Attachment C

TransformTO Net Zero Strategy

TECHNICAL REPORT

November 2021

TORONTO

Live green Toronto

CONTENTS

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This analysis includes strategic-level estimates of capital investments and related revenues, energy savings, and avoided costs of carbon. The intent of this analysis is to help inform the City and its residents about the potential costs and savings that result from actions to decarbonise the city. 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.

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Acknowledgements

Land Acknowledgement

The City of Toronto acknowledges that we are on the traditional territory of many nations including the Mississaugas of the Credit, the Anishnabeg, the Chippewa, the Haudenosaunee, and the Wendat peoples and is now home to many diverse First Nations, Inuit, and Métis peoples. The City also acknowledges that Toronto is covered by Treaty 13 signed with the Mississaugas of the Credit, and the Williams Treaties signed with multiple Mississaugas and Chippewa bands.

General Acknowledgement

The City of Toronto (The City) would like to acknowledge the community members and staff from across the city that contributed to the development of the Net-Zero Strategy. The City is grateful to all leaders and community members who have contributed their time to help advance the city's efforts to address climate change.

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Acronyms

Acronym	Definition
BAP	Business As Planned
CDR	Carbon dioxide removal
CICC	Canadian Institute for Climate Choices
CO_2e	Carbon dioxide equivalents
CDD	Cooling degree days
DE	District energy
DNS	Do Nothing Scenario
EUI	Energy use intensity
EV	Electric vehicle
GDP	Gross domestic product
GHG	Greenhouse gas
GPC	Global Protocol for Community-Scale GHG Emissions Inventories
GWP	Global warming potential
HDD	Heating Degree Days
HVAC	Heating, ventilation and cooling [equipment]
ICE	Internal combustion engine

Acronym	Definition
IEA	International Energy Agency
IESO	Independent Electricity System Operator
IPCC	Intergovernmental Panel on Climate Change
MACC	Marginal abatement cost curve
Mt	Megatonne (1,000,000 tonnes)
MURB	Multi-unit residential building
NPV	Net present value
NTCF	Near-term climate forcers
NZS	Net Zero Strategy
NZ40	Net Zero by 2040
NZ50	Net Zero by 2050
REC	Renewable energy certificate
SCC	Social cost of carbon
TEDI	Thermal energy demand intensity
TGS	Toronto Green Standard
TORR	City of Toronto's Office of Recovery and Rebuild
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
VKT	Vehicle Kilometres Travelled

Glossary

Term	Definition
Baseline	the starting point to measure changes in the amount of emissions produced over time
Carbon-free grid	an electricity grid where the power that is generated and distributed comes from only renewable sources

Term	Definition
Carbon sequestration	the process of capturing and storing carbon from the atmosphere through natural or anthropogenic methods
Consumption-based emissions	emissions from the volume of goods consumed by a population
CO_2e (Carbon dioxide equivalents)	a single unit of measurement that allows for the impact of releasing different greenhouse gases into the atmosphere to be evaluated on a common basis. Carbon dioxide equivalents are calculated using Global Warming Potential factors that represent the impact of each greenhouse gas type (such as methane (CH_4) and nitrous oxide (N_2O)) relative to that of carbon dioxide
Decarbonize	to eliminate the release of GHGs into the atmosphere from a process or system. This includes swapping out any fossil fuel sources for renewable energy
GHGs (Greenhouse gases)	compound gases that trap heat and emit longwave radiation in the atmosphere causing the greenhouse effect
Heat pump	a highly efficient heating and cooling system that transfers thermal energy from the ground or air to warm a building during winter and cool it during the summer
Mt (Megatonne)	1,000,000 tonnes
Near zero buildings	a building that is designed to be highly energy efficient but still uses a small amount of non-renewable sources. A building constructed to Toronto Green Standard Version 4 Tier 3 is considered a near-zero emissions building
Net zero	a balance between the amount of greenhouse gases released and the amount taken out of the atmosphere
Net zero building	a building that is highly energy-efficient and produces on-site, or procures, carbon-free and or renewable energy in an amount sufficient to offset the annual carbon emissions associated with its operations, or simply eliminates carbon emissions altogether
Renewable energy	a naturally-occurring energy source that is not finite or exhaustible. It includes sources such as sunlight, wind, and geothermal heat
ZEV (Zero Emissions Vehicle)	a vehicle that does not produce tailpipe emissions or other pollutants from the onboard source of power

How To Use This Document

Structure of the Net Zero Technical Report

This Net Zero Technical Report presents a pathway to reach net zero greenhouse gas (GHG) emissions for the city of Toronto by 2050 or sooner. It presents solutions that can stimulate the city's economy, such as investments in infrastructure, building retrofits, electric mobility, and energy technologies that will reduce community-wide GHG emissions and create new jobs during the COVID-19 pandemic recovery. This Technical Report provides opportunities that will benefit the residents of Toronto as well as the City's operations.

Underpinning the Net Zero Technical Modelling are the Net Zero by 2040 (NZ40) and Net Zero by 2050 (NZ50) pathways. The pathway describes a detailed transition to net zero emissions by 2040 and 2050, respectively. NZ50 is designed to meet the City's 2050 emissions target, while NZ40 pushes this target 10 years sooner to show what additional effort would be required to achieve this. This roadmap was developed using analysis of four scenarios that were explored in an energy and emissions model. The report's findings are structured in three sections.

- **Part 1: Setting the Context** describes the state of climate action as it relates to Toronto, including the basis for the technical analysis.
- **Part 2: The Pathway** describes the actions that were modelled and the resulting GHG emissions reductions.
- **Part 3: The Opportunities** evaluates co-benefits of the pathway, including considerations for economic development, health and well-being.

Notes and limitations

The modelling described in this paper uses CityInSight, an integrated, multi-fuel, multi-sector, spatially disaggregated energy systems, emissions and finance model designed specifically for projects of this nature. CityInSight uses bottom-up accounting for energy supply and demand, including renewable resources, conventional fuels, energy consuming technology stocks (vehicles, appliances, dwellings, buildings, industry) and all intermediate energy flows. CityInSight incorporates spatial resolution, enabling, for example, the testing of strategies for a specific area of geography, for a specific vintage of buildings, for a specific type of dwelling, for specific types of equipment within buildings, or for a specific technology for transportation or energy provision. CityInSight traces the flows and transformations of energy from sources through energy carriers (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. CityInSight can be used to analyze energy and emissions associated with customized policies over time and includes modelled financial information which can inform financial decision-making related to energy and emissions actions. In this project, CityInSight was used to:

- Evaluate pathways to decarbonise the City over a 30 year time horizon.
- Explore diverse scenarios that represent a range of possible futures, including system transformations in energy using and emissions generating sectors.
- Evaluate the feasibility of specific actions (physical transformations) to deliver GHG emissions reductions.
- Represent the spatial evolution of the City as a system that uses energy and generates emissions.
- Assess the societal costs and benefits of the pathways and actions.

The analysis undertaken in this study does not:

- Evaluate the physical impacts of climate change and adaptive measures that will be required, although opportunities for implementing GHG mitigation actions that also increase resilience are noted.
- Specify specific policies or incentives required to implement the actions. In many cases policies can be inferred from the actions.
- Use algorithms to optimise pathways for lowest cost, an approach which is more appropriate for a shorter time horizon with greater certainty over future costs of equipment, energy and capital and may rule out more expensive actions that result in compounding benefits. Analysts have designed the scenarios to optimise for social and economic benefits, prioritising efficiency over new renewable generation.
- Assess individual actions from the perspective of a specific stakeholder, such as an investor or household, which would involve applying varying discount rates, according to a mapping of which entity makes which investment.
- Evaluate the implications of decarbonisation pathways on hourly demand (all electricity consumption is reported on an annual basis). This is an important consideration for electricity system planning, but involves a more complex analysis.
- Assess consumption-based emissions. The analysis in this report applies a geographic-based emissions approach, accounting primarily for emissions resulting from within Toronto’s geographic boundary.
- Evaluate the economy-wide impacts on employment, prices or GDP of the scenarios. The analysis assesses the financial impacts on the specific sectors impacted by the analysis such as buildings, transportation, energy and others.

1. Executive Summary

In May 2021, the International Energy Agency (IEA) released a milestone report titled **Net Zero by 2050.**[1] Globally the IEA found that the path to net-zero is narrow, requiring the massive deployment of all available clean energy technologies, including renewables, EVs and energy efficiency building retrofits between now and 2030. IEA's key findings echo those of the analysis in this report; the net zero pathway can bring jobs and growth, leaps in clean energy innovation are required, there must be a rapid shift away from fossil fuels, electricity becomes the core of the energy system and new low emissions industries flourish. Similar to the IEA, this Net Zero Technical Report describes a pathway to completely transform the energy system.

For over three decades, the City of Toronto has demonstrated leadership in climate action. This Technical Report informs the development of the Net Zero Strategy, which is an extension of these efforts and a critical step in the City's response to the climate emergency that was declared by the City Council in 2019. The Technical Report identifies technically feasible, evidence-based, and community-informed pathways for the entire community to achieve net zero greenhouse gas (GHG) emissions by 2040 and 2050, respectively. The Technical Report presents detailed pathways for the community's decarbonization and recommends a set of near-term implementation milestones.

In July 2017, Toronto's response to the Paris Agreement, *TransformTO*, was approved, with a target of reducing GHG emissions by 80% below 1990 levels by 2050. In 2018, the United Nations (UN) scientific body on climate change (the IPCC) released a report addressing the Paris Agreement's objective of limiting global warming to 1.5°C. Titled *Global Warming of 1.5°C,* this report found that global GHG emissions need to decline by 45% by 2030 over 2010 levels and reach net zero by 2050.

Given the urgency for immediate and deep cuts in GHG emissions in order to achieve the 2030 target, Mayor John Tory and the Toronto City Council voted unanimously in October 2019 to declare a climate emergency "for the purpose of naming, framing, and deepening our commitment to protecting our economy, our ecosystems, and our community from climate change."[2] The Climate Emergency Declaration endorsed a new target to achieve net zero GHG emissions before 2050, in efforts to align with limiting global average temperature rise to 1.5°C.

In July, 2021, Council passed a motion endorsing the Fossil Fuel Non-Proliferation Treaty, joining Vancouver, Barcelona and Los Angeles. The Treaty has three pillars:

- **Non-proliferation:** Preventing the proliferation of coal, oil and gas by ending all new exploration and production

[1] IEA (2021). Net Zero by 2050. Retrieved from: https://www.iea.org/reports/net-zero-by-2050

[2] Declaring a Climate Emergency and Accelerating Toronto' Climate Action Plan - by Mayor John Tory, seconded by Councillor Mike Layton. http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2019.MM10.3

- **Fair phase out:** Phasing-out existing stockpiles and production of fossil fuels in line with the 1.5C global climate goal
- **Just transition:** Fast-tracking real solutions and a just transition for every worker, community and country

Toronto's history of engagement on climate change, including increasingly concrete policies such as the updated Toronto Green Standard and the Net Zero Existing Building Strategy, as well as important statements such as the Climate Emergency Declaration and the endorsement of the Fossil Fuel Non-Proliferation Treaty set the stage for the Net Zero Pathways presented in this Technical Report.

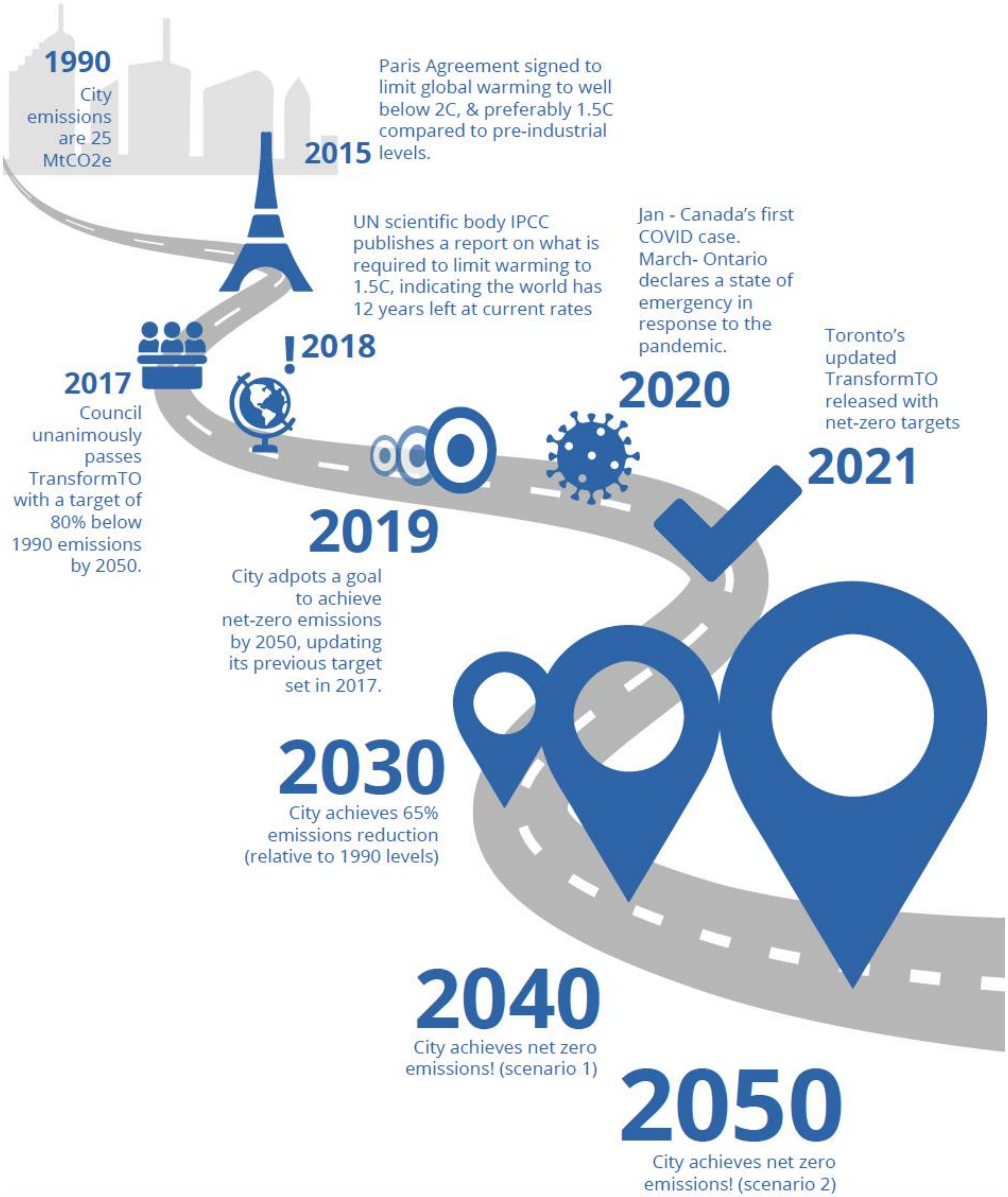

Figure 1. Timeline of climate action in Toronto.

The objective of the Technical Report is to inform the development of the Net Zero Strategy, in order to update Toronto's climate action plan, *TransformTO*, with the targets set out in the Climate Emergency Declaration, including the feasibility of actions to achieve net zero by 2040. Two scenarios were evaluated to analyze the most efficient and effective series of actions required to meet net zero by 2040 and 2050, respectively. The scenarios would also show the City what is needed to achieve its target of reducing GHG emissions by 65% (below 1990 levels), by 2030. The Technical Report includes an analysis of the technical, financial, and social/behavioural feasibility of the proposed climate actions[3], as well as climate mitigation and resilience recommendations.

The modelling and analysis followed several steps. First, the drivers that contribute to Toronto's current GHG emissions were identified. Secondly, four scenarios were defined as follows:

1) **A "Do Nothing" Scenario** (which asks "what will happen if no additional policies or actions are put in place?") was updated from the previous modelling to align with current policy contexts, including energy supply and new assumptions;

2) **A Business as Planned (BAP) Scenario** that evaluates the impacts of currently planned policies and actions;

3) **A Net Zero by 2050 (NZ50) Pathway**; and,

4) **A Net Zero by 2040 (NZ40) Pathway**.

Thirdly, actions were evaluated in regards to their contribution to environmental, social, and economic outcomes.

Figures 2 and 3 show a summary of the results, including GHG reductions, for all of the scenarios.

[3] Social and behavioural considerations were informed by literature reviews and discussions with City staff and stakeholders. In addition, the transportation modelling incorporates consumer choices.

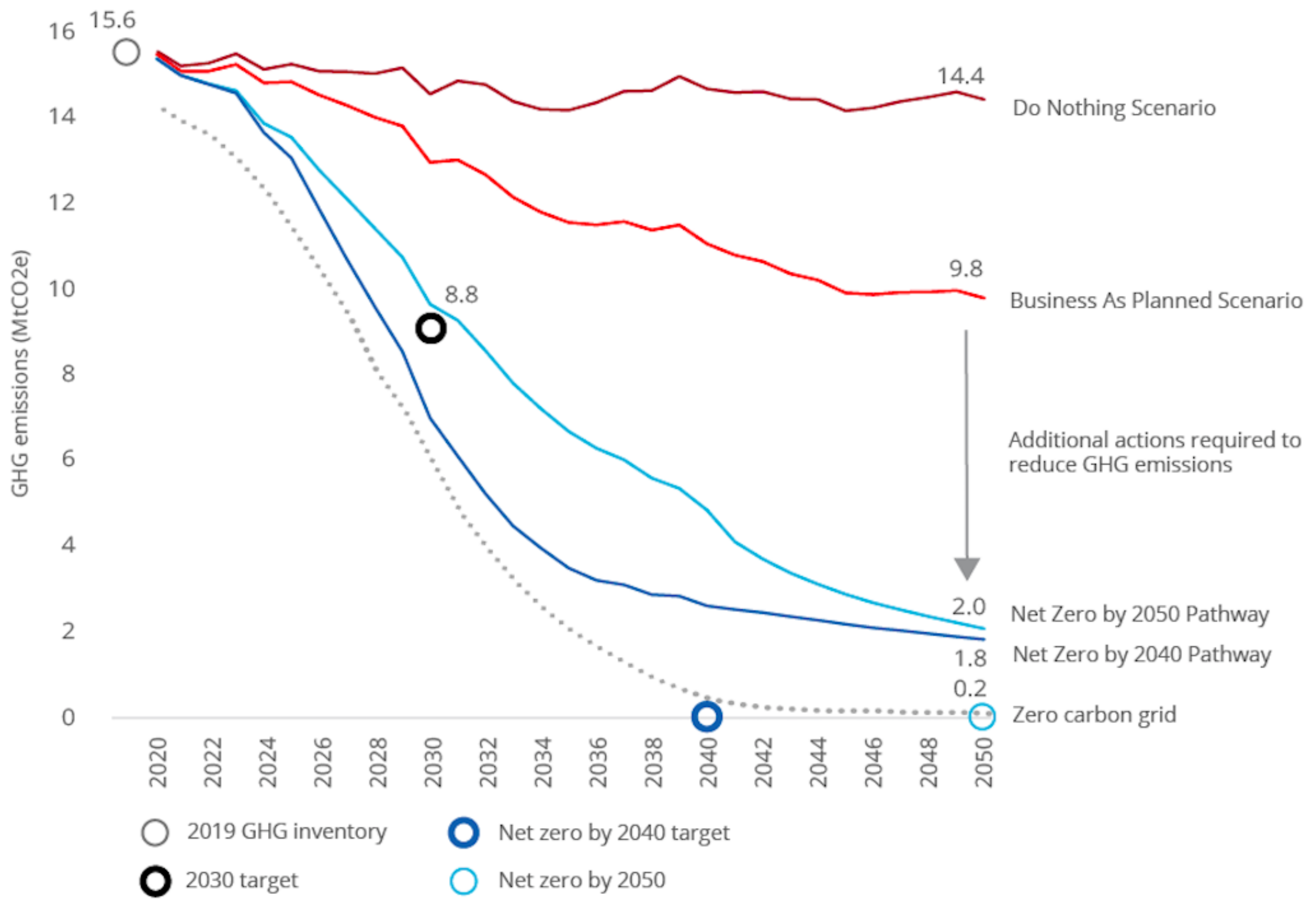

Figure 2. Pathways modelled in the scenarios.

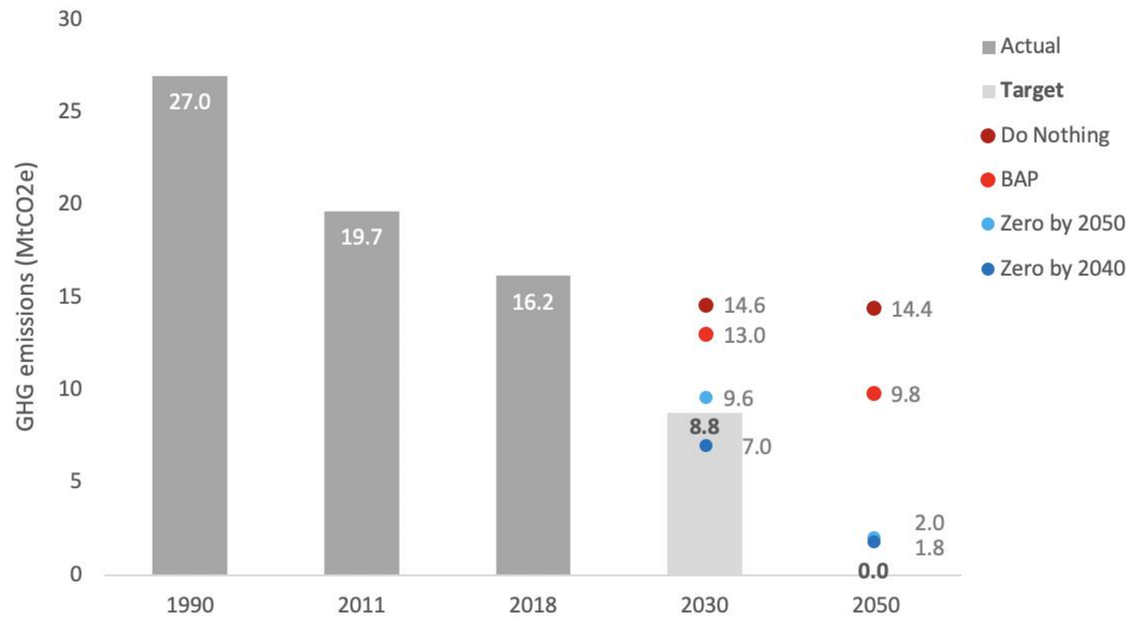

Figure 3. Summary results, GHG emissions (Mt CO_2e).

Decarbonizing the city will require new investments that will provide multiple benefits, such as improved well-being and quality of life, as well as numerous economic opportunities. Both net zero pathways require rapidly scaling up many programs and policies that the City already has underway, as well as an unprecedented mobilization of new action by the City, businesses, financial institutions, other levels of government, and residents. Many of the proposed actions not only achieve GHG emissions reductions, they synergistically support other City objectives, such as improved economic development and health and equity outcomes.

The investments that the City makes today will have long-term implications, which can either lock-in patterns of increasing or reducing GHG emissions. Therefore, in addition to considering the impacts of the proposed actions on GHG emissions reductions, the financial impacts of the scenarios were also analyzed.

This report provides a comprehensive overview of:

- the modelling process and updated scenarios from the previous analysis, including underlying assumptions, inputs, and results;
- details on the technical, financial, and behavioural/social feasibility of actions to achieve net zero by 2040, versus net zero by 2050;
- updates to existing long-term and short-term sectoral goals, targets, and actions; and,
- immediate actions that are required within the next one to two years to achieve the City's interim targets for 2030.

Figure 4. Toronto's Roadmap to Net Zero (modelled targets).

Findings

1. Only the NZ40 pathway achieves the City's 2030 target

Of the scenarios modelled, only the NZ40 pathway meets or exceeds the City's 2030 target of 8.8 $MtCO_2e$, dropping to 7 $MtCO_2e$. The expedited actions required to achieve net zero by 2040 result in a steeper emissions reduction trajectory than the NZ50 scenario. On average emissions need to decline by nearly 1 $MtCO_2e$ per year between 2021 and 2030 in the NZ40 Scenario.

2. Fossil fuels need to be phased out

In the NZ40 scenario, natural gas and gasoline need to be phased out by 2040. To achieve this target, 100% of new sales of long lasting equipment including vehicles and furnaces need to be electric by 2030, as it takes at least ten years for the stock to turn over. In order to hit the 2030 target, the City needs to send clear signals to the market and the community starting now.

3. Taking early action now saves money in the long run

The net present value of NZ40 is $135 million less than that of NZ50—a difference of 1% (Figure 4). In other words, achieving net zero by 2040 ends up costing less than achieving net zero by 2050. Reducing emissions more quickly also means that the city can collect the financial benefits of the avoided carbon costs and avoided energy costs sooner.

The early investments required for NZ40 totals just 5% of Toronto's annual GDP for the first ten years, before declining to zero and generating a net annual savings by 2040.

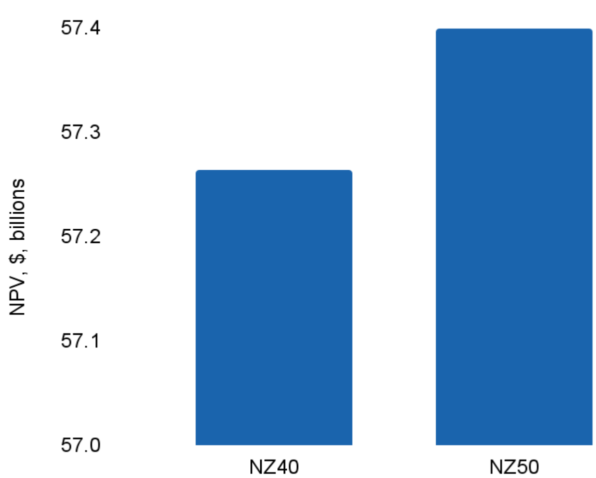

Figure 5. Net present value of the NZ40 and NZ50 scenarios.

4. There are many benefits that generate financial returns which have not been included in the analysis or quantified

The NZ pathways generate a broad range of societal benefits with direct and indirect financial benefits which are in addition to the financial analysis described in this report. For example, improved air quality as a result of electrifying transportation could deliver health benefits which this analysis valued at nearly $1 billion per year. Improved indoor air quality in dwellings and office space as a result of building retrofits will reduce health care costs and absenteeism at work. Reduced air pollution from the combustion of fossil fuels (on roads, in houses, and in electricity generation) will reduce health impacts, such as asthma and chronic obstructive pulmonary disease. Increased walking and cycling will reduce heart disease. The NZ40 scenario adds 1.5 million person-years of employment over the Do Nothing Scenario between 2020 and 2050—an average of 50,000 per year. In other words, there are opportunities to advance multiple city and society objectives while simultaneously achieving deep GHG emissions reductions, creating a win-win-win scenario.

5. The impact on equity is likely positive, but the implementation details matter

The NZ pathways reduce transportation costs for households and increase accessibility to destinations as transit is expanded, which is particularly beneficial for households for which transportation costs are a larger share of their disposable income. Energy costs are also reduced for households that pay for energy, either directly or as renters, but these benefits may not occur in the first or second decade, depending on how the retrofits are financed. Because the scenarios involve investments, the mechanisms for financing the scenarios could generate disproportionate returns for investors, which could exacerbate inequality. It is therefore important to consider the impacts on various groups when designing NZ pathway policies.

6. To achieve the net zero target, the provincial grid needs to decarbonize

In the NZ40 and NZ50 scenarios, the remaining emissions in 2040 are from grid electricity (Figure 6). These emissions would be eliminated if the provincial grid were to be decarbonized. The City has alternative options to address these emissions, however, they involve high costs and some have no returns. Options are to:

- Create a new 100% renewable grid that may have an interconnection with the Provincial grid,
- Purchase Renewable Energy Certificates to cover the electricity demand, similar to a Community Choice Aggregation (CCA) arrangement,[4] and/or
- Purchase carbon offsets to address the remaining emissions.

