City of Hamilton

Carbon Budget and Accounting Framework

Assessment of Accelerated Emissions Reduction Targets

Prepared by
Sustainability Solutions Group

Prepared for
City of Hamilton

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Hamilton

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Land Acknowledgement

SSG's work is carried out on unceded and unsurrendered Indigenous territories, including the traditional lands of the Michif Piyii in the North, the Huilliche in the South, the Hul'qumi'num Peoples in the West, and the Mi'kma'qi in the East.

We acknowledge the historical and continued oppression of the original Peoples of the land that is currently known as the Americas. We also recognize that land acknowledgements alone are insufficient, and we are committed to ensuring that our work contributes to healing and decolonization.

Abbreviations and Acronyms

BAP	Business-as-Planned
DER	distributed energy resources
DRI	direct reduced iron
EAF	electric arc furnace
EV	electric vehicle
GHG	greenhouse gas emissions
IESO	Ontario's Independent Electricity System Operator
IPCC	Intergovernmental Panel on Climate Change
ktCO2e	kiloton of carbon dioxide equivalent
LCS	Low-Carbon Scenario
LRT	light-rail transit
NPC	Nationally Determined Contributions
NZ40	Net Zero by 2040
NZ50	Net Zero by 2050
OCCI	Office of Climate Change Initiatives
PV	photovoltaic
SCC	social cost of carbon
US	United States
VKT	vehicle kilometres travelled
ZEV	zero-emissions vehicle

1 | Summary

The scientific imperative to accelerate greenhouse gas (GHG) emissions reductions is greater than ever. At the same time, there is an opportunity to simultaneously accelerate other societal objectives, including diversifying the economy, stimulating new jobs and businesses, reducing household and business operating costs, and improving health outcomes and quality of life.

This briefing evaluates the possibility of accelerating the community's GHG reduction target from net zero by 2050 to net zero by 2040. The analysis focused on the year 2040 as it aligns with best practices defined by the latest science and represents a high level of ambition.[1]

No new modelling was completed as part of this brief, rather it relies on assessing the dynamics of the city energy system as elaborated in the ReCharge Hamilton's Community Energy and Emissions model (henceforth referred to as ReCharge Hamilton).

In addition to the actions evaluated in ReCharge Hamilton's Low-Carbon Scenario (LCS), a number of other actions are required to achieve net-zero emissions by 2040, including:

- Accelerating the adoption of electric vehicles (EVs);
- Accelerating efforts to mode shift away from vehicles;
- Continuing to build on the foundational investment in decarbonizing steel by phasing out natural gas and increasing access to scrap steel;
- Securing access to green hydrogen for steel production by 2035; and
- Securing access to 100% green electricity for industry, buildings, and transportation by 2030–2035.

The costs of key technologies have declined beyond what was projected in 2019.[2] This decline strengthens the case for decarbonization and will result in additional economic benefits to accelerating the emissions reduction target from 2050 to 2040. Two key financial risk areas are the removal of the consumer carbon price—which decreases the relative benefit of zero-emissions technologies—and the economic and political disruption from the United States.

The City can develop a range of policies, programs, and investments to manage these risks and bring the community closer to achieving the accelerated net-zero target while also growing the local economic base.

[1] See C40 Cities Race to Zero Pledge and City of Toronto's TransformTO Net Zero Strategy.
[2] For instance, EV batteries cost over $1,100 per kWh in 2010, $200 per kWh in 2020 and $130 per kWh in 2025. From Battery Cost Trends: How Pricing is Transforming the EV Market in 2025.

2 | Background

The City of Hamilton adopted its climate action plan, ReCharge Hamilton, in 2021. ReCharge Hamilton set the target of net-zero emissions by 2050. The City Council has directed the Office of Climate Change Initiatives (OCCI) to explore the feasibility of accelerating this target to an earlier year. A scan of current best practices worldwide[3] and recommendations from C40 indicate that acceleration to 2040 aligns with the scientific imperative for rapid climate action, the decreasing costs of decarbonization strategies or actions, and the ability to realize the many co-benefits that GHG reductions can bring. This briefing is a desktop study using data from the 2021 ReCharge Hamilton modelling results to determine if there are sufficient factors to consider accelerating the net-zero target for Hamilton.

3 | Hamilton's Climate Plan

Hamilton's climate action plan, ReCharge Hamilton, was developed between 2019 and 2021 with input from local industry, academia, utilities, local non-profits, and the public. The plan aims for Hamilton to achieve net-zero carbon emissions citywide by 2050.

A detailed energy use and GHG emissions model of the city was calibrated for 2016. Emissions data was then combined with other datasets, such as population, number and types of houses, number of cars, and working hours, to develop a comprehensive picture of activities in Hamilton that consume energy and generate GHG emissions. From this base year, two future scenarios were developed and modelled. The Business-as-Planned (BAP) Scenario explored the continuation of current trends out to 2050. The Low-Carbon Scenario evaluated the impact of 30 modelled actions in industry, buildings, transportation, renewable electricity, and natural systems. The cumulative impact of these actions relative to the BAP Scenario is illustrated in the wedge diagram in Figure 1, where actions are bundled into the major sectors.

[3] Cities with net-zero ambition include Melbourne in Australia, Austin and San Francisco in the USA, and Toronto in Canada.

Cumulative Impact of Climate Action

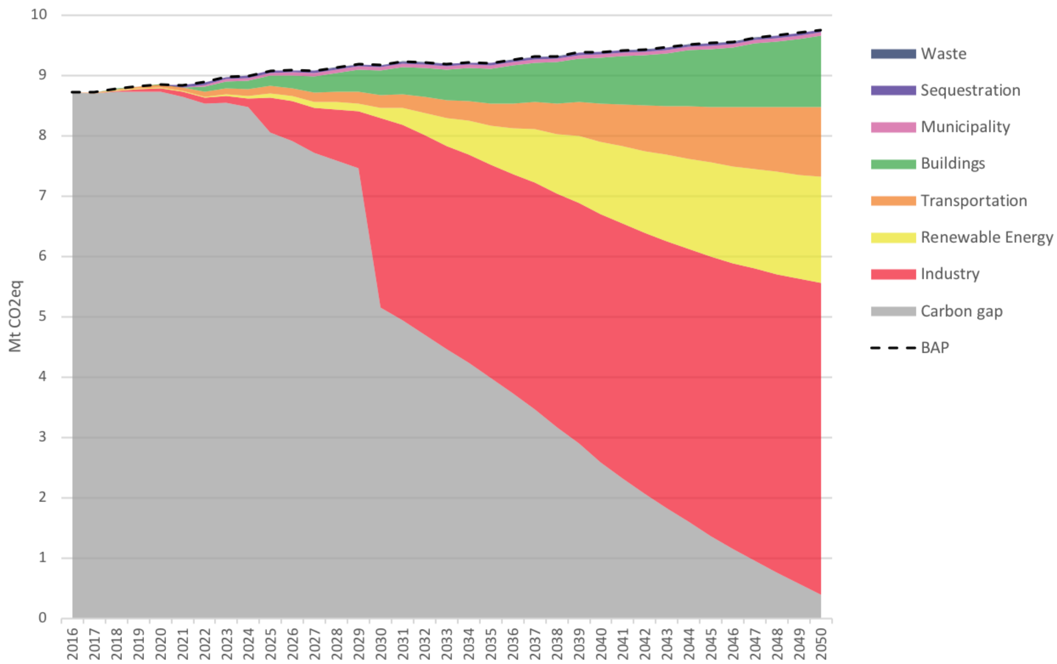

Figure 1. GHG emissions reductions (MtCO2e) in the LCS. Note: For visual clarity, modelled actions are grouped by sector.

In the LCS, by 2050, GHG emissions fall by 96% to a total of 400 ktCO2e, down from 8.7 MtCO2e in 2016. The remaining GHG emissions in 2050 are from transportation (200 ktCO2e) and industrial activity (160 ktCO2e).

4 | What Has Changed?

4.1 Urgency

Climate Impacts Are Accelerating

In August 2024, the remnants of Hurricane Debby set rainfall records and brought record-breaking floods to Quebec, inundating 55 communities. Just a month before, nearly 10 centimetres of rain fell in Toronto in three hours, causing nearly $1 billion in insured damages alone.[4] In July 2024, a wildfire devastated the iconic mountain village of Jasper. A single week of wildfire smoke in June 2023 was estimated to have cost Ontario over $1.2 billion in health impacts, including premature deaths, increased hospital visits, and health emergencies.[5] The cumulative economic toll can never be fully tallied, but without preventive action, the costs to the economy and society are potentially catastrophic.[6]

Limiting warming to 1.5°C requires rapid and deep emissions reductions.[7] As of 2020, the remaining global carbon budget to keep global warming within the Intergovernmental Panel on Climate Change's (IPCC) recommended 1.5°C threshold is 400 gigatonnes of carbon dioxide (66% likelihood).[8] Based on recent trends in annual global emissions, this 1.5°C global carbon budget would be used up by 2030.[9]

As part of the Paris Agreement commitment, countries report on their emissions reduction policies and plans to the United Nations. These national climate action plans, called the Nationally Determined Contributions (NDCs), are submitted every five years and can be used to evaluate whether the combined impact of nations' climate commitments are sufficient to alter the global emissions trajectory to below the warming threshold of 1.5°C.

