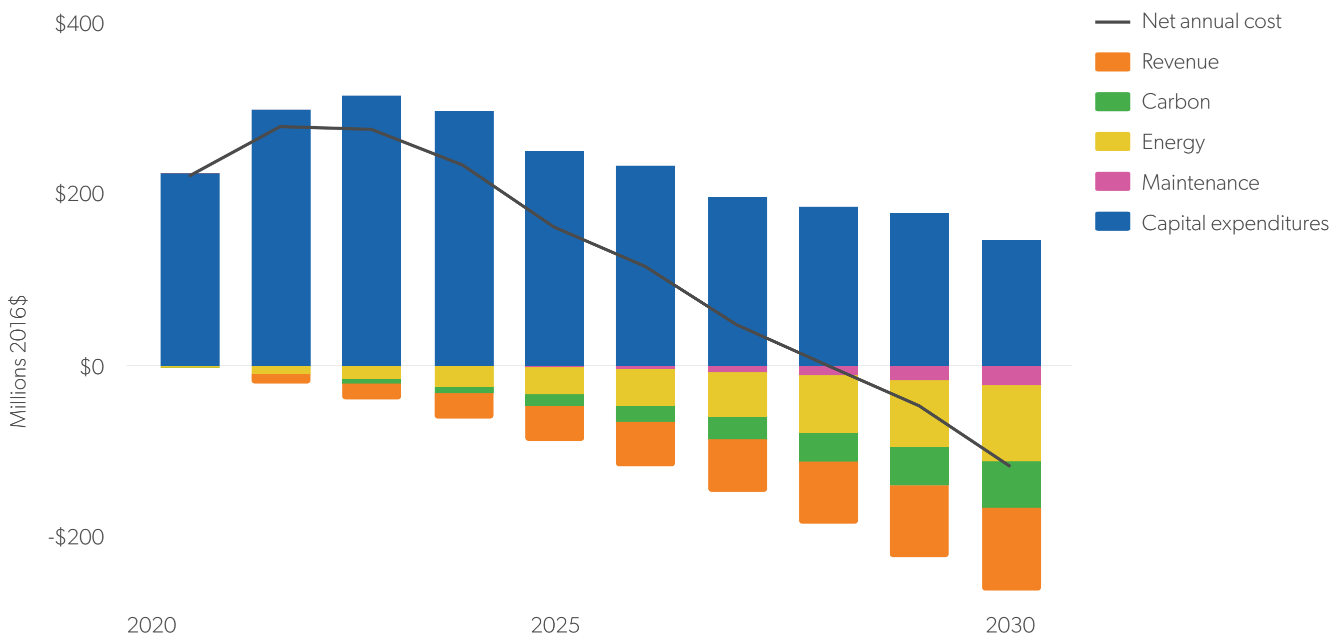


Figure 5. Capital expenditures vs. savings and revenues from the net-zero scenario, 2021-2030.

As is characteristic of net-zero transitions, the capital expenditures in the early years of the transition are significantly greater than the savings and revenues generated, but, by 2028, the annual benefits exceed the annual investments and the cumulative benefits are greater than the cumulative costs.

Figure 6 presents the same costs and benefits, but with the capital expenditures amortized over 25 years at 3%. With this approach, which presumably would reflect actual approaches for financing the transition, the annualized capital payments are about equal to the savings and revenue generation from 2024. On an annual basis, the program never has a significant annual deficit; there is a net annual benefit that grows steadily throughout the 2020s. By 2030, the annual net benefit is over $100 million. After 2030 (not shown in Figure 6), the benefits and revenues continue, resulting in continuing growth in the net annual benefit in the post-2030 period.

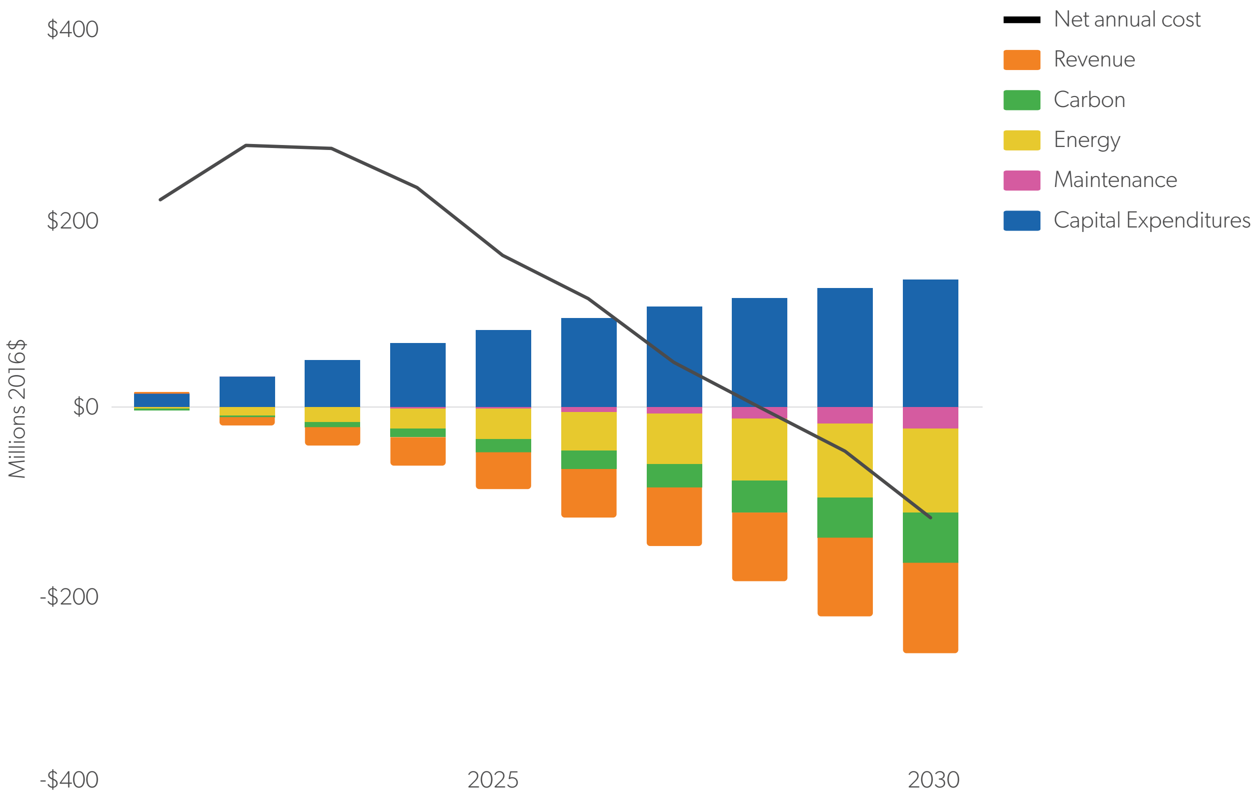


Figure 6. Annualized capital expenditures vs. savings and revenue from the net-zero scenario, 2021-2030.

Cost Savings for Households

Household expenditures on energy—natural gas, electricity, gasoline, and diesel—are projected to increase in the BAP and decline in the net-zero scenario. In the BAP, household energy expenditures are relatively flat because vehicles become more efficient due to national fuel efficiency standards and because of decreased heating requirements as the climate becomes milder due to climate change.

The net-zero scenario involves shifting away from natural gas and gasoline to electricity, a more costly energy source. The increased cost of electricity, however, is offset by the increased efficiency of homes and electric vehicles. The carbon price also adds to the cost of using fossil fuels for heating and transport.

In the net-zero scenario, an average Halton Hills household spends $2,500 on fuel and electricity (household energy and transportation expenditures) in 2030—almost 50% less than they would have in a BAP scenario ($4,700).[4]

Between 2022 and 2030, the LC scenario saves the average Halton Hills household about $12,400 in fuel and electricity expenditures. Depending on the business, policy and financing

[4] This does not include fixed energy bill charges (e.g., delivery charges), nor does it include the cost of carbon.

strategies used in the implementation of the actions, these savings will be partly offset by the incremental capital expenditures required.

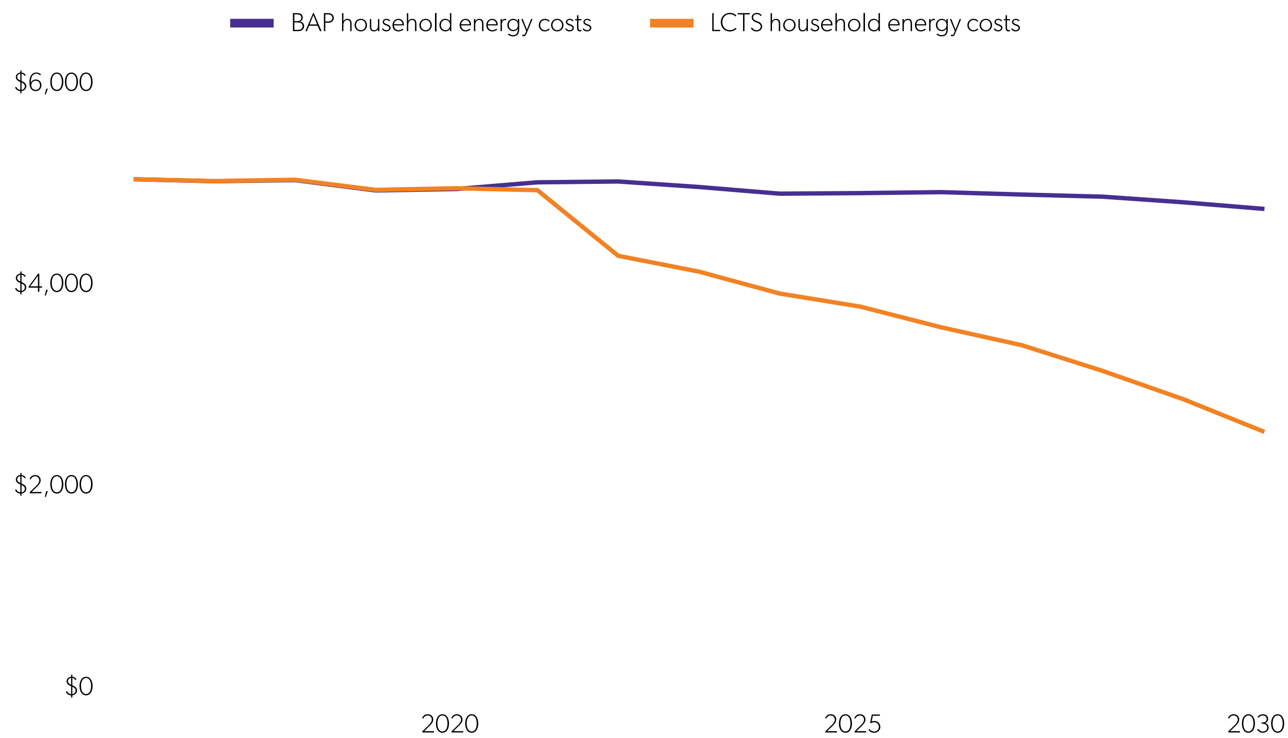


Figure 7. Average annual household energy costs in the net-zero and BAP scenarios, 2021-2030 (not including fixed delivery costs).

New Job Opportunities

Transitioning to a low- or zero-carbon economy is expected to have four categories of impacts on labour markets: additional jobs will be created in emerging sectors, some employment will be shifted (e.g., from fossil fuels to renewables), certain jobs will be reduced or eliminated (e.g., combustion engine vehicle mechanics), and many existing jobs will be transformed and redefined.

According to average job multipliers from Census Canada, the LCTS will result in a net job increase of about 1,400 jobs in Halton Hills (or 14,000-person years of employment over 10 years), primarily due to the investment in retrofits, followed by large scale solar (see Figure 8). The clean tech and renewable energy sectors have been identified by the Town's Economic Development Department as a target sector in its Economic Development and Tourism Strategy, and its Foreign Direct Investment Attraction Strategy.

The LCTS is likely to cause some minor job losses due to the proposed introduction of shared autonomous vehicle car-share service, which would replace the need for multiple personal use vehicles; however, these are minor relative to the jobs created.

Figure 8. Additional person-years of employment associated with LCTS actions.

Sensitivity Analysis

The financial analysis involves several assumptions on building, infrastructure, equipment, and energy costs. A sensitivity analysis was conducted to assess how uncertainties in future costs could affect the overall results. The following chart shows how changing key parameters (i.e., energy costs) in the model will affect the net-zero costs pathway for the Town of Halton Hills.

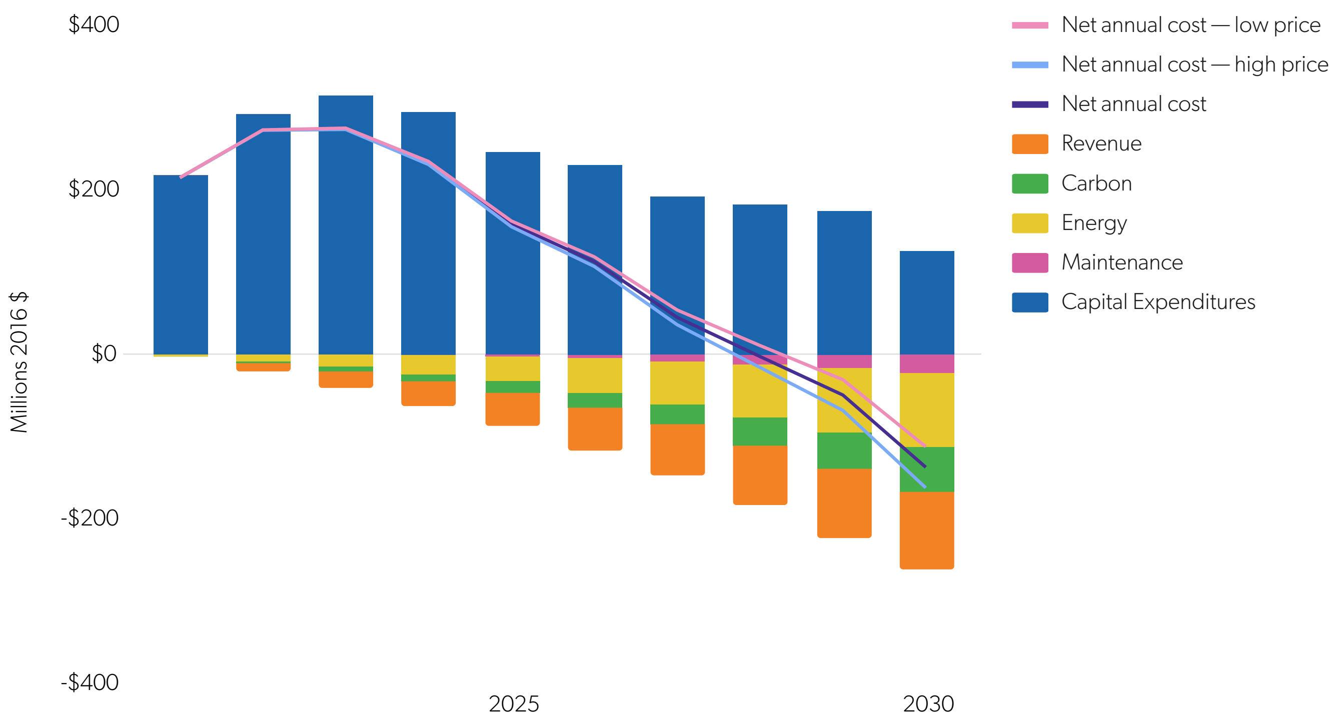


Figure 9. Sensitivity analysis of the energy costs for the LCTS investment and returns.