[4] CCA would require regulatory approval. For more information, see: https://www.epa.gov/greenpower/community-choice-aggregation

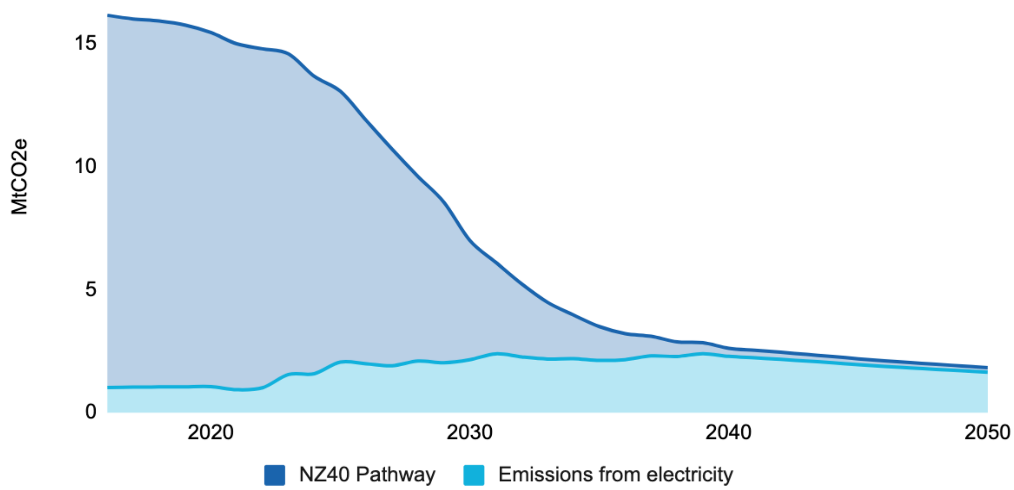

Figure 6. The imperative of eliminating GHG emissions from electricity.

7. Expanded access to transit is an equity and efficiency measure at the heart of the net zero scenarios

A major investment in the NZ scenarios is in transit system enhancements, totalling around $1.5 billion per year. Free transit is introduced which also forfeits revenues of $2 billion per year on top of these investments by 2040. These costs are partially offset by road fees, which generate just over $1 billion per year. Providing free, widespread transit is a key equity measure, ensuring access to jobs and services for all in Toronto. Implemented correctly, the measure stands to increase the efficiency of travel in the city through reduced congestion and car use, amongst many other potential benefits and paybacks.[5]

[5] Štraub, D.; Jaroš, V. Free fare policy as a tool for sustainable development of public transport services.Hum. Geogr. J. Stud. Res. Hum. Geogr. 2019,13, 45–59.

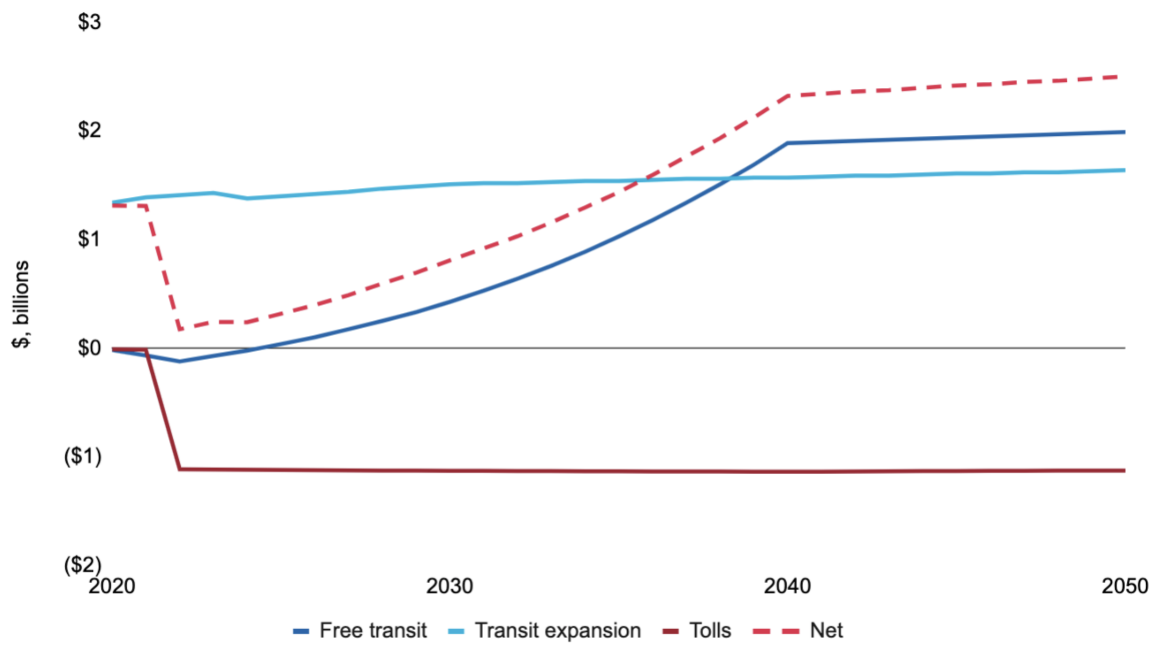

Figure 7. The financial impacts of transit actions.

8. Efficiency first

Rapidly reducing emissions in buildings and transportation is critical to achieving the net zero pathways. The pathway emphasizes measures which achieve efficiency first, followed by fuel switching to electricity for transportation and heating. Efficiency measures in buildings (e.g., thermal retrofits, electrification, smaller buildings) and transportation (e.g., avoiding trips by working at home, shifting to active modes and transit, reducing trip length through land-use planning) reduce the requirement for new renewable electricity generation and generate cost savings which can be used to finance the actions.

9. A whole-city approach to climate action

The next generation of climate action planning focuses on transformation of the built environment in a systematic approach, as opposed to a long list of actions. In particular, this means embedding consideration of climate into every policy and expenditure in alignment with the selected net zero pathway, a whole-city approach. This approach requires a cultural and organizational transformation so that the City itself is a climate mitigation mechanism, applying tools such as climate lens and an annual carbon budget.

Box: The Impact of COVID

Energy consumption and GHG emissions declined as the world slowed down. In Ontario, electricity demand declined by 14% in 2020 over 2019,[6] and Canadian civil aviation activities dropped by 72%.[7] As the world slowed down in response to the COVID-19 pandemic, there were improvements in air quality, and a reduction in environmental noise.[8] On the flip side, there was an increase in waste generation. Reductions in activity globally resulted in a 4% drop in global energy consumption in 2020 and a reduction of 5.8% in global emissions, the largest annual decline since World War II, equivalent to removing all of the European Union's emissions from the global total.[9] However, GHG emissions have since bounced back and are projected to increase as economic recovery efforts gain momentum.[10][11]Reductions of 7.6% per year for the next decade are required to prevent warming of more than 1.5 °C, the target of the Paris climate agreement.[12]

It is uncertain which- and to what extent- the trends that have emerged from COVID-19 will prove durable, but these trends could include expanded online shopping, education and government services, greater social isolation, greater inequalities, out migration from cities, increased work from home, decreased transit use, increased regional manufacturing and agriculture, increased demand for larger homes, increased emphasis on public spaces and active transportation infrastructure.[13]

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[6] Abu-Rayash, A., & Dincer, I. (2020). Analysis of the electricity demand trends amidst the COVID-19 coronavirus pandemic. Energy Research & Social Science, 68, 101682.

[7] Abu-Rayash, A., & Dincer, I. (2020). Analysis of mobility trends during the COVID-19 coronavirus pandemic: Exploring the impacts on global aviation and travel in selected cities. Energy research & social science, 68, 101693.

[8] Zambrano-Monserrate, M. A., Ruano, M. A., & Sanchez-Alcalde, L. (2020). Indirect effects of COVID-19 on the environment. Science of the total environment, 728, 138813

[9] IEA (2021). Global energy review: CO2 emissions in 2020. Retrieved from: https://www.iea.org/articles/global-energy-review-co2-emissions-in-2020

[10] IEA (2021). After a steep drop in early 2020, global carbon dioxide emissions have rebounded strongly. Retrieved from: https://www.iea.org/news/after-steep-drop-in-early-2020-global-carbon-dioxide-emissions-have-rebounded-strongly

[11] Tollefson, J. (2021). COVID curbed carbon emissions in 2020-but not by much. Nature.

[12] United Nations Environment Programme (2019). Emissions Gap Report 2019. Retrieved from: https://www.unep.org/resources/emissions-gap-report-2019

[13] For example, see: Zhang, J., Hayashi, Y., & Frank, L. D. (2021). COVID-19 and transport: Findings from a world-wide expert survey. Transport policy, 103, 68-85.

Assessments of the global response to COVID-19 have provided insights that can help shape the response to climate change,[14] emphasising the need for urgent action and the cost of delay, consideration of equity and the need to get residents on board.

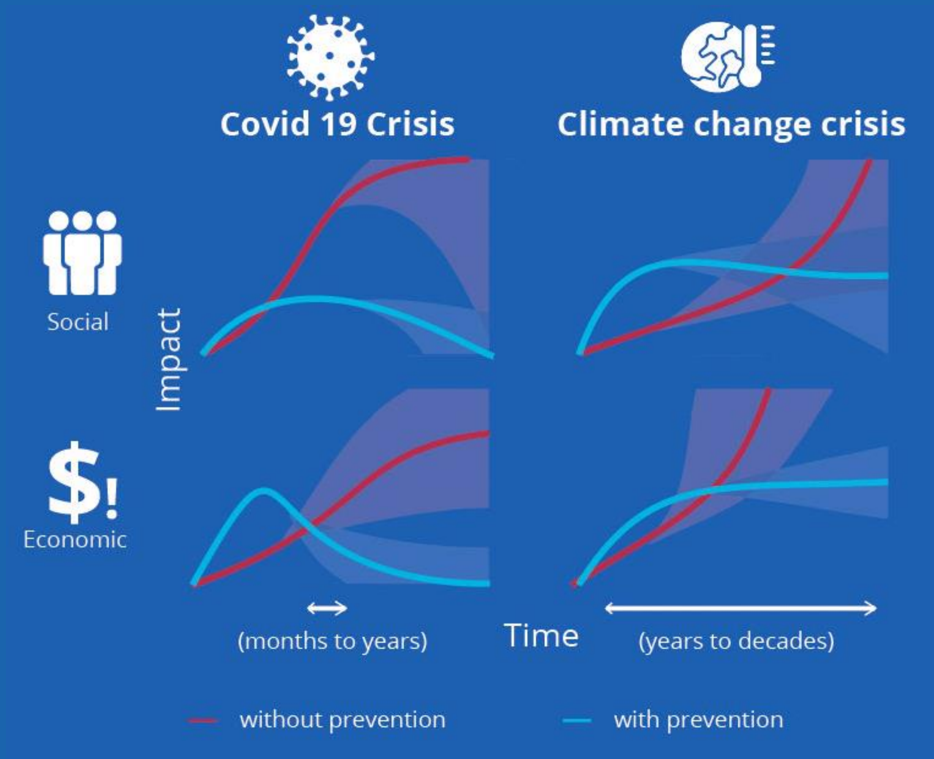

Figure 8:[15] Illustrative diagram of social and economic impacts of the COVID-19 and climate crises in the presence and absence of preventative measures, with different timescales. In the case of COVID-19 and climate change, there is a social cost of failing to take preventative measures. Without prevention the negative impact of COVID-19 is immediate, while the negative impact of climate change grows more slowly. Economic impacts follow a similar pattern. In the case of climate change, inaction can result in unimaginably high economic costs in the long term, while early action may entail a cost due to the economic transition but will prevent the large social costs of extreme events, water shortages, conflicts, etc. Uncertainties are highlighted as shaded areas around the curves.

[14] Klenert, D., Funke, F., Mattauch, L., & O'Callaghan, B. (2020). Five lessons from COVID-19 for advancing climate change mitigation. Environmental and Resource Economics, 76(4), 751-778.

[15] Manzanedo, R. D., & Manning, P. (2020). COVID-19: Lessons for the climate change emergency. Science of the Total Environment, 742.

Part 1: Setting the Context

2. The Imperative for Action

2.1 The Climate Emergency

Climate change is the greatest long-term global challenge that human society is facing. It is particularly complex because it occurs over a long time-scale, has variable impacts globally and spatially, and requires rapid and radical changes to our energy, society, and economic systems. Human-induced climate change poses risks to health, economic growth, public safety, infrastructure, livelihoods, and the world's biodiversity and ecosystems. As local and global greenhouse gas (GHG) emissions increase, the Earth continues to warm at an unprecedented rate.

In December 2015, the Paris Agreement was adopted at the COP21 by 197 countries. This legally binding international treaty on climate change set a goal to limit global warming to well below a 2°C, and preferably to a 1.5°C increase, above pre-industrial levels.[16] However, current global GHG emissions are not on a trajectory to meet these goals (Figure 9).

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

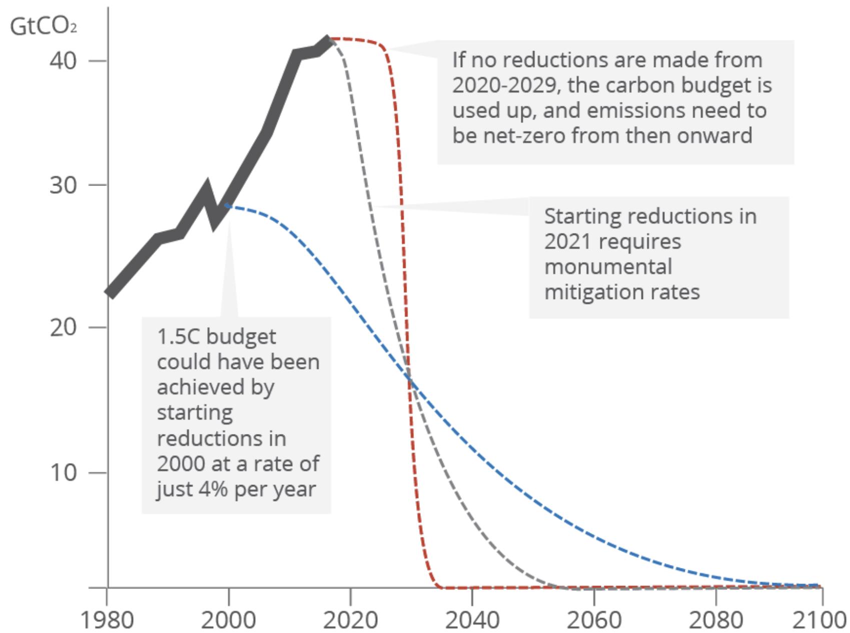

Figure 9. Likelihood of limiting warming to 1.5°Cs given a global target of achieving net zero by 2040.[17]

Despite a temporary decline in global emissions in 2020 due to the COVID-19 pandemic, the world is heading for 3°C or more of warming.[18] This degree of warming threatens human health, economic well-being, and the survival of the natural systems that humans and eight million other plant and animal species—already increasingly at risk—depend upon.[19]

Given the short timeline to achieve the required transformative changes to our economic, transportation, infrastructure, financial, and energy systems, COVID-19 recovery plans provide a unique opportunity to invest in and accelerate towards limiting global warming to 1.5°C.

Box: Defining Net Zero Carbon Emissions

Net zero carbon emissions are reached when GHG emissions released into the atmosphere are reduced nearly to zero, with any remaining emissions being removed from the atmosphere. Figure 10 illustrates a scheme for the City of Toronto's net zero emissions target.

[17] 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*. https://www.ipcc.ch/sr15/chapter/spm/

[18] United Nations Climate Change (2021). New UNEP Synthesis Provides Blueprint to Urgentaly Solve Planetary Emergencies and Secure Humanity's Future. https://unfccc.int/news/new-unep-synthesis-provides-blueprint-to-urgently-solve-planetary-emergencies-and-secure-humanity-s

[19] Ibid.

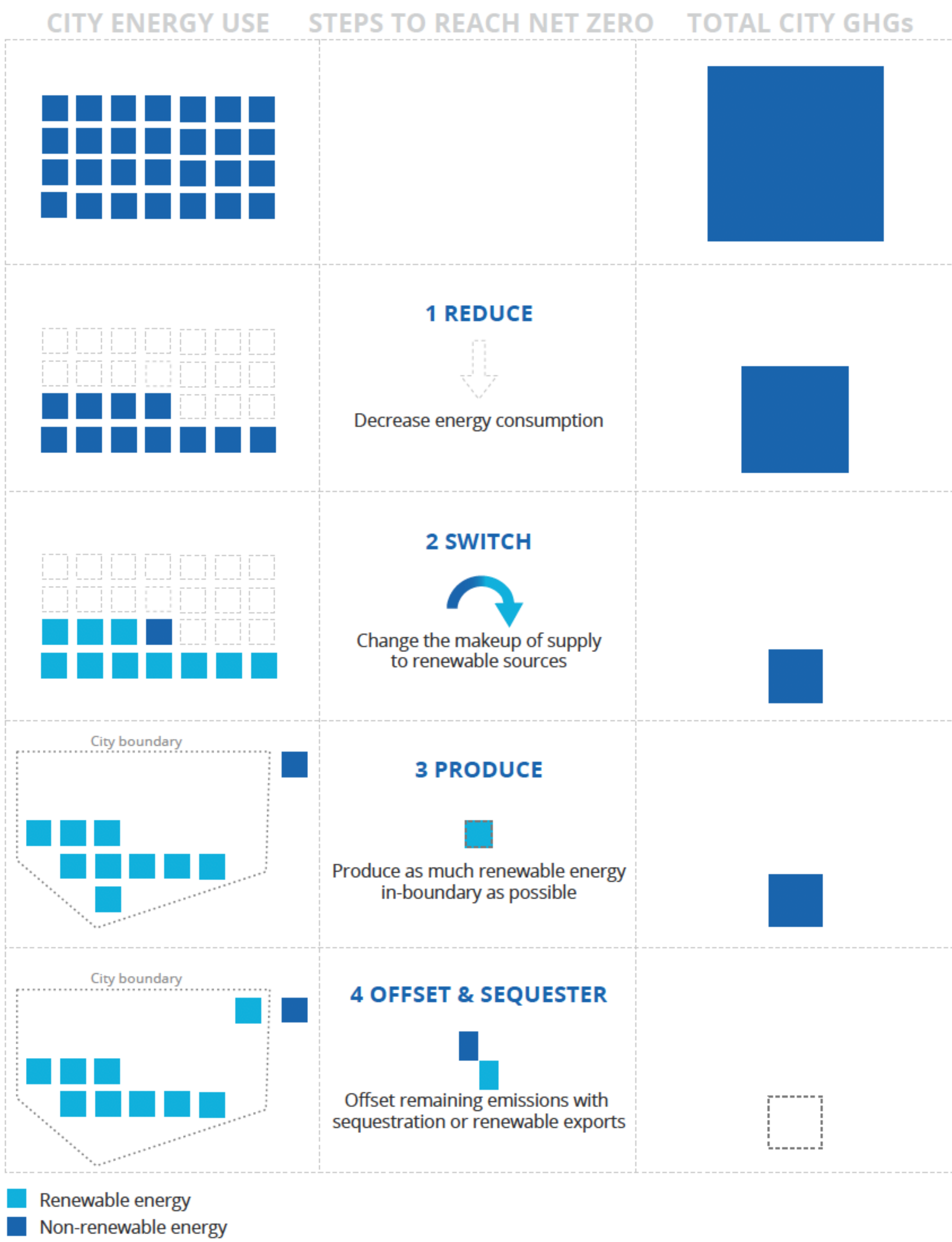

Figure 10. Schematic of net zero emissions.[20]

[20] Graphic modified from a version created for the City of Markham's Net Zero Energy Plan.

2.2 Urgency for Immediate GHG Reductions to Limit Global Warming to 1.5°C

Climate change is a wicked problem: the full impacts of GHGs are not felt until decades after they are emitted, the impacts are globally dispersed, and the global economy is dependent on fossil-fuels. These factors are difficult to counter; election cycles, the built environment, and the financial system tend to reinforce systems and patterns that run counter to reducing emissions.

Box: A Challenge and an Opportunity

Climate change is a symptom of a medley of other problems, ranging from the combustion of fossil fuels, to poverty and inequality, and from cultural norms to the structure of the economic system. This complexity, combined with disparate and often conflicting worldviews and perspectives, means that it is challenging to respond in a way that is proportionate to the magnitude of the problem. Strategies or activities that reflect this urgency will need to address core assumptions of culture, behaviour, economic norms, and governance. Dialogue between people with multiple perspectives, including Indigenous peoples, can reimagine foundational assumptions and give rise to unanticipated opportunities or solutions.[21] Governance structures and adaptation strategies have to be nimble in order to adjust to constantly changing circumstances and support risk-taking. These characteristics are antithetical to most government institutions, which are premised on risk avoidance, and predictable and controlled outcomes.

Box: The Tragedy of the Horizon

"Climate change is the Tragedy of the Horizon," according to Mark Carney, former Head of the Bank of Canada and former Governor of the Bank of England. "The catastrophic impacts of climate change will be felt beyond the traditional horizons – beyond the business cycle, the political cycle, and the horizon of financial institutions like central banks. Climate risks are a direct function of cumulative emissions, so earlier action will significantly decrease the cost of future adjustments. As such, it is in society's best interest to restrict climate change to avoid global warming above 1.5°C."[22]

In 2018, the Intergovernmental Panel on Climate Change (IPCC) reported that limiting global average warming to 1.5°C, rather than 2°C or greater, will temper the increasingly severe impacts and risks to

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[21] For a more detailed discussion on transformative change, see: Termeer, C., Dewulf, A., & Breeman, G. (2013). Governance of wicked climate adaptation problems. In J. Knieling & W. Leal Filho (Eds.), *Climate change governance* (pp. 27–39). Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-29831-8_3

[22] Carney, M. (2015). Breaking the Tragedy of the Horizon – climate change and financial stability. bankofengland.co.uk/-/media/boe/files/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability.pdf?la=en&hash=7C67E785651862457D99511147C7424FF5EA0C1A

human and natural systems.[23] The difference could result in "11 million fewer people exposed to extreme heat, 61 million fewer people exposed to drought, and 10 million fewer people exposed to the impacts of sea level rise."[24] For example, under 1.5°C of warming, almost 14% of the world's population would be exposed to severe heat waves at least once in five years; whereas under 2°C warming, 37% of the world's population will be exposed to severe heat waves at least once in five years.

According to the IPCC report *Global Warming of 1.5°C*, all available 1.5°C mitigation pathways from 2020 onwards require that global GHG emissions peak before 2030 and that emissions be reduced below 2010 levels by 2030.[25] As of 2017, the remaining global carbon budget for 1.5°C was 420 $GtCO_2e$. This global carbon budget will be reached within the next 6-8 years.[26] The current trajectory of emissions as a result of pledges made under the Paris Agreement is expected to surpass 1.5°C, unless greater action is taken now.[27]

2.3 Toronto's Climate Emergency Declaration

Limiting global warming depends on significant reductions this decade. If global emissions reach net zero in 30 years, there is a one-in-two chance of limiting warming to 1.5°C; whereas, if net zero is achieved in 20 years, the probability increases to a two-in-three chance.[28]

The imperative for immediate action to reach such deep reductions on a short timeline has led many jurisdictions to recognize that climate change needs an emergency response. Human-induced climate change poses risks to public health and safety, economic growth, infrastructure systems, water and food supplies, financial systems, and the natural world. The impacts of the changing climate, such as increases in temperature extremes, severe weather events, ocean warming, rising sea levels, thinning

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[23] 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*. https://www.ipcc.ch/sr15/chapter/spm/

[24] Science Based Targets Initiative. (2019). *1.5°C vs. 2°C - a world of difference*. Retrieved from: https://sciencebasedtargets.org/blog/1-5-c-vs-2-c-a-world-of-difference

[25] Ibid.

[26] Annual emissions are approximately 42 Gt CO_2e per year. The calculation is therefore: (420-42*3)/42= 7. The Mercator Research Institute's Climate Clock indicates that 6.5 years are remaining. See: https://www.mcc-berlin.net/en/research/co2-budget.html

[27] Rogelj, J.D. et al. (2018). "Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development." 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. et al. (eds.). Retrieved from: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter2_Low_Res.pdf

[28] Bazaz, A. et al. (2018). Summary for Urban Policy Makers. What the IPCC Special Report on Global Warming of 1.5 means for Cities. C40. http://doi.org/10.24943/SCPM.2018

glaciers, and thawing permafrost, have been observed in Canada and abroad. Past and projected warming for Canada, on average, is about double the magnitude of projected global warming.[29] According to the United Nations, small-scale, climate-related disasters now happen globally at the rate of one per week.[30]

In June 2019, Canada became the fourth nation to declare a climate emergency, following in the footsteps of Wales, Scotland, and the United Kingdom, as well as numerous cities around the world. Similarly, in October 2019, Mayor John Tory and the Toronto City Council voted unanimously to declare a climate emergency "for the purpose of naming, framing, and deepening our commitment to protecting our economy, our ecosystems, and our community from climate change."[31] The Climate Emergency Declaration endorsed a target to achieve net zero GHG emissions in line with maintaining a global average temperature rise below 1.5 °C. The declaration included a request to report back on the feasibility of actions that could achieve net zero by 2040 and 2050. This Technical Report informs the development of the Net Zero Strategy, which is a critical step in the City's response to the climate emergency that was declared by the City Council.

Box: What is a Climate Emergency?

In January 2020, 11,000 scientists signed a report titled World Scientists Warning of a Climate Emergency.[32] The scientists indicated that climate change is more severe than anticipated, threatening natural ecosystems and the fate of humanity. As of March 2021, 1,904 jurisdictions in 34 countries, including 15 national governments and the EU Parliament, had declared climate emergencies.[33] An emergency requires immediate action; it is a moment when one phones 911 to request urgent help. By declaring a climate emergency, governments at all levels are signalling that the situation is dire and urgent.

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[29] For a review of the impacts of climate change in Canada, see: Canada, & Environment and Climate Change Canada. (2019). Canada's changing climate report. http://publications.gc.ca/collections/collection_2019/eccc/En4-368-2019-eng.pdf

[30] Harvey, F. (July 7, 2019). One climate crisis disaster happening every week, UN warns. *The Guardian*. https://www.theguardian.com/environment/2019/jul/07/one-climate-crisis-disaster-happening-every-week-un-warns

[31] Declaring a Climate Emergency and Accelerating Toronto' Climate Action Plan - by Mayor John Tory, seconded by Councillor Mike Layton. Retrieved from: http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2019.MM10.3

[32] Ripple, W., Wolf, C., Newsome, T., Barnard, P., Moomaw, W., & Grandcolas, P. (2019). World scientists' warning of a climate emergency. BioScience.