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[4] The Canadian Press. "July Flash Floods in Toronto, Southern Ontario Caused Over $940M in Insured Damage." Global News, August 20, 2024. https://globalnews.ca/news/10706438/flash-floods-weather-toronto-ontario-insurance/#:~:text=Initial%20estimates%20put%20the%20total,Station%2C%20a%20key%20transit%20hub.

[5] Sawyer, Dave, Seton Stiebert, and Colin Welburn. "With the Forest Ablaze, the Health Costs Hit Home." Canadian Climate Institute, June 26, 2023. https://climateinstitute.ca/with-the-forest-ablaze-the-health-costs-hit-home/.

[6] Canadian Climate Institute. "The Costs of Climate Change - Canadian Climate Institute," January 18, 2023. https://climateinstitute.ca/reports/the-costs-of-climate-change.

[7] IPCC, "Technical Summary. In: Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty," 2018, https://www.ipcc.ch/sr15/technical-summary

[8] Calvin et al., "IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (Eds.)]. IPCC, Geneva, Switzerland."

[9] United Nations Environment Programme, "Annual Report 2023." January 24, 2024, https://www.unep.org/resources/annual-report-2023

One recent assessment found that if current trends in policy and technology development continue, there is a less than 7% chance of keeping global temperature increases below 2°C.[10] As illustrated in Figure 2, even under the most optimistic future emissions scenario, global temperatures are projected to continue rising over the next 80 years. The long-term impacts of present-day decisions will be borne disproportionately by those born today and by future generations.

How Baby Boomers, Generation X, and Millennials are Experiencing Changes in Global Surface Temperatures

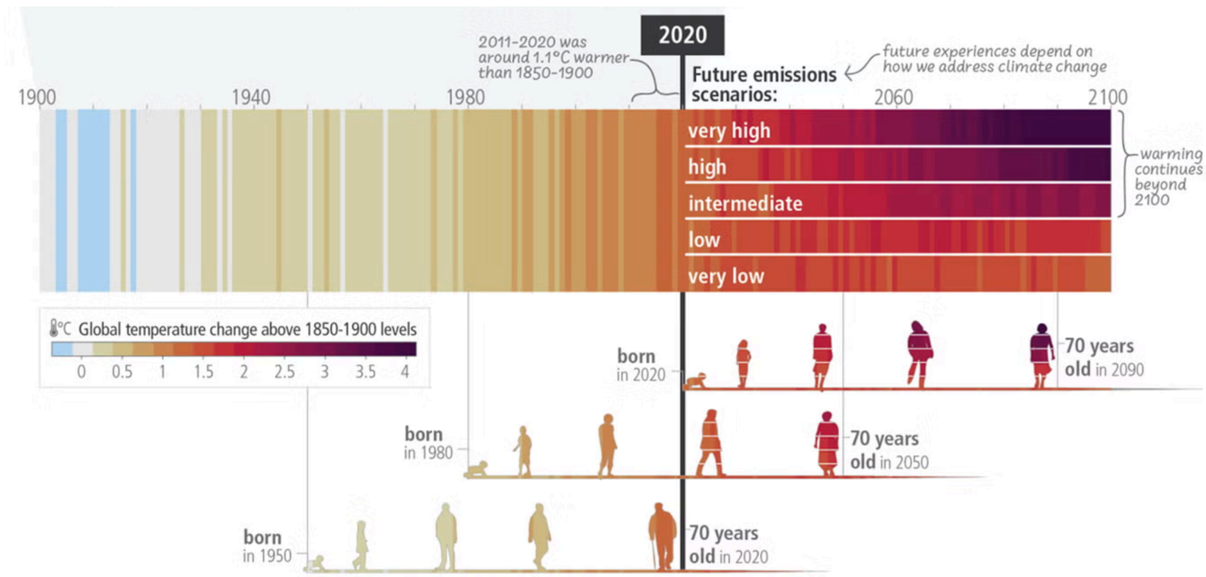

Figure 2. The extent to which current and future generations will experience a hotter and different world depends on choices now and in the near term.[11]

Climate Change Intensifies Global Vulnerabilities

Climate change's global consequences are directly linked to the degree of warming, with risks intensifying for every fractional temperature rise. Hazards and associated risks expected in the near term include an increase in heat-related human mortality and

[10] Kate Larsen, Mahmoud Mobir, Shweta Movalia, Hannah Pitt, Alfredo Rivera, Emma Rutkowski, and Marie Tamba. Rhodium Climate Outlook 2024: Probabilistic Global Emissions and Energy Projections. Rhodium Group, 2024. https://climateoutlook.rhg.com/.

[11] Calvin, Katherine, Dipak Dasgupta, Gerhard Krinner, Aditi Mukherji, Peter W. Thorne, Christopher Trisos, José Romero, et al. "IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (Eds.)]. IPCC, Geneva, Switzerland." July 21, 2023. https://doi.org/10.59327/ipcc/ar6-9789291691647.

morbidity; an increase in food-borne, water-borne, and vector-borne diseases; an increase in mental health challenges; more flooding in coastal and other low-lying cities and regions; biodiversity loss in land, freshwater, and ocean ecosystems; and a decrease in food production in some regions. These risks are increasingly complex and difficult to manage. For example, climate-driven food insecurity and supply instability are projected to worsen with increasing global warming, due to the interactions of non-climatic risk drivers such as competition for land between urban expansion and food production, pandemics, and conflict.[12]

Climate change is a threat and a threat multiplier—jeopardizing peace and security at local, national, and international levels; degrading infrastructure; undermining economies; compromising population health; and destabilizing the ecological systems that provide the physical necessities of life. The resulting social and economic disruptions are accelerating political instability, which could lead to conflict, migration, and war.[13,14]

The severity of climate change in specific geographies and the inability of states to manage those impacts is causing human migration, which is starting to cause global geopolitical tension. Future climate change will exacerbate these tensions as certain locations become inhospitable or uninhabitable due to changing climatic conditions or sea level rise.

“Climate refugees” refer to people who have been “forced to leave their traditional habitat, temporarily or permanently, because of marked environmental disruption.”[15] One study found that over one billion people are in danger of being displaced by 2050,[16] with Sub-Saharan Africa, South Asia, the Middle East, and North Africa facing the largest number of ecological threats. About 5.4 billion people—more than half of the world's projected population—will live in the 59 countries experiencing high or extreme water stress, including India and China,[17] and twice as many people as today—3.5 billion—could suffer from food insecurity by 2050.

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[12] Calvin et al., “IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (Eds.)]. IPCC, Geneva, Switzerland.”
[13] Cattaneo, Cristina, and Valentina Bosetti. “Climate-induced International Migration and Conflicts.” CESifo Economic Studies 63, no. 4 (August 1, 2017): 500–528. https://doi.org/10.1093/cesifo/ifx010.
[14] Alverio, Gabriela Nagle, Jeannie Sowers, and Erika Weinthal. “Climate Change, Conflict, and Urban Migration.” Environment and Security, August 4, 2024. https://doi.org/10.1177/27538796241259242.
[15] Hinnawi, Essam E. and UNEP. “Environmental Refugees.” United Nations Digital Library System, 1985. https://digitallibrary.un.org/record/121267?ln=en&v=pdf.
[16] Vision Of Humanity. “Peace Research, Presentations & Resources Free to Download.” Vision of Humanity, November 1, 2023. http://visionofhumanity.org/resources.
[17] Vision Of Humanity, “Peace Research, Presentations & Resources Free to Download.”Ibid.

Local Consequences of a Changing Climate

Climate change impacts are already disrupting communities at the local level, with climate-related hazards like floods and wildfires damaging infrastructure, affecting public health, and threatening local economies and livelihoods. As stated in a recent Court of Appeal for Ontario decision, "It is indisputable that, as a result of climate change, the [appellants] and Ontarians in general are experiencing an increased risk of death and an increased risk to the security of the person."[18]

Government responses are constrained by an inherent conservatism, economic lock-in, and incumbency; the application of linear, historically derived trends to non-linear change;[19] and most fundamentally, the limits of the human imagination[20]—these limitations put the safety and well-being of the community at risk. A former U.S. presidential scientific advisor said, "We will respond to climate change with a mix of mitigation, adaptation and suffering; all that remains to be determined is the mix."[21]

The rapid reduction of GHG emissions is the most direct way to limit global temperature rise and therefore reduce the risk of harm.

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[18]Roberts, Lois B, Steve A Coroza, and Sally A Gomery. "Mathur V. Ontario." Decisions of the Court of Appeal. 2024 ONCA 762, October 17, 2024. https://climatecasechart.com/wp-content/uploads/non-us-case-documents/2024/20241017_CV-19-00631627_decision.pdf.

[19] Wise, R.M., I. Fazey, M. Stafford Smith, S.E. Park, H.C. Eakin, E.R.M. Archer Van Garderen, and B. Campbell. "Reconceptualising Adaptation to Climate Change as Part of Pathways of Change and Response." Global Environmental Change 28 (January 11, 2014): 325–36. https://doi.org/10.1016/j.gloenvcha.2013.12.002.