The sensitivity analysis, which is displayed in Figure 9, shows that, when you increase or decrease the overall energy costs by 20%, the net cost of the scenario in 2050 is affected by 18% in either direction. A major conclusion that can be drawn by this sensitivity analysis is the important co-benefit of energy efficiency and local energy generation measures in terms of hedging against future energy price increases.

APPENDIX **D.1—Key Financial Assumptions**

SECTOR	CAPITAL INVESTMENT ASSUMPTION
LAND USE	
Land use intensification	Capital costs associated with land-use intensification encompass standard investment in the community, such as new housing developments. Generally speaking, with more infill development, new infrastructure spending decreases.
NEW BUILDINGS	
New residential buildings with heat pumps New industrial building efficiency New commercial building efficiency with heat pumps	The cost for new construction of buildings on a $/m^2 is estimated to be: • Single-detached: $1,776 / m^2 • Double: $1,426 / m^2 • Apt 1-6 storey: $2,314 / m^2 • Apt 7-12 storey: $2,422 / m^2 • Apt > 15 storey: $2,395 / m^2 • Commercial: $2,494/ m^2 • Industry: $3,229 / m^2 A residential heat pump has a capital cost of approximately $6,000 (non-residential is ~$10,000) and annual operating cost of approximately $160 annually (~$400 annually for non-residential).
EXISTING BUILDINGS	

Retrofits of homes and heat pumps
 	
Retrofits of commercial and industrial buildings
 	
Industrial improvements (process motors/efficiency)
	• The average cost of retrofits is assumed to be (per GJ/yr of energy saved):
	  ∘ Residential: $210-$2,100
	  ∘ Non-Res: $1,600-$2,900
	• Industrial upgrades average the following in 2022 and 2050 per GJ/year
	  ∘ Lighting system: $134 ⇢ $59
	  ∘ Space heating: $25 ⇢ $34
	  ∘ Water Heating: $32 ⇢ $49
	  ∘ Motive: $66 ⇢ $176
	  ∘ Process heat: $27 ⇢ 43

RENEWABLE ENERGY	

SECTOR	CAPITAL INVESTMENT ASSUMPTION
Rooftop Solar PV Ground Mount Solar	• Ground mount solar PV has a capital cost of approximately $1,760 per kW, which is expected to decrease to $1,463 by 2030. • Residential rooftop solar PV has a capital cost of approximately $3,437 per kW, which is expected to decrease to $1,087 by 2030.
TRANSPORT	
Establish local electric bus service Electrify municipal fleets Electrify personal vehicles Net-zero commercial transport activity	• Today electric buses cost approximately $630,000, and are expected to cost less than a diesel bus by 2031. A fast charger costs about $140,000, and is assumed to be needed on a 1:20 ratio with electric buses. Electric bus maintenance costs are approximately 30% lower than for diesel buses. • The cost of a personal electric vehicle is approximately $34,000 in 2021 and is expected to decrease to $32,000 by 2030, dropping below the cost of an average combustion engine vehicle by 2025. As of today, maintenance costs for an EV are assumed to be half of those for combustion engine vehicles. • Heavy duty combustion engine vehicles are not expected to reach cost parity with their electric counterparts by 2050. • Fuel cost of gasoline is expected to increase by 11% by 2030 due to the carbon tax and market factors.
WASTE AND WASTEWATER	
10% less water use (technology and behaviour change) Wastewater process efficiency	• The cost of behaviour change programs will be based on the cost of Town staff and communications. • Improving wastewater process efficiency will cost an estimated $210 per tonne of GHG reduced.
NATURAL ENVIRONMENT AND SEQUESTRATION	
Tree planting	• Tree planting will cost over $900,000.

APPENDIX E: LCTS Implementation Framework

September 2021

Purpose of this Document

The Implementation Framework provides guidance for the near-term implementation of the LCTS. It is not a comprehensive list. Many of these actions have the potential for greater efficiency and effectiveness if done in collaboration with other neighbouring municipalities, levels of government, and organizations. These opportunities should always be explored first.

Contents

Acronyms

CAP	Clean Air Partnership
CCAM	The Town's Climate Change and Asset Management division
EV	Electric Vehicle
GHG	Greenhouse Gas
HEN	Halton Environmental Network
KPI	Key Performance Indicator
LCTS	Low-Carbon Transition Strategy
LCTS-SC	Low-Carbon Transition Strategy Steering Committee
MSGC	Multi-Stakeholder Governance Committee
SMEs	Small and Medium Enterprises
TAF	The Atmospheric Fund
ToHH	Town of Halton Hills

Scope + Approach

This Implementation Framework provides a recommendation for the LCTS implementation oversight structures as well as series of tables that systematically address the key near-term implementation actions included in the Low-Carbon Transition Strategy (LCTS) for the following six focus areas:

1. Administration and oversight;
2. Community energy efficiency and green development;
3. Low-carbon mobility;
4. Local renewable energy;
5. Natural asset management; and
6. Waste.

Each table provides information related to the action's potential:

- timing;
- leads and partners;
- resources required;
- immediate next steps; and,
- reporting metrics.

This framework is informed by feedback provided by the LCTS Multi-Stakeholder Governance Committee (MSGC), in particular the Implementation and Governance Subcommittee, as well as the Low-Carbon Transition Steering Committee. The MSGC and its membership, and the project's engagement process, are outlined in the body of the Final Report.

It is expected that the LCTS as well as this accompanying Implementation Framework would be reviewed, revised and updated at regular intervals (i.e., every 2-3 years).

The municipal corporation's internal net-zero program's implementation will be guided by the Town's internal decision-making process.

LCTS Implementation

A specific focus of the LCTS development process was long-term implementation oversight. The Town, with input from the MSGC and the LCTS-SC, identified the following priorities for the LCTS' long-term implementation:

- community oversight,
- innovation/nimbleness/flexibility,
- ability to turn to action as soon as possible,
- access to funding (from the public and private sectors), and
- access to municipal government powers and resources.

In the Short Term...

The Town's CCAM division will continue to lead LCTS implementation. This includes Town and community energy use and GHG reporting. This reporting will expand to include reporting on LCTS program KPIs.

The Town will be the lead of LCTS implementation, as soon as possible after Council approval of the LCTS, Town staff will report back to Council with a work plan for a new community-wide governance strategy.

Based on inspiration from the UK cities of Bristol and Preston, the Town will adopt a flexible LCTS program RFP process to enable local innovative solutions that prioritize local prosperity.

Medium Term (2-5 years)...

The Town will continue to lead implementation and partner with the private sector to deliver certain programs.

Meanwhile, the Town will assess via a feasibility study whether a third-party organization would be better placed to support the implementation priorities outlined above by providing the oversight and implementation of certain LCTS programs. This study will include consideration of regional collaboration opportunities.

Longer Term (5+ years)…

Subject to the results of the third-party implementation oversight body feasibility study, initiate a third-party implementation body to implement and oversee certain LCTS initiatives.

1. ADMINISTRATION AND OVERSIGHT

ACTION & TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Establish an updated community-wide governance strategy ASAP after Council approval	ToHH, CCAM Partners • LCTS-SC	• CCAM staff • Guidance from the LCTS-SC and the MSGC Implementation + Governance Subcommittee • Advice from other municipalities that have undertaken similar initiatives (e.g., Oakville, Guelph, Bristol, UK)	• Based on input from the MSGC and LCT-SC, Town to establish a workplan for a community-wide governance strategy.	• Annual reporting on program implementation
Continue to provide annual GHG and energy use reporting (for Town and broader community) ongoing	• ToHH, CCAM	• Continued staffing commitments	• Post the most recent year's energy use and emissions inventory	• Annual reporting, by sector and fuel • Tracking changes over time

ACTION & TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Develop and implement a climate lens for all Town budget decisions 2022: Staff training 2022-onwards: Implementation	ToHH, CCAM Partners: • CAP • FCM • TAF	• staff dedicated to developing the lens and providing staff training • Other municipalities that have developed and implemented climate lenses and carbon budgets (e.g., Edmonton, City of Toronto)	• Council approval and direction to Senior Management • Undertake staff training program	• Annual reporting on direct GHG emissions associated with the Town budget, by department (shown in comparison to the Town's carbon budget)
LCTS public education campaign 2022- onwards	ToHH, CCAM Partners: • HEN • Conservation Halton, Climate Action Committee, Councillors • ToHH, Economic Development Division • Chamber of Commerce • Halton Hills Hydro	• Dedicated staff • Federal funding campaign for the Green Recovery	• Build on existing CCAM work (e.g., Sustainability Champions campaign) • Contact local businesses and property owners to communicate the benefits of relevant LCTS programs • Identify points of influence • Showcase new technologies (e.g. EV days, and passive house open houses) • Understand barriers and opportunities so messages can be effectively tailored	• TBD

ACTION & TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Prepare request for proposals for key partnerships opportunities 2022- onwards	ToHH, CCAM Partners: • ToHH, Economic Development Division	• Examples from other communities, including Bristol, UK; Preston, UK; and Ithaca, New York	• Make contact with net-zero by 2030 communities that have recently published large climate action RFPs to learn best practices, e.g., how to ensure local and small business participation, equitable program design and delivery. • Based on these best practices, develop RFPs for the major LCTS programs, i.e., building retrofits and community energy systems	• Number of businesses that bid on RFPs, including local, minority-owned, and cooperative businesses
Feasibility study for the development of a third-party implementation body 2023-2025	ToHH, CCAM	• examples from other communities with various implementation body structures	• Study examples of and seek advice from other communities with various implementation body structures • Consult with local stakeholders that are likely to be involved, e.g., as directors • Based on these best practices, develop a formal recommendation for Council.	• -completion of feasibility study
Undertake regular reviews and updates of the LCTS Every 5 years	ToHH, CCAM	• annual reporting of GHGs • annual reporting of program KPIs • feedback form stakeholders • research on best practices in climate action (technologies, policies, regulations, and program design)	• Ensure annual reporting of community-wide GHG's and LCTS program KPIs • Track stakeholder feedback on program implementation • Track and research opportunities for new programs, technologies, policies, regulations to improve existing programs and to address the carbon gap • On an ongoing basis seek to pilot new solutions, the climate emergency does not wait for the 5-year review cycle • In 2025, draft a public-facing report, that clearly summarizes annual progress to date from implementing the LCTS, lessons learned, any new solutions that have been explored in the interim period, and changes to the LCTS going forward to improve implementation and address the carbon gap for 2025-2030.	• -completion of LCTS review and update in 2025

2. ENERGY EFFICIENCY AND GREEN DEVELOPMENT

ACTION + TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Residential retrofit program 2022: Feasibility study (underway) 2022-2023: Pilot 2024: Program deployment	ToHH, CCAM Partners: • ToHH Economic Development Division • Halton Hills Hydro • Halton Environmental Network (e.g., educational campaigns, funding applications, engagement, community facilitating, program management and implementation projects) • Energy auditors • Builders • Contractors/ suppliers • Community groups • Canadian Homebuilders Association • Chamber of Commerce • Building Industry and Land Development Association • Real estate agents	• HEN's retrofit study • PACE financing • Government funding (e.g., $40k and $5k zero-interest federal government loans) • Utility incentives	• Complete feasibility study (building on HEN's retrofit study) • Undertake pilot study, based on feasibility study, including financing and education campaign for homeowners and landlords • Based on learnings from the pilot study, expand program • Provide associated home-owner educational campaign, to ensure awareness of the program, the costs and benefits of participation, and depending on how the program is designed, a list of vetted service providers and a preliminary self-assessment tool • ToHH Economic Development Division to work with local partners to help attract and grow the Town's CleanTech sector (and increase awareness) which is one of the focus areas of the Town's Economic Development and Tourism Strategy	• Resident volunteers for pilot • GJ and GHGs saved per household or m2

ACTION + TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Commercial retrofit program 2022-3: Feasibility Study 2023: Piot 2024: Program development	ToHH, CCAM Partners: • ToHH, Economic Development Division • Halton Hills Hydro • HEN • SMEs • Energy auditors • Builders • Contractors/ suppliers • Chamber of Commerce • Building Industry and Land Development Association • Commercial real estate agents	• PACE financing • Government funding • Utility incentives • The Town's Economic Development and Tourism Strategy as well as Community Improvement Plan	• Complete an evaluation with 8-10 SMEs that outline concrete actions to achieve sustainability/ climate actions • Start to map out ecosystem of business that can support transformation • Undertake pilot study, including financing and education campaign for business owners and building managers • Based on learnings from the pilot study, expand program	• Number of participants • GJ and GHG saved per commercial space m2
Industrial process efficiency working group 2022- onwards	ToHH, CCAM Partners • ToHH, Economic Development Division • Local utilities • Local industry	• Federal government funding • Utility incentives • The Town's Economic Development and Tourism Strategy	• Establish an industrial working group with the aim of sharing best practices and resources (incl. funding)	• Local industry net-zero targets • GHG emissions reductions