[33] Climate Emergency Declaration. Climate emergency declarations in 1,904 jurisdictions and local governments cover 826 million citizens. March 14, 2021. Retrieved from: https://climateemergencydeclaration.org/climate-emergency-declarations-cover-15-million-citizens/

2.4 The Risk of Complacency

Delay increases the disruption to the economy and infrastructure of an inevitable transition. Each year new investments are made in carbon-intensive infrastructure and technologies locking in an expectation of long-term returns. Undoing these investments is costly. Delay also results in increased damages from extreme events. A recent estimate of the economic damage that the global economy could experience from climate change was estimated for a subset of impacts on agriculture, heat stress, human health, sea-level rise, tourism, and energy demand. The estimate found that a 2°C to 2.6°C temperature-rise scenario results in a 10% loss in GDP by mid-century compared to a scenario wherein the Paris Agreement and net zero emissions targets are achieved.[34]

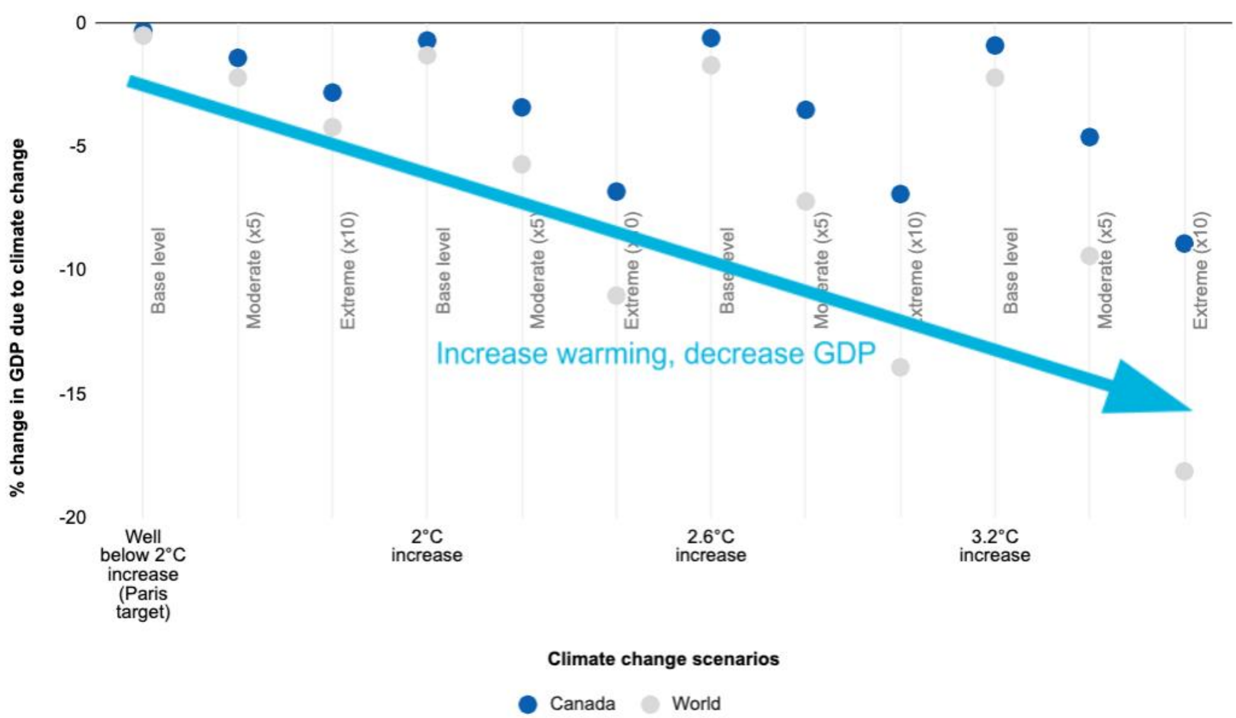

Figure 11. Percent impact on GDP of climate change for different temperature rises relative to a no climate change world.[35]

2.5 Cities as the Vanguard

Emission pathways that limit global warming to 1.5°C require significant changes in four systems: energy, land-use and ecosystems, urban areas and infrastructure, and industry. What does limiting temperature rise to 1.5°C look like for cities? Urban areas are home to more than 50% of the world's

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[34] Swiss Re. (2021). The economics of climate change: no action not an option. Retrieved from: https://www.google.com/url?q=https://www.swissre.com/institute/research/topics-and-risk-dialogues/climate-and-natural-catastrophe-risk/expertise-publication-economics-of-climate-change.html&sa=D&source=editors&ust=1619810463289000&usg=AOvVaw0h_rJ6xOqFMFzg22b4-E95

[35] Ibid.

population, as well as most built assets and economic activity. These densely populated urban areas are steadily growing. By 2050, cities are expected to comprise two-thirds of the global population.[36] The manner in which land-use, urban expansion, construction, buildings, and infrastructure are designed and built will be key determinants for reaching net zero and adapting to climate change.

According to the IPCC, global GHG emissions from buildings will need to be 80 to 90% lower, energy use for transportation will need to be reduced by about 30%, and renewables will need to supply 70 to 85% of electricity.[37] In addition, improvement of green urban infrastructure, the use of nature-based solutions, and effective land-use planning regulations and policies will be required.

Cities will be key implementers of climate action strategies. Toronto is part of C40, a global network of megacities committed to addressing climate change that responded to the Paris Agreement by providing city-specific pathways for action for C40 cities to meet their COP21 commitments. *Deadline 2020* identified C40 cities' share of the remaining global carbon budgets to 2100, for 1.5°C and 2°C temperature rise scenarios. Target emission trajectories were established for 84 member cities, including Toronto. C40 used a contraction and convergence approach to allocate the global carbon budget to cities, identifying targets of 3.2 tCO_2e per capita by 2030 and 0 tCO_2e by 2050.

Box: What is a Fair Share?

There is a limited budget of remaining emissions if we are to limit warming to 1.5°C. What is Toronto's fair share of the remaining budget? The countries of the world have spent decades seeking an agreement on what level of emissions reductions is expected from each country, primarily in the forum of the United Nations Framework Convention of Climate Change (UNFCCC). Two key principles influence what is the fair share of the remaining envelope of emissions:

- Responsibility is determined on the basis of both historic and current emissions, as well as the capability to act. In other words, wealthy countries which have emitted GHG emissions over their development trajectory have greater responsibility than countries which have only recently started to produce GHG emissions. In addition, countries which have access to more resources need to do more than those countries without resources.
- The right to sustainable development implies that all countries have the right to lift their peoples out of poverty and provide residents with sustainable living standards, meaning that countries with greater levels of poverty have the right to generate more emissions per capita than richer countries.

As a wealthy city, Toronto needs to reduce emissions more quickly than cities with fewer resources and fewer historical emissions. In practice, this means that if the world is targeting net zero by 2050, as

[36] Bazaz, A. et al. (2018). Summary for Urban Policy Makers. What the IPCC Special Report on Global Warming of 1.5 means for Cities. C40. http://doi.org/10.24943/SCPM.2018

[37] Masson-Delmotte, V., et al. (2018). Global warming of 1.5 C. *An IPCC Special Report on the impacts of global warming of*, *1*(5).Retrieved from: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter4_Low_Res.pdf

indicated by the IPCC's *Global Warming of 1.5℃* report, Toronto's responsibility is to achieve this target prior to 2050.[38]

2.6 Net Zero Gains Momentum

In December 2020, the federal government released *A Healthy Environment and a Healthy Economy*, a new economic plan to strengthen Canada's climate action, and to create and restore jobs as part of the government's COVID-19 pandemic economic stimulus. The plan includes investments that increase residential and commercial energy efficiency; provide incentives and infrastructure for electric mobility, transit, clean technology, and clean electricity; support a national active transportation strategy; and restore forests, wetlands, peatlands, and agricultural lands to boost carbon sequestration and climate resiliency.

In addition, the *Canadian Net-Zero Emissions Accountability Act* received Royal Assent on June 29, 2021.[39] The Act legislates Canada's target of net zero GHG emissions by 2050. It also establishes a legally binding process to set five-year national emissions-reduction targets, science-based emissions reduction plans, and accountability and reporting requirements for 2030, 2035, 2040, and 2045. The Act incorporates a new interim target of 40% to 45% emissions reductions below 2005 levels by 2030.[40]

The number of net zero pledges by organizations and jurisdictions roughly doubled in less than a year. By 2019, about 11 regions, 100 cities, and roughly 500 businesses had established targets. As of September 2020, 823 cities, 101 regions, and 1,541 companies had committed to net zero targets. These governments and companies have pledged to fully decarbonize their emissions footprints and have adopted specific net zero targets or signed onto initiatives with net zero targets for 2020, 2030, 2040, or 2050.[41]

The finance sector, particularly relevant for Toronto, has launched initiatives to support the goal of net zero GHGs by 2050. For example, in December 2020, the Net Zero Asset Managers Initiative committed to support net zero by 2050 or sooner, in line with global efforts to limit warming to 1.5°C. This initiative consists of a leading group of global asset managers representing over $9 trillion of

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[38] For a detailed review of effort sharing and its implications for GHG targets, see: Holz, Christian, Eric Kemp-Benedict, Tom Athanasiou and Sivan Kartha (2019) "The Climate Equity Reference Calculator" in *Journal of Open Source Software*, 4 (35), 1273. DOI:10.21105/joss.01273

[39] Government of Canada (2021). Government of Canada legislates climate accountability with first net-zero emissions law. Retrieved from: https://www.canada.ca/en/environment-climate-change/news/2021/06/government-of-canada-legislates-climate-accountability-with-first-net-zero-emissions-law.html

[40] *Prime Minister Trudeau announces increased climate ambition*. April 22, 2021. Retrieved from: https://pm.gc.ca/en/news/news-releases/2021/04/22/prime-minister-trudeau-announces-increased-climate-ambition

[41] Data-Driven EnviroLab & NewClimate Institute. (2020). Accelerating Net Zero: Exploring cities, regions, and companies' pledges to decarbonise. Retrieved from: http://datadrivenlab.org/wp-content/uploads/2020/09/Accelerating_Net_Zero_Report_Sept2020.pdf

assets under management.[42] Their commitment includes prioritizing real economy emissions reductions for companies and sectors in which they invest, working with asset owner clients on decarbonization goals and reviewing interim targets at least every five years to ratchet up the proportion of assets until 100% of assets are net zero.

Box: Avoiding Delay: The Risk of the "Net" in the Net Zero Target

In an influential article, three climate scientists describe how net zero targets were developed because climate models could no longer identify safe pathways with GHG reductions alone; the only viable pathways also require removal of emissions from the atmosphere.[43] They argue that these pathways are more theoretical than real as large scale carbon dioxide removal (CDR) technologies do not yet exist. As a result, a net zero pathway can mislead, conveying opportunities for reductions where they may not exist. For this reason, the scenarios analysed in TransformTO focus solely on efficiency gains and emissions reductions, highlighting any remaining emissions as a gap that may need to be addressed using CDR or other strategies as they emerge.

2.7 Managing the Financial Risk

The City of Toronto is Canada's financial hub and the second largest financial centre in North America, which creates an imperative for the City to evaluate the impact of climate-related financial risks on the City's viability as a corporation and as a community. Assessments of the financial risk of climate change have, until recently, focussed primarily on physical and economic impacts. A second category of impacts—the transition risk—refers to the impacts of a low-carbon transition on financial risk, such as the impact of new public policies in response to the climate emergency on investments and expenditures by households, businesses, and governments. Governments and regulators are increasingly requiring public companies to report on how they are managing these risks in a framework called the Task Force on Climate-Related Financial Disclosures (TCFD).[44] The City has taken steps in this direction including transparent reporting on climate in Corporate Financial Reporting and the release of an Environmental, Social and Governance (ESG) Report.[45] In the TCFD framework, scenario planning is a foundational tool for disclosing risks and opportunities of climate change. The modelling described in this approach uses scenario analysis to explore a variety of future outcomes for Toronto, directly aligning with the TCFD disclosure requirements.

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[42] Net Zero Asset Managers Initiative (2021).Net Zero Asset Managers Initiative. https://www.netzeroassetmanagers.org/

[43] Dyke, J., Watson, R., and Knorr, W. (2021). Climate scientists: concept of net zero is a dangerous trap. Retrieved from: https://theconversation.com/climate-scientists-concept-of-net-zero-is-a-dangerous-trap-157368

[44] TCFD (2017). Recommendations of the Task Force on Climate-related Financial Disclosures. Retrieved from: https://assets.bbhub.io/company/sites/60/2020/10/FINAL-2017-TCFD-Report-11052018.pdf

[45] City of Toronto (2021). City of Toronto releases first-ever Environmental, Social and Governance Report. Retrieved from: https://www.toronto.ca/news/city-of-toronto-releases-first-ever-environmental-social-and-governance-report/

2.8 A Climate-Safe City

Climate resilience is often an indirect or co-benefit of mitigation actions. Figure 12 illustrates how climate hazards impact infrastructure, cultural and ecological systems and how there are feedback loops between these systems. In this analysis, efficiency measures reduce the stress on grid electricity demand and therefore the risk of blackouts during extreme weather conditions, relative to a less efficient system. Health benefits from reduced air pollution are an important co-benefit of climate mitigation, which reduces the sensitivity of individuals to climate impacts such as extreme heat. Extreme heat is also mitigated by more efficient dwellings.

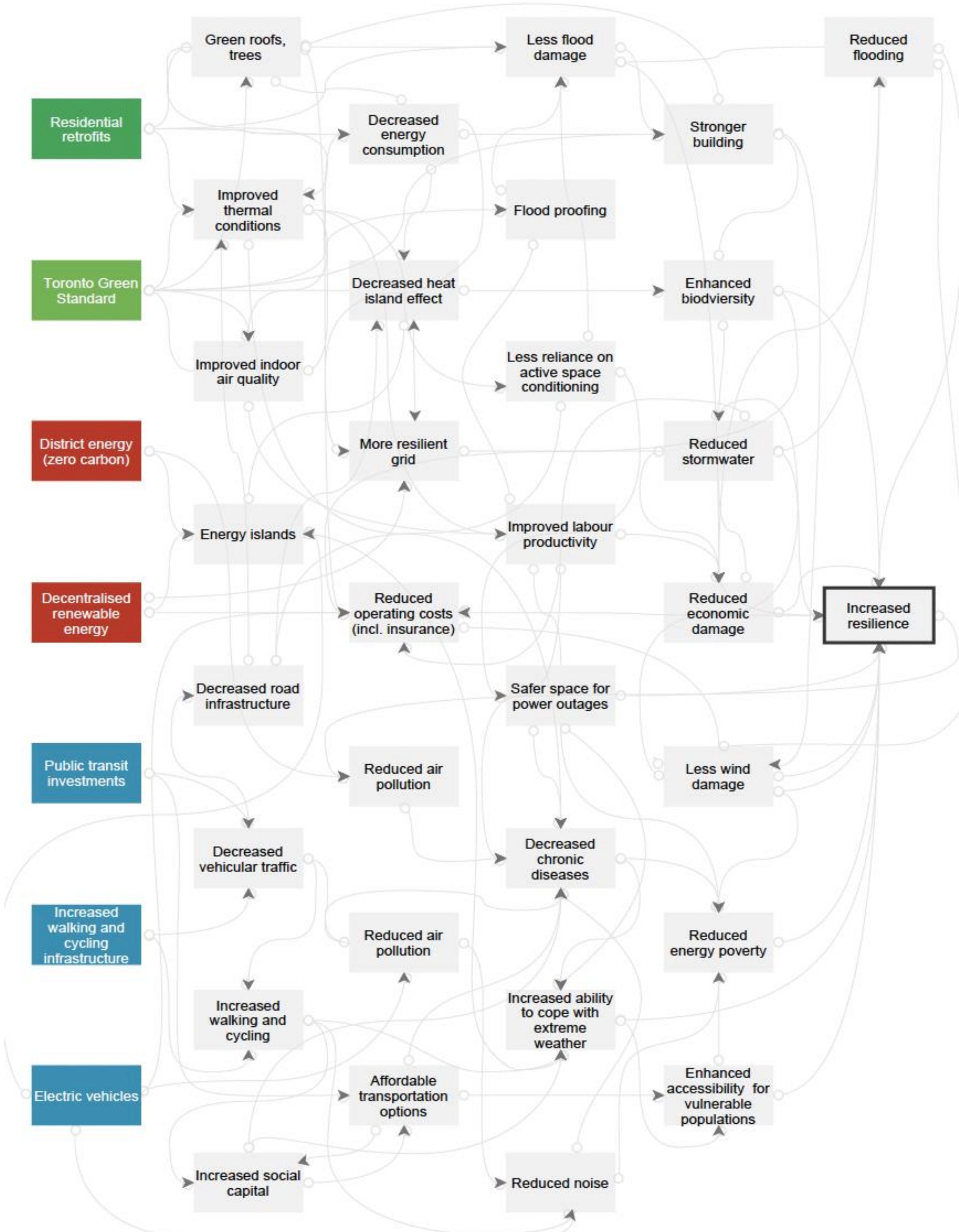

Figure 12. Schematic on the relationships between mitigation actions and increased resilience.[46]

2.9 A Green Recovery

The COVID-19 pandemic has radically transformed the world's societies, economies, culture, and city services, resulting in disruptions to work, education, and home life.[47] COVID-19 has impacted most aspects of life including the activities that drive energy use and GHG emissions. Global energy demand dropped by nearly 4% in 2020 due to changes in transportation use, shutdown of businesses, and work-from-home policies. As a result, global energy-related GHG emissions fell by 5.8% –the equivalent of removing all of the European Union's emissions from the global total. It was the largest annual percentage decline since World War II.[48] However, this was a temporary decline. Global GHG emissions are already on the rise again and concentrations in the atmosphere continue to climb as global temperatures increase.[49]

As Canada initiates efforts to recover from the impact of the coronavirus, investments that stimulate the economy can simultaneously address the climate crisis. Climate change is our greatest long-term threat, but it also provides immense economic opportunities. Studies demonstrate the benefits of climate action including new employment opportunities, greater productivity, and cleaner air. For example, the New Climate Economy estimates that low-carbon urban actions are an economic opportunity worth $17 trillion by 2050.

The City of Toronto's Office of Recovery and Rebuild (TORR) prepared a report titled *COVID-19: Impacts and Opportunities*. The analysis highlighted the need to reduce the health and socioeconomic inequalities across the city; that existing plans and strategies can be utilized and in some cases accelerated for recovery and rebuild purposes; and that decision-makers need to consider the social and financial impacts of COVID-19 on Toronto businesses and residents.[50] The report includes relevant sections on infrastructure and mobility, and climate change and resilience.

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[46] SSG (2019). Benefits of actions to reduce greenhouse gas emissions in Toronto: Climate resilience. Retrieved from: https://www.toronto.ca/wp-content/uploads/2019/06/971c-Benefits-of-Actions-to-Reduce-Greenhouse-Gas-Emissions-in-Toronto-Climate-Resilience.pdf

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

[48] IEA (2021). Global Energy Review: CO2 Emissions in 2020. Retrieved from: https://www.iea.org/articles/global-energy-review-co2-emissions-in-2020

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

[50] Mowat, D. and Rafi, S. (2020). COVID-19 Impacts and Opportunities. City of Toronto. September 15, 2020. Retrieved from: https://www.toronto.ca/wp-content/uploads/2020/09/9133-torr-covid19-impacts-opportunities-2020.pdf

Box: Toronto's Recovery

"Toronto should continue to address climate change and improve resilience through its recovery and long-term rebuild efforts to ensure the momentum and ground gained through past strategies are not lost. The City's existing efforts under the TransformTO Climate Action Strategy and the Resilience Strategy are generating ideas and partnerships that can help accelerate recovery and align rebuild with the City's strategic goals." - City of Toronto's COVID-19 Impacts and Opportunities

3. Toronto's Future: Net Zero

3.1 Defining Net Zero

Net zero emissions is achieved when decarbonization of the economy reduces GHG emissions as close to zero as possible, and any remaining human-driven emissions are balanced out by an equivalent amount of carbon removals. Carbon removals or sequestration can be achieved by restoring natural lands and soils, or through direct air capture and storage technology.

For the City of Toronto, net zero will be achieved by decarbonizing rapidly and thereby reducing GHG emissions from how people move around, how residents operate buildings, how goods are produced and manufactured,[51] and how people consume and dispose of waste.

Table 1 presents a checklist that provides an overview of the scope of Toronto's net zero strategy evaluated in this analysis.[52]

Table 1. What does a net zero target mean for Toronto?

Questions	Response based on this analysis
1. Scope	
What global temperature goal does this plan contribute to (to stabilize global temperature, or see it peak and decline)?	1.5°C
What is the target date for net zero?	2040, 2050
Which GHGs are considered?	CO_2, CH_4, NO_2

[51] While consumption-based emissions are not addressed in this analysis, the City of Toronto is seeking to influence these emissions through additional projects.

[52] Rogelj, J., Geden, O., Cowie, A., & Reisinger, A. (2021). Net-zero emissions targets are vague: three ways to fix.

Questions	Response based on this analysis
How are GHGs calculated (GWP100 or another metric)?	GWP100
What is the extent of the emissions (over which territories, time frames or activities)?	City of Toronto's geographic boundary, with some exceptions
What are the relative contributions of reductions, removals, and offsets?	To be determined
How will risks be managed around removals and offsets?	To be determined
2. Fairness / Equity	
What principles are being applied?	The City of Toronto is aiming to align with the Science-Based Climate Targets: A Guide for Cities.
Would the global climate goal be achieved if everyone did this?	Yes
What are the consequences for others if these principles are applied universally?	Cities with the highest levels of poverty would be allowed to increase their emissions to raise their populations out of poverty, while cities with lower levels of poverty would reduce their emissions.
How will your target affect others' capacity to achieve net zero, and their pursuit of other Sustainable Development Goals?	By minimizing the demand for scarce low-carbon resources such as RNG and hydrogen, the pathway creates opportunities for other sectors and jurisdictions that are less flexible to use these resources. The pathway will also help reduce costs for low-carbon strategies which will have regional and international implications.
3. Roadmap	
What milestones and policies will support achievement?	This report details milestones against which to measure progress but does not identify specific policies.
What monitoring and review system will be used to assess progress and revise the target?	An annual climate lens and carbon budget is proposed.
Will net zero be maintained, or is it a step towards net negative?	This analysis provides a pathway to net zero which creates the possibility for going net negative. However, net negative strategies have not yet been evaluated.
4. Limitations/Opportunities for Additional Investigation	
Impacts on peak electricity demand	The impacts on peak demand and the required electricity capacity to

Questions	Response based on this analysis
	support the demand was outside of the scope of this analysis. Marginal emissions factors for electricity that result from using natural gas for peaks were also not assessed in the analysis.
Consideration of embodied carbon	The impact of the production of equipment and materials for the City of Toronto was not evaluated. The choice of materials can have a significant impact on the GHG profile of building retrofits, for example. Or the benefit of a walking trip is much greater when the embodied carbon in infrastructure and vehicles is considered.

3.2 The Net Zero Vision Goals

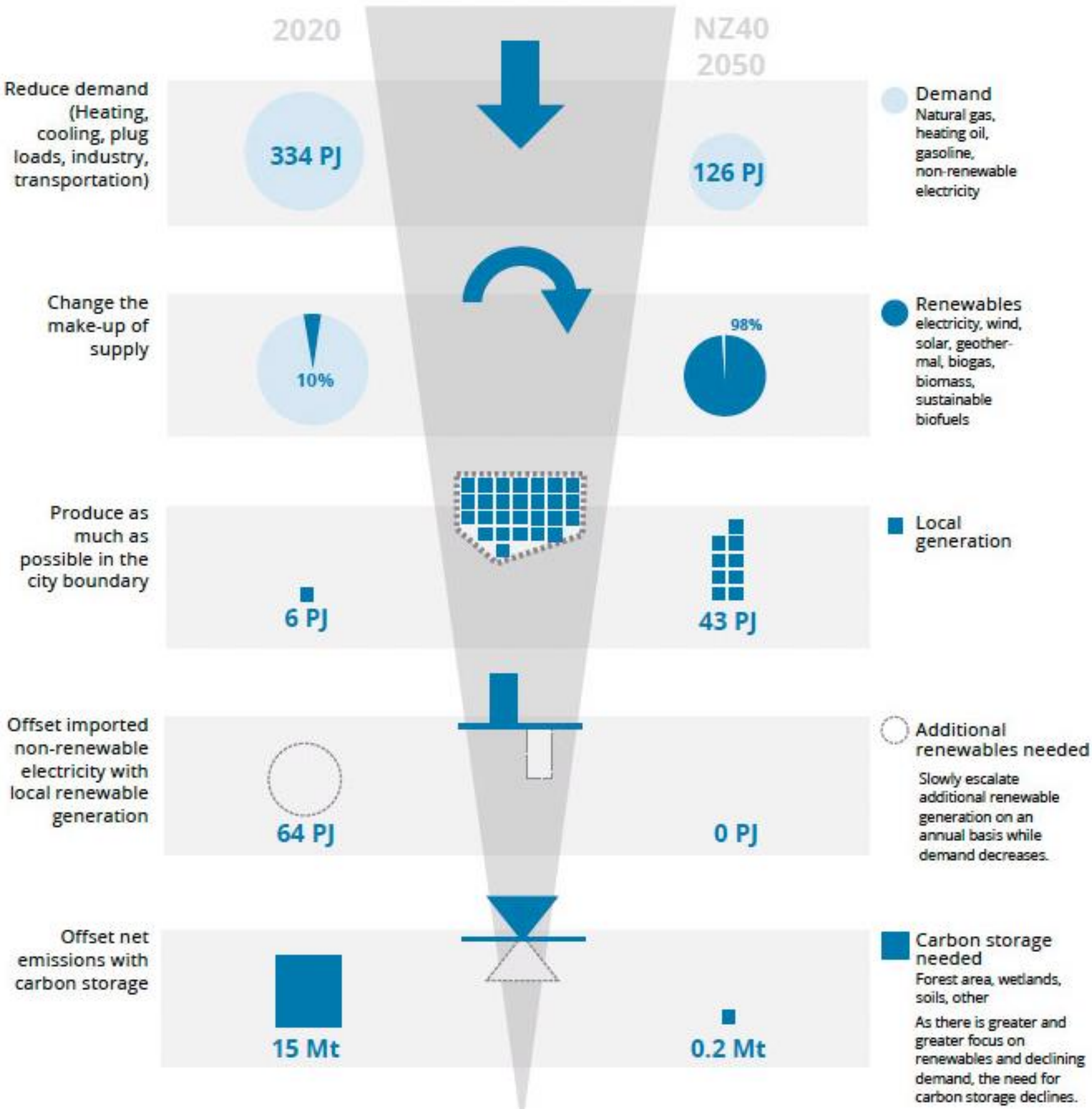

Figure 13. Net zero goals and trajectory. Note that in the image above, it is assumed that the provincial grid is fully decarbonized by 2050 in the NZ40 Scenario.

3.3 A Just Transition

Deep emission reductions require innovation, rapid diffusion of new technologies, and the reshaping of markets and socio-economic systems. The low-carbon transition is as much a social transition as a technological and economic shift. The key to success is the alignment of interests so that governments, business, and society support each other in a reinforcing feedback or "ambition loop".

Transitions are, by definition, disruptive. A just transition is an approach that aims to minimize the negative impact on workers and communities and maximize the positive impacts by identifying new opportunities and providing bridging mechanisms, such as income support and retraining for new occupations and technologies.

While the primary objective of the Net Zero Strategy is to meet the targets that the City has set for net zero by 2040/2050, an integral component of city planning and a just transition is to apply a lens of health, equity, and prosperity. For example, the City can prioritize strategies and actions that deliver GHG emission reductions while meeting other City objectives related to health, equality, poverty alleviation, and reconciliation. The City recognizes equity as a fundamental issue of respect and fairness, as well as an economic driver that, "by unlocking increased human potential, ultimately increases everyone's quality of life and income."[53]

The transition to a net zero economy offers opportunities to achieve social, economic, and environmental objectives. It also has the potential to provide a burst of economic growth. If the transition is managed well and rooted in the context of sustainable development, it can generate well paying, green jobs, and enterprises that can be inclusive across the population, reduce inequalities, and reduce poverty.

Policies and programmes will be required to provide an enabling environment for enterprises, workers, and investors. This will include anticipating the impacts on employment, adequate and sustainable social protection for job losses and displacement, skills development, and clear and open communications.

3.4 Guiding Principles

The Net Zero Strategy incorporates a robust process of best practices research, public engagement input from the City's consultations, and technical modelling of future scenarios. The Strategy has been guided by the following principles[54]:

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[53] Mowat, D. and Rafi, S. (2020). COVID-19 Impacts and Opportunities. City of Toronto. September 15, 2020. Retrieved from: https://www.toronto.ca/wp-content/uploads/2020/09/9133-torr-covid19-impacts-opportunities-2020.pdf

[54] City of Toronto (2018). TransformTO: Climate Action for a Healthy, Equitable & Prosperous Toronto. Implementation Update. https://www.toronto.ca/wp-content/uploads/2020/02/92f8-TransformTO-Climate-Action-for-a-Healthy-Equitable-Prosperous-Toronto-Implementation-Update-2017-and-2018.pdf

Figure 14. Guiding principles for the Net Zero Strategy.

3.5 Indigenous Knowledge and Worldview for Net Zero

In 2018, the City collaborated with Indigenous Climate Action to convene a workshop to seek Indigenous communities' input on the City's climate strategies. The discussions were summarized in a report titled *Indigenous Climate Action,* prepared by an organisation with the same name.[55] The paper described a need for more meaningful Indigenous engagement and to situate climate action in a broader framework on culture, while considering environmental racism and colonialism. The recommendations were also to consider emissions from consumption, to respect and engage meaningfully with Indigenous knowledge and practices, to find ways to accommodate urban Indigenous cultural resurgence, to reflect and relate to the realities of people "on the street", and to support Indigenous relationships with urban land, water and food.