[20] Abbas, Ansar, Dian Ekowati, Fendy Suhariadi, and Rakotoarisoa Maminirina Fenitra. "Health Implications, Leaders Societies, and Climate Change: A Global Review." Springer Climate, January 1, 2022, 653–75. https://doi.org/10.1007/978-3-031-15501-7_26.

[21] Roberts, David, and David Roberts. "Preventing Climate Change and Adapting to It Are Not Morally Equivalent." Grist, April 1, 2021. https://grist.org/climate-energy/preventing-climate-change-and-adapting-to-it-are-not-morally-equivalent/.

4.2 Opportunity

The world now invests almost twice as much in clean energy as it does in fossil fuels.[22]

In the past, climate action was motivated by a moral imperative to future generations. While the moral imperative remains, it is now complemented by a broadening range of economic opportunities. Indicators of these economic opportunities include the growth of clean electricity[23] and the adoption of clean technologies such as electric vehicles[24] and heat pumps.[25]

The global energy system is transitioning due to rapid technological change and the evolution of sub-national, national, and international policies in response to the climate change threat.[26] A large-scale, socio-economic transition refers to a fundamental change in the fulfillment of societal needs, with implications across sectors; the introduction of new technologies and new ways of applying these technologies; and changes in markets, cultural discourses, and governance at all levels.[27]

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[22] IEA. "World Energy Investment 2024 – Analysis - IEA," June 1, 2024. https://www.iea.org/reports/world-energy-investment-2024.
[23] International Renewable Energy Agency, "Record Growth in Renewables Achieved Despite Energy Crisis," March 21, 2023, https://www.irena.org/News/pressreleases/2023/Mar/Record-9-point-6-Percentage-Growth-in-Renewables-Achieved-Despite-Energy-Crisis
[24] Tom Randall, "US Crosses the Electric-Car Tipping Point for Mass Adoption," Bloomberg, July 9, 2022, https://www.bloomberg.com/news/articles/2022-07-09/us-electric-car-sales-reach-key-milestone
[25] Yannick Monschauer, Chiara Delmastro, and Rafael Martinez-Gordon, "Global Heat Pump Sales Continue Double-Digit Growth," *International Energy Agency*, March 31, 2023, https://www.iea.org/commentaries/global-heat-pump-sales-continue-double-digit-growth
[26] Hirt, Léon F., Guillaume Schell, Marlyne Sahakian, and Evelina Trutnevyte. "A review of linking models and socio-technical transitions theories for energy and climate solutions." Environmental Innovation and Societal Transitions 35 (2020): 162-179.
[27] Coenen, Lars, Rob Raven, and Geert Verbong. "Local niche experimentation in energy transitions: A theoretical and empirical exploration of proximity advantages and disadvantages." Technology in Society 32, no. 4 (2010): 295-302.

The Transformation of the Energy System[28]

"The energy world is in the early phase of a new industrial age—the age of clean energy technology manufacturing. Industries that were in their infancy in the early 2000s, such as solar photovoltaic and wind, and the 2010s, such as EVs and batteries, have mushroomed into vast manufacturing operations today. The scale and significance of these and other key clean energy industries are set for further rapid growth. Countries around the world are stepping up efforts to expand clean energy technology manufacturing with the overlapping aims of advancing net zero transitions, strengthening energy security and competing in the new global energy economy. The current global energy crisis is a pivotal moment for clean energy transitions worldwide, driving a wave of investment that is set to flow into a range of industries over the coming years. In this context, developing secure, resilient and sustainable supply chains for clean energy is vital."

IEA (2023). Energy Technology Perspectives 2023, P. 4

Foundationally, the energy transition involves shifting away from fossil fuels, the source of the majority of the world's GHG emissions. Fossil fuels currently provide 81.5% of the world's primary energy.[29] An economic, policy, and cultural ecosystem has evolved around the production, transportation, and consumption of fossil fuels, which has shaped global trade, infrastructure, and political dynamics for decades. The energy transition is disrupting this entrenched system—triggering shifts in investment patterns, labour markets, and geopolitical influence.

Technologies Are Paving the Way to a Low-Carbon Future

Efficiency gains are a key driver of the energy transition, reducing overall energy demand while maximizing the benefits of renewable energy adoption. Improved energy efficiency in buildings, transportation, and industrial processes lowers overall fossil fuel consumption by reducing energy demand. For example, advanced heat pumps and electric vehicles use three to four times less energy than the gas furnaces and gasoline and diesel cars that they typically replace.

The energy transition is predominantly driven by increases in wind and solar generation, resulting in lower carbon intensity of electricity systems in all regions of the world since the turn of the century.[30] In the past few years, owing to enabling federal government policies and the falling cost of the technology,[31] solar installations have increased exponentially to the point where more than a gigawatt of solar is being installed globally every day.

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[28] International Energy Agency, "Energy Technology Perspectives 2023," January 2023, https://www.iea.org/reports/energy-technology-perspectives-2023

[29] Energy Institute, "Statistical Review of World Energy," 2023, https://www.energyinst.org/statistical-review

[30] Ian Tiseo, "CO_2 Intensity of Electricity Generation Worldwide 2000-2050, by Region," *Statista*, June 20, 2023, https://www.statista.com/statistics/1257765/global-emission-intensity-electricity-generation-region/

[31] Lazard, "Levelized Cost of Energy," 2024, https://www.lazard.com/media/xemfey0k/lazards-lcoeplus-june-2024-_vf.pdf

A notable offshoot of the wind and solar generation trend is the regionalization of the global energy markets. This regionalization, and even localization, provides enhanced energy security as communities no longer rely solely on long supply lines for fuel or equipment that can be imperiled by geopolitical events and natural disasters across the globe. Localization of the energy supply, typically in the form of electricity, has become so pervasive as to merit its own terminology—distributed energy resources (DERs). Ontario's IESO is currently designing a program that will enable broader deployment.[32]

Electrification is also happening extensively in both transportation and building heating. Globally, electric vehicle sales are growing at 25% annually and have just reached 17 million in sales.[33] In the building heating sector, heat pumps are the avenue for electrification, providing both heating and cooling. Although market growth of heat pumps has been slower compared to electric vehicle growth, 2022 marked the first year in which U.S. heat pump sales exceeded the sales of gas furnaces.[34] In Canada, a market survey has forecasted a compound annual growth rate for heat pumps of 8.8%[35] between 2023 and 2030.

These trends represent opportunities for households and businesses to stimulate new businesses and jobs, reduce household costs, increase resilience, and create new revenue opportunities from energy generation.

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[32] IESO. Local Generation Program, 2025 Retrieved from: https://www.ieso.ca/Sector-Participants/Engagement-Initiatives/Engagements/Local-Generation-Program

[33] International Energy Agency, "Growth in Electric Car Sales Remains Robust as Major Markets Progress and Emerging Economies Ramp Up," 2024, https://www.iea.org/reports/global-ev-outlook-2024/executive-summary

[34]State of New York., "U.S. Heat Pump Sales Surpass Gas Furnaces," 2023, https://www.nyserda.ny.gov/Featured-Stories/US-Heat-Pump-Sales

[35] "Canada Heat Pump Market Size &Amp; Outlook, 2030." 2024. October 16, 2024. https://www.grandviewresearch.com/horizon/outlook/heat-pump-market/canada.

5 | An Accelerated Pathway

5.1 Net Zero by 2040

This brief assesses the technical viability of accelerating Hamilton's net-zero GHG target from 2050 to 2040. The 2040 target aligns better with the latest science-based targets and pathways. If all cities and governments were to select and work towards this target, the world would have a better chance of limiting the catastrophic impacts of climate change.

Assessing opportunities for an accelerated GHG target begins with identifying which emissions can be mitigated more quickly using the analysis completed for ReCharge Hamilton's LCS pathway.

In 2040, the main sources of GHG emissions in the LCS are natural gas, hydrogen, coal, and gasoline, with smaller amounts from grid electricity and diesel (Figure 3). By 2045, the emissions from these four fuels are roughly half of the 2040 projections. Nearly all of these emissions are from the industrial sector (natural gas, hydrogen, which is produced from fossil fuels, and gasoline), with smaller amounts from transportation (gasoline), as illustrated in Figure 4.

A 2040 target requires the following strategies:

1. Implementing the full suite of actions in ReCharge Hamilton;
2. Accelerating the decarbonization of the steel industry—the primary source of emissions in the industrial sector; and
3. Accelerating the electrification of vehicles.

Accelerating steel industry decarbonization and vehicle electrification both rely on the availability of clean electricity.

Actions identified and detailed in ReCharge Hamilton represent the starting point of this analysis. Pathways for building-related actions (retrofits, heat pumps, etc.) were found to be still ambitious with little scope for acceleration to 2040. These building-related pathways are therefore not considered in this briefing paper, and progress in implementing these actions was not evaluated.

A comprehensive update of the modelling in ReCharge Hamilton would be required to determine the specific actions, timelines, and resources associated with implementation. In comparison, this briefing leverages the original model results and complementary analysis to investigate the viability of accelerating GHG emissions reductions in the industrial sector and reducing transportation emissions.