ACTION + TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Industrial retrofit program 2023: Pilot + Feasibility Study 2023: Pilot 2024: Program development	ToHH, CCAM Partners: • Industrial process efficiency working group • ToHH, Economic Development Division • Halton Hills Hydro • HEN • SMEs • Energy auditors • Builders • Contractors/ suppliers	• PACE financing • Government funding • Utility incentives • The Town's Economic Development and Tourism Strategy as well as Community Improvement Plan	• Complete an evaluation with 3-6 local businesses that outline concrete actions to achieve sustainability/ climate actions, where possible, apply learnings from the commercial retrofit program • Start to map out ecosystem of business that can support transformation • Undertake pilot study, including financing and education campaign for industrial business owners and their energy managers • Based on learnings from the pilot study, expand program, leveraging any opportunity to link with the commercial retrofit program	• Number of participants • GJ and GHG saved per industrial space m2
New Construction Green Development Standards ongoing	ToHH, CCAM Partners: • ToHH, Economic Development Division • The Atmospheric Fund • Clean Air Partnership	• Green Development Standards • The Town's Economic Development and Tourism Strategy as well as Community Improvement Plan	• Start to reach out to developments as early as possible, highlight long-term costs and savings	• Number of developments achieving net zero

3. LOW-CARBON MOBILITY

ACTION + TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Expansion of EV charging infrastructure 2022-2025	• ToHH Partners • Halton Hills Hydro • Local businesses	• Halton Hills Hydro capital investment • Federal funding	• Assess current EV charging infrastructure and identify priority gaps in the system	• Number of publicly accessible EV charging stations • Number of EV charging stations per km2 in urban areas
Develop a Clean Transportation Education Program 2022- onwards	• ToHH Partners • Halton Hills Hydro • Local businesses • Plug & Drive	• In-kind staffing from all three partners • Space loaned from one partner • Vehicles from local dealers	An education program to encourage and incentivize zero emissions travel will include: • A first of a series of regular EV days is already being planned by MSGC members • Lessons learned from this session can be applied to ensure greater success of future session • An education program for resident personalized transportation planning, will also be developed	• Number of residents that attend and/or interact with staff • Number of test rides • Number of vehicles sold
Commercial fleet decarbonization working group 2022-ongoing	• ToHH Partners • Region • Local Conservation Authority (e.g., Credit Valley, Halton, and Toronto Region) • Chamber of Commerce • Local car dealerships • Local car and truck mechanics	• The Credit Valley Conservation Authority has developed a fleet decarbonization tool and associated training, and would be willing to share these resources with local organizations and enterprises	ToHH &/or IOB to establish: • A series of workshops on commercial fleet decarbonization planning (incl. access to and training on the tool) • Encourage the adoption of fleet decarbonization targets in line with the Town's net-zero by 2030 target	• Number of businesses setting fleet decarbonization targets • Number of zero-carbon fleet vehicles in use

ACTION + TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Bike share program 2022-2023: Complete a feasibility study. 2023-2024: Pilot Bike Share, based on outcome of feasibility study. 2024-2025: Evaluate the level of service of the program, based on the outcomes, consider expansion. 2026: Based on evaluation of level of service, explore the opportunity of a program expansion (possibly more bikes itself, e-bikes or e-scooters).	• ToHH Partners • Bike manufacturer • Bike mechanics • School board	• Neighbouring municipalities that have already undertaken bike-share programs (e.g., Hamilton) • Funding from the Town's climate action fund &/or from climate action funds available from the federal government or TAF	• Complete a feasibility study • Undertake a pilot program, with associated marketing campaign • Based on learnings from the pilot, and public feedback, expand the program	• Number of bikes in circulation • Number of bike rides and average duration • Individual interviews of bike share users
Local e-bus deployment 2022-2023: study (incl. identifying funding sources) 2023-onwards: deployment	ToHH & Region	• Federal funding	• Based on the results of the WSP study undertaken for the Town on the most effective local e-bus system routes (within and between the Town's major population and employment hubs, with a focus on connections to active transportation and regional transit networks), consult on proposed solutions with key stakeholders (i.e., Region, residents, major employers, etc.)	• Transit ridership

ACTION + TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Expansion of walking and biking trails 2021-onwards	ToHH & Region	• Town (esp. the Town's road infrastructure budget)	• Prioritize the Town's active transportation plan implementation • Prioritize connections between existing trails • Prioritize road diets rather than expanding roads in order to include active transportation infrastructure • Instead of looking for new budget, first reallocate road budgets where possible to active transportation	• Trail use data • kms of trails

4. LOCAL RENEWABLE ENERGY

ACTION + TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Ensure electricity system is planning to manage new demand and new supply mix 2022-onwards	IESO &/or Halton Hills Hydro Partners • -IESO or HHH • -Town • -Region	• Consultant with hourly electricity system planning expertise	• Hire a consultant to undertake an hourly analysis of how the energy efficiency improvements and electrification included in the LCTS will affect the electricity system, and how the demand can be balanced to ensure a stable, reliable grid	• Completion of study

ACTION + TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Large-scale solar 2022- onwards	ToHH (CCAM & Ec. Dev.) & Halton Hills Hydro Partners (ideally local) • - Developers • - Suppliers • - Manufacturers • Landowners	• A list of criteria for ideal large-scale solar sites (already developed by an MSGC working group) • a list of potential sites based on the above criteria (already developed by an MSGC working group) • ToHH Economic Development and Tourism Strategy	• Initiate a community energy mapping exercise to identify suitable locations and opportunities/barriers to implementation. • Publish an RFP for a project developer	• Express modelled ground mount capacity in clear layman terms
Renewable natural gas potential and anaerobic digester feasibility study 2023	Region Partners • ToHH (CCAM & Ec. Dev.) • HEN • Enbridge	• local organic waste from residences, businesses, agriculture • ToHH Economic Development and Tourism Strategy	• Town to meet with Region to discuss aligning the Region's organic waste management policies with the Town's net-zero target • Town collaborate with the Region undertake a feasibility and economic analysis of developing a centralized anaerobic digestion facility and gas refining facility, or potentially a gas sharing arrangement with a neighbouring facility like a greenhouse	• Study completion

ACTION + TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Renewable energy cooperative (REC) public education campaign & search for local leads 2022- onwards	ToHH (CCAM & Ec. Dev.) & Community LCTS Committee Partners - Local groups (TBD) - Halton Hills Hydro	Existing RECs, e.g.: - Toronto REC - Ottawa REC - Lake of Bays REC - ToHH Economic Development and Tourism Strategy	- Town to provide public education campaign - Community LCTS Committee to support search for potential local groups to establish REC - Town to design renewable energy RFPs to enable participation by RECs	- Establishment of web page featuring key information/resources - Memo summarizing results of Committee search

5. NATURAL ASSET MANAGEMENT

ACTION + TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Ensuring appropriate density targets are established in new and existing urban areas, while investigating options to minimize additional settlement boundary expansions and policies to offset, where possible, any impacts of urban development in line with the LCTS 2022-onwards	ToHH Planning Department & Region of Halton Partners: • Local community organizations	• ToHH and Region's land planning expertise	• Town to identify opportunities to influence the Region's current land planning process to better align with the LCTS • Building local support for density/ intensification by providing a vision of what this looks like and why it is good, while maintaining the small-town characteristics of Halton Hills • revise planning policies and others that prevent/obstruct development of walkable communities. ie. minimum parking requirements, zoning, etc. • Ensure enabling active transportation and transit networks are in place (per the ToHH Transportation Master Plan)	• People per hectare (urban areas) • Jobs per hectare (urban areas) • number of zoning applications to convert single family dwellings to multi-family dwellings • Km2 of greenfield development (with the aim of avoiding as much new greenfield development as possible)

ACTION + TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Low-Carbon Vision Georgetown 2022-onwards	ToHH Planning Department Partners • Developers • Local utilities	• Municipal capital budget • Neighbouring municipalities that have recently developed low-carbon communities (e.g., Markham and Brampton)	• Hire a consultant to develop a study of energy solutions for the community that are aligned with the net-zero by 2030 target (in progress) • Speak with staff contacts from neighbouring communities to gather information on best practice and key resources • Hold a developer workshop(s) • Develop an energy plan for the community that is aligned with the LCTS (underway)	• The development of an net-zero aligned energy plan for the community
Tree planting program 2022-onwards	ToHH Partners • Local Conservation Authority (e.g., Credit Valley, Halton, and Toronto Region) • Trees 4 Halton Hills	• Town tree inventory (in development) • Conservation Authority funding (or advice on other sources of funding) • Local experience of Trees 4 Halton and Halton Conservation planting millions of trees with federal funding	• Develop a tree planting target and associated planting program	• Number of trees planted

ACTION + TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Soil health program assessment 2021-onwards	ToHH Partners • Province • Local Conservation Authority (e.g., Credit Valley, Halton, and Toronto Region) • Farming associations • Ontario Ministry of Agricultural, Farming and Rural Affairs	• Local sustainable soil management expertise (e.g., retired University of Guelph Prof. Ralph Martin) • Ontario Ministry of Agricultural, Farming and Rural Affairs	• Town to contact the Province, local Conservation Authorities, and farming associations to: • Identify applicable sustainable soil management programs and related carbon sequestration monitoring; and then, • Strategize key opportunities for the Town and local partners to build on this work	• Soil carbon measurement, over time

6. WASTE

ACTION + TIMING	POTENTIAL LEADS + PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Collaborate with the Region to help align the Region's waste management plan with the LCTS net zero by 2030 target and the goal of increasing local renewable energy production (incl. solutions for commercial and industrial facilities) 2022- onwards	CCAM Partners: • Region • HEN • Local businesses • Enbridge	• Regions' waste management department expertise • Regional, provincial and federal funding • HEN study on ToHH food waste, where it comes from, its impacts, and opportunities to reduce it • Enbridge's expertise and potential funding for anaerobic digester capacity potential studies	• Collaborate with Region to discuss their plans and how to collaborate to achieve net-zero and maximize production of local emissions-free energy	• Diversion rates • GJ of local RNG produced (if applicable)

APPENDIX F: Data, Methods, and Assumptions Manual

July 2021

Purpose of this Document

The Data, Methods, and Assumptions Manual has been created for the Town of Halton Hills to give an overview of the modeling approach and provide a summary of the data and assumptions being used as the foundation for the energy and emissions modeling. This allows for the elements of the modelling to be fully transparent, as well as lays a foundation for replication and updates of future modelling efforts that the Town of Halton Hills may wish to embark upon.

Contents

Glossary

Base Year: the starting year for energy or emissions projections.

Carbon dioxide equivalent (CO_2e): a measure for describing the global warming potential of a greenhouse gas using the equivalent amount or concentration of carbon dioxide (CO_2) as a reference. CO_2e is commonly expressed as million metric tonnes of carbon dioxide equivalent ($MtCO_2e$).

Cooling degree days (CDD): the number of degrees that a day's average temperature is above 18¨C, requiring cooling.

District energy: Energy generation within the municipal boundary that serves more than one building.

Emissions: In this report, the term 'emissions' refers exclusively to greenhouse gas emissions, measured in metric tonnes (tCO_2e), unless otherwise indicated.

Electric vehicles (EVs): an umbrella term describing a variety of vehicle types that use electricity as their primary fuel source for propulsion or as a means to improve the efficiency of a conventional internal combustion engine.

Greenhouse gases (GHG): gases that trap heat in the atmosphere by absorbing and emitting solar radiation, causing a greenhouse effect that unnaturally warms the atmosphere. The main GHGs are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

Heating Degrees Days (HDD): number of degrees that a day's average temperature is below 18oC, requiring heating.

Local electricity: Electricity produced within the municipal boundary and sold to the electricity system operator or used behind the meter.

Reference scenario: a scenario illustrating energy use and greenhouse gas emissions which aims to reflect current and planned policies and actions that are likely to be implemented.

Renewable Natural Gas (RNG): Biogas resulting from the decomposition of organic matter under anaerobic conditions that has been upgraded for use in place of fossil natural gas.

Sankey: a diagram illustrating the flow of energy through a system, from its initial sources to points of consumption.

Vehicle kilometres travelled (VKT): distance traveled by vehicles within a defined region over a specified time period.

Units of Measurement:

To compare fuels on an equivalent basis, all energy is reported primarily as petajoules (PJ) or sometimes as gigajoules (GJ) (a PJ is a million GJ). Greenhouse gas emissions are primarily characterized as Kilotonnes or megatonnes of carbon dioxide equivalents ($ktCO_2e$ or $MtCO_2e$) (a Mt is a thousand kt).

- An average house uses about 100GJ of energy in a year
- 100 liters of gasoline produces about 3.5 GJ
- A kilowatt-hour is .0036 GJ
- A terawatt-hour is 3.6 PJ
- Burning 50,000 tonnes of wood produces 1 PJ

A typical passenger vehicle emits about 4.7 metric tons of carbon dioxide per year.*

**Data provided by United States Environmental Protection Agency*

EMISSIONS AND ENERGY UNITS

GHG emissions	Energy
1 $mtCO_2$ = 1,000,000 tCO_2e	1 PJ = 1,000,000,000 J
1 $ktCO_2e$ = 1,000 tCO_2e	1 GJ = 1,000,000 J
1 tCO_2e = 1,000 $kgCO_2e$	1 MJ = 0.001 GJ
1 $kgCO_2e$ = 1,000 gCO_2e	1 TJ = 1,000 GJ
	1 PJ = 1,000,000 GJ

Accounting Framework

GLOBAL PROTOCOL FOR COMMUNITY-SCALE GREENHOUSE GAS EMISSION INVENTORIES (GPC)

The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) is used as the framework for reporting in CityInSight. The GPC is the result of an effort to standardize city-scale inventories by the World Resources Institute, C40 Cities Climate Leadership Group and ICLEI – Local Governments for Sustainability (ICLEI).[1]

The GPC provides a robust framework for accounting and reporting city-wide greenhouse gas emissions. It seeks to:

- Help cities develop a comprehensive and robust greenhouse gas inventory in order to support climate action planning;
- Help cities establish a base year emissions inventory, set reduction targets, and track their performance;
- Ensure consistent and transparent measurement and reporting of greenhouse gas emissions between cities, following internationally recognized greenhouse gas accounting and reporting principles;
- Enable city inventories to be aggregated at subnational and national levels;
- Demonstrate the important role that cities play in tackling climate change, and facilitate insight through benchmarking – and aggregation – of comparable data.

To date, more than 100 cities across the globe have used the GPC (current and previous versions) to measure their greenhouse gas emissions.