Box: Excerpt from Indigenous Climate Action Summary Report[56]

Indigenous peoples will determine our own future–not merely as vulnerable people, but people with knowledge, who have ways to solve our own problems and contribute to broader strategies for addressing what is coming. Indigenous forms of knowledge need to be engaged with meaningfully in

[55] Indigenous Climate Action (2018). Indigenous Climate Action Summary Report: Indigenouse Strategic Discussions on City of Toronto Climate Strategies. Retrieved from: https://www.toronto.ca/wp-content/uploads/2019/05/8eb4-2019-03-25_Indigenous-Climate-Report_final.pdf

[56] Ibid. Extract from page 5.

addressing climate change. The knowledge is misunderstood and incomplete if non-Indigenous researchers merely "extract the knowledge." "We don't need to change our knowledge and laws, even when the data changes" (for example, signs of when to harvest certain things may change, but the underlying knowledge structures and processes remain). Indigenous people need to deconstruct external, colonial forces and replace these with Indigenous presence from within. Our own prophecies and natural phenomena are informing us of changes, and we already know how to adapt. If the city does not account for and address colonization in its policies it will keep repeating the same problematic behaviours. So Toronto's Biodiversity strategy, for example, needs "decolonizing." We need to look at indicators for biodiversity differently - not just counting things, but rather asking, in a much wider way, questions that have a much more comprehensive focus: "Are we good ancestors?" "What do women's economies look like that are not consumptive?" Our culturally rooted principles are fundamental truths or guideposts for right behaviour, and are legitimate unto themselves. Western Eurocentric values are not everybody's values. For example, we need not centre individualism; we can centre collective wellbeing. We can and must consider how our children and the generations hundreds of years ahead can have a viable and safe future. In all these ways and more, the gifts of Indigenous peoples are vital to all people of all backgrounds.

Part 2: The Pathway to Net Zero

4. Getting to Net Zero

4.1 Exploring the Future

New scenario modelling was undertaken to align and update TransformTO's climate action planning with the City's Climate Emergency Declaration's targets of achieving a 65% emissions reduction (relative to 1990 levels), by 2030, and achieving net zero emissions by 2050 or sooner. The results include:

- GHG mitigation actions for key sectors, including buildings, energy, transportation and waste;
- A comparative financial analysis of the costs and benefits for each of the scenarios;
- Insights on the feasibility of implementing climate actions (i.e. technical, financial, and social/behavioural); and,
- Recommendations on integrating climate resilience considerations into mitigation policies and measures.

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

4.2 A City as a System

Toronto's energy systems, with so many moving parts, are highly complex and require a sophisticated model to track all of the variables and their relationships. CityInSight, the model used for this project, is a comprehensive energy, emissions and finance model developed by Sustainability Solutions Group (SSG) and whatIf? Technologies Inc.[57]

[57] For detailed information on the modelling approach, refer to Modelling Toronto's Low Carbon Future: Data, Methods and Assumptions Manual (DMA).

Base Year

A representation of the City of Toronto's energy and GHG emissions was developed for the base year of 2016 in order to align with a census year. This required a calibration of the components of the model with observed data. For example, the total electricity consumption from end-uses for each building (such as heating, cooling, appliances) was adjusted to equal the total electricity consumption reported by the electricity utility. This process of calibration was applied to each sector within the model, in which the representation of activity and the built environment is "tuned" in the model so that the modelled energy consumption aligns with observed energy consumption. It should be noted that the year 2020 was used as a more up-to-date base year for targets and trajectories throughout the report, which was established from the modelling projections.

Stocks and Flows

The modelling integrates the useful lifetimes of different capital assets, based on the concept of stocks and flows, a method that highlights urgency and financial risk. For example, CityInSight tracks the stock of vehicles by type and vintage; the flow consists of the retirement of vehicles as they reach the end of their lifecycle and the addition of new vehicles to the stock. The concept of stocks and flows has significant implications for the cost of the net zero pathways. If a natural gas boiler at the end of its useful life is replaced with a heat pump, the associated cost is significantly lower than if the natural gas boiler is replaced prior to the end of its useful life.

Different types of equipment turn over more quickly than others. For example, between now and 2050, buildings are likely to last; however, equipment such as trains for the transit system and industrial boilers are likely to be replaced once, and light fixtures will be replaced about three to five times. Ensuring that the low-carbon option is introduced as soon as possible, particularly for the longer lasting assets is, therefore, key to avoiding significant additional costs associated with incentivizing early replacement.

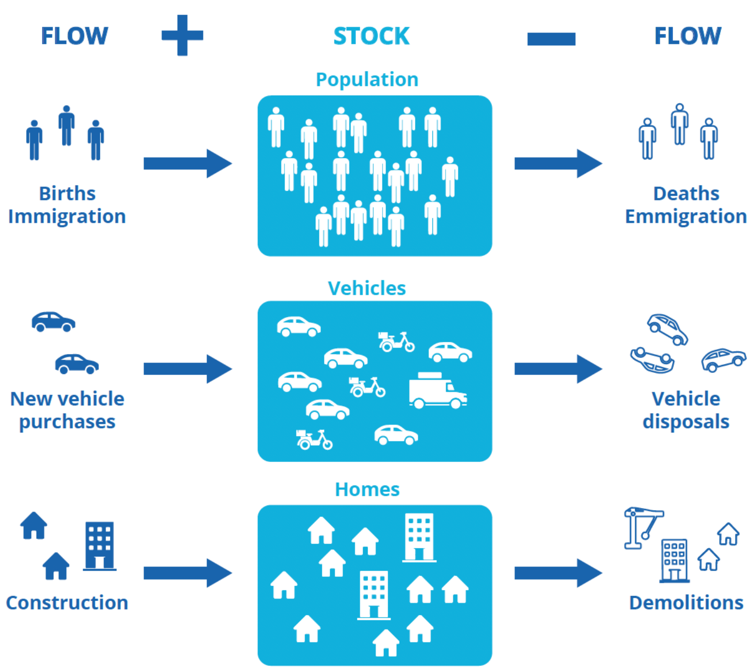

Figure 15. Examples of stocks (light blue) and flows (dark blue).

Box: Making Climate Safe Investments Now

Every expenditure on infrastructure either locks in new GHG emissions or reduces GHG emissions. The longer the investment life (period over which it pays off) of a type of infrastructure that results in emissions, the more vulnerable it is to transition risk. In other words, if a natural gas boiler is projected to have an operating lifetime of 20 years, it will likely need to be replaced within the decade in order to stay within 1.5°C, forfeiting half of its planned lifetime. A new house which generates emissions will likely need to be retrofit to be zero emissions within the next decade. As a result, if those decisions are climate safe or climate proofed moving forward, society can avoid significant transition costs. For example, retrofitting a house to zero emissions can cost between $70,000-$100,000, whereas building a new net zero home can have an incremental cost of less than $10,000.[58]

GHG Accounting Framework

The GHG emissions accounting framework used by CityInSight is based on the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) framework,[59] a global standard that is designed to enable comparability amongst cities in different countries. The baseline GHG inventory accounts for emissions from generating activities including buildings, transportation, energy production, and waste. GHG emissions and removals from land use and land cover change are not included.[60,61]

Residual Emissions

"Residual emissions" are the emissions remaining after all opportunities to maximize reductions have been implemented. Technical scenario modelling shows that in 2050 in Toronto, it may be difficult to eliminate some residual emissions from landfills, industrial processes, and older buildings. The net zero carbon pathway assumes there will be approximately 2 megatonnes of residual emissions in 2050.

Although Toronto's net zero strategy prioritizes efforts to maximize GHG emission reductions through climate actions that limit the amount of emissions created, it is recognized that there will be a need to compensate for remaining residual emissions to achieve a balance of net zero.

Toronto will need to reduce or eliminate remaining emissions by strategies such as encouraging or creating natural carbon sequestration, applying negative emissions technologies such as carbon capture and storage if they become viable and/or purchasing offsets.

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[58] These costs are based on analysis completed by SSG for various projects.

[59] WRI, C40 Cities & ICLEI. (2014). Global protocol for community-scale greenhouse gas emission inventories—An accounting and reporting standard for cities. Retrieved from http://www.ghgprotocol.org/city-accounting

[60] Changes in land cover (from greenfield to brownfield) to 2050 is assumed to be negligible; new growth is targeted to already developed areas in the form of densification/infill.

[61] Annual net carbon sequestration of the City's urban forest accounts for 36,500 t CO_2e, less than 0.2% of baseline emissions (Every Tree Counts, City of Toronto, 2013).

4.3 Pathways to Net Zero

The development of actions and the approach to modelling was informed by a framework of Reduce-Improve-Switch-Generate. The framework is adapted from similar approaches such as Reduce-Reuse-Recycle (from the waste sector) and Avoid-Shift-Improve (from the transportation sector).

In general, emissions reductions are realized through actions that reduce energy use (e.g. behaviour change, building envelope improvements), that improve the use of energy (e.g. appliance efficiencies, lighting), and that switch from the use of carbon-intensive fuels to low- or zero-carbon fuels (e.g. electric vehicles). When a steep decline in emissions is needed, actions in all three areas are required, accompanied by the generation of local renewable or low- or zero-carbon energy. The logic of this approach is that reducing and improving energy use not only reduces emissions directly, but also reduces the size of renewable energy generation that will be needed, a necessary step towards deep decarbonization.

Figure 16 provides a visualization for the steps taken to determine the City's net zero scenarios.

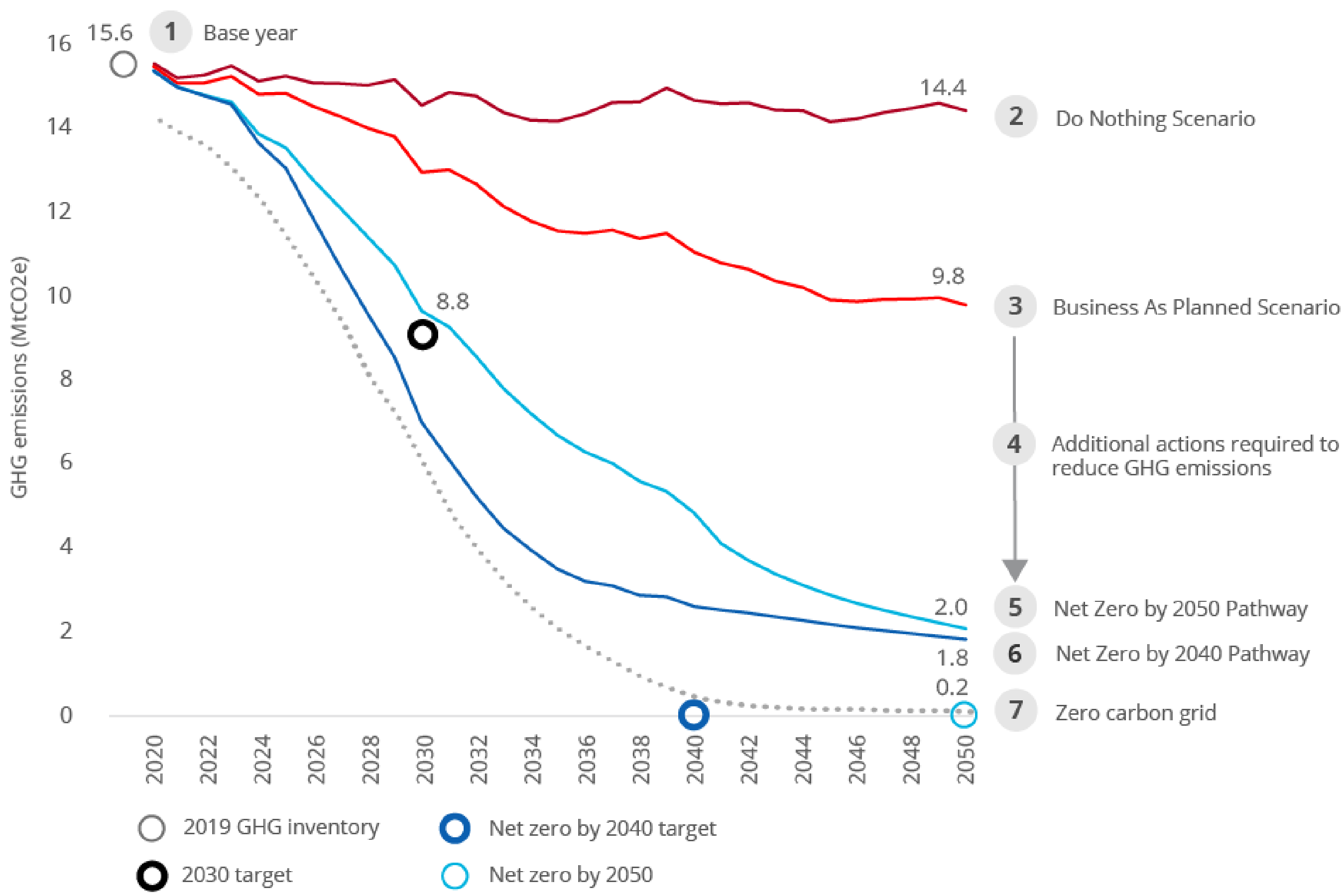

Figure 16. Overview of the net zero scenario development process.

Step 1: Base year: The year 2016 was used as the baseline, in order to align with the most recent Canadian census year. Bottom-up data for buildings (i.e., size, shape) and transportation (i.e., driving distances) were calibrated with observed energy consumption data from utilities and other sources for this year to ensure that the model portrays the existing energy system in Toronto.

Step 2: Do Nothing Scenario: The Do Nothing scenario was designed to reflect what would happen if the City itself put little to no additional effort or investment into climate action. It captures anticipated population growth as well as current patterns of activity and deployment of technologies. Existing climate actions at upper levels of government are considered, including provincial building code, federal fuel efficiency standards, and the national carbon levy. The impact of climate change on heating and cooling requirements in buildings is also captured.

Step 3: Business as Planned (BAP) scenario: The BAP scenario reflects what the City has "in the books", incorporating its projects and plans that are already approved. Projects considered include district energy expansion, transit expansion, personal vehicle and City fleet electrification, and roll out of the Toronto Green Standard (TGS).

Step 4: Actions to Reduce GHG Emissions: The NZ40 and NZ50 pathways were informed by extensive research of low-carbon actions and best practices to reduce GHG emissions at the city scale, as well as consultations with City divisions on what aggressive action on climate could be deployed.

The city-based actions were reviewed by the City of Toronto staff to ensure that:

1. actions that were not applicable to Toronto were excluded;
2. actions that the City was already undertaking were included in the BAP; and,
3. actions that were relevant and aligned with the outcomes of the TransformTO engagement process were included.

Following these considerations, the modelling included all possible and relevant actions, regardless of the impact on emissions reductions with one caveat: the scenarios emphasize actions that incorporate existing and available technologies, or what the Canadian Institute for Climate Choices (CCIC) defines as "safe bets."[62] This approach aligns with best practices for identifying net zero pathways, and reduces the transition risk, or indeed, failure risk that comes with relying on untested technologies. A further caveat is that, while the technologies are generally tested and proven, their deployment at scale will require innovation in policy, financing, and workforce deployment.

Box: Safe Bets Versus Wild Cards[63]

The CICC defines safe bets as emission-reducing technologies and solutions that are already commercially available and face no major constraints to widespread implementation. Wild cards are solutions that may come to play a significant and important role on the path to net zero, but whose ultimate prospects remain uncertain. The actions explored in the Technical Report are primarily safe bets with a few exceptions. Given the emphasis of the Canadian and European governments on green hydrogen,[64] a limited deployment was modelled, in order to explore the implications of hydrogen relative to electrification and position Toronto to be able to take advantage of green hydrogen if this becomes a viable option.

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[62] Canadian Institute for Climate Choices (2021). Canada's Net Zero Future: Finding Our Way in the Global Transition. Retrieved from: https://climatechoices.ca/wp-content/uploads/2021/02/Canadas-Net-Zero-Future_FINAL-2.pdf

[63] Ibid.

[64] Government of Canada. (2020). The Hydrogen Strategy. https://www.nrcan.gc.ca/climate-change/the-hydrogen-strategy/23080

Step 5: Net Zero by 2050 Pathway (NZ50): Two net zero pathway explored potential pathways for achieving Toronto's 2050 target. The Net Zero by 2050 (NZ50) pathway involved the modelling and quantification of GHG reductions of key low carbon actions to support this effort. Actions including switching to renewable energy sources, increasing energy efficiency, and reducing or altering emissions-producing activities were identified; and their energy, emissions, and financial impacts were compared to the BAP and Do Nothing scenarios. The design of the two net zero pathway include Toronto's BAP context plus new recommended GHG mitigation policies, actions, and initiatives to reach the City's net zero target by 2050.

Step 6: Net Zero by 2040 Pathway (NZ40): The Net Zero by 2040 (NZ40) pathway explored an alternate pathway for the city to achieve net zero emissions on an earlier schedule that would also result in lower overall cumulative GHG emissions. The modelling and quantification of low carbon actions were similar to the NZ50 pathway, but with shorter timelines and greater and deeper immediate and near-term actions.

Step 6: Gap to Reaching 1.5°C (net zero emissions): For each scenario, the gap between emissions reductions resulting from policies and actions and the reductions needed to reach 1.5°C was calculated. These emissions would be mostly eliminated by securing access to 100% clean electricity. Otherwise, they would need to be reduced through some combination of emerging technologies, purchasing renewable energy certificates, carbon credits or offsets, or by carbon dioxide removal (CDR).

Step 7: Cleaning the Grid: Most of the remaining GHG emissions in the system are the result of the combustion of natural gas in the electricity grid. A key strategy is securing access to 100% clean electricity.

Box: What is CDR?

Pathways to stay within 1.5°C are now reliant on negative emissions, which means extracting emissions from the atmosphere using carbon dioxide removal (CDR) strategies;[65] however, CDR is needed less in pathways with an emphasis on efficiency. CDR can include enhancement of terrestrial and coastal carbon storage in plants and soils, such as afforestation and reforestation; capturing atmospheric carbon dioxide and storing it in geological formations; and chemically extracting carbon dioxide from the atmosphere. Each CDR approach has different social, financial, energy and environmental impacts. While "most CDR technologies are largely unproven to date and raise substantial concerns about the adverse side-effects on environmental and social sustainability,"[66] there are opportunities available

[65] Rogelj, J., D. Shindell, K. Jiang, S. Fifita, P. Forster, V. Ginzburg, C. Handa, H. Kheshgi, S. Kobayashi, E. Kriegler, L. Mundaca, R. Séférian, and M.V. Vilariño, 2018: Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. 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.

[66] Ibid, section 2.3.4

today. For example, CarbonCure's technologies today inject CO2 into concrete at the rate of 17 kgCO2 per m3.[67]

4.4 A Growing City

Demographics provide important information in establishing a community's energy and emissions baseline. Population trends, rate of employment, and expected number of dwellings are the basis for documenting current—and estimating future—energy use and emissions production, and to ensure comparability they are held constant across all of the scenarios. The 2016 National Census (performed every 5 years) provides this information for past years. For future years, growth projections to 2041 were used[68], and then carried forward to 2050 using the same rate of growth as expected from 2016 and 2041. Based on these assumptions, Toronto's population is expected to increase from approximately 3 million (2020) to 3.7 million by 2050, increasing by 638,566 people. Dwellings are expected to increase with population growth, with 322,000 added between 2020 and 2050. Similarly, employment numbers increase from 1.7 million to over 2.2 million, with a total of 490,552 new jobs to be added between 2020 and 2050, slightly increasing per-capita employment from 0.57 to 0.61 jobs per resident. Personal vehicle numbers are expected to increase by 41% over the time period, following a similar rate of vehicles owned per household by dwelling unit type as in 2020. Since most of the new dwelling units added are apartments and these have lower rates of vehicle ownership than other dwelling types (such as single-family and semi-detached homes), city-wide vehicles owned per household decrease slightly over the time period.

Table 2. City of Toronto Demographic Trends Underlying the Scenarios, 2020 and 2050.

	2020	2050	Change 2020-2050	% Change 2020-2050
Population	3,030,486	3,669,051	638,566	+21%
Employment	1,729,892	2,220,444	490,552	+28%
Dwellings	1,156,643	1,478,389	321,747	+28%
Personal vehicles	1,175,400	1,655,055	479,655	+41%

[67] CarbonCure (n.d.). CarbonCure's Path to the Decarbonisation of Concrete. Retrieved from: http://go.carboncure.com/rs/328-NGP-286/images/CarbonCure%27s%20Path%20to%20the%20Decarbonization%20of%20Concrete%20eBook.pdf

[68] Strategic Regional Research Alliance. City of Toronto Population Projections by Traffic Zone, 2011 - 2041. Note: The Low Scenario was used.

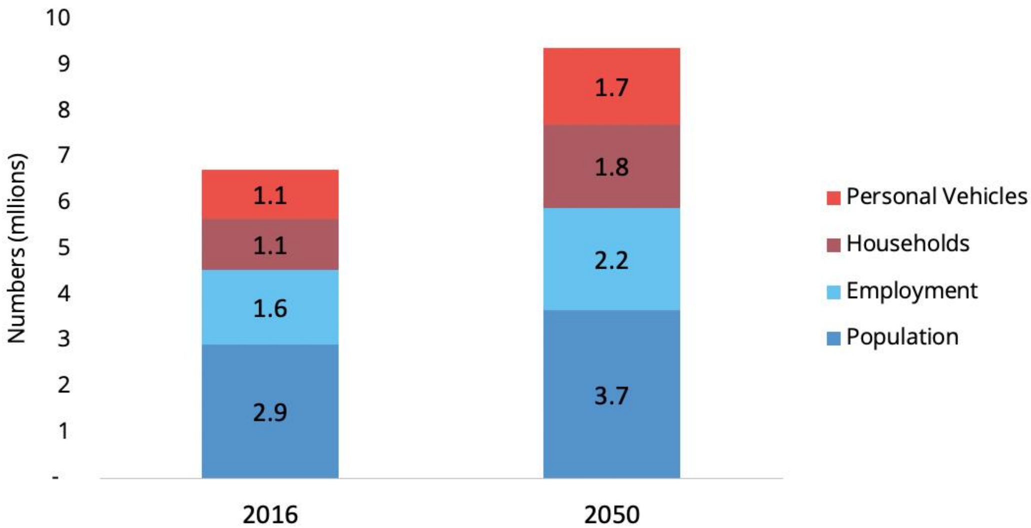

Figure 17. Key drivers of GHG emissions by the numbers.

4.5 A Dirtier Electricity Grid

Ontario's electricity system is relatively clean in comparison to other provinces, but is projected to become more GHG intensive per unit of electricity generated (Figure 18) due to nuclear retirements and the addition of gas generation.[69] This trend has wide-ranging implications for Toronto's ability to rapidly reduce GHG emissions, as electrification of transportation and heating is the primary pathway.

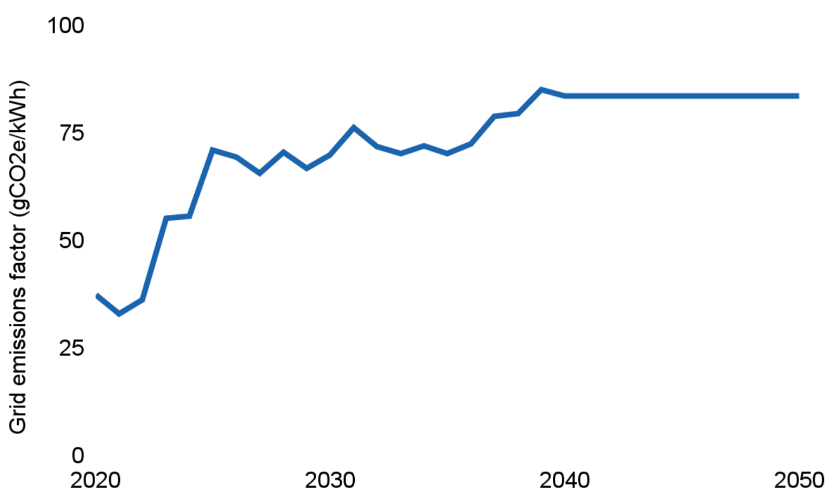

Figure 18. Projection of the GHG emissions intensity of the Ontario grid.

[69] IESO (2020). Annual Planning Outlook- Ontario's electricity system needs: 2022-2040.

4.6 The Current Situation: A Snapshot

In 2019, Toronto's community-wide GHG emissions were 15.6 megatonnes (MT) CO_2e, 38% lower than 1990 levels (Figure 19). Emissions from buildings remain the highest contributors, followed by emissions from transportation and waste.[70]

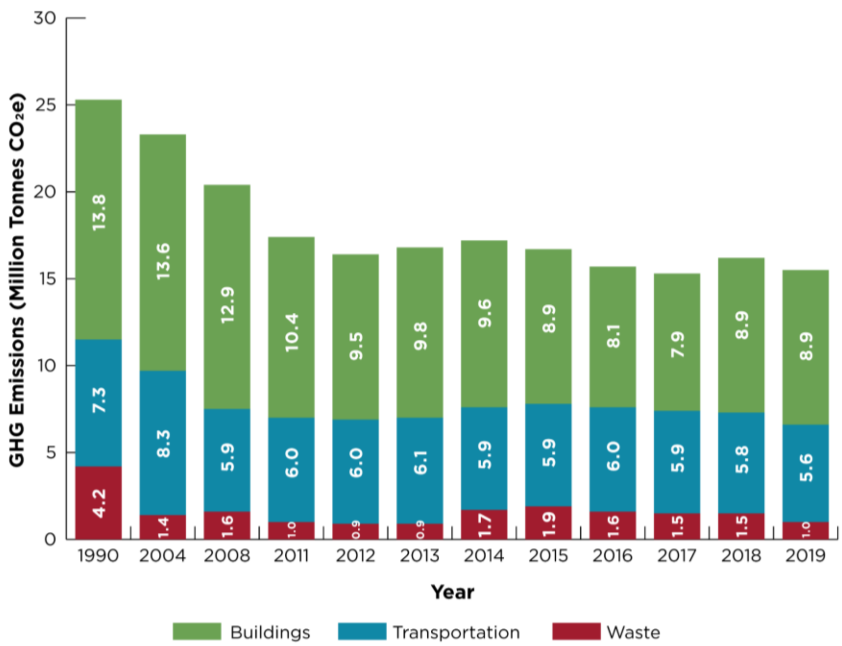

Figure 19. GHG Emissions by Sector, 1990-2019.

The three dominant sources of GHGs in Toronto are:

- energy use in buildings: 57% of GHG emissions come from homes and buildings, primarily from burning natural gas to heat indoor spaces and water;
- transportation fuels: 36% of GHG emissions are generated by transportation (73% of which are attributed to personal vehicles); and,
- waste in landfills: 7% of emissions are generated by waste, with organics, yard waste and wastewater treatment processes being the primary sources.

Figure 20 shows GHG emissions by source, indicating that natural gas consumption to heat buildings is the largest source of community-wide emissions (approximately 53% of all emissions). Gasoline accounts for almost 26%, while 7% result from the release of methane from landfills. Electricity consumption accounts for about 5% of city-wide emissions.