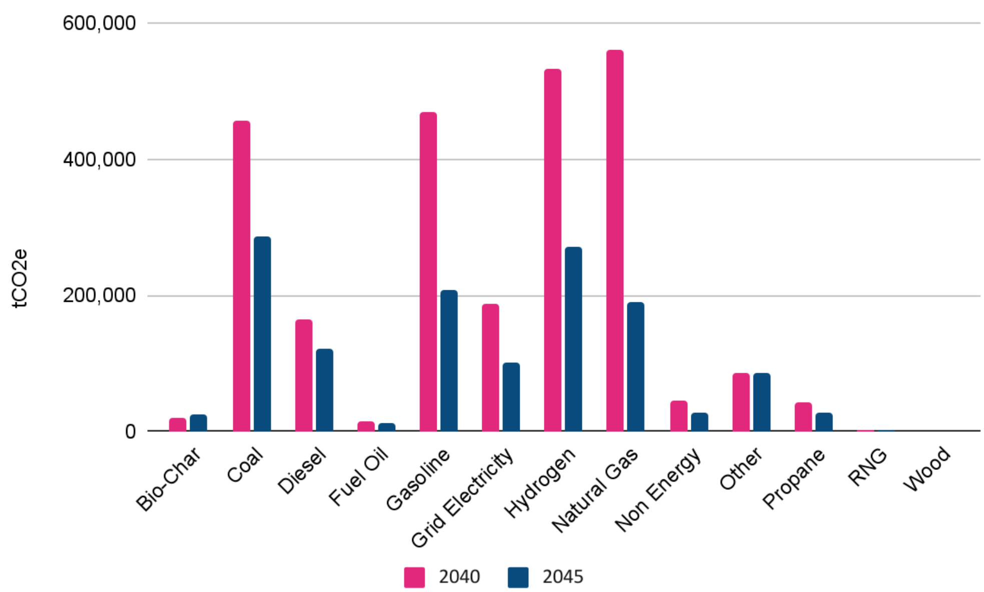

Figure 3. GHG emissions by fuel type in the LCS for 2040 and 2045.

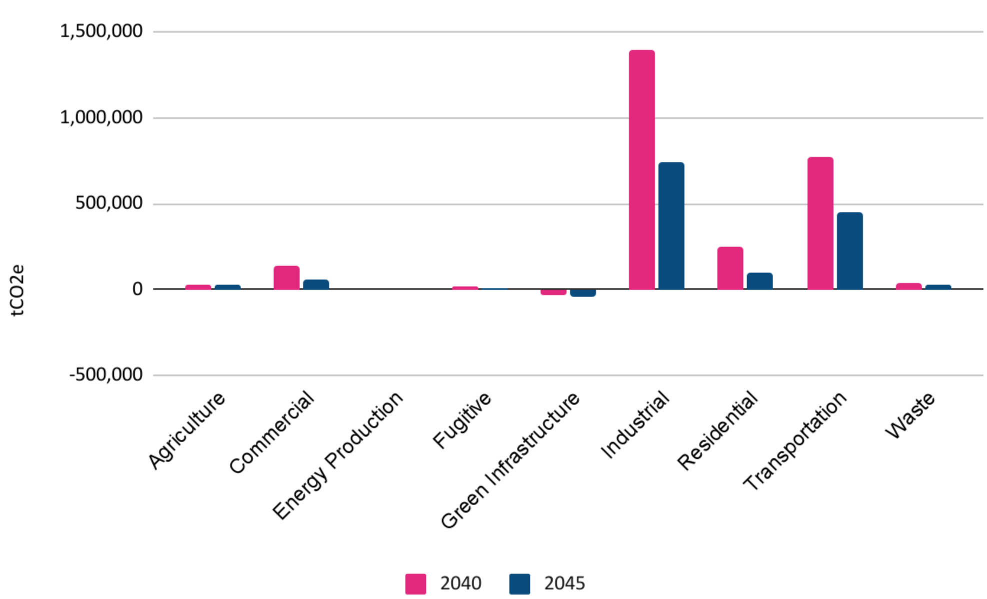

Figure 4. GHG emissions by sector in the LCS in 2040 and 2045.

5.2 Accelerating Clean Transportation

There are two key steps to accelerating transportation decarbonization. Assuming that the average vehicle is on the road for 10 years, switching the entire on-road fleet to zero-emissions vehicles (ZEVs) requires 100% sales of new vehicles 10 years earlier than the 2040 target, or in 2030. As demonstrated below, a 100% share of ZEVs by 2030 is technically possible but culturally and politically challenging. Hamilton can accommodate a slower-than-required vehicle electrification trajectory with a concentrated effort to shift travel to other zero-emissions modes, like walking, cycling, and transit.

ZEV Adoption Rate

ReCharge Hamilton included a ZEV adoption rate of 10% of light-duty vehicles sales per year by 2025, 30% by 2030, and 100% by 2040, illustrated by the orange line on Figure 5. This trajectory results in a nearly 100% ZEV adoption of the total light-duty fleet by 2050 (the black line). In 2022, the Government of Canada announced the target of 100% zero-emission vehicle sales by 2035 for all new light-duty vehicles, as well as interim targets of at least 20% by 2026 and at least 60% by 2030,[36] represented by the green line. With this federal target, the total fleet will be electrified approximately five years earlier than was modelled in the LCS, cutting the projected GHG emissions from transportation in half by 2040.[37]

Eliminating Hamilton's GHG emissions by 2040 would require accelerating ZEV adoption to 100% EVs by 2030—a target that would require an even more ambitious adoption curve than that of the Canadian government (NZS 2040 trajectory is represented by the pink line). Growth in the share of ZEV sales nationally relative to total sales is on an exponential curve (light purple line in Figure 5). When extrapolated mathematically, the EV share reaches 100% of new vehicle sales by 2030. However, it is unlikely that the formula that defines this curve will reflect the reality of ZEV adoption when accounting for costs, barriers to charging, politics, etc.

In comparison, the UK government has adopted a 2030 target for 100% EV sales,[38] but the UK is already further along the adoption curve than Canada. The UK EV share of sales in 2024 was approximately twice that of Ontario, at just under 20%.

[36] Government of Canada (2022). 2030 Emissions Reduction Plan: Clean Air, Strong Economy. Retrieved from: https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/emissions-reduction-2030.html
[37] GHG emissions from transportation in 2045 will shift to 2040 based on the acceleration of EV adoption rates required by the federal government.
[38] Government of UK (2025). Phasing out the sale of new petrol and diesel cars from 2030 and support for zero emission vehicle (ZEV) transition. https://www.gov.uk/government/speeches/phasing-out-the-sale-of-new-petrol-and-diesel-cars-from-2030-and-support-for-zero-emission-vehicle-zev-transition

As a further point of comparison, Norway's adoption rate (dark blue line in Figure 5) illustrates the possibilities of an adoption rate similar to that envisioned by the federal government. Norway's EV adoption rate was supported by incentives and investments in infrastructure beyond what is currently available in the Canadian context. On the flip side, adoption rates in Canada will benefit from more competition and diversity in the ZEV market and decreasing costs.

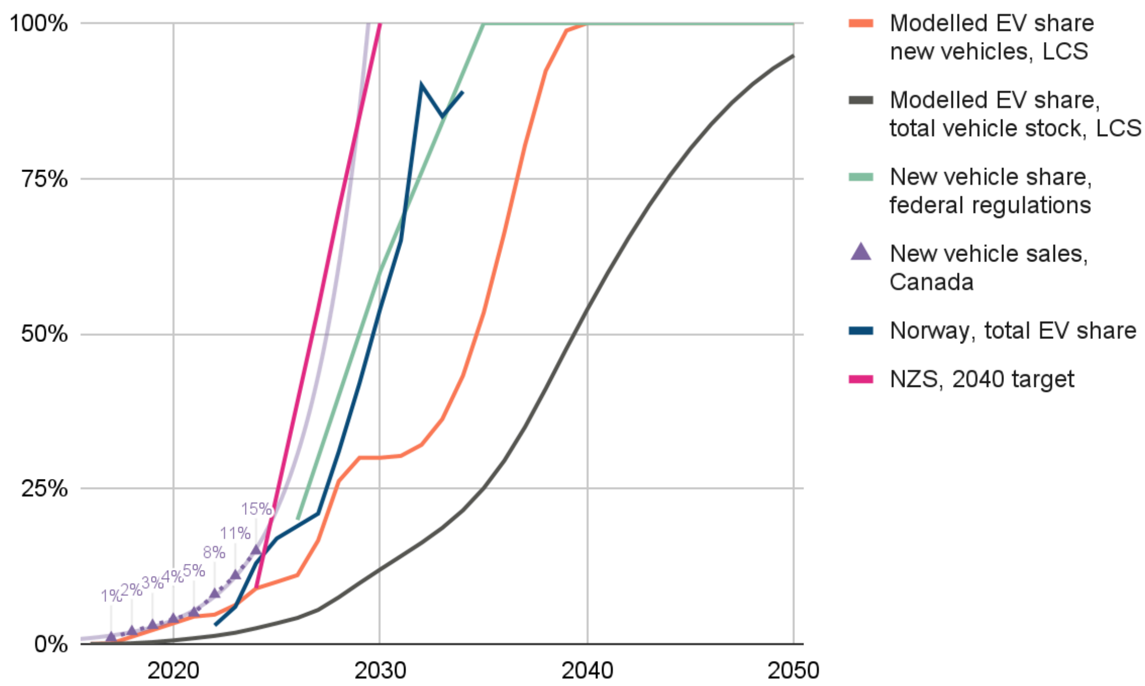

Figure 5. EV adoption rates for the LCS (new vehicle share and total stock share), federal regulations, sales in Norway (transposed), and sales in Ontario (Q3 2024).