The GPC has been adopted by the following programs and initiatives:

- The Compact of Mayors (CoM)[2] is an agreement led by city networks to undertake a transparent and supportive approach to reduce city emissions and enhance resilience to climate change. CoM cities are required to measure and report greenhouse gas emissions using the GPC. The City of Toronto is currently committed as a Compact of Mayors city.
- 'carbonn Climate Registry' is the common, publicly available repository for the Compact of Mayors. It provides standard reporting templates to help cities report their GHG emissions using the GPC. Currently about 300 cities have reported their emissions using the carbonn Climate Registry.
- CDP runs the world's largest environmental reporting platform. More than 5,000 companies, 200 cities, and 12 states and regions use CDP's platform every year to report on their environment-related data, including GHG emissions, climate risks, water risks, and economic opportunities. CDP serves as the official reporting platform for C40 cities, the Compact of Mayors and the Compact of States and Regions. CDP supports cities in reporting their emissions using the GPC. The City of Toronto currently reports to CDP.

The GPC is based on the following principles in order to represent a fair and true account of emissions:

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[1] www.ghgprotocol.org/city-accounting.

[2] www.compactofmayors.org/.

- Relevance: The reported GHG emissions shall appropriately reflect emissions occurring as a result of activities and consumption within the city boundary. The inventory will also serve the decision-making needs of the city, taking into consideration relevant local, subnational, and national regulations. Relevance applies when selecting data sources, and determining and prioritizing data collection improvements.
- Completeness: All emissions sources within the inventory boundary shall be accounted for. Any exclusions of sources shall be justified and explained.
- Consistency: Emissions calculations shall be consistent in approach, boundary, and methodology.
- Transparency: Activity data, emissions sources, emissions factors and accounting methodologies require adequate documentation and disclosure to enable verification.
- Accuracy: The calculation of GHG emissions should not systematically overstate or understate actual GHG emissions. Accuracy should be sufficient enough to give decision makers and the public reasonable assurance of the integrity of the reported information. Uncertainties in the quantification process should be reduced to the extent possible and practical.

ROLE OF THE CITYINSIGHT MODEL: FUTURE EMISSIONS PROJECTIONS

A GHG reporting protocol, such as the GPC described above, defines a standard set of categories, breakdowns, scopes, boundary treatment methods, and estimation methods. These protocols are typically geared towards reporting historical periods of observed data, designed for governments or companies to disclose the emissions impacts or progress of recent years activities. However, such protocols offer limited guidance for the development of GHG emissions projections for future years, which requires additional layers of data, inputs, and assumptions to establish a trajectory of emissions estimates. Figure 1 below shows reported versus projected GHG emissions on a conceptual timeline.[3]

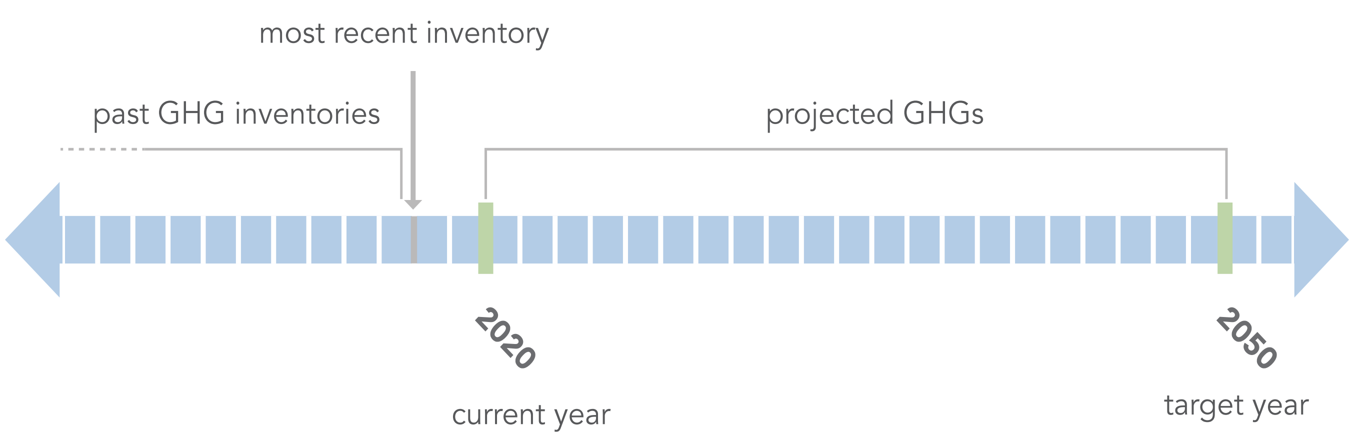

Figure 1. Conceptual timeline showing inventory reporting period and projection period.

[3] When a model is introduced things can become more complicated, with overlapping reported and modelled time ranges. A more detailed version of this diagram is presented in the appendix.

Projecting GHG emission scenarios in support of net-zero action planning requires:

1. the consideration of various alternative city plans, policies and contextual assumptions, and
2. the definition of the quantitative relationships between a city's activities, infrastructure, energy consumption, finances, and GHG emissions.

The CityInSight model facilitates this process by capturing these relationships in a computable form, allowing them to be altered, examined, and understood.

CityInSight, initially developed in 2015, is designed so that its representation of a city's GHG emissions can be exported to the GPC reporting standard. The model is calibrated for a specific model base year (2016 in the latest update) and can effectively produce a GPC inventory report for that year, as well as for all subsequent years in its projection horizon. Figure 2 below shows the major components of CityInSight and the relationship to the GPC reporting standard.

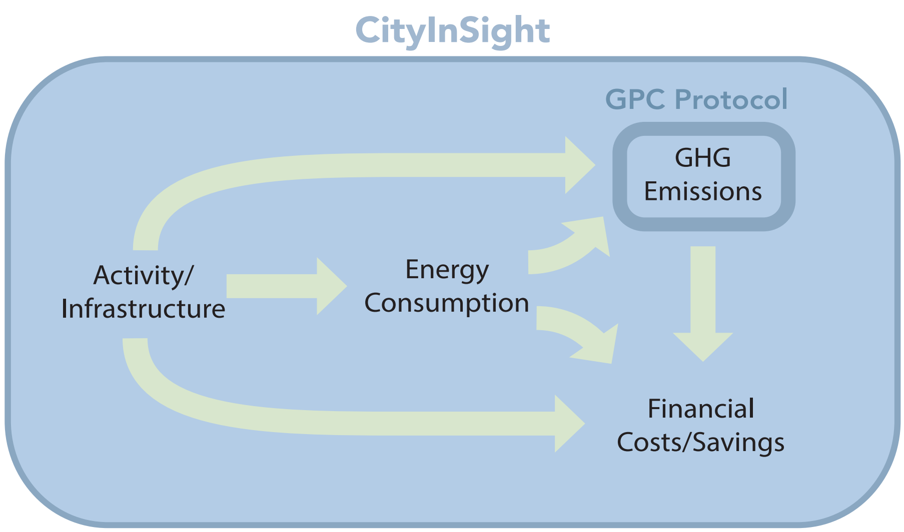

Figure 2. High-level components of CityInSight and relationship to the GPC reporting standard.

The GPC is billed as an accounting framework for city-level GHG emissions. CityInSight, as an integrated systems model, offers an extended accounting framework for community infrastructure, activity, energy, and financial flows, which is aligned with the GPC accounting framework. A description of the energy accounting structure in CityInSight is provided in Section 4.

Emissions Scope

GHG EMISSIONS SCOPE

The inventory and projects will include Scopes 1 and 2, and some aspects of Scope 3 emissions.

Table 1. GHG emissions scopes.

SCOPE	DEFINITION
1	All GHG emissions from sources located within the city boundary.
2	All GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the city boundary.
3	All other GHG emissions that occur outside the city boundary as a result of activities taking place within the city boundary.

The inventory addresses carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_20). Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6) and nitrogen trifluoride (NF_3) are not included. Emissions are expressed in CO_2 equivalents per the assumptions in Table 2.

Table 2. Global Warming Potentials for selected greenhouse gases.

GREENHOUSE GAS	CO_2 EQUIVALENTS	NOTES
CO_2	1	
CH_4	34	These have been updated in the IPCC 5th Assessment Report to include climate-carbon feedback.
N_20	298	These have been updated in the IPCC 5th Assessment Report to include climate-carbon feedback.

Modelling

ABOUT CITYINSIGHT

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

CityInSight incorporates and adapts concepts from the system dynamics approach to complex systems analysis. Energy and GHG emissions are derived from a series of connected stock and flow models. The model accounts for physical flows (i.e., energy use, new vehicles, vehicle kilometres travelled) as determined by stocks (buildings, vehicles, heating equipment, etc). For any given year within its time horizon, CityInSight traces the flows and transformations of energy from sources through energy currencies (e.g., gasoline, electricity) to end uses (e.g., personal vehicle use, space heating) to energy costs and to GHG emissions. The flows evolve on the basis of current and future geographic and technology decisions/assumptions (e.g., EV penetration rates). An energy balance is achieved by accounting for efficiencies, conservation rates, and trade and losses at each stage in the journey from source to end use. Characteristics of CityInSight are described in Table 3.

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

Table 3. Characteristics of CityInSight.

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

MODEL STRUCTURE

The major components of the model (sub-models), and the first level of modelled relationships (influences), are represented in Figure 3. These sub-models are all interconnected through various energy and financial flows. Additional relationships may be modelled in CityInSight by modifying inputs and assumptions—specified directly by users, or in an automated fashion by code or scripts running "on top of" the base model structure. Feedback relationships are also possible, such as increasing the adoption rate of non-emitting vehicles in order to meet a particular GHG emissions constraint.

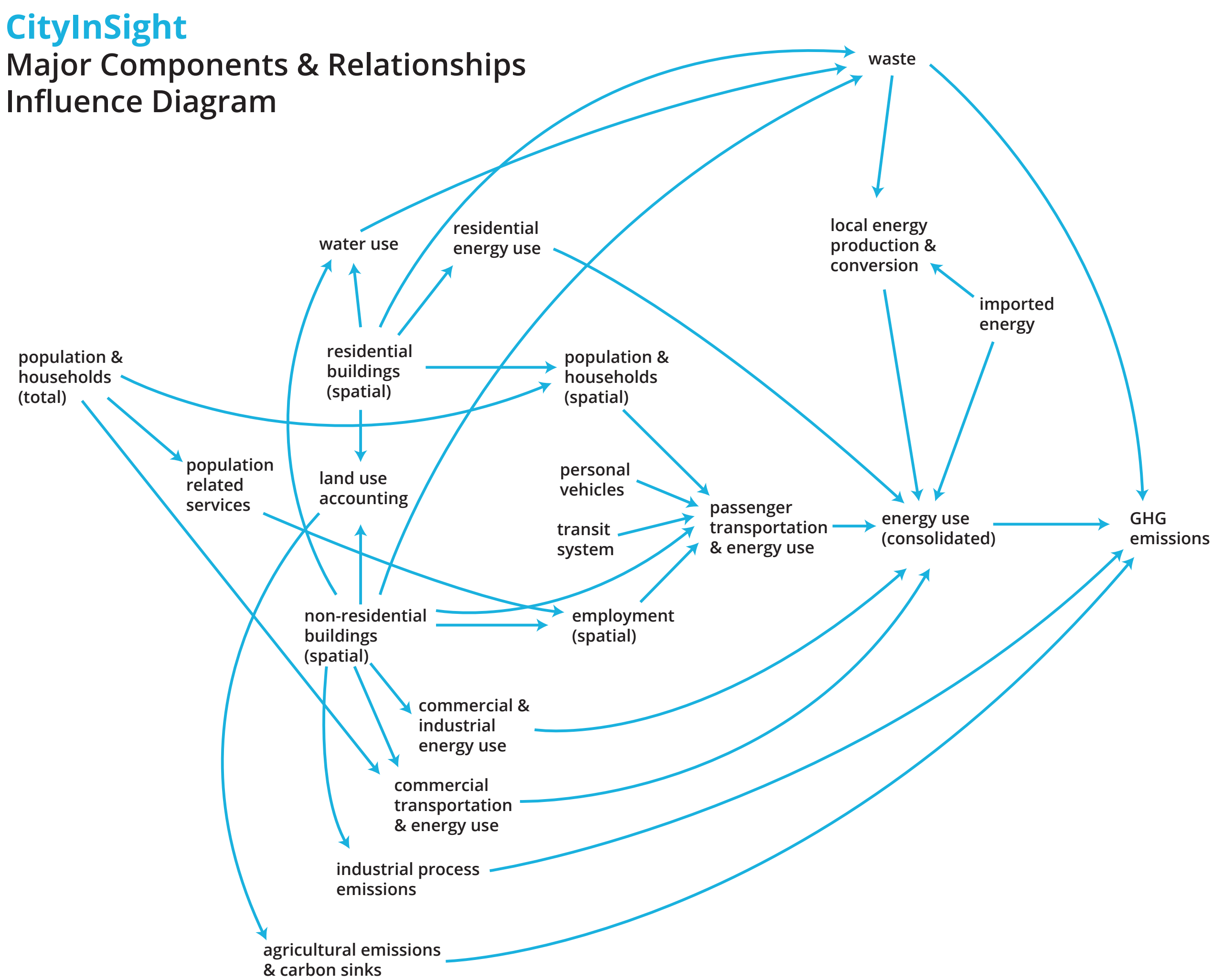

Figure 3. Representation of CityInSight's structure.

STOCKS AND FLOWS

Within each sub-model is a number of stocks and flows that represent energy and emissions processes in cities. For any given year various factors shape the picture of energy and emissions flows in a city, including: the population and the energy services it requires; commercial floorspace; energy production and trade; the deployed technologies which deliver energy services (service technologies); and the deployed technologies which transform energy sources to currencies (harvesting technologies). The model makes an explicit mathematical relationship between these factors—some contextual and some part of the energy consuming or producing infrastructure—making up the energy flow picture.