[70] City of Toronto 2018 Greenhouse Gas Emissions Inventory. Retrieved from: www.toronto.ca/transformto

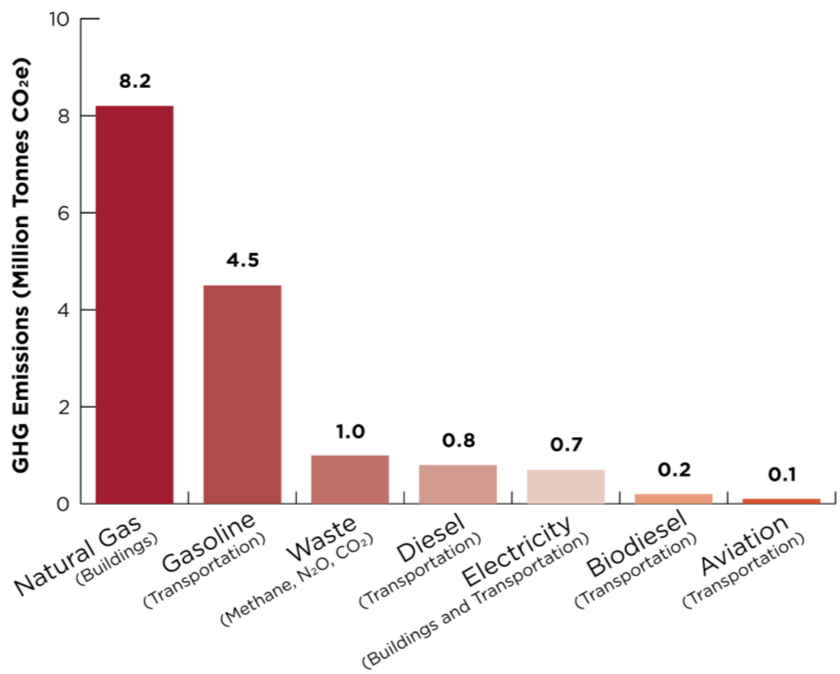

Figure 20. Greenhouse gas emissions by source (2019).

4.7 Low-Carbon Actions

Table 3 summarizes the key actions that were modelled for the net zero scenarios and their contributions to GHG emissions reductions.

Table 3. Key Net Zero Scenario Action Targets and Proportion of GHG Emission Reductions by Sector.

Action	Business as Planned (BAP) Target	0x50 Target	0x40 Target	Emissions reductions compared to previous scenario (2050) (kt)			Cumulative emissions reduction of BAP (2020-2050) (Mt)	% of total cumulative emissions reductions	Cumulative emissions reductions over DN (2020-2050), all scenarios	% of total cumulative emissions reduced
				BAP	NZ 50	NZ 40				
Buildings- residential										
Improved performance for new buildings	TGS Tier 4 for new residential buildings by 2031	100% Tier 2 by 2021 100% Tier 3 by 2022 100% tier 4 by 2027	-	385	44	-	6.0	2%	7.1	3%

Action	Business as Planned (BAP) Target	0x50 Target	0x40 Target	Emissions reductions compared to previous scenario (2050) (kt)			Cumula-tive emiss-ions reduc-tion of BAP (2020-2050) (Mt)	% of total cumula - tive emiss-ions reduc-tions	Cumula-tive emis-sions reduc-tions over DN (2020-2050), all scenarios	% of total cum-ula-tive emiss -ions redu-ced
				BAP	NZ 50	NZ 40				
Retrofit existing buildings	Retrofit 6,000 units per year. Annual electricity percent savings per building - 10% Annual thermal demand percent savings per building - 35%	Retrofit 100% of existing buildings by 2050. Savings of 15% electricity, and 75% thermal energy consumption	-	147	1029	-	2.2	1%	24.4	9%
Electrify heating and appliances	-	Convert 100% of residential water and space heating to heat pumps by 2050 Phase out residential natural gas appliances by 2050	Convert 100% of residential water and space heating to heat pumps by 2040 Phase out residential natural gas appliances by 2040	-	1468	77	-	-	41.4	16%
Smaller homes	-	30% increase in floorspace intensity per person) from 2016 by 2040 (for all new dwellings)		-	59		-	-	0.7	0%
Buildings- industrial										
Improve industrial buildings	-	Industrial new buildings energy intensity reduction (45% from base year) reached by 2031 and applies to lighting, space heating and water heating end uses. Retrofit all industrial buildings by 2050 to achieve 50% reduction of industrial energy use intensities for lighting and space and water heating end uses	-	-	145		-	-	2.4	1%
Industrial process improve-ments and fuel switching	-	Reduce natural gas consumption by 30% by 2030 and 60% by 2050 Convert 100% of remaining natural gas for process heat to hydrogen by 2050 Capture 90% of waste heat from industry	Use hydrogen for 100% of process heating by 2040	-	761	0	-	-	15.0	6%
Buildings- commercial										

Action	Business as Planned (BAP) Target	0x50 Target	0x40 Target	Emissions reductions compared to previous scenario (2050) (kt)			Cumula-tive emiss-ions reduc-tion of BAP (2020-2050) (Mt)	% of total cumula - tive emiss-ions reduc-tions	Cumula-tive emis-sions reduc-tions over DN (2020-2050), all scenarios	% of total cum-ula-tive emiss -ions redu-ced
				BAP	NZ 50	NZ 40				
Improved performance for new buildings	TGS Tier 4 for new commercial buildings by 2031	100% Tier 2 by 2021 100% Tier 3 by 2022 100% tier 4 by 2027	-	850	44	-	17.1	7%	18.4	7%
Retrofit existing buildings	Retrofit 4,500 buildings by 2050	Retrofit 100% of existing buildings by 2050. Savings of 15% electricity, and 75% thermal energy consumption	-	144	102 9	-	2.3	1%	24.4	10%
Electrify heating	-	100% electric heat pumps for space and water heating in non-residential buildings by 2050	Convert 100% of non-residential heating to heat pumps by 2040	-	319	10	-	-	9.6	4%
Intensify office space per employee	-	Reduced office floorspace per employee by a 'mobility factor' of 1.7 (i.e. 20 people per 12 desks), then allocated new commercial floorspace along lines of employment projection. Results in reduced growth in commercial/office floorspace (for new office)	-	-	23	-	-	-	0.6	0%
Energy										
Wastewater RNG	Generate RNG from wastewater	-	-	29	-	-	0.7	0%	0.7	0%
District Energy	Maintain 2016 DE + build planned/ontracted DE systems	All DE systems are 100% renewable by 2030- natural gas and electric cooling are replaced by RNG and cold water. All of the city's currently planned DE expansions are installed.	-	71	116	-	1.4	1%	4.9	2%

Action	Business as Planned (BAP) Target	0x50 Target	0x40 Target	Emissions reductions compared to previous scenario (2050) (kt)			Cumulative emissions reduction of BAP (2020-2050) (Mt)	% of total cumulative emissions reductions	Cumulative emissions reductions over DN (2020-2050), all scenarios	% of total cumulative emissions reduced
				BAP	NZ 50	NZ 40				
Renewable energy	-	Wind capacity scaled up to 200 MW by 2050 Onsite battery storage scaled up to 2000 MW by 2050 Ground mount PV on 50% of parking lots 100% of buildings have solar PV installed by 2050, where feasible 10% hydrogen incrementally blended into natural gas in residential and commercial buildings by 2050	-	-	966	-	-	-	12.4	5%
Transportation										
Increase and encourage transit and alternative travel modes	Active and transit mode shares improved through as-planned infrastructure improvements	Convert one lane of traffic to exclusive bus lanes on all arterials Increase service frequency on all transit routes: bus by 70%, streetcar by 50%, subway off-peak service increased to every 3 mins" Tolls of $0.66/km on all arterial roads No transit fares 50% of professional/ management/technical and general office/clerical workers in the GTHA work from home on any given day Shift 75% of car and transit trips under 5km to bikes or ebikes by 2040 Shift 75% of trips under 2km to walking by 2040	-	0	63	-	0	0%	3.4	1%
Electrify transit	50% of fleet electric by 2030; 100% by 2050 100% electrification of GO by 2025	Electrify 100% of transit by 2040	-	362	0	-	6.2	2%	7.7	3%

Action	Business as Planned (BAP) Target	0x50 Target	0x40 Target	Emissions reductions compared to previous scenario (2050) (kt)			Cumula-tive emiss-ions reduc-tion of BAP (2020-2050) (Mt)	% of total cumula - tive emiss-ions reduc-tions	Cumula-tive emis-sions reduc-tions over DN (2020-2050), all scenarios	% of total cum-ula-tive emiss -ions redu-ced
				BAP	NZ 50	NZ 40				
Zero emissions City fleet	Transition 45% of City-owned fleet to low-carbon vehicles by 2030; 65% greenhouse gas reduction by 2030 (from 1990 levels)	Electrify 100% of City fleet by 2050 In 2025, begin purchasing renewable diesel for diesel vehicles and equipment (30% renewable diesel for City fleet)`	-	31	16	-	0.7	0%	1.0	0%
Electrify personal vehicles	Electrify 98% of personal vehicles by 2050 (achieved from 100% EV sales in 2040)	Switch all remaining ICE vehicles 11 years or older to electric from 2040 onwards	Electrify 100% of personal vehicles by 2040	2125	26	17	33.4	13%	52.8	21%
Electrify commercial vehicles	Light duty commercial - 50% new sales EV by 2040 Long-haul - background 2.5% electrification rate	Electrify 100% of commercial vehicles by 2050	Electrify 100% of commercial vehicles by 2040	469	557	29	5.7	2%	19.7	8%
Biofuels in rail and aviation	-	Aviation runs on 100% low emissions fuels by 2050 Rail runs on 100% biofuel by 2050	-		17	-	-	-	0.3	0%
Waste/Water/Wastewater										
Increase efficiency of water pumps	Increase efficiency of water distribution pumps	-	-	3	-	-	0.1	0%	0.1	0%
Waste reduction and diversion	Increase waste diversion rate to 70% by 2025	Increase waste diversion rates beyond the 70% by 2026 target, to 95% by 2050.	Zero by 2050 Scenario targets, plus: Zero organics in landfills by 2025	95	276	117	1.9	1%	9.5	4%
Sequestration										
Increase tree canopy cover	Increase tree canopy cover city-wide to 40% by 2050	-	-	14	-	-	0.2	0%	0.2	0%

Box: GHG Emissions From Natural Gas

GHG emissions from natural gas are commonly reported based on the carbon dioxide (CO2) released as a result of combustion, however the impact of natural gas on climate change is more serious when the lifecycle impacts are considered. Natural gas primarily consists of methane and methane escapes or is released during production, processing, transmissions, and storage and distribution.

Near-term climate forcers (NTCF) refers to those gases that impact the climate most significantly in the first decade after their release. The current default reporting practice is to report on the GHG impact of the NTCFs over a 100-year period, a choice of time horizon that originated with administrators responsible for the development of the Kyoto Protocol. The impact of each NTCF is reported in terms of its Global Warming Potential (GWP), which translates its impact on warming relative to carbon dioxide. Carbon dioxide is removed from the atmosphere through slow geological processes such that 40% of the carbon dioxide emitted will remain after one hundred years, and approximately 20% will remain after two thousand years. On the other hand, NTCFs such as methane make very strong contributions to global warming, but over relatively short time scales. Given the current imperative to avoid exceeding 1.5°C in global warming, planning to reduce GHG emission reductions over the next 20 years is of greater importance than the next 100 years. Given this timeline, calculating the short-term impact of methane becomes more important.

Table 5. How the choice of time horizon affects Global Warming Potential (GWP) for methane.

Time Horizon (years)	1	10	20	50	100
Global Warming Potential of methane	120	104	84	49	34

When the releases of methane are accounted for and multiplied by a 20-year GWP (84) instead of the 100-year GWP (34), the global warming impact of using natural gas as a fuel is much more significant, and the need to rapidly reduce and eliminate natural gas consumption becomes more urgent.

4.8 The Pathway to Zero

The actions evaluated constitute a pathway to virtually eliminate all GHG emissions generated within the city by 2040 and 2050, respectively. There is one major remaining source of emissions, which is the provincial electricity grid.

Figure 21 illustrates curves for the total annual GHG emissions for each scenario between 2016 and 2050. The NZ40/NZ50 scenarios achieve 64%/74% reduction from 2018 levels by 2030, 93%/92.6% by 2050 with approximately 2.0 $MtCO_2e$ annual emissions remaining in 2050 in both scenarios.

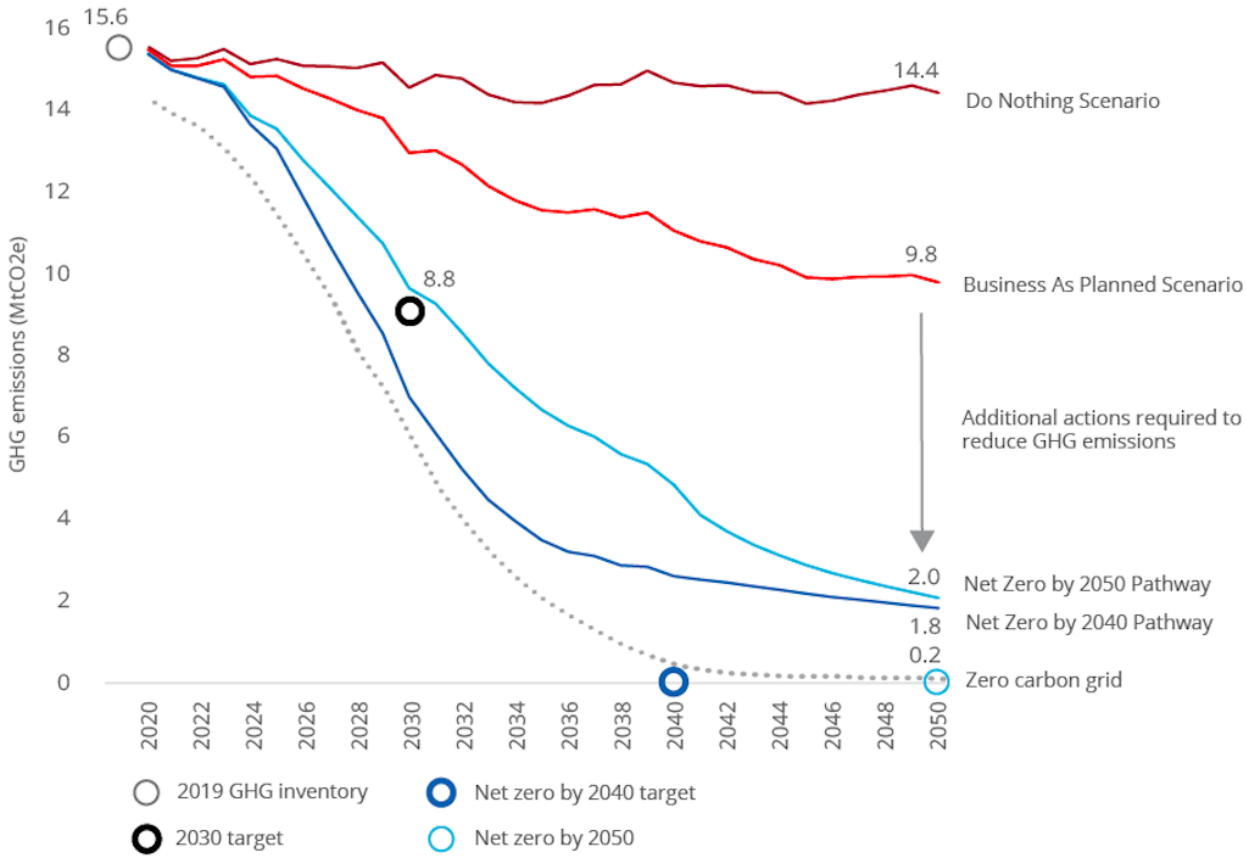

Figure 21. Total GHG emissions for each of the scenarios.

Figure 22 demonstrates the GHG reductions per person (i.e. per capita) achieved by the net zero scenarios for the city. The net zero scenarios reduce per capita emissions by 5 tonnes of carbon dioxide equivalent (tCO_2e) from 5.5 tCO_2e in 2016 to 0.5 per capita in 2050. The per capita GHG emissions are reduced more quickly in the NZ40 scenario. In comparison, the BAP reduces per capita emissions by 2.8 tCO_2e (2.7 tCO2e) by 2050, whereas the Do Nothing scenario reduces per capita emissions by 1.6 tCO_2e (3.9 tCO_2e).

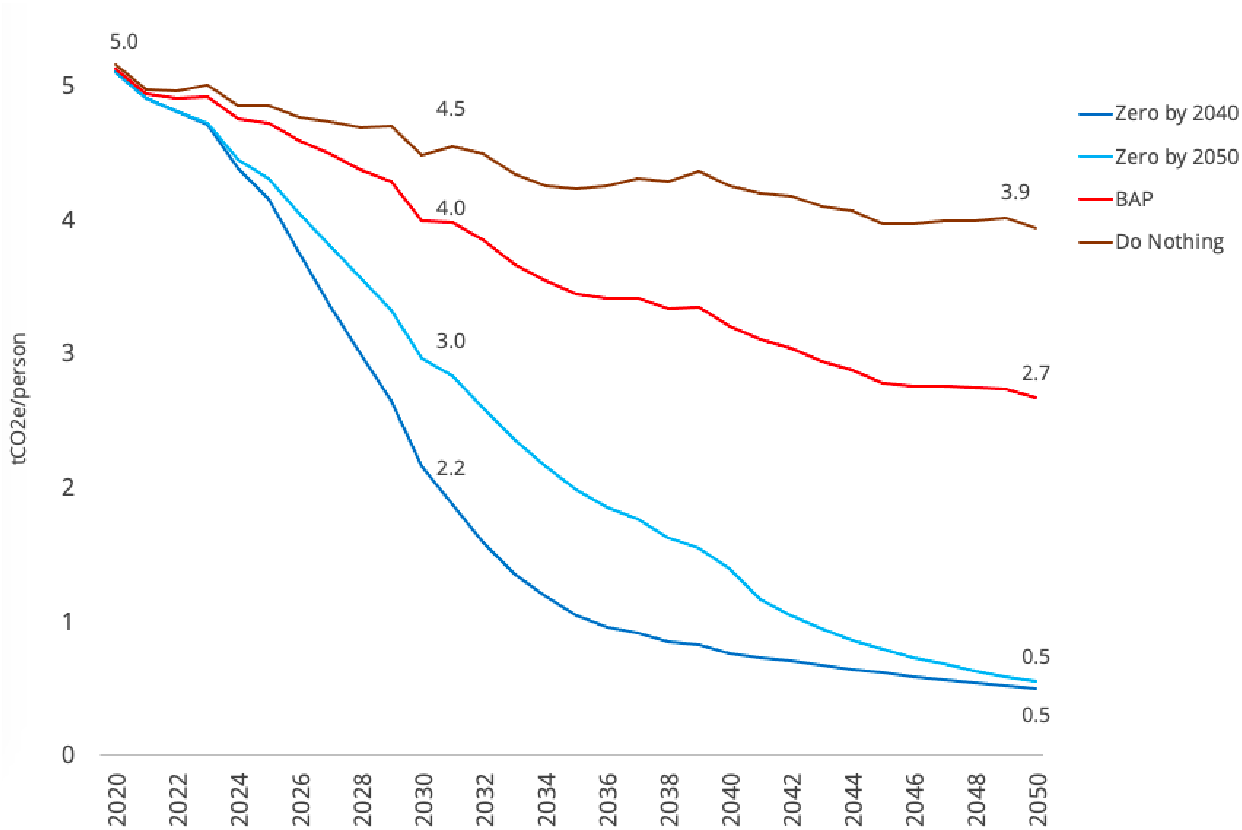

Figure 22. GHG emission per person achieved by the net zero scenarios.

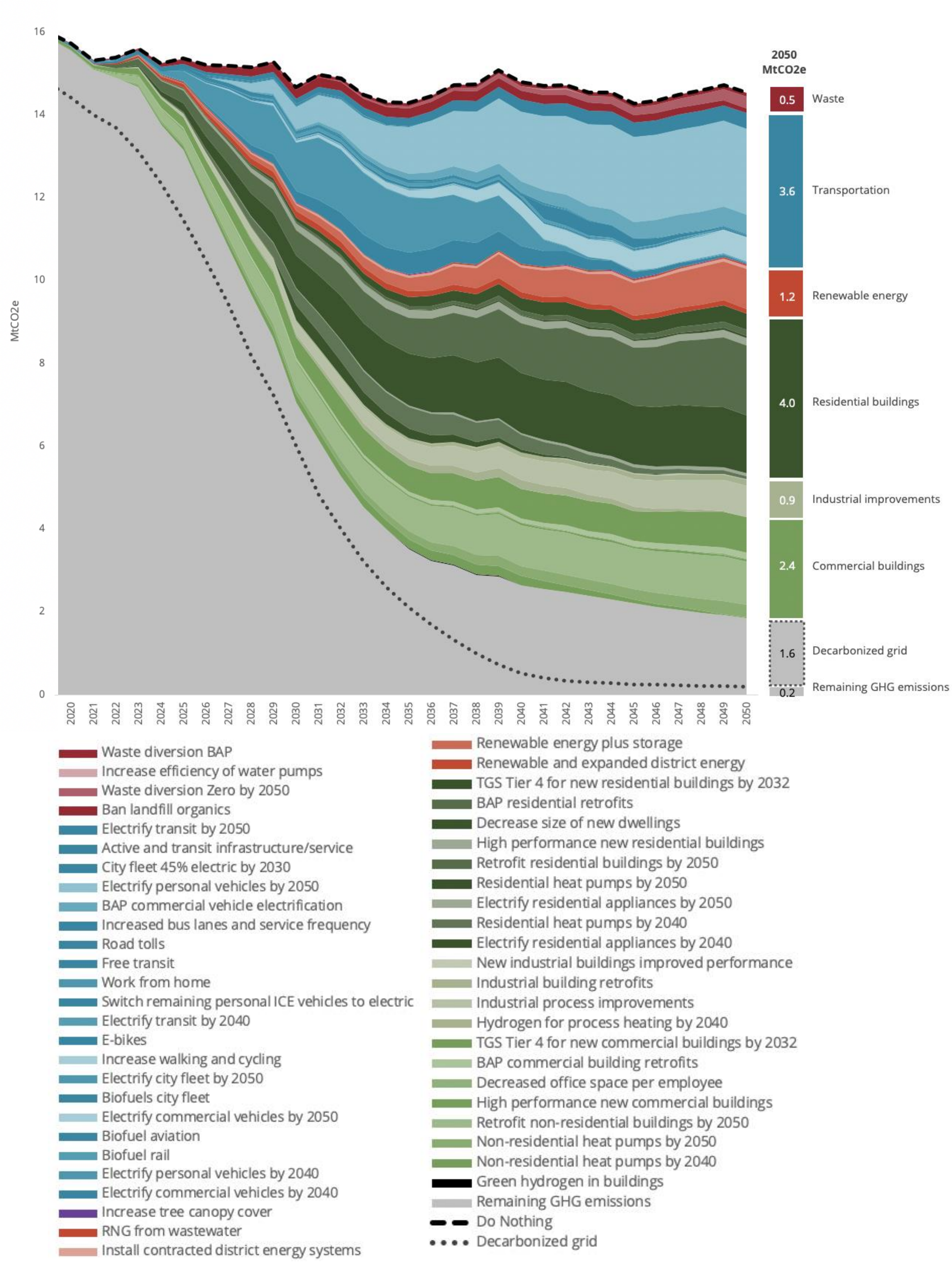

Figure 23. Net Zero Scenario by 2050 Wedge Summary: The relative impact of the key actions modelled.

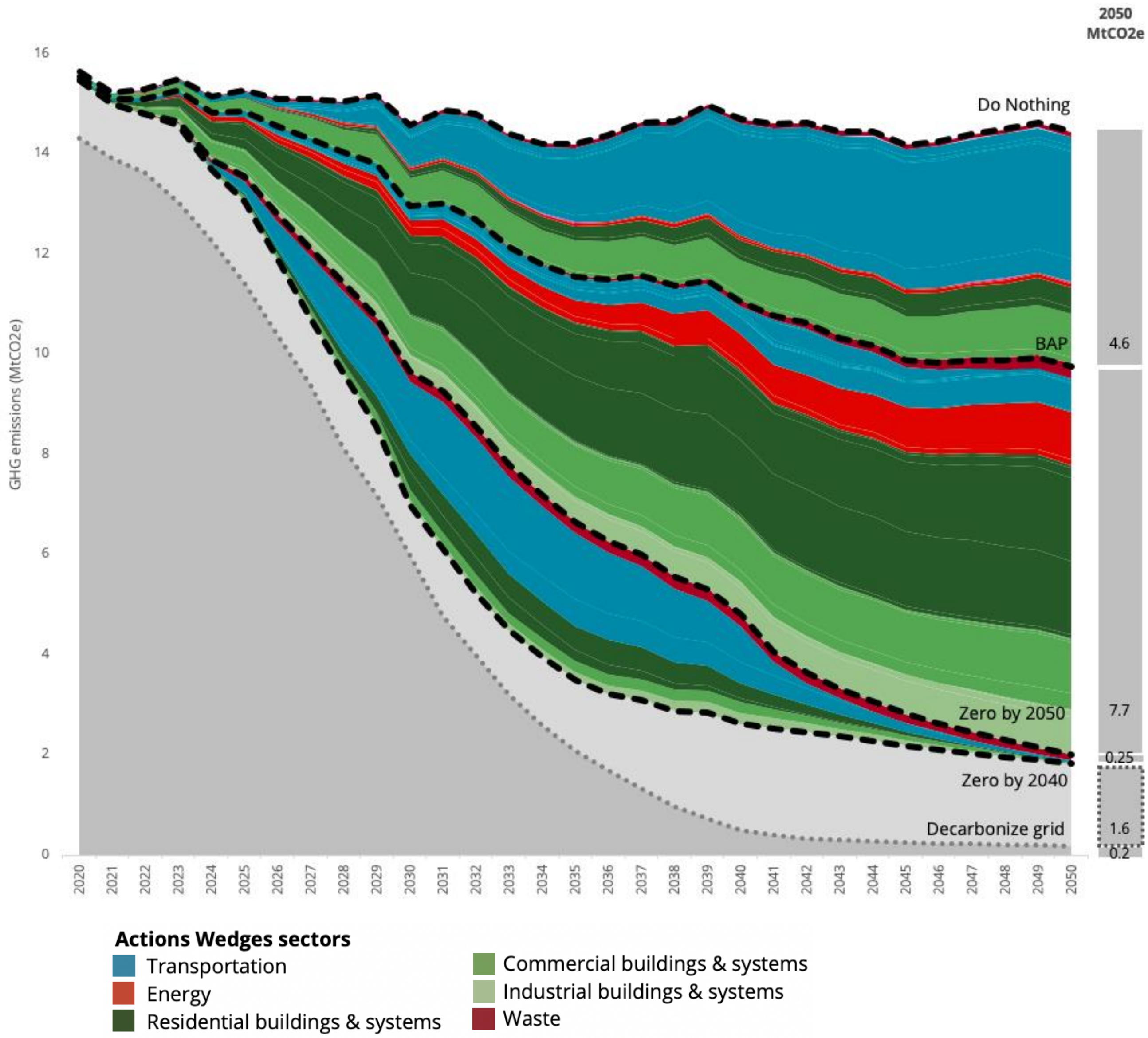

Figure 24. Net Zero Scenarios Wedge Summary: The relative impact of the actions modelled.

Table 4. Net Zero by 2040 Scenario (NZ40): the numbers in 2016, 2030, and 2050.

Indicator	Result			Units
	2016	2030	2050	
Annual GHG emissions	16.2	7.0	1.8	$MtCO_2e$
Annual GHG per person	5.5	2.2	0.5	tCO_2e

Indicator	Result			Units
	2016	2030	2050	
Average floor area per dwelling	123	118	109	m^2
Total non-residential space per person	37	35	32	m^2
Annual percent of trips made by car	63%	56%	51%	%
Annual VKT per person	5,700	6,500	6,400	km
Energy costs per dwelling	$2,900	$1,550	$890	$/year
Annual solid waste to landfill per person	190	14	15	kg

Table 5. Net Zero by 2050 Scenario (NZ50): the numbers in 2016, 2030, and 2050.