Mode Shifting

The City of Hamilton has additional GHG reduction levers beyond the ZEV adoption rate, including increased walking and cycling rates, car sharing, and transit use. Success with these levers would not only advance the City towards its net-zero target with less reliance on ZEV adoption but would also improve affordability, livability, equity, and public health.

A reassessment of the LCS estimates from ReCharge Hamilton indicates a wealth of opportunities for mode shifting away from vehicles. Trips of 2 km or less could be switched to walking (1% of all km travelled), trips of between 2 km and 10 km in length could be shifted to cycling (30% of all km travelled), trips between 10 km and15 km could be shifted to e-bikes (20% of all km travelled), and a share of longer trips could be shifted to transit (Figure 6). Mode shifting away from vehicles reduces the requirement for rapidly shifting the vehicle fleet to ZEVs by diminishing vehicular travel[39] and increasing the affordability and accessibility of decarbonizing transportation.

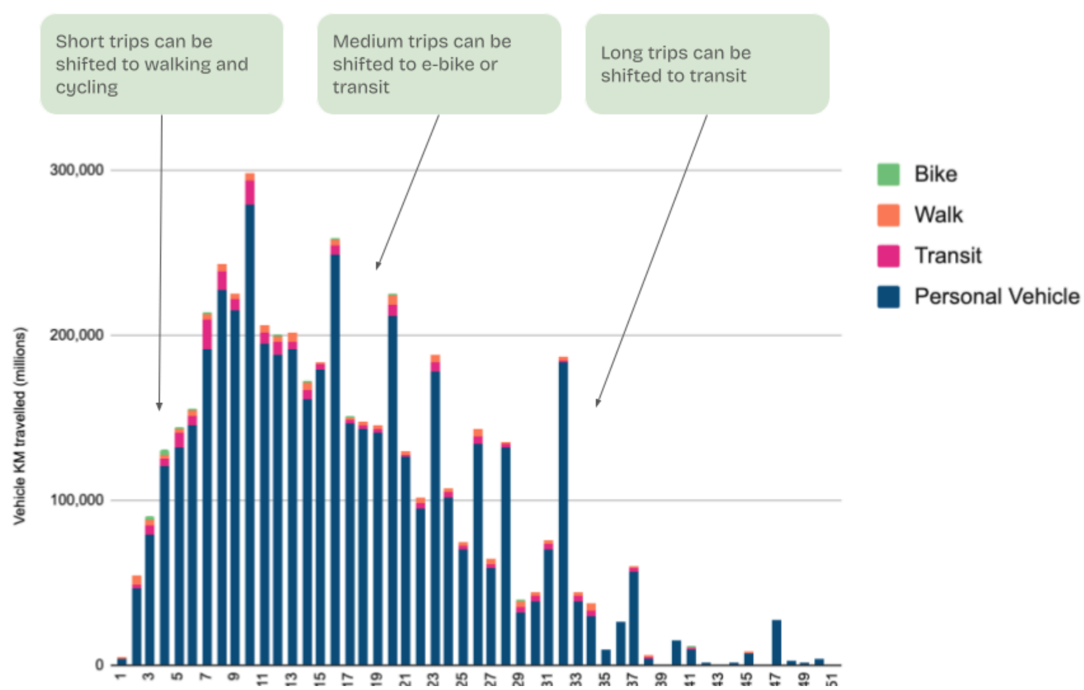

Figure 6. Modelled vehicle kilometres travelled (VKT) by trip length in the LCS in 2050.

[39] For example, see: fka Andersson, A. S., Adell, E., & Hiselius, L. W. (2021). What is the substitution effect of e-bikes? A randomised controlled trial. Transportation research part D: transport and environment, 90, 102648.

Table 1 describes a list of potential strategies that the City should consider to accelerate transportation decarbonization.

Table 1. Potential strategies to advance transportation decarbonization.

Theme	Strategy	Description
Reduce the need for vehicles	Develop personalized transportation planning	This strategy involves direct support from a transportation advisor for each household. The advisor supports the development of a household transportation plan and provides access to incentives as well as ongoing support.
	Implement superblocks	Superblocks are a planning strategy developed in Barcelona[40] that removes or limits vehicular traffic to a peripheral street and enables existing neighbourhoods to redesign their public spaces to encourage social cohesion.
	Enhanced transit	Enhanced transit includes implementing a planned LRT, on-demand transit, and etc.
	Introduction of *collectivos*	*Collectivos*[41] are an innovation from Latin America that facilitate group travel from one location to another, a mixture of a bus and a taxi. The *collectivos* are typically private contractors.
Accelerate retirement of gas- and diesel-powered vehicles	Develop a Cash for Clunkers program	A cash for clunkers program pays people to remove older gasoline and diesel vehicles from the road, targeting low-income households. This program could also provide scrap metal to the steel industry.
	Implement zero-emissions zones	A zero-emissions zone limits vehicular traffic in a specific area, emphasizing non-vehicular modes while providing preferential treatment to zero-emissions vehicles.
Accelerate deployment of EVs	Create an incentive program, such as Clean Cars for All	Clean Cars for All is a program developed in California to help lower-income households replace their old higher-polluting vehicles with EVs, electric bikes, or even transit passes.

[40] Postaria, R. (2021). "Superblock (Superilla) Barcelona—a city redefined." Retrieved from https://www.citiesforum.org/news/superblock-superilla-barcelona-a-city-redefined/
[41] González, J.F. (2023). "Concealed Public Transportation in Latin America: A Rediscovery by Bus." *Revista: Harvard Review of Latin America.* Retrieved from https://revista.drclas.harvard.edu/concealed-public-transportation-in-latin-america-a-rediscovery-by-bus/

Theme	Strategy	Description
	Implement free or discounted parking for EVs	Parking fees for EVs can either be free or discounted from parking fees for gas- and diesel-powered vehicles. Parking fees can also be adjusted according to the size of the vehicle.
	Develop a vehicle- to-grid program	A vehicle-to-grid program allows EVs to charge at an off-peak rate and allows them to provide ancillary services to the grid as a revenue source. This approach can accelerate the adoption of EVs by turning them into a business opportunity.
	Create a bulk procurement program	The City can negotiate a bulk procurement program to reduce EV costs for qualified residents or corporate fleets.
	Develop a dealer encouragement program	The City can incentivize dealers that achieve specific outcomes in terms of selling EVs through financial incentives or recognition awards.
	Coordinate fleet procurement	The City can partner with other fleet owners in the City and beyond—including private, public, and even other municipalities—to develop joint fleet decarbonization strategies and joint procurement strategies.
	Support car-sharing programs	The City can develop and enable car-share programs, which reduce the need for individually owned vehicles.
Accelerate EV infrastructure	Install chargers in public locations, workplaces, and residences	The City can install EV chargers on streets, particularly in locations where residents do not have access to chargers at their homes, such as in apartments.
	Provide rebates for charging installations	The City can provide rebates or other incentives for installing charging infrastructure in public and private locations.
	Require EV chargers in Green Building Standards	EV chargers are part of the Council-endorsed draft Green Building Standards, which is currently in the approval process, and the upcoming EV Strategy for Hamilton. The City could consider setting higher requirements for EV chargers in future iterations of the Green Building Standards and Parking Standards.

Theme	Strategy	Description
	Partner with utilities on EV infrastructure and EVs	The City can partner with utilities on programs to encourage EV charging infrastructure development and EV fleet purchases. For example, it could develop a leasing model where the utility owns the vehicles, which are rented or leased by the City, its agencies, or others in Hamilton.
Communications	Communicate the benefits of EVs	In collaboration with partners, the City can develop and implement programs to help community members understand how EVs work, what they cost, and the different procurement strategies available.

5.3 Decarbonizing Industry

ReCharge Hamilton describes GHG emissions from the industrial sector (particularly from the steel industry) as the other major source that must be quickly reduced to achieve a net-zero target by 2040 (dark blue area in Figure 7).