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

SUB-MODELS

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

Population, Households, and Demographics

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

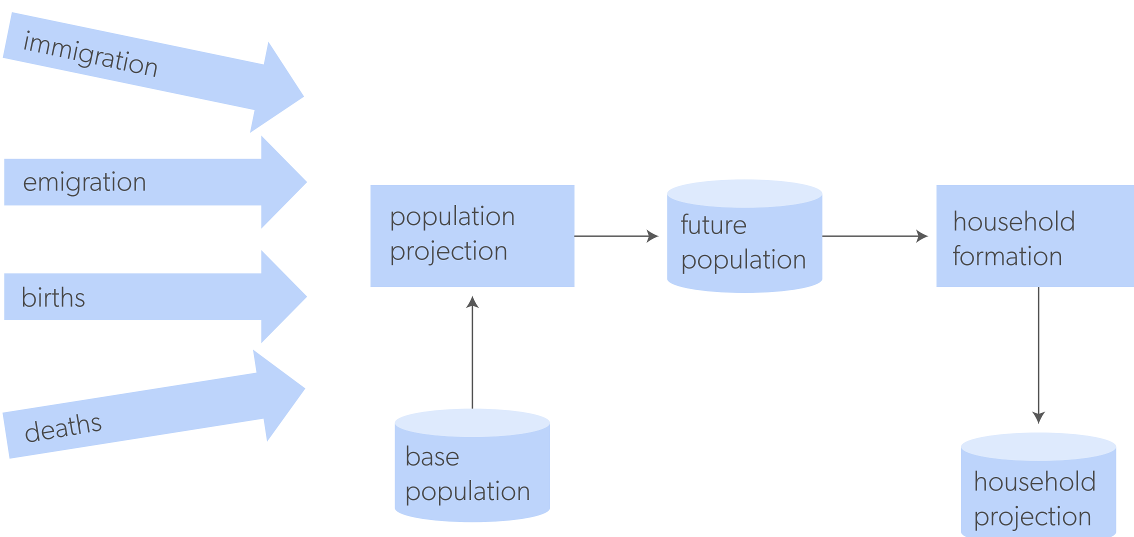

Figure 4. Representative diagram of stocks and flows in the population sub-model.

Building Land Use Accounting

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

- Quantitative spatial projections of residential dwelling units, by:
  - Type of residential structure (single detached, semi detached, row house, apartment, etc)
  - Development type (greenfield, intensification)
  - Population is assigned to dwelling units
- Quantitative spatial projections of non-residential buildings, by:
  - Type of non-residential structure (retail, commercial, institutional)
  - Development type (greenfield, intensification)
  - Buildings are further classified into archetypes (such as school, hospital, industrial - see Table 4).[4] This allows for the model to account for differing intensities that would occur in relation to various non residential buildings.
  - Jobs are allocated to zones via non-residential floor area, using a floor area per worker intensity.
- Land-use accounting takes "components of change" into account, year over year:
  - New development
  - Removals / demolitions
  - Year of construction
- Land use accounting influences other aspects of the model, notably:
  - Passenger transportation: the location of residential buildings influences where home-to-work and home-to-school trips originate, which in turn also influences their trip length and the subsequent mode selected. Similarly, the location and identification of non-residential buildings influences the destination for many trips. For example, buildings identified as schools would be identified in home-to-school trips.
  - Access to energy sources by buildings: building location influences access to energy sources, for example, a rural dwelling may not have access to natural gas or a dwelling may not be in proximity to an existing district energy system. It can also be used to identify suitable projects: for example, the location and density of dwellings is a consideration for district energy development.
  - Non-residential building energy: the identification of non-residential building archetypes influences their energy consumption based on their use type. For example, a building identified as a hospital would have a higher energy use intensity than a building identified as a school.

This relationship is simplified in Figure 5.

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

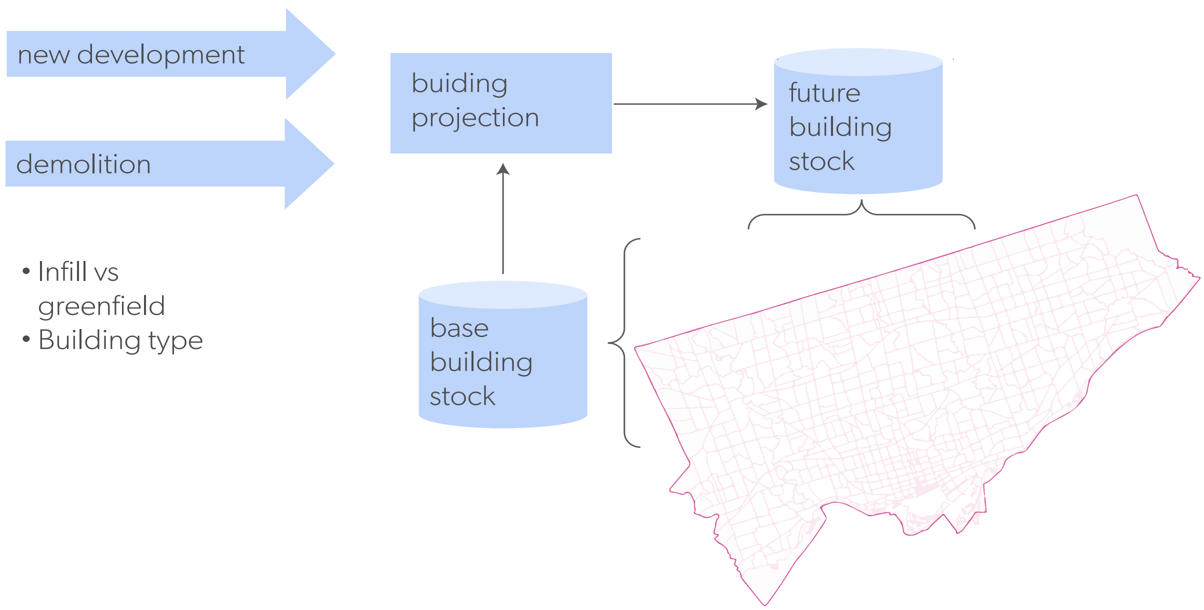

Figure 5. Diagram of land-use accounting sub-model.

Table 4. Non-residential archetypes represented in the model.

BUILDING ARCHETYPES	
college_university	commercial_retail
school	commercial
retirement_or_nursing_home	commercial_residential
special_care_home	retail_residential
hospital	warehouse_commercial
municipal_building	warehouse
fire_station	religious_institution
penal_institution	surface_infrastructure
police_station	energy_utility
military_base_or_camp	water_pumping_or_treatment_station
transit_terminal_or_station	industrial_generic
airport	food_processing_plants
parking	textile_manufacturing_plants
hotel_motel_inn	furniture_manufacturing_plants
greenhouse	refineries_all_types
greenspace	chemical_manufacturing_plants
recreation	Printing_and_publishing_plants
community_centre	fabricated_metal_product_plants
golf_course	manufacturing_plants_miscellaneous_processing_plants
museums_art_gallery	asphalt_manufacturing_plants
retail	concrete_manufacturing_plants
vehicle_and_heavy_equiptment_service	industrial_farm
warehouse_retail	barn
restaurant	

Residential and Non-Residential Building Energy

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

- Total energy use intensity of the building type (including the proportion from thermal demand) is built up from energy end uses in the building. End uses include heating, lighting, auxiliary demand, etc. The energy intensity of end uses is related to the building or dwelling archetype and its age.
- Then, energy use by fuel is determined based on the technologies used in each building (electricity, heating system types). From here, heating system types are assigned to building equipment stocks (heating systems, air conditioners, water heaters).
- Building energy consumption in the model also considers:
    - solar gains and internal gains from sharing walls;
    - local climate (heating and cooling degree days); and
    - energy losses in the building.
- Building equipment stocks (water heaters, air conditioners) are modelled with a stock-turnover approach that captures equipment age, retirements, and additions. In future projections, the natural replacement of stocks is often used as an opportunity to introduce new (and more efficient) technologies.
- The residential and non-residential building energy sub-model are two core components of the model. They influence and produces important model outputs:
    - Model outputs:
        - » total residential energy consumption and emissions and residential energy and emissions by building type, by end use, by fuel
        - » total non-residential energy consumption and emissions and residential energy and emissions by building type, by end use, by fuel
    - Local/imported energy balance: how much energy will need to be imported after considering local capacity and production.

Figure 6 details the flows in the energy sub-model at the building level. This is then aggregated across all buildings within the assessment boundary.

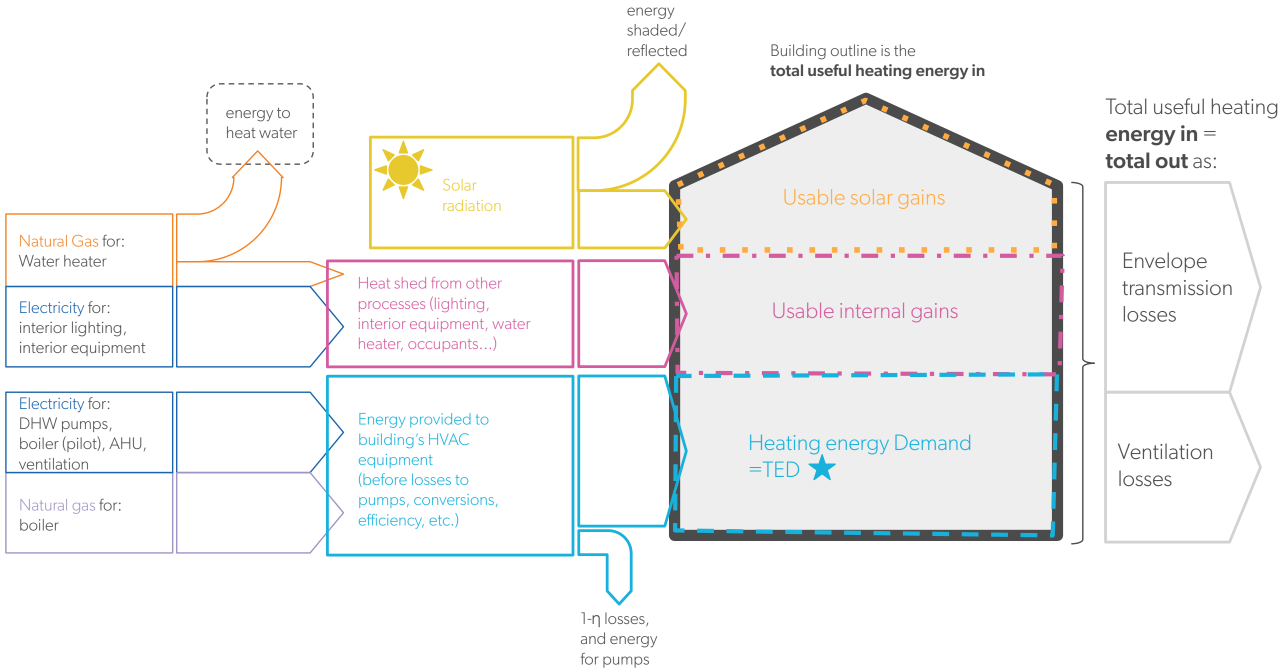

Figure 6. Building energy sub-model schematic.

Transportation

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

- CityInSight uses the induced method for accounting for transportation related emissions; the induced method accounts for in-boundary tips and 50% of transboundary trips that originate or terminate within the city boundary. This shares energy and GHGs between municipalities.
- The model accounts for "trips" in the following sequence:
    - Trip generation. Trips are divided into four types (home-work, home-school, home-other, and non-home-based), each produced and attracted by different combinations of spatial influences identified in the land-use accounting sub-model: dwellings, employment, classrooms, non-residential floorspace.
    - Trip distribution. Trips are then distributed with the number of trips specified for each zone of origin and zone of destination pair. Origin-Destination (O-D) matrix data is based on local travel surveys and transportation models.
    - Mode share. For each origin-destination pair, trips are shared over walk/bike, public transit and automobile.
        - » Walk / bike trips are identified based on a distance threshold: ~2 km for walking, ~5-10 km for biking.
        - » Transit trips are allocated to trips with an origin or destination within a certain distance to a transit station.

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

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

Trips accounted for in the model are displayed in Figure 7.

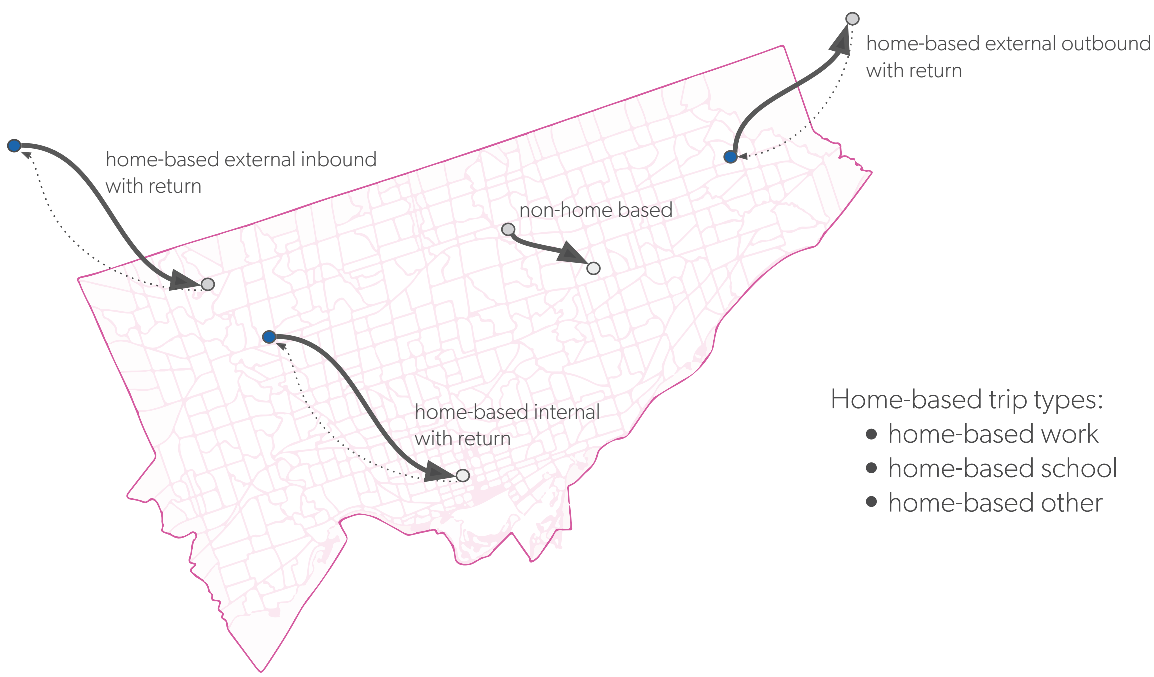

Figure 7. Trips assessed in the personal mobility sub-model.

Waste

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

Local energy production

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

Financial and Employment Impacts

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

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

ENERGY AND GHG EMISSIONS ACCOUNTING

CityInSight accounts for the energy flows through the model, as shown in Figure 8.