Indicator	Result			Units
	2016	**2030**	**2050**	
Annual GHG emissions	16.2	10.0	2.0	tCO_2e
Annual GHG per person	5.5	3.1	0.5	tCO_2e
Average floor area per dwelling	123	118	109	m2
Total non-residential space per person	37	35	32	m2
Annual percent of trips made by car	63%	56%	51%	%
Annual VKT per person	5,700	6,500	6,400	km
Energy costs per dwelling	$2,900	$1,760	$880	$/year
Annual solid waste to landfill per person	190	93	15	kg

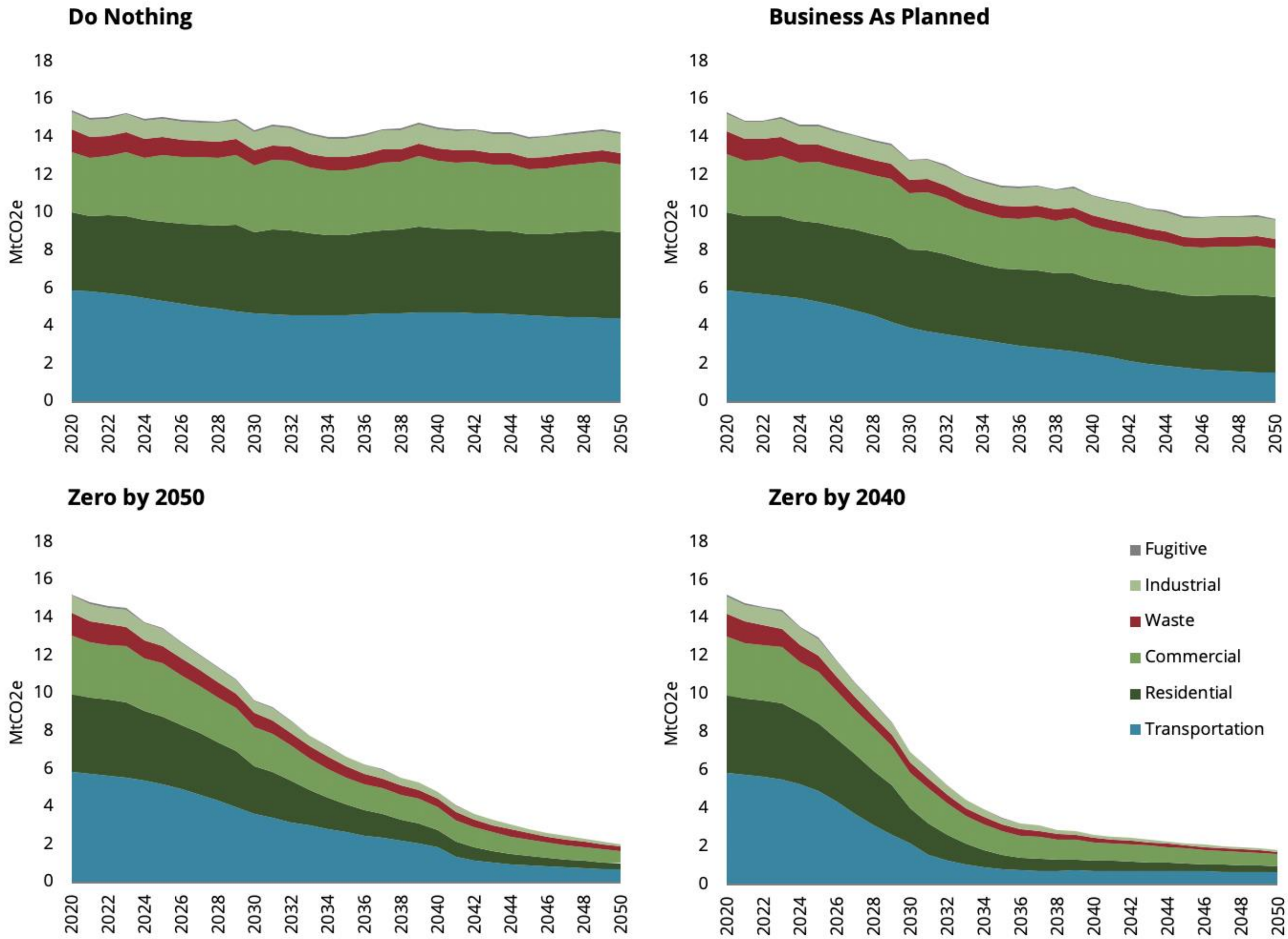

Figure 25. GHG emissions by scenario and sector, 2016-2050.

4.9 The Challenge of the Provincial Grid

In order to achieve net zero emissions, the city requires clean electricity. Currently, there are no commitments to ensure that the provincial electricity grid in Ontario will become zero emissions by 2050 or sooner.[71] Figure 26 illustrates four different ways in which this scenario could play out.

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[71] During the drafting of this report, the IESO launched a consultation on phasing out natural gas generation in Ontario. For more information, see: https://www.ieso.ca/en/Learn/Ontario-Supply-Mix/Natural-Gas-Phase-Out-Study

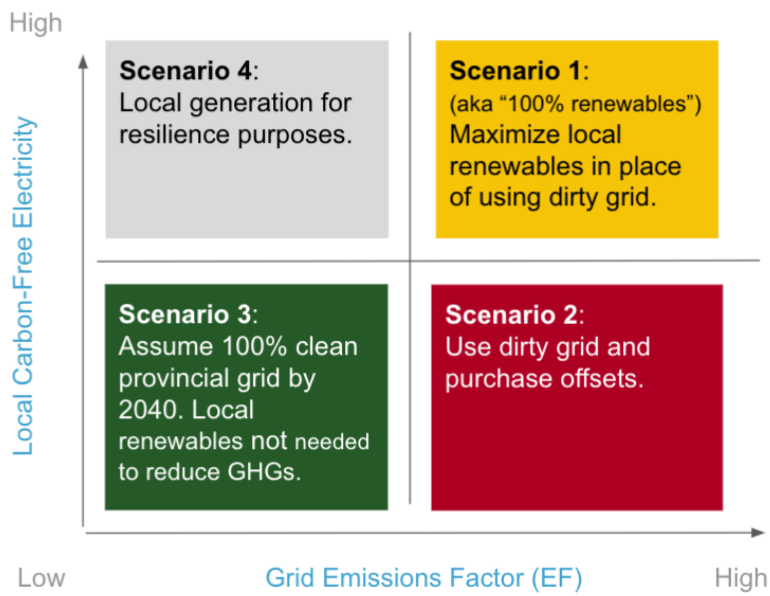


Figure 26. Descriptions of scenarios for reaching net zero emissions based on variations in the provincial grid emissions factor and extent of deployment of local renewable energy.

Objectively, Scenario 3 is the most desirable, because the flexibility of demand and supply on the provincial grid means that it is likely a lower cost option than local generation for zero emissions electricity. In Scenario 1, if the provincial grid is not clean, the City generates 100% renewable electricity to meet its electricity requirements. This objective could be achieved through community choice aggregation (CCA)[72] or a similar approach in partnership with Toronto Hydro, given regulatory approval, or through direct purchase of new renewable generation through the development of a large "micro-grid." An increasingly common strategy in the US, CCA allows local governments to procure power on behalf of resident, businesses, and municipal accounts from an alternative supplier while still receiving transmission and distribution services from their existing utility provider.

In Scenario 2, the City continues to use electricity from the provincial grid but purchases carbon offsets to address the incremental emissions. The downside of this scenario is the ongoing cost of the emissions and ongoing questions about the integrity of carbon offsets as a substantive carbon mitigation strategy. Carbon offsets act as an additional "carbon tax" on emissions, as every additional tonne requires the purchase of an offset at an assumed minimum cost of $25 per tonne. Achieving NZ40 implies offset costs of $607 million (purchasing offsets for a decade) while achieving NZ50 (offsetting emissions just in 2050) requires a purchase totalling $53 million (Figure 27). For comparison, the cost of offsetting emissions in the BAP scenario just for 2050 is $245 million, and if BAP emissions were to be offset from 2040-2050 this would cost $2.8 billion.

Scenario 4 implies high levels of local renewable generation, while the provincial grid emissions factor is clean. This scenario imagines a rapidly increasing deployment of net zero buildings and local decentralized generation. In this case, the local generation is a major contributor to the decarbonizing of the grid.

[72] For more details on CCA, see: NYSERDA (n.d.). Community Choice Aggregation. Retrieved from: https://www.nyserda.ny.gov/All-Programs/Programs/Clean-Energy-Communities/How-It-Works/Toolkits/Community-Choice-Aggregation

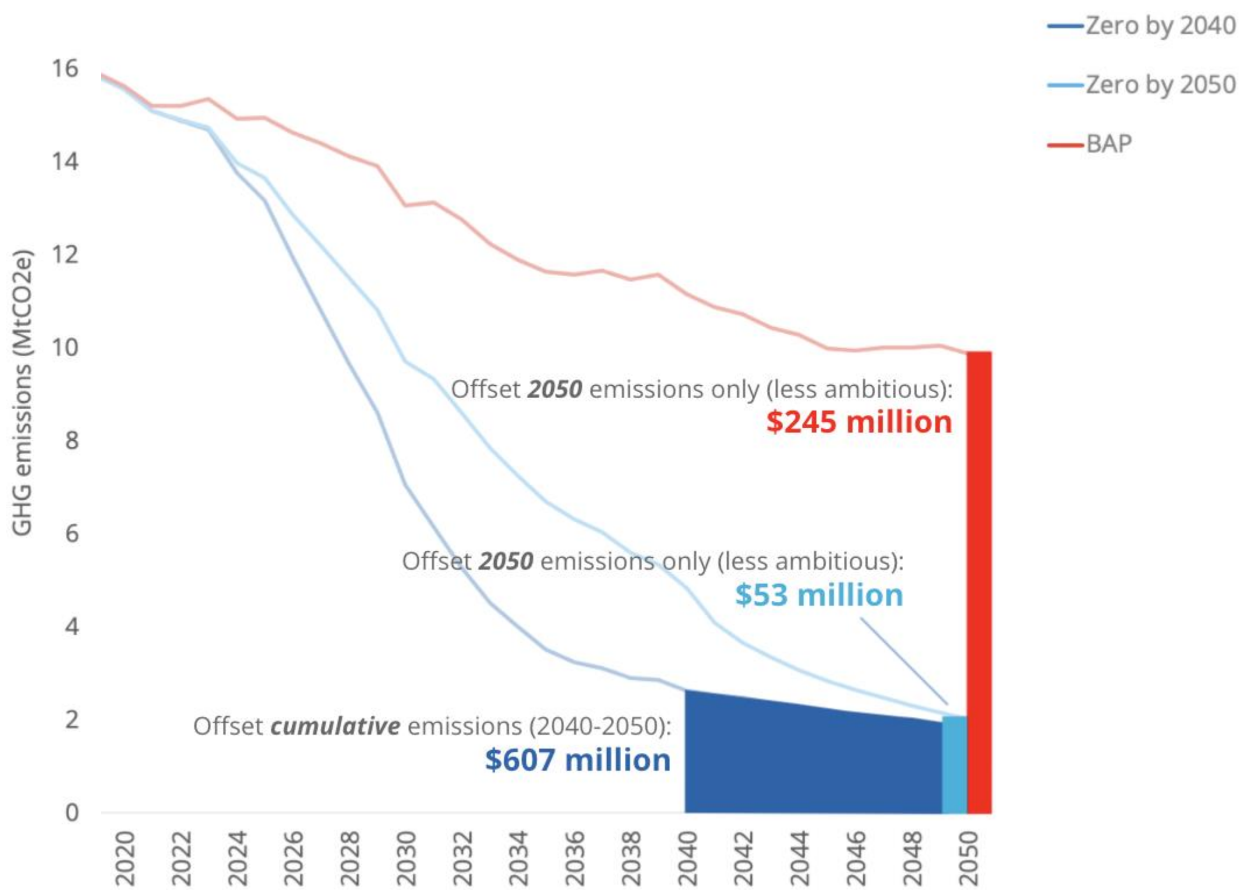


Figure 27. Carbon offset costs for the NZ40, NZ50, and BAP scenarios.

The Challenges of Clean Hydrogen

Full electrification of heating is a major challenge and will likely create stranded assets for natural gas distributors. Other possible options that are being broadly explored include the deployment of hydrogen and renewable natural gas, both of which are included to a limited extent in the NZ scenarios, particularly for sectors such as industries in which electrification is difficult (Figure 28). The clean hydrogen future is constrained by the low efficiencies of manufacturing clean hydrogen, which results in electricity generation requirements that are 2-14 times higher than direct electrification and a risk that hydrogen could lock in requirements for continued fossil fuel production with the promise of carbon (grey hydrogen). A recent paper in *Nature Climate Change* explains: "Betting on the future large-scale availability of hydrogen and e-fuels risks a lock-in of fossil-fuel dependency if their upscaling falls short of expectations. Hydrogen and e-fuels are a potential distraction from the urgent need for an end-use transformation towards wide-scale direct electrification, which is cheaper, more efficient and generally part of well-advanced available technology in many sectors, such as light-duty vehicles or low-temperature heating in buildings and industry."[73]

[73] Ueckerdt, F., Bauer, C., Dirnaichner, A. et al. (2021). Potential and risks of hydrogen-based e-fuels in climate change mitigation. Nat. Clim. Change. https://doi.org/10.1038/s41558-021-01032-7

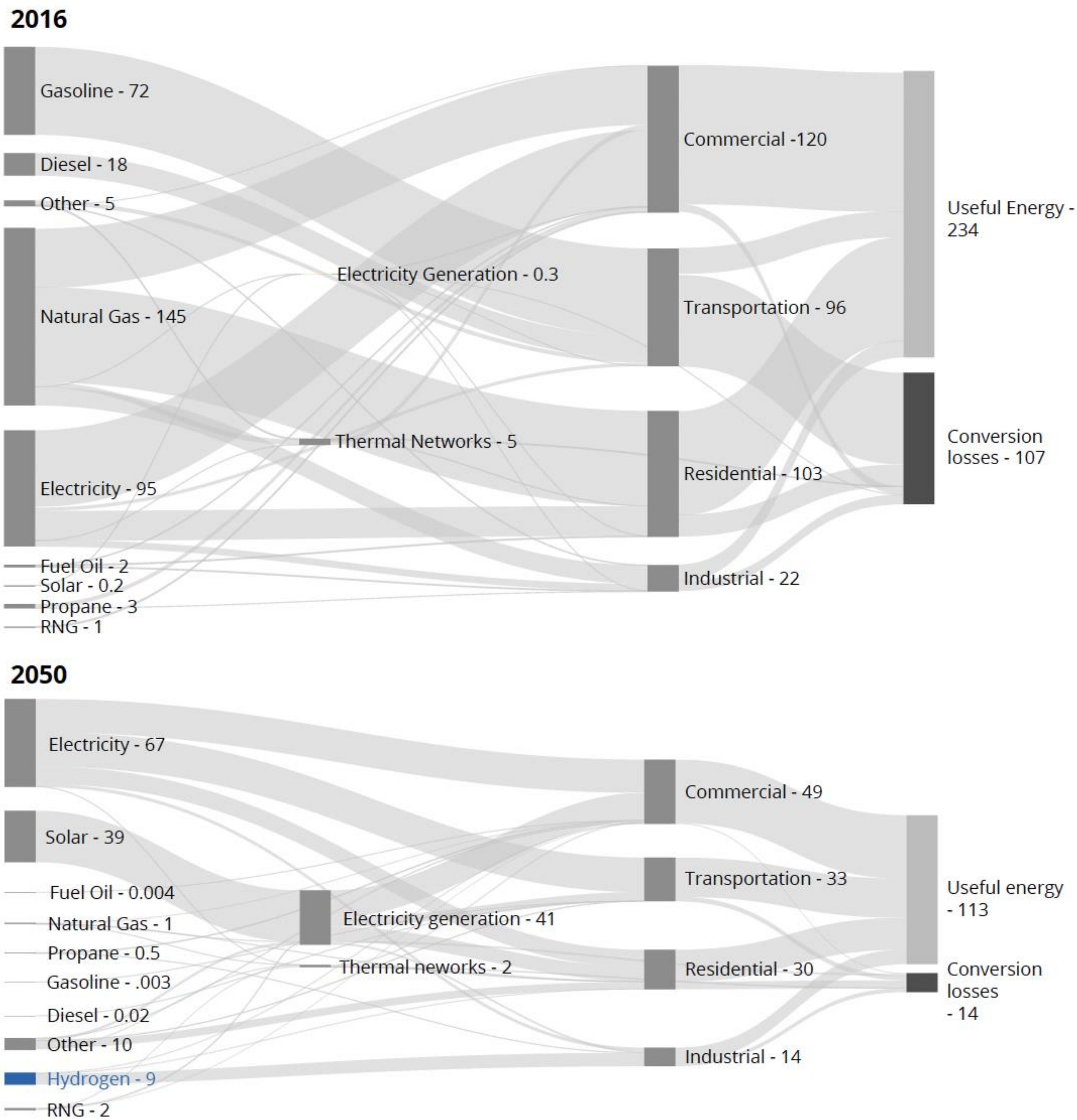


Figure 28. Illustration of the energy system flows in 2016 (top) and NZ40 in 2050 (bottom). The dark grey bars show the amounts of energy with their values indicated in PJ, and the thickness of the light grey flowing lines show the quantities of energy that are distributed for different uses, based on their thickness. Hydrogen is highlighted in blue.

4.10 Early Action Needed for the 2030 Target

Early action to cut emissions by at least 50% is required to meet the IPCC's recommendation to limit global warming to 1.5°C. The City of Toronto's 2030 target is to reduce GHG emissions by 65% (below 1990 levels), which translates to a goal of reducing total emissions to approximately 8.8 $MtCO_2e$ (Figure 29). Both the Do Nothing and BAP scenarios do not meet this target. Total GHG emissions for these scenarios in 2030 are projected to be 14.6 and 12.9 $MtCO_2e$, respectively. The NZ50 scenario just misses the City's target with total GHG emissions at 9.6 $MtCO_2e$, however, the NZ40 is well below the target with total GHG emissions at 7.0 $MtCO_2e$. The earlier action in the NZ40 scenario therefore needs to be taken to achieve the 2030 target. These actions are summarized in Table 4 and in the following sections and include, amongst others, electrifying vehicles sooner, retrofitting buildings sooner, and eliminating organic materials from landfills sooner.

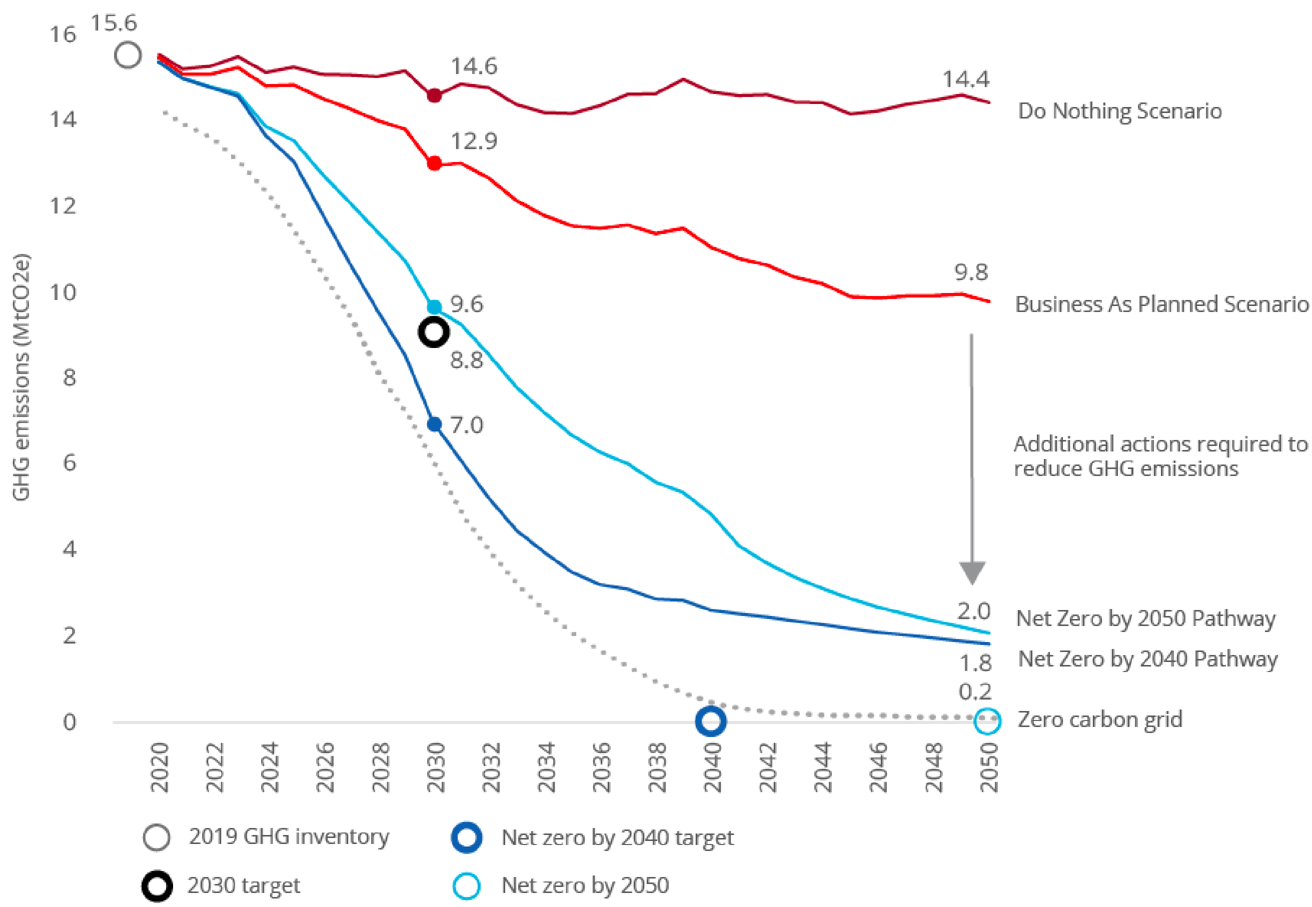


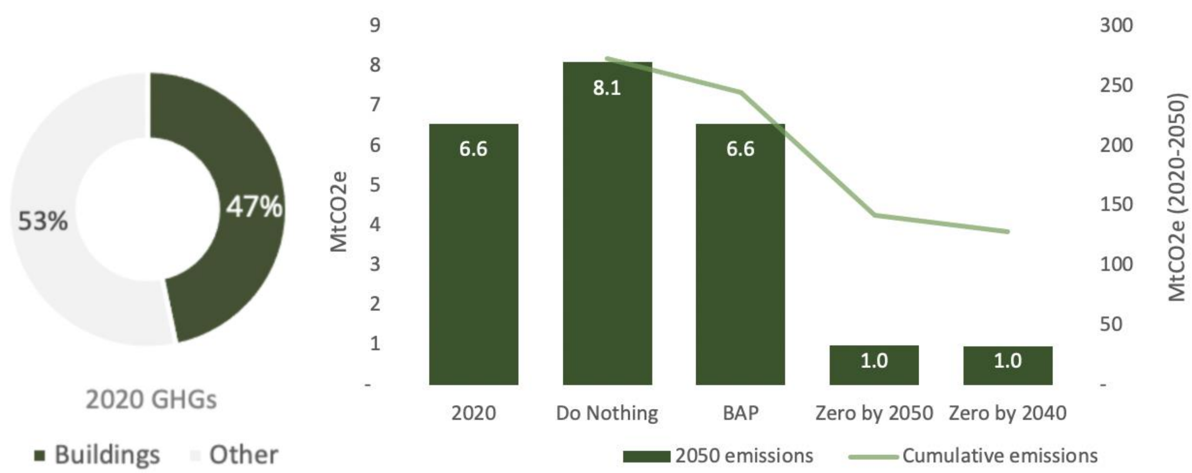
Figure 29. Total GHG emissions for each of the scenarios, 2020-2050.

5. Green Buildings

5.1 Overview

According to the 2019 GHG Inventory, emissions from energy use in buildings (residential, commercial, and industrial) accounted for 57% of Toronto's community GHG emissions. Natural gas used to heat buildings continues to be the largest emissions source at approximately 8.9 $MtCO_2e$.

Modelled GHG emissions indicated that in 2020 buildings emissions were 6.6 $MtCO_2e$. Each scenario outcome for the sector in 2050 is illustrated by Figure 30. The Do Nothing scenario results in annual emissions of 8.1 $MtCO_2e$; BAP results in 6.6 $MtCO_2e$; and, the NZ40 and NZ50 result in 1.0 $MtCO_2e$ remaining annual emissions. The cumulative GHG reduction potential between 2020 and 2050 is 134 $MtCO_2e$.



CUMULATIVE GHG REDUCTION POTENTIAL 2020-2050 **134 MtCO2e**

Figure 30. GHG emissions from buildings in 2050, by scenario.

The GHG reduction actions for the buildings sector by scenario are provided in Table 6. This section details the interventions needed to increase the efficiency of the building stock and fuel switch from fossil fuels to renewables.

Table 6. Description of GHG reduction actions for the buildings sector.

Sector	Wedge	Wedge Description	Scenario
Buildings-residential	TGS version 3 Tier 4 for new residential buildings by 2032	All new buildings for which the TGS applies are built to TGS version 3 Tier 4 for new residential buildings by 2032. Passive house scaling up to 100% by 2040. Fuel switching to electric heat pumps for all new dwellings	BAP

Sector	Wedge	Wedge Description	Scenario
	BAP residential retrofits	Retrofit 6,000 units per year. Annual electricity per cent savings per building: 10%. Annual thermal demand per cent savings per building: 35%.	
	Decrease size of new dwellings	30% increase in floorspace intensity from 2016 by 2040 (for all new dwellings)	Net Zero by 2050
	New high performance residential buildings	Rows and apartments: 100% TGS version 3 Tier 2 by 2021. 100% Tier 3 by 2022. 100% Tier 4 by 2027.	
	Retrofit residential buildings by 2050	Retrofit 100% of existing buildings by 2050 (~29,000 per year). Savings of 15% electricity, and 75% thermal energy consumption	
	Residential heat pumps by 2050	Convert 100% of residential water and space heating to heat pumps by 2050.	
	Electrify residential appliances by 2050	Phase out residential natural gas appliances by 2050.	
	Residential heat pumps by 2040	Convert 100% of residential water and space heating to heat pumps by 2040.	Net Zero by 2040
	Electrify residential appliances by 2040	Phase out residential natural gas appliances by 2040.	
Buildings-industrial	New industrial buildings improved performance	100% TGS tier 4 in 2032	BAP
	Industrial building retrofits	Apply OBC requirements for retrofits that require building permits, and similarly to any buildings not covered by TGS. Rate of retrofits: ~ 2,300 C/I retrofits per year	
	New industrial buildings improved performance	Industrial new build energy intensity reduction (45% from base year) reached by 2031 and applies to lighting, space heating and water heating end uses.	Net Zero by 2050
	Industrial building retrofits	Retrofit all industrial buildings by 2050 to achieve 50% reduction of industrial energy use intensities for lighting and space and water heating end uses.	
	Industrial process improvements	Reduce natural gas consumption by 30% by 2030 and 60% by 2050. Convert 100% of remaining natural gas for process heat to hydrogen by 2050. Capture 90% of waste heat from industry.	
	Hydrogen for process heating by 2040	Use green hydrogen for 100% of process heating by 2040.	Net Zero by 2040

Sector	Wedge	Wedge Description	Scenario
Buildings-commercial	TGS version Tier 4 for new commercial buildings by 2032	TGS version 3 Tier 4 for new commercial buildings by 2032.	BAP
Buildings-commercial	BAP commercial building retrofits	Retrofit 4,500 buildings by 2050.	BAP
Buildings-commercial	Decreased office space per employee	Reduce office floorspace per employee by a "mobility factor" of 1.7 (i.e., 20 people per 12 desks), then allocate new commercial floorspace along lines of employment projection. Results in reduced growth in commercial/office floorspace (for new office space).	Net Zero by 2050
Buildings-commercial	High performance new commercial buildings	100% TGS version 3 Tier 2 by 2021. 100% Tier 3 by 2022. 100% Tier 4 by 2027.	Net Zero by 2050
Buildings-commercial	Retrofit non-residential buildings by 2050	Retrofit 100% of existing buildings by 2050. Savings of 15% electricity, and 75% thermal energy consumption annually	Net Zero by 2050
Buildings-commercial	Non-residential heat pumps by 2050	100% electric heat pumps for space and water heating in non-residential buildings by 2050.	Net Zero by 2050
Buildings-commercial	Non-residential heat pumps by 2040	Convert 100% of non-residential heating to heat pumps by 2040.	Net Zero by 2040
Buildings-commercial and residential	Green hydrogen in buildings	10% hydrogen blended into natural gas in residential and commercial buildings by 2050.	Zero by 2050

In order to reach net zero by 2050, the following measures for the building sector will be required:

- reduce floorspace per person by 30% for all new dwellings by 2040
- high performance standards for new residential and commercial buildings:
  - 100% TGS version 3 Tier 2 by 2021
  - 100% Tier 3 by 2022
  - 100% Tier 4 by 2027
- retrofit 100% of existing buildings (residential, commercial, industrial)
- convert 100% of building water and space heating to heat pumps
- phase out residential natural gas appliances by 2050
- decrease energy intensity by 45% for new industrial buildings by 2031
- reduce industrial process natural gas consumption by 30% by 2030, and 60% by 2050
- convert 100% of remaining natural gas for process heat to hydrogen by 2050
- capture 90% of waste heat from industry
- decrease office space per employee
- blend 10% green hydrogen in remaining natural gas use by residential and commercial buildings by 2050

And in order to reach net zero by 2040, several key actions need to be implemented faster including:

- convert 100% of building water and space heating to heat pumps by 2040,
- phase out residential natural gas appliances by 2040, and
- use hydrogen for 100% of process heating in industrial buildings by 2040.