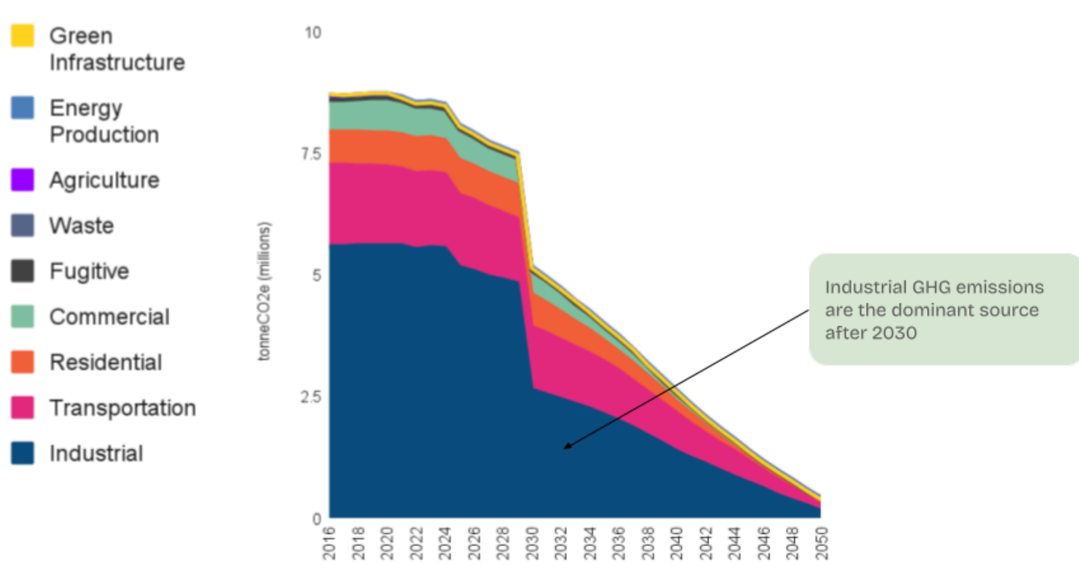

Figure 7. GHG emissions by sector in the LCS, 2016–2050.

Some recent critical developments support the feasibility of accelerating the assumptions for industrial decarbonization. In 2021, ArcelorMittal Dafasco and the Canadian and Ontario governments announced an investment of nearly $2 billion to transition from coke ovens and blast furnaces to a Direct Reduced Iron (DRI) facility combined with an existing and new Electric Arc Furnace (EAF), which would reduce facility emissions by approximately 60%.[42, 43] An industrial decarbonization pathway, which included similar actions, was modelled in the LCS prior to this announcement. This pathway resulted in industrial GHG emissions reductions of 53% over 2021 levels by 2030, or 3 MtCO2e, with 2.6 MtCO2e remaining in 2030. This result is comparable to the savings projected by the ArcelorMittal Dafasco investment announcement.[44]

In the LCS pathway, GHG emissions from coal continue until 2050. As a result of the DRI-EAF investment, coal will likely be replaced by natural gas and electricity by 2030—increasing the possibility for an accelerated decarbonization pathway. In a 2040 scenario, natural gas emissions will increase in 2030, then decrease due to the addition of blue and then green hydrogen. The LCS included emissions from blue hydrogen.

Blue hydrogen is produced by reacting natural gas (methane) with high-temperature steam in the presence of a catalyst to produce hydrogen gas and carbon dioxide. If the carbon dioxide is captured and stored, it is blue; if it is released, it is grey. Depending on methane leakage rates and carbon capture efficiency, blue hydrogen's GHG emissions can be comparable to natural gas combustion. Green hydrogen refers to using renewable electricity to split hydrogen from water—its GHG footprint is very low.

[42] ArcelorMittal (2021). ArcelorMittal and the Government of Canada announce investment of CAD$1.765 billion in decarbonisation technologies in Canada. Retrieved from: https://corporate.arcelormittal.com/media/press-releases/arcelormittal-and-the-government-of-canada-announce-investment-of-cad-1-765-billion-in-decarbonization-technologies-in-canada

[43] ArcelorMittal (2022). ArcelorMittal breaks ground on first transformational low-carbon emissions steelmaking project. Retrieved from: https://corporate.arcelormittal.com/media/press-releases/arcelormittal-breaks-ground-on-first-transformational-low-carbon-emissions-steelmaking-project

[44] Ibid.

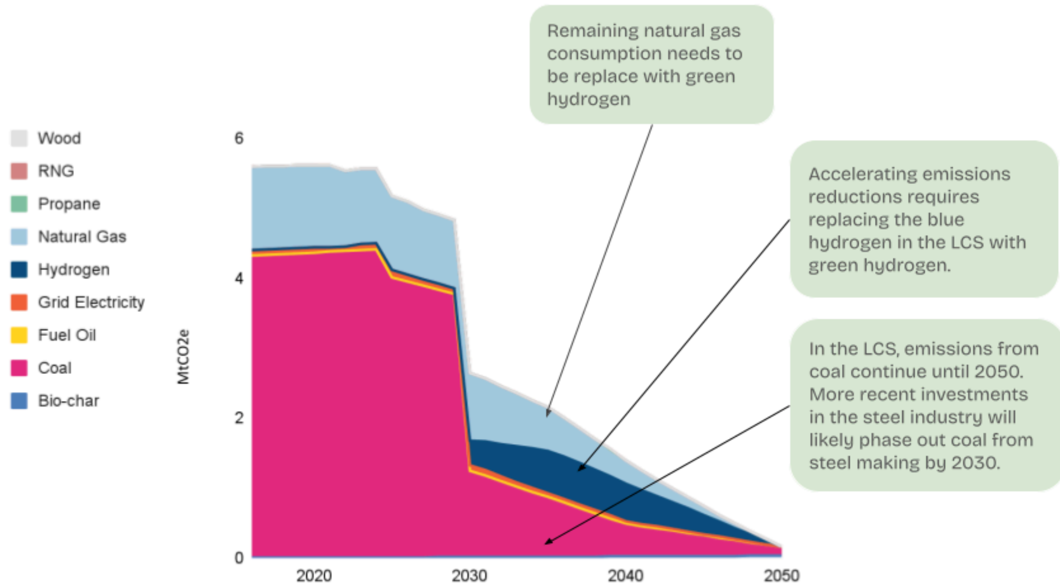

Figure 8. Industrial sector GHG emissions by fuel type in the LCS, 2016—2050. Note that this scenario pre-dated ArcelorMittal Dafasco's investment announcement. While the GHG emissions reductions are similar, the pathway is somewhat different.

Following the DRI-EAF investment, there are three additional elements required to complete the decarbonization of steel in Hamilton:

1. **Replace natural gas use with green hydrogen:** Hydrogen replaces coal to reduce iron ore to DRI, emitting only water vapor—if coal is used, then carbon dioxide is emitted. DRI can then be melted in the EAF. Green hydrogen production requires investments in clean electricity production, pipelines, and storage. Blue or green hydrogen can be phased in and mixed with natural gas prior to full implementation by 2035–2038.

2. **Maximize scrap steel use:** Scrap steel as a feedstock is more energy efficient than making structural steel from iron ore, bypassing the requirement for DRI. Other types of steel require DRI as a feedstock. This aspect requires scaling up steel recycling and enhancing the sorting processes in Ontario. The supply of scrap steel is also finite and demand will increase as the industry decarbonizes.

3. **Ensure 100% clean electricity:** Clean electricity is required to power the EAFs. Clean electricity can be secured through Power Purchase Agreements by the City or industry, provincial or federal policies on the decarbonization of the grid, etc.

Assuming the DRI-EAF project is completed by 2030, the steel industry has 10–15 years from now to scale up scrap steel collection, secure green hydrogen, and provide access to 100% green electricity. The City of Hamilton can support industry in this process with the potential strategies described in Table 2.

Table 2. Potential strategies to support industry to advance zero-emissions steel.

Theme	Strategy	Description
Procurement	Develop a Green Steel Policy	The City can require the use of green steel for its construction projects.
	Create a Green Steel Coalition	The City can work with other municipalities, businesses, and governments to develop a green steel procurement commitment.
Policy and Infrastructure	Provide incentives for green industrialization	The City can provide expedited permitting and property tax incentives to support investments in industrial decarbonization.
	Invest in green steel	The City can issue bonds to support investments, loans, or guarantees in green steel projects.
	Develop and support clean energy projects	The City can enable permitting for, invest in, or develop renewable electricity projects on public or private lands.
	Invest in facilities for scrap steel-based circular economy	The City can develop or enable facilities that collect and sort scrap steel.
	Accelerate development of district energy from waste heat	The City can accelerate efforts to develop a district energy system based on waste heat from industrial processes.
Coordination	Develop a green hydrogen hub	The City can develop a green hydrogen hub that provides hydrogen expertise, facilitation, and economic development capabilities.
	Develop a green steel innovation hub	The City can develop a green steel innovation hub that provides expertise, facilitation, and economic development capabilities in green steel.
	Develop a green steel workforce training	The City can coordinate with McMaster and Mohawk on a green steel workforce training

Theme	Strategy	Description
	program	program.
Advocacy	Advocate for funding	The City can advocate to provincial and federal governments for investments in and policies to support green steel.
	Encourage a border carbon adjustment	The City can advocate for a border carbon adjustment to ensure the competitiveness of green steel.

5.4 Financial Impacts

The financial parameters have shifted significantly since the ReCharge Hamilton analysis was completed in 2019. While this analysis does not include an update of the financials, it is instructive to consider key drivers of costs and savings and the implications of an accelerated net-zero target on those drivers.

The economic impact of accelerating Hamilton's net-zero target to a point earlier than 2050 is threefold:

1. Investments need to be scaled in the near term, particularly in the next decade.
2. Financial savings from reduced energy costs will increase quicker as a result of reduced energy consumption.
3. Non-direct financial benefits to the community will increase, including from public health, equity, reputation, and resilience. Table 5 describes examples of these benefits.

The annual costs, savings, and revenue associated with fully implementing the actions in the LCS are shown in detail in Figure 9, with capital expenditures shown in full in the years in which they are incurred. The black line indicates annual net costs or net savings. In the LCS, annual costs exceeded savings until 2050.