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

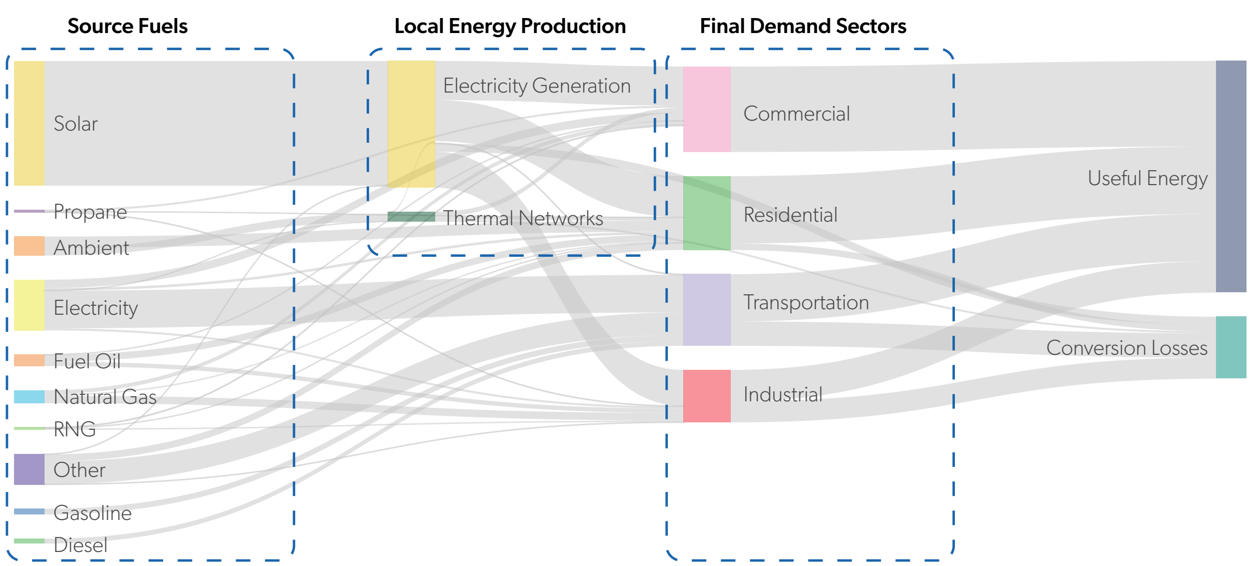

Figure 8. An example of an energy flow Sankey diagram showing main node groups.

Figure 8 above shows the potential for ambiguity when energy is reported: which of the energy flows circled are included and how do you prevent double counting? To address these ambiguities, CityInSight defines two main energy reports:

- Energy Demand, shown in Figure 9. Energy Demand includes the energy flows just before the final demand sectors (left of the dotted red line). Where the demand sectors are supplied by local energy production nodes, the cut occurs after the local energy production and before demand.
- Energy Supply, shown in Figure 10. Energy Supply includes the energy flows just after the source fuel nodes (left of the dotted red line). Where the source fuels supply local energy production nodes, the cut occurs between the source fuels and local energy production.

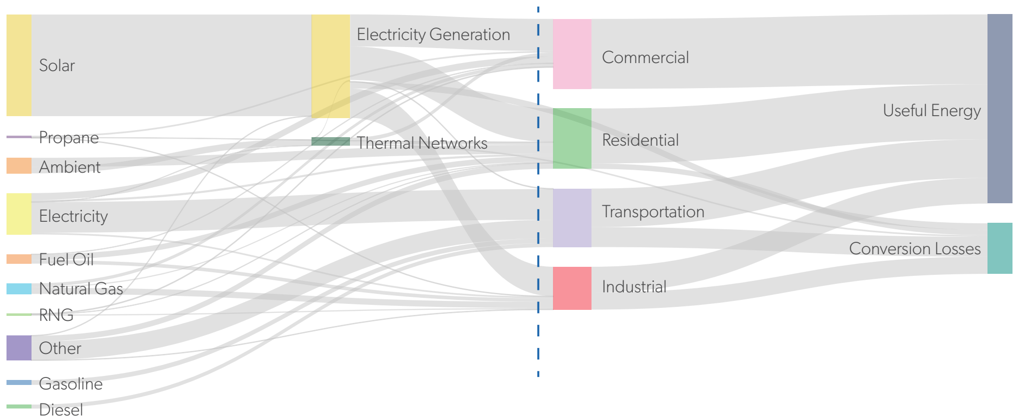

Figure 9. An example of an Energy Demand report definition.

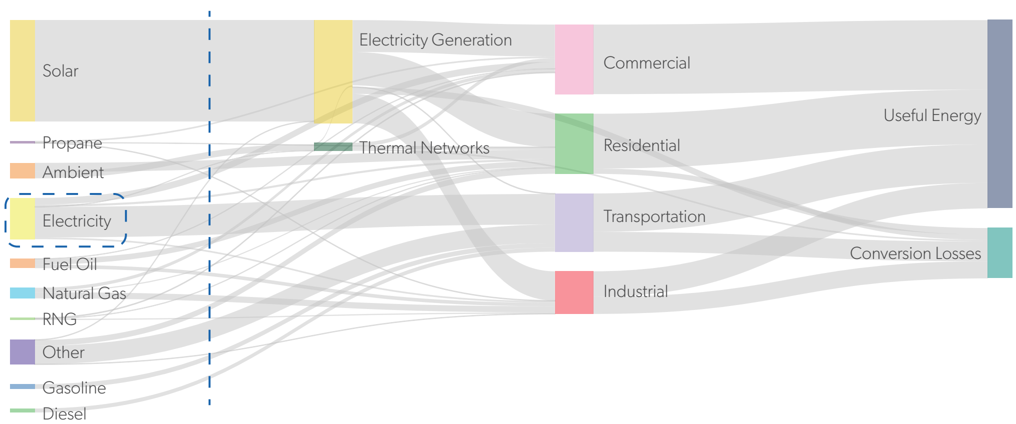

Figure 10. An example of an Energy Supply report definition.

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

FINANCIAL ACCOUNTING

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

- Upfront capital expenditures: this is related to new stocks, such as new vehicles or new building equipment.
- Operating and maintenance costs: Annualized costs associated with stocks, such as vehicle maintenance.

- Energy costs: this is related to energy flows in model, accounting for fuel and electricity costs, and
- carbon pricing: Calculated by on emissions generation.

Expenditure types that are evaluated in the model are summarized in Table 5. Financial assumptions will be included in further iterations of the Halton Hills model.

Table 5. Categories of expenditures.

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

Financial Reporting Principles

The financial analysis is guided by the following reporting principles:

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

INPUTS AND OUTPUTS

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

Base Year

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

Future Projections

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

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

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

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

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

SPATIAL DISAGGREGATION

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

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

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

Modelling Process

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

DATA COLLECTION, CALIBRATION, AND THE BASE YEAR

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

THE BASE YEAR AND REFERENCE PROJECTION

Once the base year is completed, a reference projection to the target year of the scenario exercise is developed. The purpose of the reference projection is to build an informed projection of what future energy and emissions might look like. This projection helps ensure that the net-zero scenario is designed in a manner that strategically addresses likely future energy use and emissions sources.

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

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

LOW-CARBON SCENARIO AND ACTION PLAN

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

Addressing Uncertainty

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

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

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

Data and Assumptions for the Town of Halton Hills

ASSESSMENT SCOPE

Geographic Boundary

The geographic boundary of the modelling assessment is the municipal boundary of the Town of Halton Hills (Figure 11).

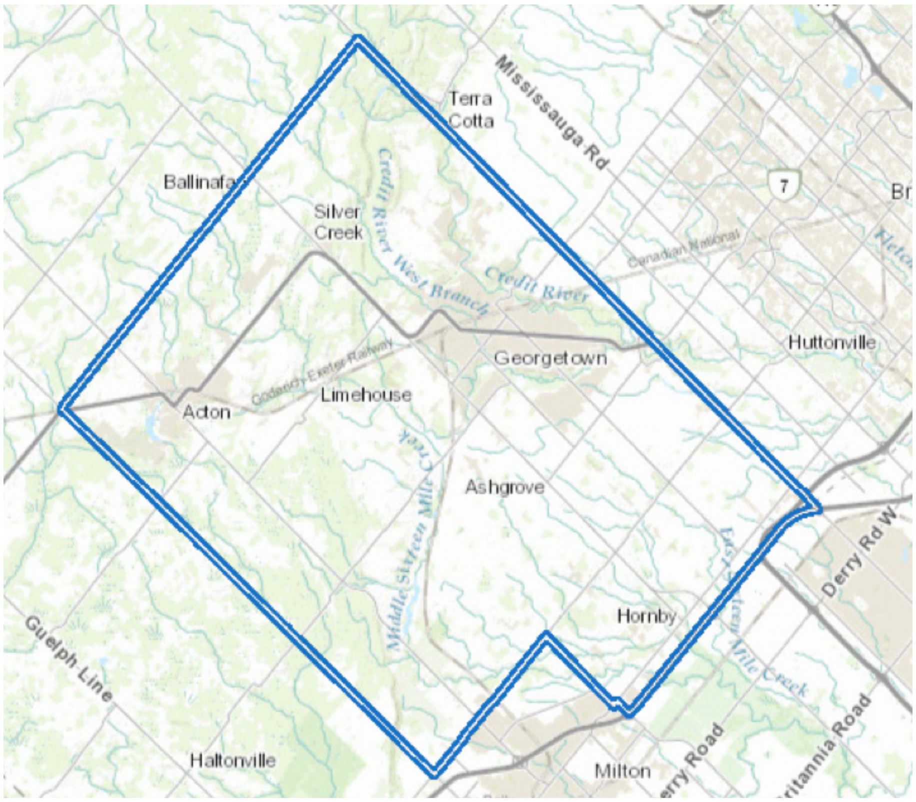

Figure 11. Assessment boundary for the Town of Halton Hills.

Time Scope

- The assessment will cover the years from 2016 to 2030.
- The year 2016 will be used as the base year within the model. The rationale for using this as the base year is that:
    - The model requires the calibration of a base year system state (initial conditions) using as much observed data as possible in order to develop an internally consistent snapshot of the city.
    - A key data source for the model is census data. At the time of modelling, the last census year for which there is data available is 2016.
    - Transportation Tomorrow Survey and the long range transportation modelling conducted in the Greater Toronto Area follow the census year 2016.
- 1-year increments are modelled from the 2016 base year. 2016 is the first simulation period/ year.
- Projections will extend to 2050, although reporting in this report is limited to the year 2030.

Emissions Scope

The relevant emissions sources for Halton Hills and their emissions scope are detailed in Table 6. Of note is treatment of local electricity supplied to the grid: all emissions reductions from new local energy generation are accounted for locally, rather than distributed through the central electricity grid. However, central electrified generation facilities located within municipal boundaries are only accounted for through the electricity grid emissions factor. This distinction is made because the current central electricity generation is already accounted for through the grid emissions factor. Reporting on such a facility is not required under GPC Protocol BASIC or BASIC+. New local energy generation projects are not included in electricity emissions factor projections.

Table 6. Sources included in Halton Hills model.

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

	SCOPE 1	SCOPE 2	SCOPE 3	NOTES
Incineration and open burning of waste generated outside the city				NA
Wastewater generated in the city	Y		Y	
Wastewater generated outside the city				NA
Industrial processes and product use (IPPU)				
Industrial processes	Y			
Product use				
Agriculture, forestry and other land use (AFOLU)				
Livestock	Y			
Land	Y			
Aggregate sources and non-CO_2 emissions sources on land	Y			
Other Scope 3			Y	

BASE YEAR DATA

The following data was used to calibrate the model to the Town of Halton Hills and to develop its 2016 inventory base year.

Table 7. Base year data used to populate the Halton Hills model.

DATASET	UNIT	DESCRIPTION	SOURCE(S)
Demographics			
Population	# persons	Total by zone College and university student enrollment	Halton Hills Official Plan
Households / Dwellings	# households	Total (households from census)	Statistics Canada. 2016 Census.
Employment	# jobs (place of work)	Employment by sector/industry (NAICS) by zone	Halton Hills Official Plan
Buildings			
Parcel fabric		GIS parcel layer including attributes: - Parcel ID - Assessment roll number	From Town of Halton Hills
Building footprints	For the Region	GIS: Building footprints shapefile (anything available)	From Town of Halton Hills
Property assessment roll	For the Region	MPAC tables: general, structure	Municipal Property Assessment Corporation Data
Residential (dwellings)	# dwelling units	dwellings by: - structure type - zone	From Town of Halton Hills

DATASET	UNIT	DESCRIPTION	SOURCE(S)
Non-residential	ft^2 or m^2	for each building: - sector/industry - zone/GIS coordinates - year built - floorspace	Municipal Property Assessment Corporation Data
Municipal		For subset of non-residential buildings under the jurisdiction the Town of Halton Hills: - Operation Name - Operation Type - Address - Floor Area - Electricity Consumed - Natural Gas Consumed	Town of Halton Hills. Energy Conservation and Demand Management Plan. Ontario Broader Public Sector data identifies buildings and their energy intensity values but does not include floor area or energy consumption.
Land-use			
Municipal boundaries		GIS: Regional and municipal boundaries (CD & CSDs?)	Statistics Canada. 2016 Census
Policy boundaries		GIS maps showing: built boundary, designated greenfields, green belt / protected, etc	Town of Halton Hills. Official Plan.
Energy infrastructure		Energy infrastructure; including district energy infrastructure, NG network, utilities, pipelines, EV charging.	Enbridge Gas. Service Network Areas. Enbridge serves Georgetown and Acton No natural gas in most of the smaller hamlets and villages. There is a planned expansion into Ballinafad, Limehouse, and Silver Creek.
Land Cover		GIS: Agricultural (include type- crop, dairy, etc.), forest (include status- woodlot, protected, or indicate that you don't have this), urban forest (street trees, shrubs, green roofs), roads, parks, vacant, etc.	
Fuel Consumption			
Natural gas	GJ preferred; m^3 ok	2016-2019 (annual) Total natural gas consumption by as much sectoral and geographic detail as possible; from all natural gas providers. Cost ($\$/m^3$) by sector.	From Town of Halton Hills, via Enbridge Gas.