Box: What Constitutes a Deep Retrofit?

Toronto's Net Zero Existing Buildings Strategy defines a GHG reduction retrofit as meeting two criteria:[74]

- A minimum upgrade package performance of 50% reduction in GHG emissions, reflecting established best practice in retrofit activities.
- A near-net zero pathway of at least an 80% reduction in GHG emissions, including a complete or near-complete fuel switch to electricity or other zero carbon fuel source.

A deep retrofit typically includes improvements to the envelope and fuel switching from natural gas to electricity. The combination of the efficiency of heat pumps and the improved performance in the thermal envelope can reduce total electricity consumption. An additional benefit is that the improved performance of the building envelope can reduce the size of the HVAC equipment required and therefore reduce capital costs, to "tunnel through the cost barrier".[75]

[74] Integral, WSP, Windfall Ecology Centre and Reep Green Solutions (2021). The City of Toronto's Net Zero Existing Buildings Strategy. Retrieved from: https://www.toronto.ca/legdocs/mmis/2021/ie/bgrd/backgroundfile-168402.pdf

[75] Hawken, P., Lovins, A. B., & Lovins, L. H. (2013). Natural Capitalism: The Next Industrial Revolution. Routledge.

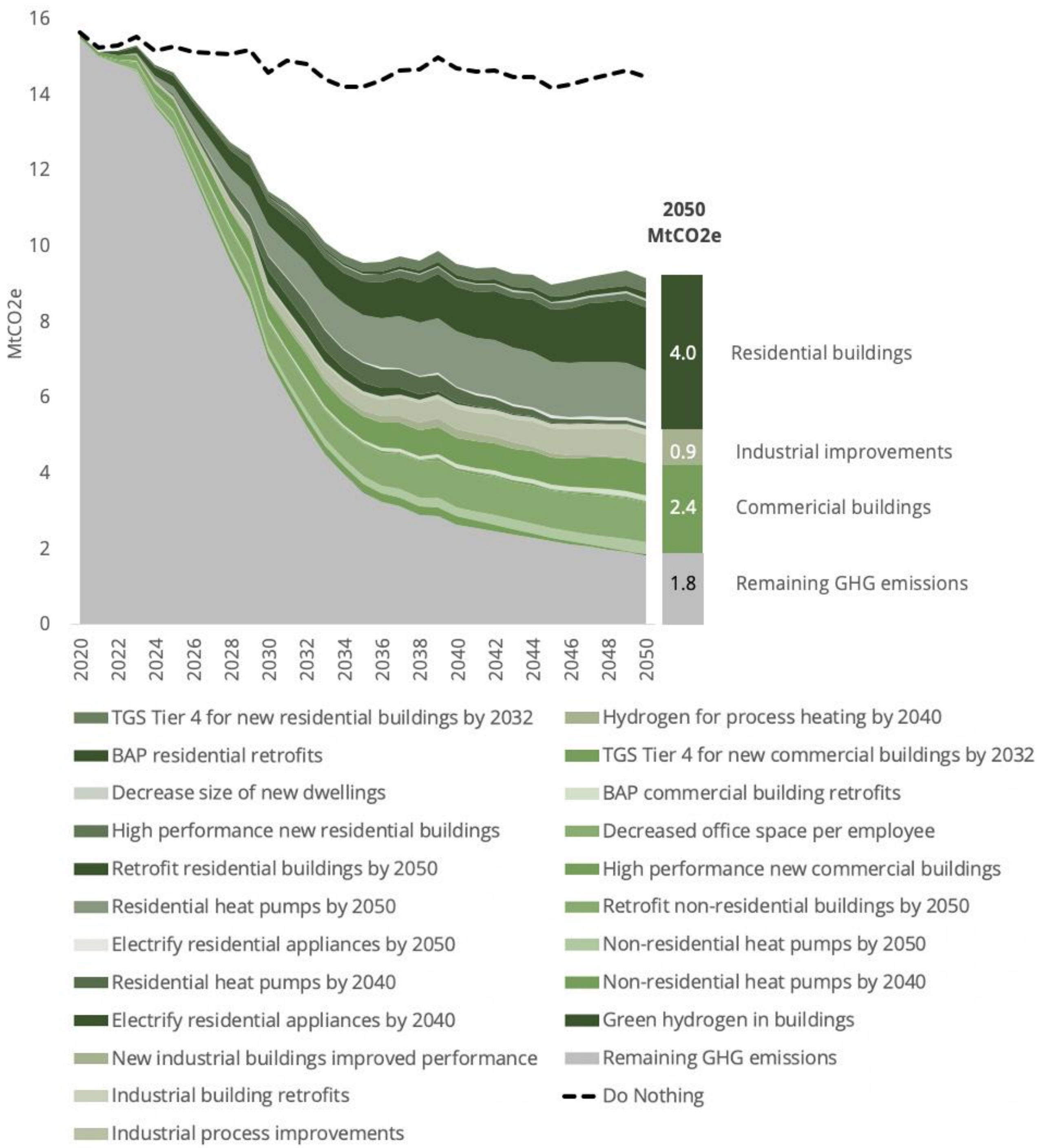


Figure 31. Wedge diagram of buildings GHG reduction actions.

New Buildings

The Technical Report envisions an incremental transition to high-performance, net zero energy new construction by 2030. Net zero buildings are super insulated, have efficient HVAC systems, and take advantage of passive solar heating, ambient heat sources (e.g., air source heat pumps), and thermal mass. More high-performance buildings completed sooner means fewer retrofits later on.

Existing Buildings

Improving energy performance in existing buildings is a greater challenge given that the building design is already “locked in”. Up-front costs of deep retrofits can be high, but this investment can be recovered over time through avoided energy costs. The Technical Report envisions building retrofits in all sectors, achieving an average of 15% electrical and 75% thermal energy savings by 2050.

In 2016, natural gas accounted for 81% of the GHG emissions in the buildings sector, which is primarily used for space and water heating. To decarbonise buildings, this energy source must be phased out and replaced with electric heat pumps. The rapid decline in emissions from natural gas requires that the installation of natural gas furnaces be prohibited by 2030 at the latest in order to phase out the stock of natural gas furnaces by 2040.

While natural gas is phased out by 2040, there are still emissions remaining from electricity. Ensuring that 100% clean electricity is available is necessary to remove these remaining emissions.

The combination of the improved performance of the building stock due to retrofits and the efficiency of heat pumps reduces overall energy consumption in the city over the period, most notably for space heating. Solar PV is integrated into many buildings increasing the resilience of the electricity system and enabling many buildings to achieve net zero emissions.

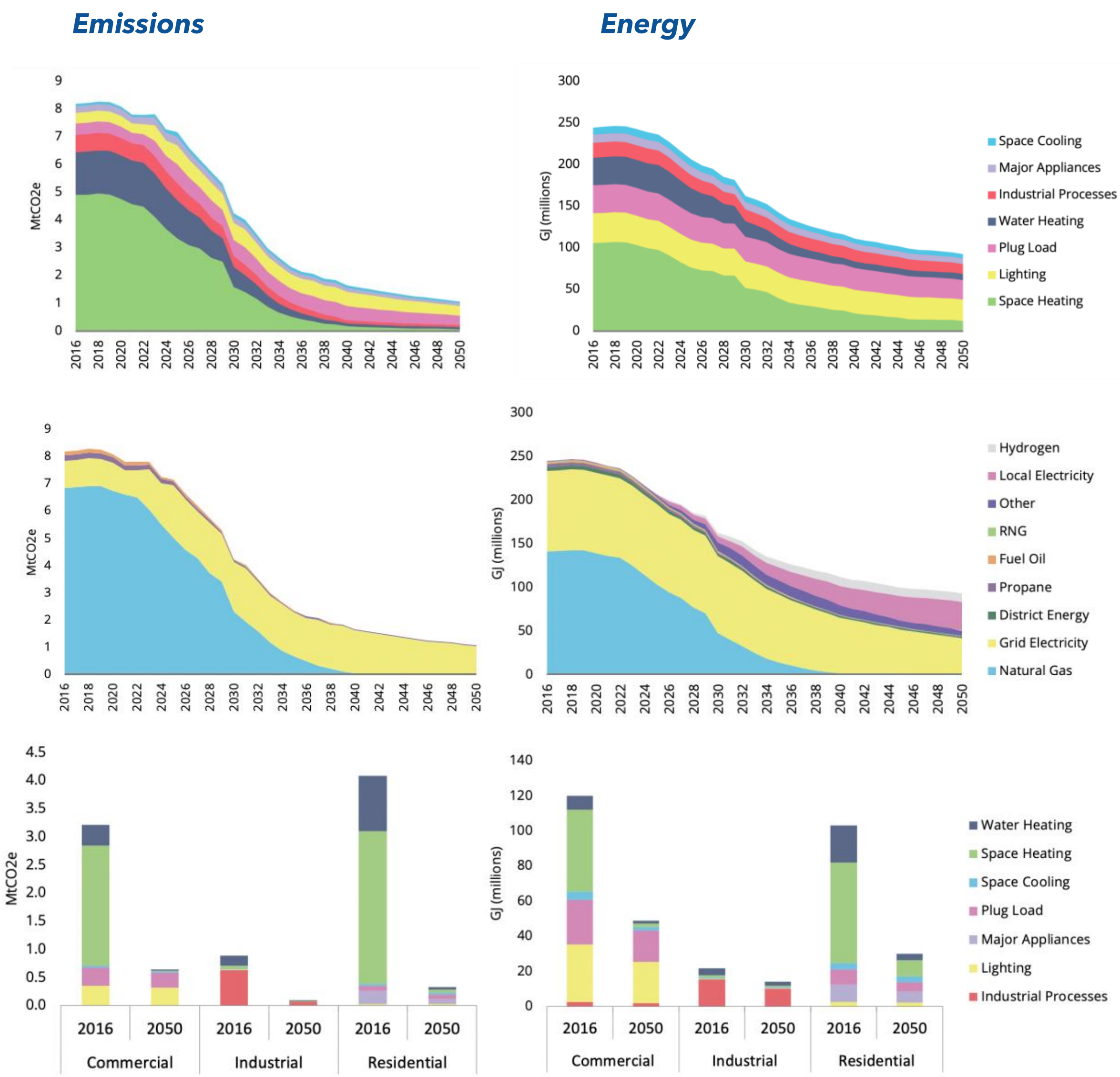


Figure 32. Emissions and energy use from buildings for NZ40.

5.2 Targets

Targets for the building sector are provided in five year increments for the next decade and then subsequently for each decade until 2050 (Table 7). The targets serve as indicators against which the City can track performance over time.

Table 7. Targets for Buildings Sector

	2021-2025	2026-2030	2031-2040	2041-2050
% of new buildings that achieve TGS level X	100% T2	100% T3	100% T4	100% T4
Average EUI/TEDI (MJ/sqm) of new non TGS buildings	450/180	450/180	434/172	430/170
Number of dwelling units built prior to 2016 that are retrofit	128,059	150,012	298,881	292,632
Non-residential buildings constructed prior to 2016 that are retrofit	2,580	2,640	4,010	2,240
Non-residential floor area constructed prior to 2016 that is retrofit (m2)	11,746,000	14,619,000	17,767,000	6,090,000

5.3 Key Actions

The key actions for the building sector will include the following:

1. Retrofit existing buildings: Retrofit 100% of existing residential and commercial buildings by 2050 will reduce cumulative emissions by 19%, (10% for residential and 9% for commercial).
    - Average of 29,000 residential units per year
    - Average of 400 commercial/institutional buildings per year

2. Conversion of 100% of residential water and space heating to heat pumps and a phase out of residential natural gas appliances by 2050 will reduce cumulative emissions by 16% in the NZ50 scenario, with additional cumulative reductions if completed by 2040. This action can be bundled with the retrofits in #1.

3. Improved performance for new buildings: 100% Tier 4 by 2027 will achieve a total of 10% in cumulative GHG emission reductions.

Box: Industrialization of retrofits

In both Europe and North America, the industrialization of retrofits is an increasingly common solution to rapidly retrofit the building stock in order to achieve GHG reduction targets. Energiesprong, a Dutch public-private partnership, has pioneered a semi-industrialized net-zero energy retrofit package and applied this approach to approximately 5,000 low- and mid-rise multifamily retrofits, with roughly another 100,000 units of multifamily demand aggregated across Europe.[76] Similar projects are under development in New York State, California, and Massachusetts.[77] The EU has advanced retrofit industrialization programs underway.[78] The City of Seattle has developed a mechanism to transform deep retrofits into power purchase agreements, described as Energy Efficiency as a Service (EEaS) contracts. A pilot project for thirty commercial buildings is currently underway.[79] Efficiency Canada has identified policies to scale up retrofits in Canada including integrated design and project delivery,

prefabrication of building facades and HVAC systems, mass customization tools that manage distinct building characteristics with greater ease and aggregation of retrofit projects into single portfolios.[80]

6. Energy

6.1 Overview

Municipalities have a pervasive impact on the level of GHG emissions in the community. Community energy and emissions planning begins by developing a quantitative inventory of the community's GHG emissions and systematically identifying the ways in which municipalities can influence the level of community emissions.

Figure 34 shows that energy is a cross-cutting theme, which includes buildings, transportation and industry. In sum, modelled GHG emissions from energy account for 92% of the City's emissions in 2020. The actions in this section focus on the generation of energy, while other sections focus on electrification and the efficiency of its use. The cumulative GHG emissions reduction of improving emissions from energy (efficiency, electrification and renewable energy generation) in the NZ40 scenario totals 252 MtCO_2e. This reduction is primarily from displacing both fossil fuels and relatively clean electricity with 100% clean electricity.

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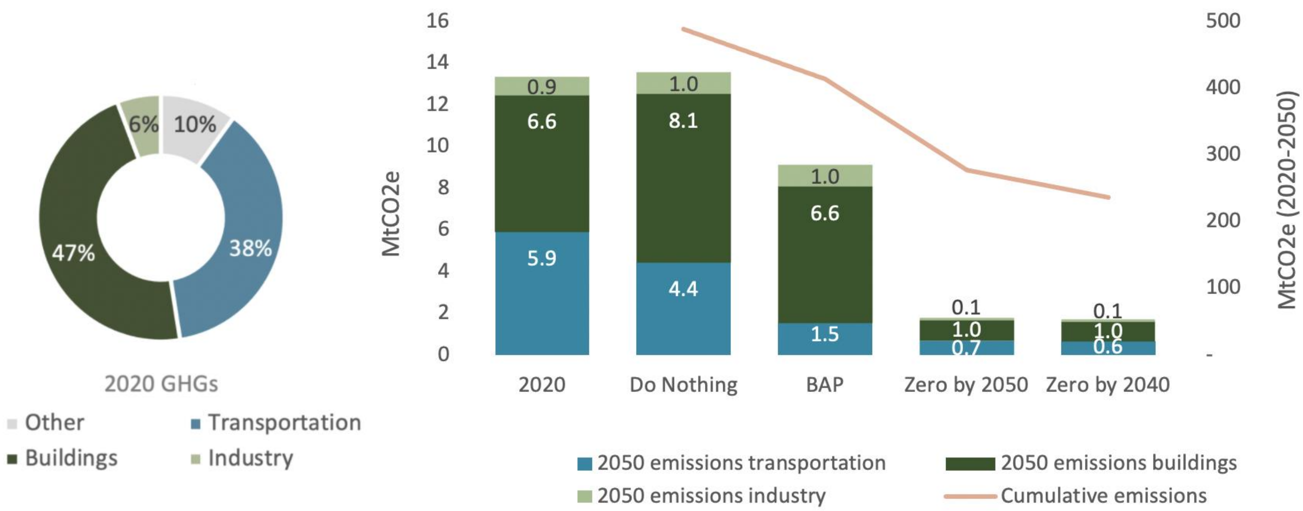
[76] Egerter, A., & Campbell, M. (2020). *Prefabricated zero energy retrofit technologies: A market assessment* (DOE/GO-102020-5262, 1614689). https://doi.org/10.2172/1614689

[77] The hub of the US work is a project called REALIZE: https://rmi.org/our-work/buildings/realize/

[78] An example of one project that is a partnership of major industries is BRESAER: http://www.bresaer.eu/

[79] A description of the City of Seattle's program is available here: https://www.bdlaw.com/publications/seattle-launches-energy-efficiency-as-a-service-program-encouraging-deep-energy-efficiency-building-retrofits/

[80] Haley, B and Torrie, R. (2021). Canada's Climate Retrofit Mission. Retrieved from: https://www.efficiencycanada.org/wp-content/uploads/2021/06/Retrofit-Mission-FINAL-2021-06-16.pdf



CUMULATIVE GHG REDUCTION POTENTIAL 2020-2050 **252 MtCO₂e**

Figure 33. GHG emissions from energy.

The key actions in the energy sector include wastewater, renewable natural gas, district energy systems (DES), and scaled up wind, solar and onsite battery storage, and hydrogen[81] (Table 8).

Table 8. Description of GHG reduction actions for the energy sector.

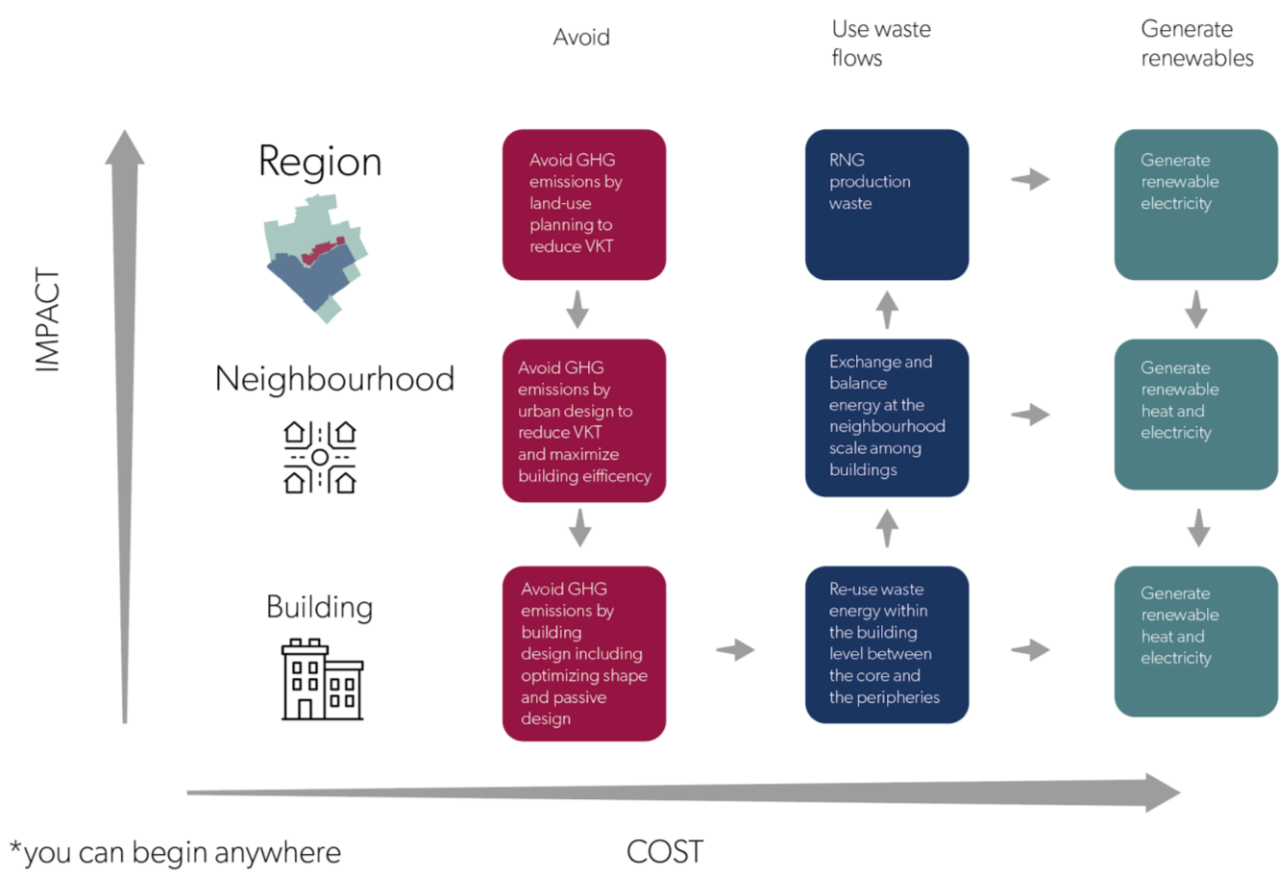
Wedge	Wedge Description	Scenario
RNG from waste and wastewater	RNG facilities at Green Lane and Keele Valley; All wastewater plants include biodigesters by 2050.	BAP
Install contracted district energy systems	Existing district energy systems in 2016 plus district energy systems with contracts to the Enwave expansion (Well, 100 Queens Quay and One Yonge), Mirvish Village. The existing DE system at University of Toronto is switched to renewable sources.	BAP
Renewable energy plus storage	Wind capacity scaled up to 200 MW by 2050. Onsite battery storage scaled up to 2000 MW by 2050. Ground mount PV on 50% of parking lots. 100% of buildings have solar PV installed by 2050, where feasible.	Zero by 2050

[81] Note that clean hydrogen is blended with natural gas, which contributes to GHG emissions reductions until 2050 when heating in the residential and commercial sectors is electrified.

Wedge	Wedge Description	Scenario
Renewable and expanded district energy	All existing DE systems are 100% renewable by 2030- natural gas and electric cooling are replaced by RNG and deep lake cooling. The City's planned DE expansion targets are achieved using ambient DE systems.	

Box: Climate Action Planning

A key aspect of community energy planning includes prioritizing interventions in terms of a hierarchy based on what lasts longest.[82] The first priority is land-use planning and infrastructure, including density, mix of land uses, energy supply infrastructure, and transportation infrastructure. The second is major production processes, transportation modes, and buildings, including industrial process, choice of transportation modes, and building and site design. The final priority is energy-using equipment including transit vehicles, motors, appliances, and HVAC systems.



[82] Jaccard, M., Failing, L., & Berry, T. (1997). From equipment to infrastructure: community energy management and greenhouse gas emission reduction. Energy Policy, 25(13), 1065–1074.

Figure 34. Reducing GHG emissions from a systems perspective.[83]

The hierarchy of climate action interventions shown in figure 34 and described in the Climate Action Planning box prioritizes higher-impact interventions where there are fewer options to intervene between now and 2050, above easier interventions which are likely to have greater short term returns. The World Bank defines this consideration in terms of urgency,[84] posing the question: "Is the option associated with high economic inertia such as a risk of costly lock-in, irreversibility, or higher costs, if action is delayed or not? If the answer is yes, then action is urgent; if not, it can be postponed." From this perspective, land-use planning is likely the more urgent mitigation option because of its durability and how difficult it is to undo.

The Reduce-Improve-Switch approach is complementary to community energy planning. This approach, which we have adapted from similar well-known approaches such as Reduce-Reuse-Recycle (from the waste sector) and Avoid-Shift-Improve[85] (from the transportation sector), seeks to consider the energy system as a whole across sectors. It focuses on the concept of reducing energy consumption and improving the efficiency of the energy system (supply and demand), and then fuel switching to low-carbon or zero-carbon renewable sources.

The energy system is complex and the linear application of reduce-improve-switch is not simple, neither should it be the only approach considered. Many actions have cross-cutting impacts; for example, building retrofits can reduce the amount of energy required for space heating (through envelope improvements) and improve the efficiency of the energy used in the building (through equipment upgrades). Additionally, solar PV could be installed on the roof, facilitating a switch to a zero-carbon renewable source. In general, whether it be buildings, transport, or waste, the idea is to first reduce the amount of energy needed by as much as possible (through reduced consumption and efficiencies) and then to fuel switch away from fossil fuels to low- or zero-carbon fuel source to supply the remainder of the demand.

The concepts of reduce-improve-switch and community energy planning guided the analysis and identification of a final list of actions for modelling, as well as the sequencing of actions in modelling.

Figure 35 illustrates the transformation of the energy system in Toronto across the relevant sectors, while Figure 36 shows a point in time comparison by sector and fuel. Fossil fuels are phased out by 2040 (light and dark blue) and total energy consumption is more than cut in half due to efficiency gains in transportation and buildings. By 2050, the energy system has been electrified, some of which is locally generated, while the majority is provided by the provincial grid. The charts illustrating end-use highlight the importance of retrofits and the efficiency of the electric engine in limiting growth in electricity consumption as electrification occurs.

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[83] Based on a method developed in: Dobbelsteen, A., Tillie, N., Joubert, M., de Jager, W., & Doepel, D. (n.d.). Towards CO2 neutral city planning—The Rotterdam Energy Approach and Planning (REAP). Retrieved from https://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1342044185050/8756911-1342044630817/V2Chap08.pdf

[84] Fay, M., Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Narloch, U., & Kerr, T. M. (2015). Decarbonizing development: three steps to a zero-carbon future. Washington, DC: World Bank Group.

[85] GIZ. (2011). Sustainable urban transport: Avoid-shift-improve. Retrieved from http://www.sutp.org/files/contents/documents/resources/E_Fact-Sheets-and-Policy-Briefs/SUTP_GIZ_FS_Avoid-Shift-Improve_EN.pdf

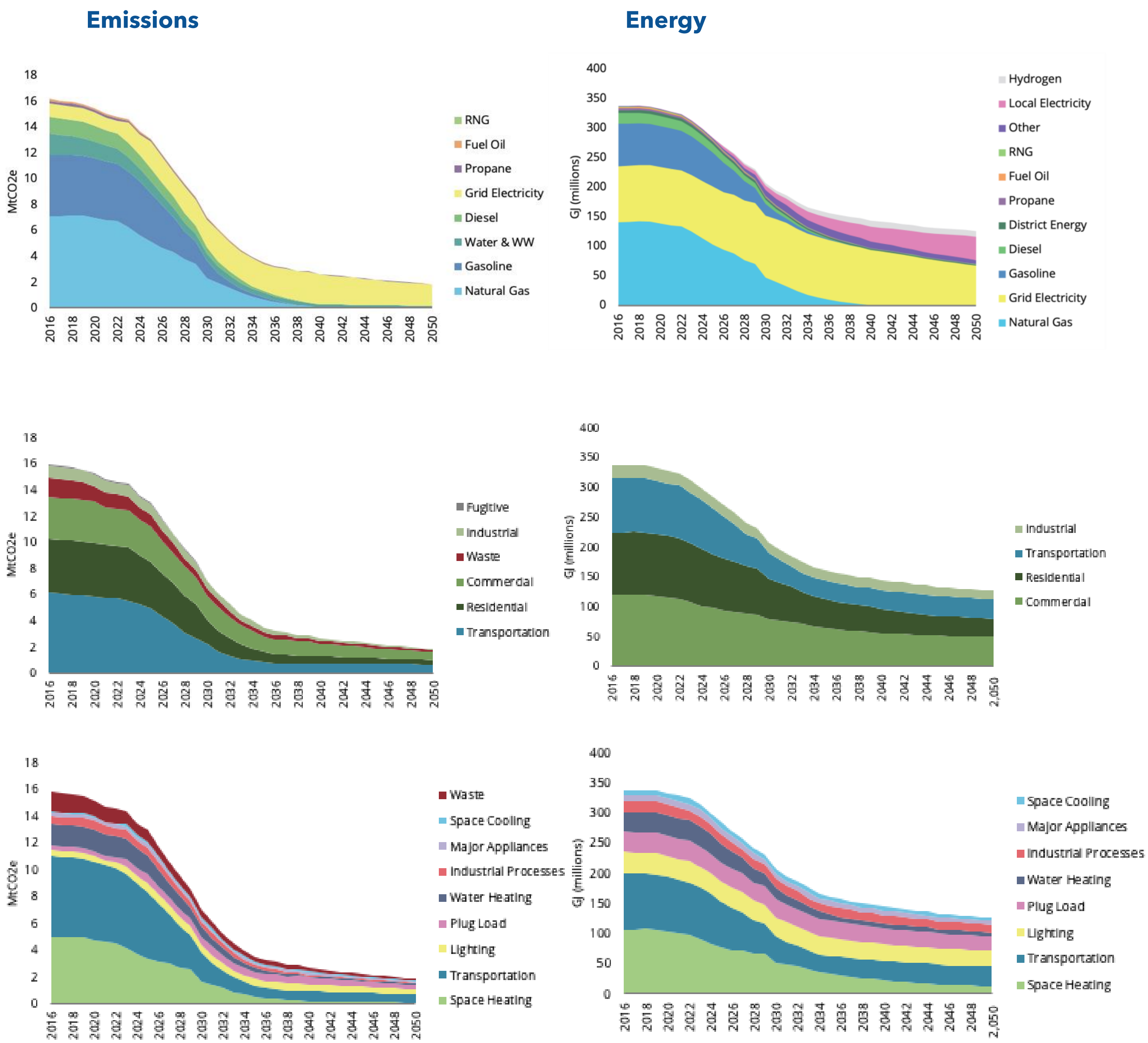

Figure 35. GHG Emissions and Energy Reductions by Energy Type, Sector, and Action Type (2016 to 2050), NZ40.