Hamilton's cost profile is less compelling than that of other cities, where annual savings exceed annual costs earlier in the study period, primarily due to the massive investments required for decarbonizing steel. The scale of these investments was more uncertain when the LCS was modelled in 2019.

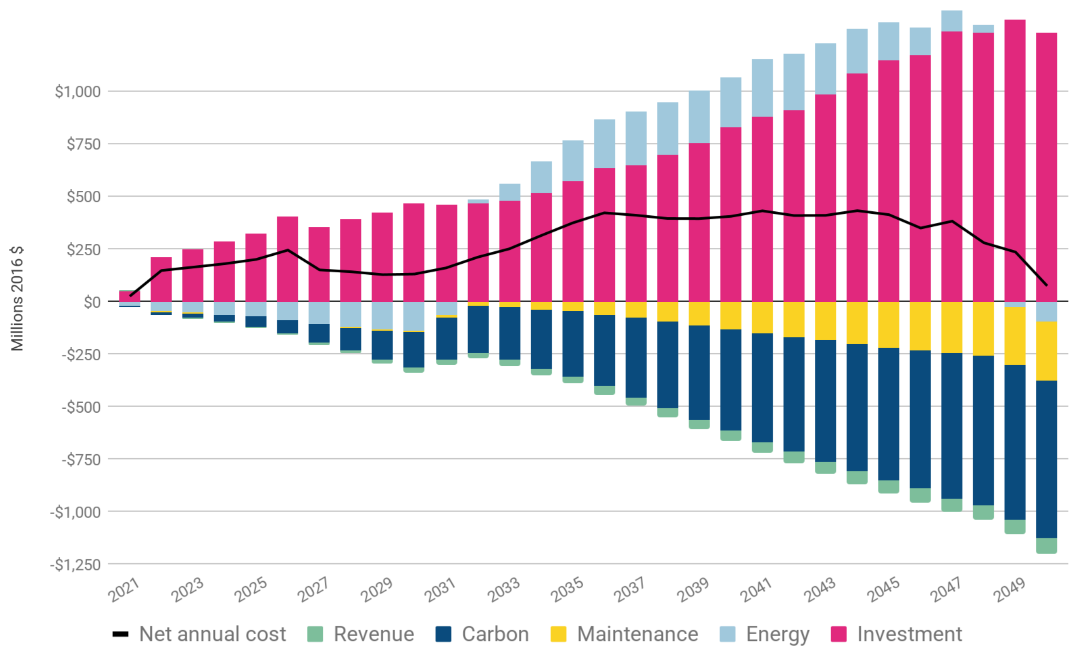

Figure 9. Incremental capital and operating expenditures in the LCS, 2021–2050.

Assuming all else is equal (i.e., the financial assumptions for the cost of low-carbon technologies), accelerating the net-zero target by a decade will have the effect of front loading capital expenditures in the next decade. The inflection point where savings exceed costs will also move forward so that households and businesses experience financial benefits sooner, as was the case in an analysis comparing two scenarios for the City of Toronto (Figure 10). Hamilton would likely see similar trends with an updated financial analysis.

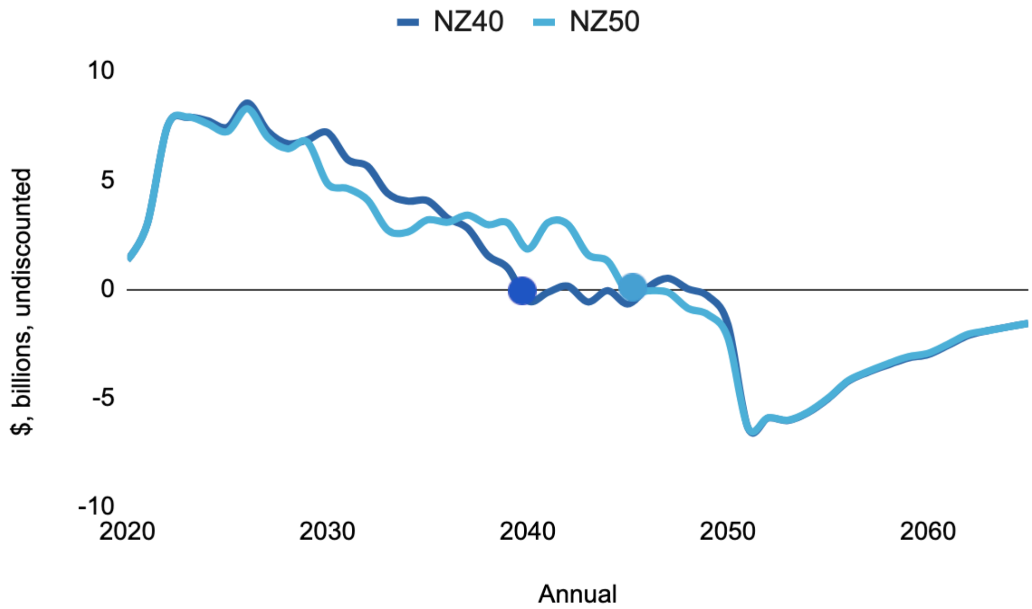

Figure 10. The net financial impact of the net-zero-by-2040 (NZ40) and net-zero-by-2050 (NZ50) scenarios for the City of Toronto.

Capital Expenditures

Capital costs for low-carbon technologies have generally decreased since 2019, with the largest decreases occurring for industry and EVs. Cost decreases will improve the financial profile of these projects and the net-zero pathway overall. The capital cost projections for heat pumps and solar photovoltaic (PV) were low compared to 2025 prices, which will decrease the projected financial benefits for these actions relative to what was presented in ReCharge Hamilton.

Table 3. Change in capital costs since the LCS projections.

Technology	Change in unit cost assumption relative to the LCS	Impact	Description
Industry	Decline	High	Industrial investments, totalling $12.2 billion between 2023 and 2050 in the LCS, are likely much lower. While the $12.2 billion covers all industrial activity in the city, the steel industry is the primary industrial activity. Recent estimates indicate that decarbonizing steel facilities has costs ranging from $2 billion to $7 billion.[45,46]
EVs	Decline	Medium	The LCS assumed a premium for an average EV capital cost above gas- and diesel-powered vehicles. New estimates consider EVs to be at cost parity with comparable gas- and diesel-powered vehicles.
Solar PV	Increase	Medium	A relatively low capital cost, below current prices, was used in the LCS for residential solar, which will result in a less favourable economic case for solar compared to the LCS.
Heat pumps	Increase	Medium	The projected cost for heat pumps has increased from just over $6,000 to just over $8,000 for 2025, a less favourable economic case for heat pumps compared to the LCS.

[45] Acuity Knowledge Partners (2025). Public and Private Funding in Green Steel Production Worldwide. https://www.acuitykp.com/blog/public-private-funding-green-steel-production/
[46] Hasanbeigi, Ali; Zuo, Bonnie; Kim, Daseul; Springer, Cecilia; Jackson, Alastair; Heo, Esther Haerim. 2024. Green Steel Economics. Global Efficiency Intelligence, TransitionAsia, Solutions for Our Climate.

Operating Expenditures

Operating expenditures are a function of the differential between the cost to provide the energy services with fossil fuels (natural gas, gasoline, and coal) versus the cost to provide the same services with clean electricity and hydrogen. The cost is determined by equipment efficiency and the unit cost of energy.

Figure 11 illustrates the unit costs modelled in the ReCharge Hamilton LCS versus the updated energy unit costs from 2019 to 2025. Notably, electricity projection in the LCS was much higher than the electricity projection from 2023, while unit costs for natural gas and gasoline were comparable.

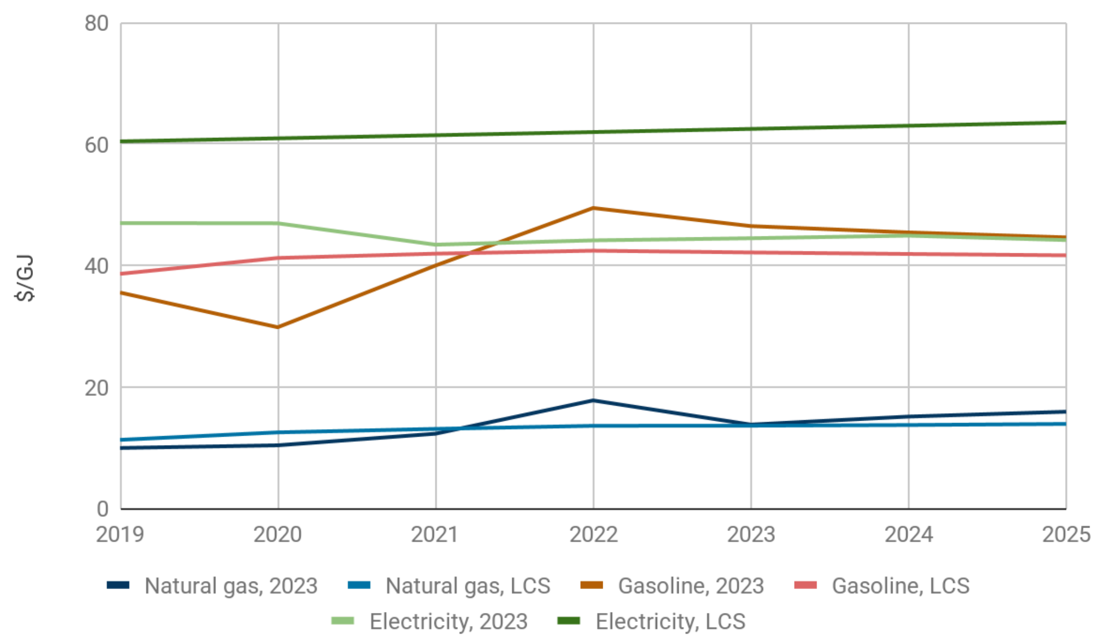

Figure 11. Comparison of the LCS and the 2023 energy cost projections for electricity, natural gas, and gasoline, 2019–2025.[47]

[47] Canada Energy Regulator (2023). Canada's Energy Future 2023. Retrieved from: https://www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2023/canada-energy-futures-2023.pdf23

The implication is that the financial case will be better for an updated net-zero target, as the differential between electricity and natural gas and electricity will be lower. The removal of the consumer carbon price decreases the spread between the cost intensities of natural gas, gasoline, and electricity, diminishing the business case for electrification; this impact is not yet reflected in this analysis. Findings from an analysis of another city indicate that even without the consumer carbon price, the decarbonization pathway can have a positive return.