DATASET	UNIT	DESCRIPTION	SOURCE(S)
Electricity	kWh	2016-2019 (annual) Total electricity consumption by as much sectoral and geographic detail as possible; from all electricity providers. Cost ($/kWh) by sector.	Data from Halton Hills Hydro Inc
Gas and diesel sales	litres	2016-2019 (annual) Total sales (L) by fuel type.	Kent Group Ltd. Gasoline and Diesel fuel data.
Grid electricity emissions factors	g/kWh	CO_2, CH_4, N_2O	CanESS model
Decentralized electricity generation (excluding district energy); behind the meter and grid-connected generation	kWh (elec); GJ (preferred) or volume for fuel use	2016-2019 (annual) Total electricity generated by decentralized plant by zone by fuel/ technology types; fuel use by type. Decentralized electricity capacity (MW).	IESO. (2020). Active Contracted Generation List March 2020.
District energy and network	kWh (elec); GJ (preferred) or volume for fuel use	2016-2019 (annual) DE plant capacity and generation by fuel/technology type; fuel use by type; electricity generated from CHP; location of DE system & plant. Buildings served by DE systems: location, use type, floor area, consumption.	-
Centralized electricity capacity	MW	2016-2019 (annual)	IESO. (2020). Active Contracted Generation List March 2020.
Centralized electricity generation	kWh	2016-2019 (annual)	IESO. (2020). Active Contracted Generation List March 2020.
Centralized electricity generation fuel use	GJ	2016-2019 (annual)	IESO. (2020). Active Contracted Generation List March 2020.

DATASET	UNIT	DESCRIPTION	SOURCE(S)
Energy costs			Halton Hills Hydro. Electricity. Retrieved from:https://haltonhillshydro.com/for-home/rates/electricity/ Ontario Energy Board. Historical natural gas rates. Retrieved from: www.oeb.ca/rates-and-your-bill/natural-gas-rates/historical-natural-gas-rates#enbridge
Residential energy consuming stocks		zone, fuel type, and stock type water heater types: conventional, solar, on demand, heat pump heat system types: oil, gas, electric, heat pump, combinations aircon types: room, central, heat pump	whatIf? Technologies. CanESS model.
Transportation			
Zones (traffic)		GIS: Traffic zones Any additional zone systems used for transportation modelling by the City Attribute of zones: greenfield or urbanized.	Town of Halton Hills.
Household travel survey		Household survey used for regional transportation modelling.	Transportation Information Steering Committee. (2018). 2016 Transportation Tomorrow Survey.
Modelled origin-destination trip matrix	person trip	24hr (not peak hour). By origin zone, destination zone, trip purpose, primary mode (auto, transit, active modes).	Transportation Information Steering Committee. (2018). 2016 Transportation Tomorrow Survey.
Distance matrix	km	Zone-to-zone road network distance matrix.	Transportation Information Steering Committee. (2018). 2016 Transportation Tomorrow Survey.
Vehicle fleet		2016 Vehicle registration counts for Passenger and Commercial vehicles in the region.	Transportation Information Steering Committee. (2018). 2016 Transportation Tomorrow Survey.
Corporate vehicle fleet		2016-2019 (annual) By body type (car, light truck); fuel type; technology type (internal combustion, hybrid, electric); weight class. VKT and/or fuel consumption.	Town of Halton Hills.

DATASET	UNIT	DESCRIPTION	SOURCE(S)
Local and regional (in-boundary) transit system		2016 Route/network GIS files; Fleet by type (subway, commuter train, bus, streetcar); VKT; energy/fuel use; vehicle fuel consumption per km.	Metrolinx. (2019). Kitchener go expansion initial business case www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/2019-11-14-Kitchener-Mid-Term-Service-Expansion-IBC-Update-FINAL.pdf
School bus fleet		2016-2019 (annual) Fleet by fuel type; VKT; fuel consumption.	
VKT	km	2016-2019 (annual) Any existing studies or estimates of regional VKT (traffic count based or other).	Transportation Information Steering Committee. (2018). 2016 Transportation Tomorrow Survey.
Rail fuel use	GJ or L	Fuel use for passenger and freight railway trips that start in or end in region indicate whether transit fuel use is included in this data	Statistics Canada. Table: 25-10-0029-01 (formerly CANSIM 128-0016) Provincial data will be allocated to region on the basis of population by default
Aviation fuel use	GJ or L	Fuel use for passenger and freight aviation trips that start in or end in region	Statistics Canada. Table: 25-10-0029-01 (formerly CANSIM 128-0016) Provincial data will be allocated to region on the basis of population by default
Waste			
Solid waste produced	tonne / year	2016-2019 (annual) By waste type AND by sector	Resource Productivity and Recovery Authority. 2016 Residential Waste Diversion Rates by Municipal Program.
Waste disposal routing		2016-2019 (annual) Fraction of waste generated within city handled within city boundary & handled outside of city, by type	From Town of Halton Hills
Solid waste facilities capacity	tonne	Waste handling facilities capacity (within and outside of city boundary), by facility type	From Town of Halton Hills
Solid waste facilities	-	% capacity used up by landfill in base year	From Town of Halton Hills

DATASET	UNIT	DESCRIPTION	SOURCE(S)
	tonne / year	2016-2019 (annual) Quantities of waste taken in by handling facilities within boundary, by facility type What percentage of waste taken in by handling facilities is imported?	From Town of Halton Hills
	-	2016-2019 (annual) Methane recovery fraction by handling facilities; where is recovered methane used?	From Town of Halton Hills
Diversion rates	-	2016-2019 (annual) Recycling and compost diversion rates for residential and ICI waste.	Resource Productivity and Recovery Authority. 2016 Blue Box Program Marketed Tonnes.
Industry			
Industrial processes & product use		Any information on industrial processes, production levels & emissions; by location	Government of Canada. National Pollutant Release Inventory.
Waste heat		GIS: locations of waste heat producers, amount of waste heat	-
Agriculture			
Livestock		Heads of livestock in region by type	Government of Canada. National Pollutant Release Inventory.
Cropland	ha	Area of cropland by tillage practice for 2011 and 2016	Statistics Canada. Table: 32-10-0408-01 (formerly CANSIM 004-0205)
Forest area	ha	Area of forest for 2016	Government of Ontario. Wooded Areas. GeoHub.

EMISSIONS FACTORS

Table 7. Emissions factors for fuels in Halton Hills model.

FUEL GWP	GHGS BY SECTOR	REFERENCE

FUEL	GHGS BY SECTOR	REFERENCE
Greenhouse gases	Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_20) are included. GWP: CO_2 = 1 CH_4 = 34 N_2O = 298	Myhre, G. et al., 2013: Anthropogenic and Natural Radiative Forcing. Table 8.7. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
EMISSIONS FACTORS		
Natural gas	49 kg CO_2e/GJ	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Tables A6-1 and A6-2.
Electricity	2016: CO_2: 7.47 g/kWh CH_4: 0.000403 g/kWh N_2O: 0.0000175 g/kWh 2051: CO_2: 10.7 g/kWh CH_4: 0.000952 g/kWh N_2O: 0.000243 g/kWh	National Energy Board. (2016). Canada's Energy Future 2016. Government of Canada. Retrieved from www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016pt/nrgyftrs_rprt-2016-eng.pdf IESO. (2020) Annual Planning Outlook
Gasoline	g / L CO_2: 2316 CH_4: 0.32 N_2O: 0.66	NIR Part 2 Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Diesel	g / L CO_2: 2690.00 CH_4: 0.07 N_2O: 0.21	NIR Part 2 Table A6–12 Emission Factors for Energy Mobile Combustion Sources

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

FUEL	GHGS BY SECTOR	REFERENCE
Waste/WW	wastewater emissions factors CH_4: 0.48 kg CH_4/kg BOD N_2O: 3.2 g / (person * year) from advanced treatment 0.005 g /g N from wastewater discharge landfill emissions are calculated from first order decay of degradable organic carbon deposited in landfill derived emission factor in 2016 = 0.015 kg CH_4 / tonne solid waste (assuming 70% recovery of landfill methane), .05 kg CH_4 / tonne solid waste not accounting for recovery	CH_4 wastewater: IPCC Guidelines Vol 5 Ch 6, Tables 6.2 and 6.3, we use the MCF value for anaerobic digester N_2O from advanced treatment: IPCC Guidelines Vol 5 Ch 6 Box 6.1 N_2O from wastewater discharge: IPCC Guidelines Vol 5 Ch 6 Section 6.3.1.2 Landfill emissions: IPCC Guidelines Vol 5 Ch 3, Equation 3.1

Electricity Emissions Factor

Table 8. Projected electricity emissions intensity (g/kWh).

	2020	2022	2024	2026	2028	2030
CO_2	36.78	35.62	54.79	68.24	69.35	68.69
CH_4	0.01	0.01	0.01	0.02	0.02	0.02
N_2O	0	0	0	0	0	0

Source:

- IESO. (2020). Annual Planning Outlook.

REFERENCE SCENARIO ASSUMPTIONS SUMMARY

Table 10 summarized the reference scenario assumptions. Where assumptions are noted to be held constant, base year data is carried forward annually in the projection. Detailed inputs for each assumption are outlined in Section 8.5.

Table 9. Reference scenario assumptions summary.

CATEGORY	ASSUMPTION	SOURCE
DEMOGRAPHICS		
Population & employment		
Population	Population growth according to Town projections	Environics Analytics. (2019). Demo Stats 2019.
Employment	Employment growth according to Town projections	
BUILDINGS		
New buildings growth		
Building growth projections	Dwelling projections according to Environics data.	Environics Analytics. (2019). Demo Stats 2019.
New buildings energy performance		
Residential	25% of all new construction built to GDS. (res) 2016-2020: 20% better than OBC 2012 2020-2026: 15% better than OBC 2020 non-res: Energy performance under code improves by 10% every five years. Once energy performance under OBC is higher than updated GDS, 100% of buildings will be constructed to OBC.	Town of Halton Hills. 2014. Green Development Standard. Assumption development as per assumptions made in Town of Halton Hills. (2018). Vision Georgetown Energy Master Plan. Post 2020 assumptions as per discussions with HH

CATEGORY	ASSUMPTION	SOURCE
Multi-residential	2020 and on: 20% better than a 2016 new building (representing obc 2020) for 75% of buildings; 15% improvement on top of that (so I guess 30%) (for 25% of buildings) representing new GDS,	
Commercial & Institutional		
Industrial		
Existing buildings energy performance		
Residential	Existing building stock efficiency remains constant	
Multi-residential		
Commercial & Institutional		
Industrial		
End use		
Space heating	Fuel shares for end use unchanged; held from 2016-2050.	Canadian Energy Systems Analysis Research. Canadian Energy System Simulator. http://www.cesarnet.ca/research/caness-model .
Water heating		
Space cooling		
Projected climate impacts		
Heating & cooling degree days	Heating Degree days are expected to decrease, and cooling degree days will increase	Climateatlas.ca - BCCAqv2 downscaled climate data from Pacific Climate Impacts Consortium
ENERGY GENERATION		
Low- or zero-carbon energy generation (community scale)		
Rooftop Solar PV	Existing solar PV hold constant - 4.08 MW for IESO contracts New growth based on market uptake: 5% uptake by 2050 and 15% of res building energy needs (5% for apartment)	Town of Halton Hills. 2014. Green Development Standard. IESO active generation contract list (as of March 2020) www.ieso.ca/en/Power-Data/Supply-Overview/Distribution-Connected-Generation
Ground mount solar	0.5 MW	IESO active generation contract list (as of March 2020) www.ieso.ca/en/Power-Data/Supply-Overview/Distribution-Connected-Generation

CATEGORY	ASSUMPTION	SOURCE
District Energy Generation	No district energy applied. While a Natural Gas CHP Unit (<1MW) will be used to provide heat and electricity to a maximum of 2,589 units connecting to the district heating system at Vision Georgetown, this system is expected to be installed in 2035 (beyond the model end date)	Scenario 1 from Arup. (2018). Vision Georgetown Energy Master Plan.
Wind	None	IESO active generation contract list (as of March 2020) www.ieso.ca/en/Power-Data/Supply-Overview/Distribution-Connected-Generation
Grid scale energy generation		
Centralized electricity gen	Centralized electricity generation is not included in Reference scenario reporting. There is a 641.5 MW NG generation station in the boundary of HH but its impact on emissions is captured within the Ontario grid emissions factor.	IESO active generation contract list (as of March 2020) www.ieso.ca/en/Power-Data/Supply-Overview/Distribution-Connected-Generation
TRANSPORT		
Transit		
Expanded transit	GO Kitchener line increasing two-way all-day complete by 2025. Current ridership: Acton: 121 daily trips Georgetown: 618 daily trips 2025: Acton: 220 daily trips Georgetown: 643 daily trips There is an assumed 5x increase in train VKT as a result of the project.	Metrolinx. 2019. Kitchener go expansion initial business case www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/2019-11-14-Kitchener-Mid-Term-Service-Expansion-IBC-Update-FINAL.pdf Metrolinx. (2020). Full Schedules. Retrieved from: www.gotransit.com/static_files/gotransit/assets/pdf/TripPlanning/FullSchedules/FS20062020/Table31.pdf Town of Halton Hills. (2019). Transit Service Strategy. WSP. https://drive.google.com/file/d/1QJzcEhCFLIRnhVuxi1sHiOxtmVDLIkVs/view

CATEGORY	ASSUMPTION	SOURCE
Electrify transit system	No electrification on GO or Universal Access Service. Go train remains diesel.	Metrolinx. 2019. Kitchener go expansion initial business case www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/2019-11-14-Kitchener-Mid-Term-Service-Expansion-IBC-Update-FINAL.pdf. Town of Halton Hills. (2019). Transit Service Strategy. WSP. https://drive.google.com/file/d/1QJzcEhCFLIRnhVuxi1sHiOxtmVDLIkVs/view.
Active		
Mode share	Proportional change in mode share: doubling transit mode share. By 2031, pm peak: 82% vehicle trips 4% transit 7% active 7% school bus 2006 pm peak: 84% vehicle trips 2% transit 7% active 7% school bus	Town of Halton Hills. (2011). Transportation Master Plan. https://drive.google.com/file/d/1CDEdQhEwkRzB84OI5Eq3ZF-1zek63Z_l/view
Private/personal use		
Electrify municipal fleet	No change to municipal fleets.	Town of Halton Hills. 2019. 2020-2025 Corporate Energy Plan.
Electrify personal vehicles	14% new sales by 2030	Axsen, J., Wolinetz, M. (2018). Reaching 30% plug-in vehicle sales by 2030: Modeling incentive and sales mandate strategies in Canada. Transportation Research Part D: Transport and Environment Volume 65, Pages 596-617
Electrify commercial vehicles	No change	

CATEGORY	ASSUMPTION	SOURCE
Vehicle fuel efficiencies / tailpipe emission standards	CAFE Fuel standards: Vehicle fuel consumption rates reflect the implementation of the U.S. Corporate Average Fuel Economy (CAFE) Fuel Standard for Light-Duty Vehicles, and Phase 1 and Phase 2 of EPA HDV Fuel Standards for Medium- and Heavy-Duty Vehicles. ------ Light duty: 2015: 200gCO_2e/km 2025: 119 gCO_2e/km 2030: 105gCO_2e/km Heavy Duty: 20% reduction in emissions intensity by 2025, relative to 2015, 24% reduction in emissions intensity in 2030 relative to 2015	EPA. (2012). EPA and NHTSA set standards to reduce greenhouse gases and improve fuel economy for model years 2017-2025 cars and light trucks. Retrieved from https://www3.epa.gov/otaq/climate/documents/420f12050.pdf www.nhtsa.gov/fuel-economy SOR/2010-201. Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations. Available from: http://laws-lois.justice.gc.ca SOR/2018-98. Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations and other Regulations Made Under the Canadian Environmental Protection Act, 1999. Available from: https://pollution-waste.canada.ca
Vehicle stock	Personal vehicle stock changes between 2016-2050. Commercial vehicle stock unchanged 2016-2050.	CANSIM and Natural Resources Canada's Demand and Policy Analysis Division.
WASTE		
Waste generation	1250 kg / household / year - no change	Halton Region. (2011). Solid Waste Management Strategy.
Waste diversion	Base year waste diversion rate 57.4% (2010), 65% by 2016, to increase to 70% (2025) 59% was reported for 2016 to RPRA.	Halton Region. (2011). Solid Waste Management Strategy.
Waste treatment	Waste is treated outside the boundary, and partially flared, partially run through landfill gas electricity generation. No change is waste treatment.	
Wastewater	No change to wastewater treatment systems.	
OTHER		
Industrial efficiencies	No change.	
Agriculture	No change.	
Aviation	No change.	