Table 4 describes the underlying interactions between fuel cost and operating expenditures and how this has changed since the initial LCS assumptions in ReCharge Hamilton.

Table 4. Change in assumptions for operating expenditures relative to the LCS.

	Change in unit cost relative to cost assumptions in the LCS	Impact	Description
Carbon price	Removed for consumers. No change in the assumption for the industrial price of carbon.	High	The carbon price increases the financial differential between lower-and higher-carbon projects. The elimination of the carbon price will have a major impact on the financial profile of low-carbon projects.
Electricity	The LCS used a much higher projection for electricity costs. Additional time-of-use costs enable much more affordable electricity.	High	The differential in costs between electricity and natural gas is a key driver in the positive financial returns for low-carbon projects.
Natural gas	No major changes. The removal of the carbon price will reduce the cost going forward.	Medium	The removal of the carbon price will reduce the natural gas costs going forward.
Gasoline	No major changes.	Medium	The removal of the carbon price will reduce the gasoline cost going forward.
Hydrogen	The cost of blue hydrogen in the LCS was relatively high.	Unknown	If green hydrogen can be procured at below $40/GJ, it will strengthen the financial case for decarbonizing steel.

The incremental operating costs are primarily driven by the cost of clean electricity relative to natural gas and gasoline. Overall electricity expenditure can be lower even if electricity is more expensive than natural gas on a per unit basis because electrical devices are more efficient than their fossil-fuel equivalents.

Non-Direct Financial Impacts

Beyond emissions reductions, climate action has co-benefits that have tangible impacts on finances. Table 5 describes these co-benefits..

Table 5. Financial benefits of the Low-Carbon Pathway.

Category	Strategy	Description
Lock-In	Avoid stranded assets	The longer that households, governments, and businesses continue to add high-carbon infrastructure, the higher the transition costs. These investments cause two sets of financial damages: consuming capital that could otherwise be used to decarbonize and requiring additional capital to replace or undo the built infrastructure, likely prior to end of life.
Operating impacts	Efficiency gains	Low-carbon technologies use less energy to provide the same services (heat, transportation) thus reducing the direct fuel costs but also the capital and operating costs of maintaining or expanding the broader electricity system.
	Maintenance savings	Low-carbon technologies have fewer moving parts (EVs, solar PV) and therefore have lower maintenance costs than their fossil-fuel-powered equivalents.
	Free energy inputs	Renewable energy technologies generate electricity from energy sources that are free (wind and solar) and require no processing, transportation, or other additional infrastructure.
	New revenue opportunities	New revenue opportunities include monetizing decentralized electricity generation, energy storage, vehicle-to-grid, and microgrids.
Health Benefits	Reduced health care costs	Accelerated emissions reductions decrease population exposure to harmful air pollutants. Increased walking and cycling improve public health outcomes.

Category	Strategy	Description
	Reduced disruption due to improved health outcomes	Improved public health outcomes translate into lower public healthcare costs and improved workforce productivity.
Risks	Increased resilience	Delaying action means more extreme weather events (flooding, heatwaves, storms), and increasing expenditures on adaptation. Faster emission cuts reduce long-term climate damages and adaptation costs. Low-carbon actions also can increase resilience of the built environment.
	Legal risks	Governments are increasingly exposed to lawsuits for an inadequate response to climate change, with remedies ranging from financial damages to policy requirements.
Reputation	Business attraction and retention	Moving more quickly on emissions reductions will provide a competitive advantage in attracting investment in green industries and jobs.

Reduced Climate Damages

An accelerated target avoids a decade of additional damages from climate change. Scientists and economists use the social cost of carbon (SCC) as a metric to illustrate the damages caused by climate change globally.[48] Adjusting the LCS curve to reflect a net-zero target avoids emissions of 21 MtCO2e, which is valued at between $10 billion and $16 billion depending on the discount rate applied (Figure 12). A recent assessment indicates that the SCC understates the value of these emissions reductions by a factor of 5–10.[49]

[48] National Center for Environmental Economics (2023). Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances. Retrieved from: https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf#page=17.09
[49]Bilal, A., & Känzig, D. R. (2024). The macroeconomic impact of climate change: Global vs. local temperature (No. w32450). National Bureau of Economic Research.

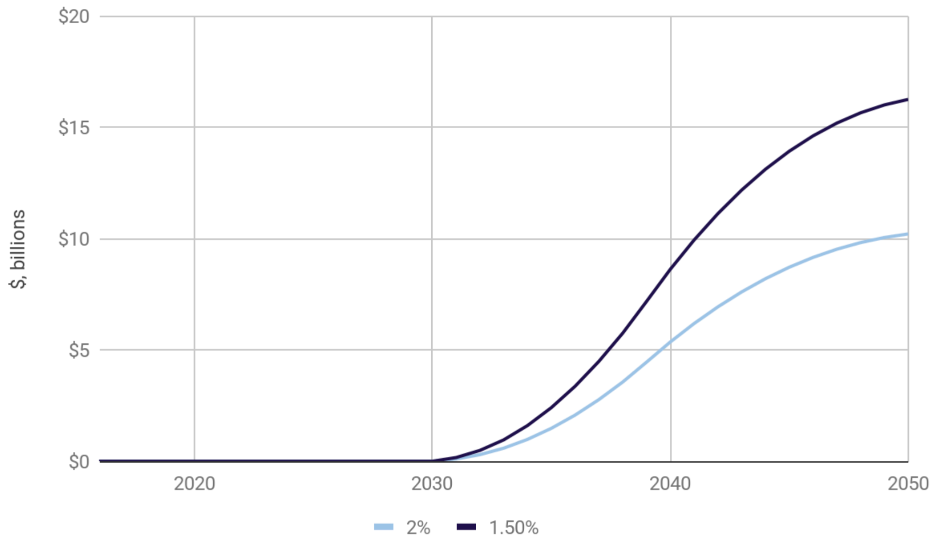

Figure 12. Estimated cumulative value of avoided damages from climate change as a result of accelerating Hamilton's target from 2050 to 2040, under different discount rates.

Risks

Table 6 outlines several key risks that threaten the success of Hamilton's climate action efforts. Understanding these threats is essential for developing effective strategies and policies to mitigate their impact and ensure that climate action remains on track.

Table 6. Risks and mitigation strategies for Hamilton's net-zero target.

Category	Description	Mitigation Strategies
Tariffs	Slowed or disrupted investments in zero-emissions steel	Advocate for the ongoing public and private investment in decarbonized steel.
	Decreased availability of EVs	Develop policies that focus on mode shifting (walking, cycling, transit, and electric bikes), as well as car-share programs, which deliver multiple benefits.

Category	Description	Mitigation Strategies
Political insecurity	The Canada-U.S. relationship could revitalize and/or stimulate investments in fossil-based infrastructure.	Develop a community economic development strategy focused on import substitution, including for energy. Advocate for climate-aligned public investments, such as electricity transmission, deep retrofits, and renewable energy projects, that are less vulnerable to geopolitical dynamics.
	Increased social anxiety	Develop neighbourhood and community-based low-carbon actions such as community energy projects and collaborative retrofit programs.

6 | Summary

This desktop study confirms that there is a technical pathway for the City of Hamilton to achieve net zero by 2040. It will require the City to implement the actions in ReCharge Hamilton and to accelerate emissions reductions in transportation and industry. The City has a number of levers it can apply to influence the emissions reduction trajectory in both of these sectors.

This briefing recommended potential strategies the City should consider for advancing transportation decarbonization and zero-emissions steel. These are high-level recommendations and are intended to outline the strategic direction. A more comprehensive investigation will be necessary to assess the practical implementation—including cost analysis, resource requirements, risk assessment, and timeline estimation.

The economic case for implementing this target is clear given the overwhelming costs that climate change will impose on society. The direct financial benefits to implementing entities are less clear, although the costs of key technologies have declined. The removal of the consumer carbon price acts as a counterbalance to these trends.

These times require bold leadership, and a net-zero-by-2040 target signals that leadership to the community of Hamilton.