DETAILED REFERENCE SCENARIO ASSUMPTIONS

Population and Employment

Environics data did not include Vision Georgetown projections. Therefore, Town-average projections were applied to zone 558 (Vision Georgetown zone).

Table 10. Population and employment input assumptions in the reference scenario.

	2016	2020	2025	2030
Population	63,333	68,668	80,005	91,868
Employment	32,712	35,973	37,996	39,363

Source:

- Environics Analytics. (2019). Demo Stats 2019.

Building Growth Projections

Residential dwelling unit projections come from Environics data, provided by the Town (Table 12). Environics data did not include Vision Georgetown projections. Therefore, town-average projections were applied to zone 558 (Vision Georgetown zone). Share of dwelling type in Vision Georgetown was based on the density targets in the Vision Georgetown Secondary Plan (Table 13).

Commercial and industrial floor space are based on employment projections.

Table 11. Building growth assumption in the reference scenario.

	2016	2020	2025	2030
Dwelling units	21,732	22,598	26,680	30,636
Non res floor space (m^2)	1,440,077	1,579,788	1,685,980	1,759,862
Industrial floor space				

Table 12. Residential building type input assumption for Vision Georgetown in the reference scenario.

DENSITY	BUILDING TYPE	SHARE OF TOTAL
Low density	Single detached	44.90%
Low density	Semi detached	
Medium density	Row	39.50%
High density	Apt (5+ units)	
High density	Apt (<5 units)	15.60%

Source:

- Environics Analytics. (2019). Demo Stats 2019.
- Town of Halton Hills. (2018). Vision Georgetown Secondary Plan.

New Building Energy Performance

From 2016-2020, 25% of all new buildings will be constructed to meet the Green Development Standard (GDS), reaching 20% better performance than the Ontario Building Code 2012 (OBC). 75% of buildings will be constructed to meet OBC 2012.

After 2020, 75% of new buildings will be constructed according to Ontario Building Code 2020, which is estimated to be 10% better than OBC 2012. The remaining 25% of all new buildings will reach the updated GDS, which will achieve 15% better energy performance than OBC 2020. The Reference scenario assumes that the OBC will require10% energy improvements every five years, but that the GDS is not updated again. Once the energy performance required under OBC is greater than that prescribed under GDS, all buildings will be constructed to OBC.

New construction efficiency improvements are summarized in Table 14.

Table 13. Schedule of efficiency improvements for new construction in the reference scenario.

	2016-2021	2022-2026	2027-2031	2032-2036	2037-2041	2042-2046
OBC energy improvement over previous version	10%	10%	10%	10%	10%	10%
Uptake	0.75	0.75	0.75	1	1	1
GDS energy performance relative to code	20%	25%	10%			
GDS uptake	0.25	0.25	0.25			

This translates to an improvement in energy performance of 12.5% across the residential building stock (new and existing) until 2021, 13.75% until 2026 and 10% until 2030 in the model. For non-residential buildings, there is a 10% improvement in energy performance every five years.

Source:

- Arup. (2018). Vision Georgetown Energy Masterplan.
- Discussion with the Town of Halton Hills.
- Environmental Commissioner of Ontario. (2016). Conservation: Let's Get Serious 2015-2016.

Existing Building Energy Performance

Municipal existing buildings are upgraded according to the Town's Corporate Energy Plan, as detailed in Table 15. Energy performance improvements are applied in the year 2025.

Table 14. Energy use intensity change at corporate buildings.

FACILITY	2018 TOTAL ENERGY USE INTENSITY	TARGET TOTAL ENERGY USE INTENSITY	TOTAL ENERGY SAVINGS POTENTIAL
Mold-Masters SportsPlex	38.26	24.06	37%
Gellert Community Centre	80.82	51.81	36%
Action Arena	29.3	22.75	22%
Robert C Austin Operations Centre	53.25	33.83	36%
District One Stations (Acton)	33.05	12.52	62%
District Two Station (Georgetown)	24.12	8.94	63%
Town Hall	22.17	15.05	32%
District Three Station - HHFD HQ	22.38	8.94	60%
Action Yard - Equipment Depot	54.99	25.89	53%
Cedarvale Community Centre	14.22	9.28	35%
Halton Hills Cultural Centre and Library	14.83	9.75	34%
Acton Library Branch	16.02	9.58	40%
Prospect Park Pavilion	12.71	7.08	44%

Non-municipal existing building stock efficiency remains constant to base year levels, as there are no comprehensive retrofit programs available. Assuming that potential efficiencies may be offset by increasing plug loads.

Building Energy End Use

Fuel shares for end uses remain unchanged.

Source:

- Canadian Energy Systems Analysis Research. Canadian Energy System Simulator. www.cesarnet.ca/research/caness-model.

Heating and Cooling Degree Days

Heating degree days are expected to decline, while cooling degree days are expected to increase under an RCP8.5 climate future. HDD and CDD assumptions are the median results from a series of global climate models.The table below shows the HDD and CCD assumptions for the Town of Halton Hills.

Table 15. HDD and CDD values used in the reference scenario.

	1950	1975	2000	2016	2025	2050
HDD	4235.3	4301.8	3969.7	3882	3700.4	3255.8
CDD	201.6	191.4	261.8	331.6	333	524

Source:

- Climate Atlas of Canada. (n.d.). BCCAqv2 downscaled climate data from Pacific Climate Impacts Consortium for RCP8.5, Kitchener, Ontario. Retrieved from climatetlas.ca

Low- or Zero-Carbon Energy Generation

Rooftop Solar PV

- Existing rooftop solar PV of 4.08 MW in IESO contracts are held constant. Contracts that expire are assumed to be renewed.
- New growth related to Green Development Standards, where 5% of new

Ground mount solar PV

- Existing ground mount solar PV capacity of 0.5 MW is held constant. Contracts that expire are assumed to be renewed.

District energy generation

- Natural gas combined heat and power unit (1MW) will be used for heat and electricity for a maximum of 2,859 units in the core of Vision Georgetown development. Assumed to be operational in 2035, and is therefore excluded from the reference scenario projection.

Wind

- No wind generation.

Source:

- Town of Halton Hills. 2014. Green Development Standard.
- IESO. (2020). IESO active generation contract list (as of March 2020). Retrieved from: www.ieso.ca/en/Power-Data/Supply-Overview/Distribution-Connected-Generation
- Scenario 1 from Arup. (2018). Vision Georgetown Energy Master Plan.

Grid-connected Energy Generation

Although there is an existing 641.5 MW natural gas generating station in Halton Hills, it is not included in the reference scenario projectiongt because the influence of this generating station is already captured in Ontario's electricity emissions factor.

Source:

- IESO. (2020). IESO Active Generation Contract List (as of March 2020). Retrieved from: www.ieso.ca/en/Power-Data/Supply-Overview/Distribution-Connected-Generation

Transit

Kitchener GO Line Expansion is assumed to increase ridership in Halton Hills. The expansion is assumed to be operational in 2025. Trains will remain fueled by diesel. The ridership assumptions are as follows:

- Trips:
  - Current ridership:
    - » Acton: 121 daily trips
    - » Georgetown: 618 daily trips
  - 2025:
    - » Acton: 220 daily trips
    - » Georgetown: 643 daily trips
- VKT is also expected to increase five-fold—directly proportional to the increasing service in Halton Hills.

The Town of Halton Hills is also increasing its Universal Access Transit Service; however, it is modelled as personal-use vehicles in the model.

Source

- Metrolinx. (2019). Kitchener GO expansion initial business case. Retrieved from: www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/2019-11-14-Kitchener-Mid-Term-Service-Expansion-IBC-Update-FINAL.pdf.
- Town of Halton Hills. (2019). Transit Service Strategy. Prepared by WSP.

Active Transportation

Active transportation mode share is expected to increase according to Table 17. GO Transit expansion is assumed to override assumptions made in the Transportation Tomorrow Survey.

Table 16. Mode share assumptions.

	2016	2020	2025	2030
Personal-use automobiles	88.90%	88.65%	85.17%	83.54%
Transit	4.95%	5.04%	8.78%	10.77%
School bus	2.29%	2.40%	2.54%	2.52%
Walk	3.36%	3.41%	3.06%	2.74%
Bike	0.50%	0.50%	0.45%	0.43%

Source

- Transportation Information Steering Committee. (2018). 2016 Transportation Tomorrow Survey.
- Metrolinx. (2019). Kitchener GO expansion initial business case. Retrieved from: http://www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/2019-11-14-Kitchener-Mid-Term-Service-Expansion-IBC-Update-FINAL.pdf

Personal and Commercial-Use Vehicles

Municipal fleet

- Municipal fleet remains constant at 213 vehicles, and is not electrified.

Electrification of personal vehicles

- EVs make up 14% of new sales by 2030; share holds constant from 2030 to 2050. Proportion of EVs in total vehicle share are shown in Table 18.

Table 17. Personal-use vehicle stock input assumptions in the reference scenario.

	2016	2020	2025	2030
Car (gasoline)	1,404	1,484	1,720	1,679
Car (hybrid)	1	1	1	1
Car (diesel)	25	28	33	33
Car (plug-in hybrid)		12	32	52
Car (electric)	0	53	173	296
Light truck (gasoline)	1,145	1,477	1,855	1,925
Light truck (hybrid)	0	1	1	1
Light truck (diesel)	6	99	127	135
Light truck (plug-in hybrid)		15	40	65
Light truck (electric)	0	55	195	356
Total	2,581	3,222	4,178	4,544

Electrification of commercial vehicles:

- Commercial vehicles are not electrified.

Vehicle fuel efficiency:

- Vehicle fuel efficiency improves according to CAFE standards, enshrined in Canadian legislation through SOR-2010-201 and SOR/2018-98.
- Light duty vehicles:
    - 2015: 200 gCO_2e/km
    - 2025: 119 gCO_2e/km
    - 2030: 105 g/CO_2e/km
- Heavy duty vehicles: 20% reduction in emissions intensity by 2025, relative to 2015, 24% reduction in emissions intensity in 2030, relative to 2025.

Source:

- Town of Halton Hills. 2019. 2020-2025 Corporate Energy Plan.
- Axsen, J., Wolinetx, M. (2018). Reaching 30% plug-in vehicle sales by 2030: Modeling incentive and sales mandate strategies in Canada. Transport and Environment, 65,

596-617.

- SOR/2010-201. Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations. Retrieved from: http://laws-lois.justice.gc.ca.
- SOR/2018-98. Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations and other Regulations Made Under the Canadian Environmental Protection Act, 1999. Retrieved from: https://pollution-waste.canada.ca.

Waste

Waste generation is assumed to remain constant at 1250 kg/household/year. The waste diversion rate is assumed to be 65% in 2016, up to 70% in 2025. Waste is assumed to be treated in a landfill gas capture and utilization system. This results in emissions from flaring and from a 2.3 MW landfill gas facility. The facility is operated in partnership with Halton Region and Oakville Hydro, so the electricity generated from the plant is not included in the Halton Hills inventory. This results in the total waste generation and diversion patterns described in Table 19.

Table 18. Waste generation and diversion input assumptions in the reference scenario.

WASTE DESTINED TO LANDFILL	TONNE/YEAR			
	2016	2020	2025	2030
Compostable waste	3,398	3,577	3,932	4,491
Paper waste	2,339			
Plastic and metal	7,885	8,522	9,102	9,741
Other waste	8,860	8,148	6,258	6,846
Food and beverage	5,343	5,199	4,354	4,527
Textile				
Wood	4,356	4,779	5,100	5,323
Pulp and paper				
Petroleum products				
Rubbers				
Construction and demolition	1,399	1,535	1,638	1,710
WASTE DIVERSION	**TONNE/YEAR**			
	2016	2020	2025	2030
Compostable waste	n/a	n/a	n/a	n/a
Paper waste	18,926	23,267	25,341	27,086
Plastic and metal	329	464	698	751
Other waste	4,771	6,713	10,367	11,457
Food and beverage	2,078	2,942	4,334	4,541
Textile	n/a	n/a	n/a	n/a
Wood	n/a	n/a	n/a	n/a
Pulp and paper	n/a	n/a	n/a	n/a
Petroleum products	807	885	945	986

WASTE DESTINED TO LANDFILL	TONNE/YEAR			
Rubbers	684	750	801	836
Construction and demolition	n/a	n/a	n/a	n/a
WASTE DIVERSION	**TONNE/YEAR**			
	2016	2020	2025	2030
	7,026	7,734	9,175	10,479

There are two wastewater treatment plants within the Town of Halton Hills. No major changes to the wastewater system are expected, but wastewater volumes are expected to increase with growing population.

Table 19. Wastewater treatment volumes.

	2016	2020	2025	2030
Wastewater treatment volumes (m^3)	9,415,476	10,353,024	11,420,400	12,484,611

Source:

- Halton Region. (2011). Solid Waste Management Strategy.

Other

- There are no assumed changes to industrial process efficiencies.
- Agricultural emissions from livestock remain unchanged.
- Aviation emissions remain unchanged.