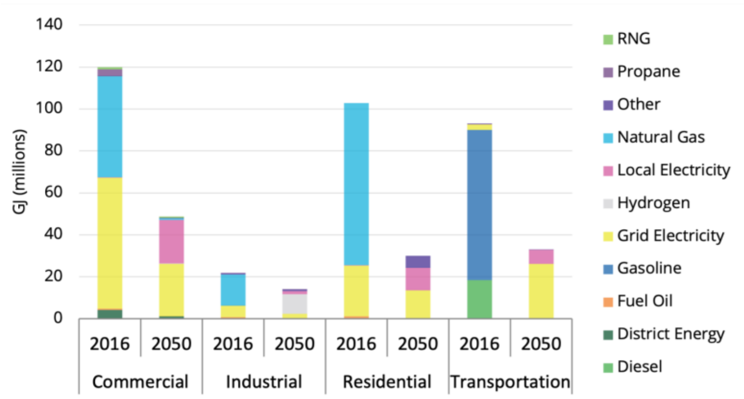

Figure 36. Total energy for NZ40, 2016 and 2050.

6.2 Targets

Targets for the energy sector are provided in five year increments for the next decade and then subsequently for each decade until 2050 (Table 9). The targets serve as indicators against which the City can track performance over time.

Table 9. Selected Targets for Energy Sector Actions.

	2016	2017-2025	2026-2030	2031-2040	2041-2050
District energy: Non-residential floor area connected to zero-emissions District Energy Systems (DES (m2)	6,989,600	421,612	514,100	707,600	703,000
District energy: Residential floor area connected to zero-emissions DES	763,800	246,000	144,400	167,300	115,500
Renewable energy: Groundmount solar PV installed (MW)	-	62.9	70.0	140	112
Renewable energy: Wind turbines (MW)	0.4	-	-	100	100
Renewable energy: Storage installed (MW)	-	0.1	-	1000	1000
Renewable energy: Rooftop solar PV installed (MW)	72	138	1,368	2,367	1,783

6.3 Key Actions

Figure 38 illustrates the recommended actions for the energy sector in order to achieve net zero emissions. The wedge diagram also includes decarbonization of the grid as an additional action that addresses the gap in getting to zero. The key actions for reducing GHG emissions in the energy section for the NZ40 and NZ50 scenarios include:

1. **Scale up renewable energy and storage**: Wind capacity scaled up to 200 MW; onsite battery storage to 2,000 MW; ground mount PV on 50% of parking lots; PV solar installed on 100% of buildings (where feasible). These actions result in 5% reduction in cumulative GHG emissions by 2050.
2. **Renewable and expanded DES**: All planned DE systems are installed and 100% renewable by 2030; natural gas and electric cooling are replaced by renewable natural gas and cold water, which achieves 2% reduction in cumulative GHG emissions by 2050.
3. **Decarbonize the grid:** Electrification of heating and transportation is a key strategy and for this effort to reduce GHG emissions nearly to zero, there needs to be a source of clean electricity, of which the most likely candidate is the provincial grid.

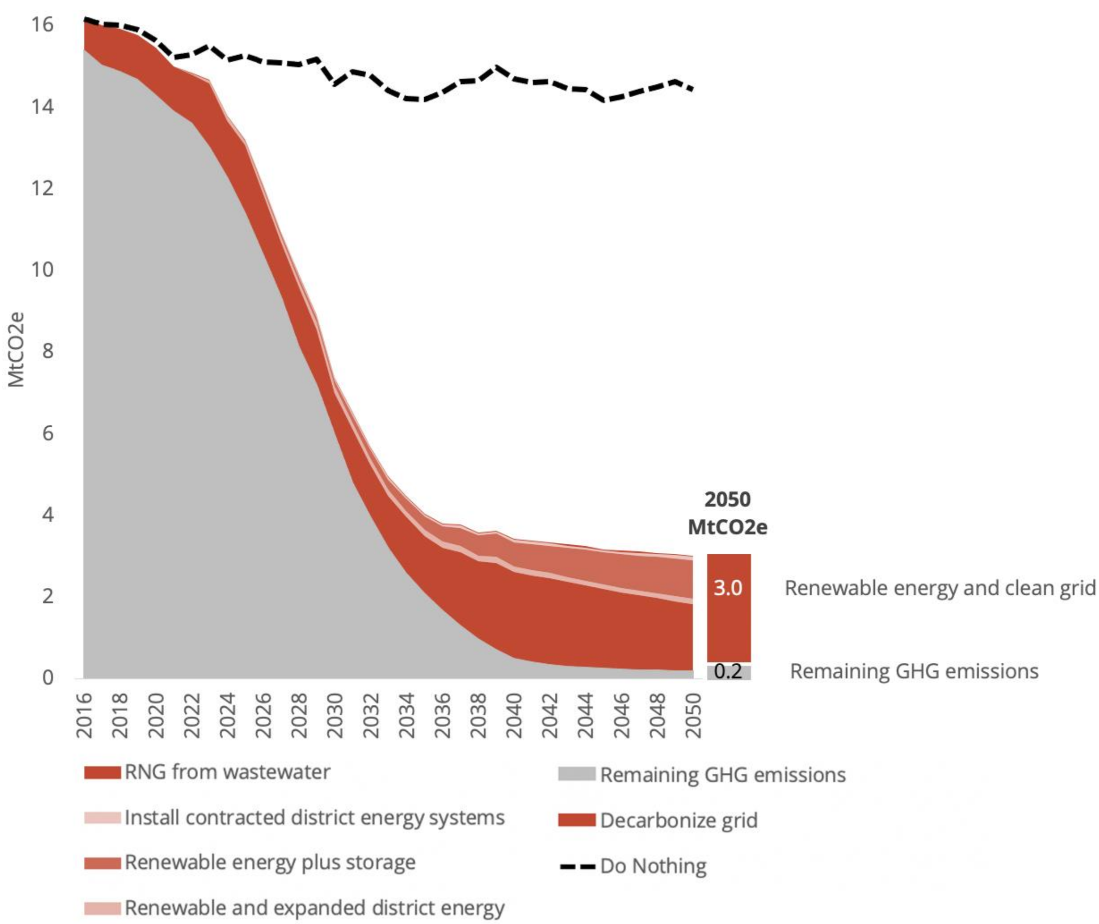

Figure 37. Wedge diagram of energy GHG reduction actions, NZ40, 2020-2050.

Box: Decarbonization and Peak Electricity Demand

Electrifying two of the most significant energy consuming activities—heating and transportation—in society has broad implications for the electricity grid. The way in which electrification is implemented and whether or not this process is accompanied by other actions will influence the impact of decarbonization on the capacity of the electricity grid needed for peak demand, the speed at which the grids can be decarbonized, and the cost to society of the transformation.

While the analysis for Toronto did not evaluate the impact on peak demand on an hourly basis, an analysis of the aggregate impact of deep retrofits and fuel switching on a major portfolio of buildings in Ontario provides insight on the electrification of heating[86]. For natural gas heated buildings, electricity demand of the portfolio currently peaks at 70 MW in the middle of the summer in the afternoon. After full electrification and retrofitting, these same buildings peak at 74 MW on a winter morning when the buildings are ramping up for the workday. It is the effect of improving the thermal envelope—the insulation and window upgrades—that keeps the peak from being much higher as a result of the electrification of heating.

The portion of the simulated portfolio that is electrically heated has a baseline peak that already occurs in the winter. While the shape of the load in the electrically heated buildings does not change very much as a result of the retrofits and heat pump transition, the peak drops by 26%, reflecting the impact of the heat pump efficiencies on electricity consumption for heating.

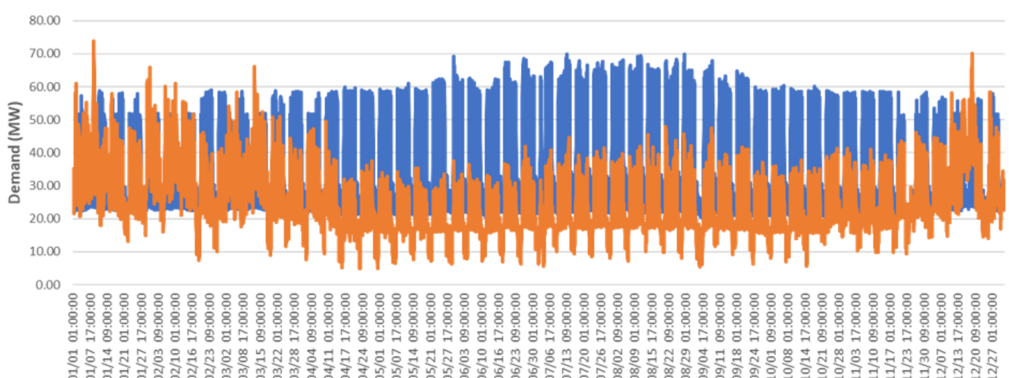

Figure 38. Daily peak demand of simulated natural gas heated buildings, baseline (blue) and post-retrofit and heat pump conversions (orange).

[86] Torrie, R. and Herbert, Y. (2021). The Implications of Deep Decarbonization Pathways for Electricity Grids. Retrieved from: https://emi-ime.ca/wp-content/uploads/2021/03/EMI-2020-Herbert_report_The-Implications-of-Deep-Decarbonization-Pathways-for-Electricity-Grids.pdf

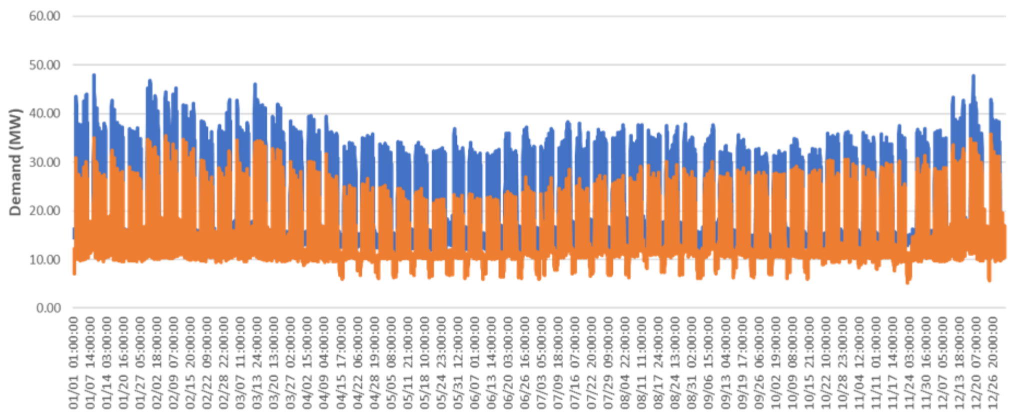

Figure 39. Daily peak demand of simulated electrically heated buildings, baseline (blue) and post-retrofit and heat pump conversions (orang).

The buildings included in these two portfolios have similar occupancy patterns and end uses, and including residential dwellings or other types with different demand patterns (e.g., hospitals, supermarkets) will result in additional opportunities for balancing peaks to minimize the impact of electrification of heating on the grid. The variability of changing requirements for heating and cooling as a result of climate change will also have an influence on the peak demand.

7. Sustainable Mobility and Transportation

According to the 2019 GHG Inventory, emissions from transportation accounted for 36% of Toronto's community GHG emissions, 73% of which are attributed to personal vehicles. Transportation is the second greatest source of GHG emissions for the city, after energy use by buildings, with approximately 5.6 $MtCO_2e$.

GHG emissions projections indicate that, in 2020, emissions from transportation were 5.9 $MtCO_2e$. Each scenario outcome for the sector in 2050 is illustrated by Figure 40. The Do Nothing scenario results in annual emissions of 4.4 $MtCO_2e$; BAP results in 1.5 $MtCO_2e$; and, the NZ40 and NZ50 result in 0.6 and 0.7 $MtCO_2e$, respectively. The cumulative GHG reduction potential between 2020 and 2050 is 86 $MtCO_2e$.

7.1 Overview

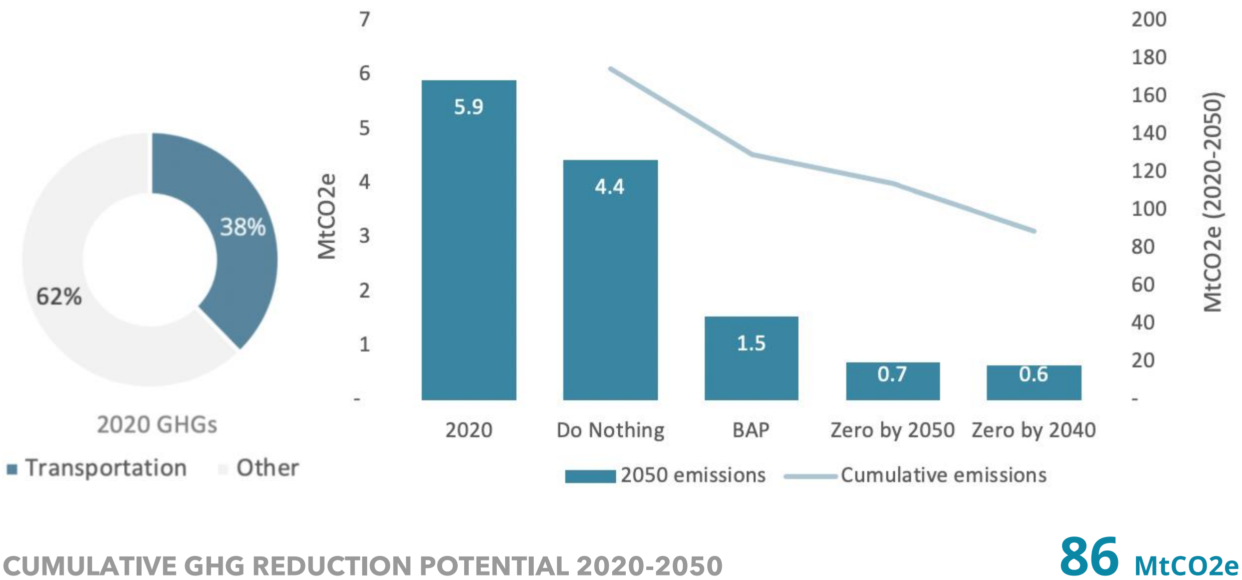

Figure 40. GHG emissions from transportation.

7.2 Targets

Targets for the transportation sector are provided in five year increments for the next decade and then subsequently for each decade until 2050 (Table 10). To illustrate the impact of the NZ scenarios, the results for the other scenarios are included as reference. The results may not sum to 100% due to rounding.

Table 10. Targets for Transportation Sector Actions.

	2016	2025	2030	2040	2050
Share of total personal vehicles which is electric	Negligible	2% (DN) 2% (BAP) 2% (NZ50) 4% (NZ40)	4% (DN) 9% (BAP) 10% (NZ50) 31% (NZ40)	9% (DN) 67% (BAP) 67% (NZ50) 100% (NZ40)	23% (DN) 98% (BAP) 100% (NZ50) 100% (NZ40)
Share of total energy used for transit which is electric	Negligible	48% (DN) 56% (BAP) 59% (NZ50) 59% (NZ40)	50% (DN) 71% (BAP) 91% (NZ50) 91% (NZ40)	49% (DN) 90% (BAP) 100% (NZ50) 100% (NZ40)	49% (DN) 100% (BAP) 100% (NZ50) 100% (NZ40)

	2016	2025	2030	2040	2050
Mode share (NZ40)[87]	Bike/e-bike: 4% Walk: 9% Transit: 25% Vehicle: 63%	Bike/e-bike: 8% Walk: 13% Transit: 26% Vehicle: 54%	Bike/e-bike: 14% Walk: 16% Transit: 24% Vehicle: 47%	Bike/e-bike: 23% Walk: 23% Transit: 22% Vehicle: 32%	Bike/e-bike: 23% Walk: 23% Transit: 23% Vehicle: 32%

7.3 Key Actions

The recommended actions for the transportation sector are illustrated in the wedge diagram (Figure 41) and in Table 11. The key actions recommended for reaching net zero include:

1. **Electrify personal vehicle**s: Electrify 100% of personal vehicles by 2040. This means that 100% of vehicles sold are electric by 2030. Achieves 21% of cumulative GHG emission reductions.
2. **Electrify commercial vehicles**: Electrify 100% of commercial vehicles by 2050 (by 2040 for NZ40). Achieves 8% in cumulative GHG emission reductions.
3. **Electrify transit**: Electrify 100% of transit by 2040, which results in 3% of cumulative GHG emission reductions.

[87] Mode share targets are the same in NZ50 and NZ40 scenarios.

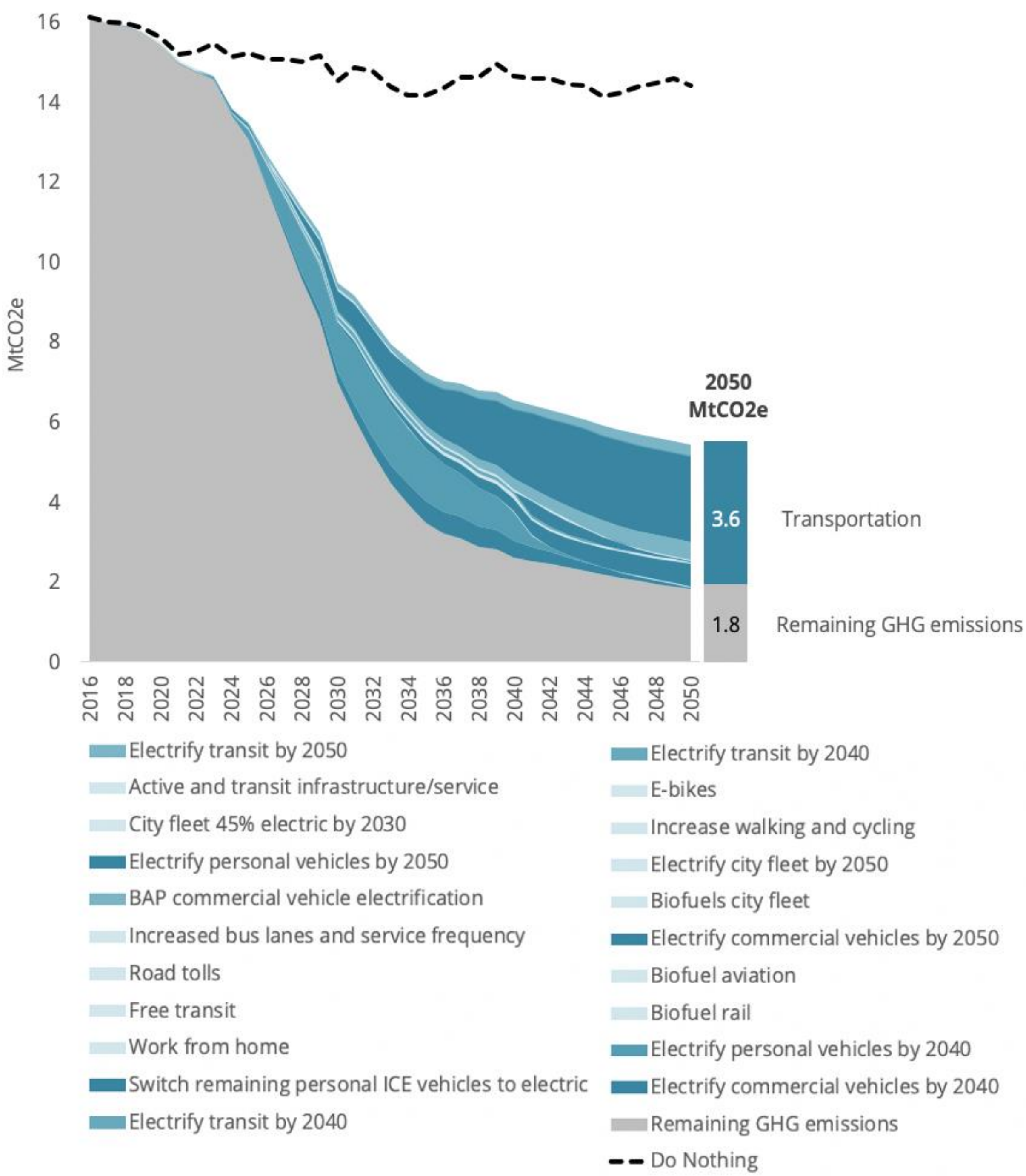

Figure 41. Wedge diagram of transportation GHG reduction actions, NZ scenarios.

Table 11. Description of GHG reduction actions for the transportation sector.

Wedge	Wedge Description	Scenario
Electrify transit by 2050	50% of fleet electric by 2030; 100% by 2050. 100% electrification of GO Transit by 2025.	BAP
Active and transit infrastructure/ service	Active and transit mode shares improved through as-planned infrastructure improvements.	
City fleet 45% electric by 2030	Transition 45% of City-owned fleet to low-carbon vehicles by 2030; 65% greenhouse gas reduction by 2030 (from 1990 levels).	
Electrify personal vehicles by 2050	Electrify 98% of personal vehicles by 2050 (achieved from 100% EV sales in 2040).	
BAP commercial vehicle electrification	Light duty commercial: - 50% new sales EV by 2040. Long-haul: - background 2.5% annual electrification rate.	
Increased bus lanes and service frequency	Convert one lane of traffic to exclusive bus lanes on all arterials. Increase service frequency on all transit routes: bus by 70%, streetcar by 50%, subway off-peak service increased to every 3 mins.	Zero by 2050
Road tolls	Tolls of $0.66/km on all arterial roads.	
Free transit	No transit fares.	
Work from home	50% of professional/management/technical and general office/clerical workers in the GTHA work from home on any given day.	
Switch remaining personal ICE vehicles to electric	Switch all remaining ICE vehicles 11 years or older to electric from 2040 onwards.	
Electrify transit by 2040	Electrify 100% of transit by 2040.	
E-bikes	Shift 75% of car and transit trips under 5km to bikes or e-bikes by 2040.	
Increase walking and cycling	Shift 75% of trips under 2km to walking by 2040.	
Electrify city fleet by 2050	Electrify 100% of the city fleet by 2050.	
Biofuels city fleet	In 2025, begin purchasing renewable diesel for diesel vehicles and equipment (30% renewable diesel for city fleet).	
Electrify commercial vehicles by 2050	Electrify 100% of commercial vehicles by 2050.	

Wedge	Wedge Description	Scenario
Biofuel aviation	Aviation runs on 100% low-emissions fuels by 2050.	
Biofuel rail	GO rail runs on 100% biofuel by 2050.	
Electrify personal vehicles by 2040	Electrify 100% of personal vehicles by 2040.	Zero by 2040
Electrify commercial vehicles by 2040	Electrify 100% of commercial vehicles by 2040.	

The transformation of the transportation system is evident in Figure 43 as emissions decline rapidly beginning in 2023. By 2030, no more internal combustion engines are sold, but the s-curve of the adoption rate means that the private vehicle fleet turns over rapidly between 2026 and 2034 (Figure 42). S-curves describe the diffusion of innovations[88] in which a technology is adopted by pioneers, it then becomes mainstream experiencing rapid growth, before slowing down as laggards are slow to adopt; the trajectory of EV adoption is similar in the BAP and NZ50 scenarios. To achieve the GHG reduction targets in NZ40, internal combustion engines are retired early, resulting in a steep s-curve and then a drop-off before the earlier vehicles reach their end-of-life and need to be replaced.

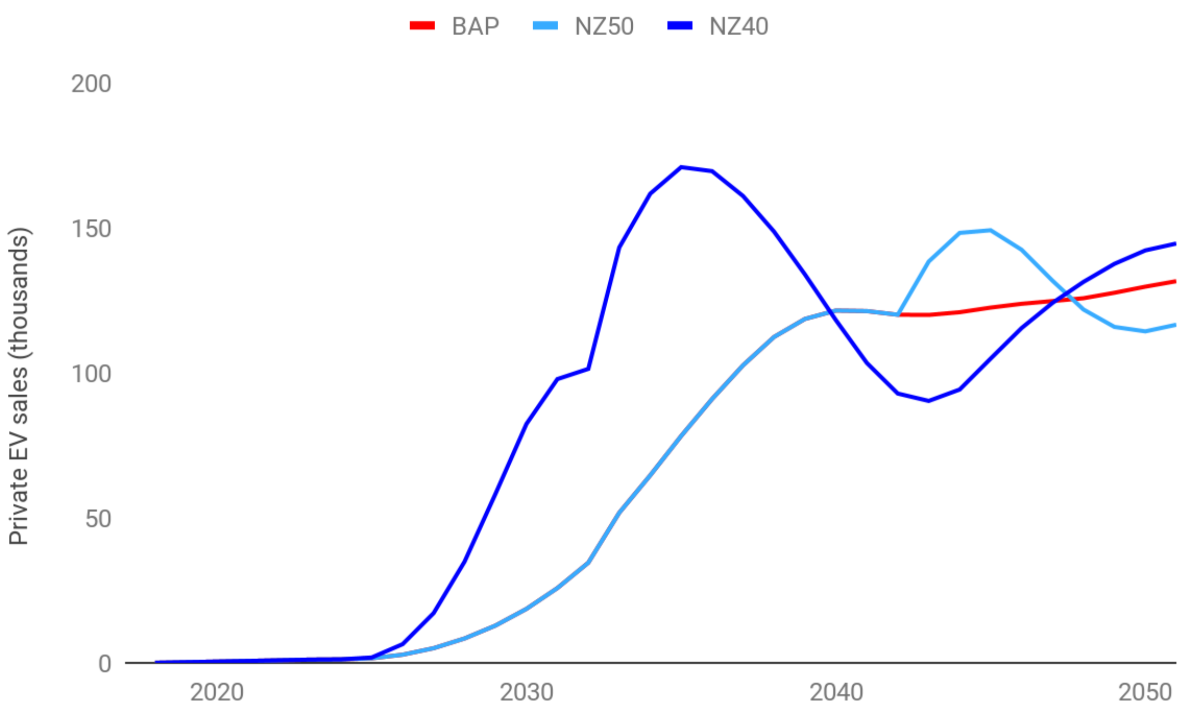

Figure 42. Private EV sales in each of the scenarios, using S-curves

[88] Rogers, E. M. (2010). Diffusion of innovations. Simon and Schuster.

In 2016, emissions are split between cars and light trucks, while heavy trucks and urban buses have progressively smaller slivers of emissions. The efficiency improvements resulting from the switch to electric vehicles are apparent from the fourfold decline in energy consumption. Gasoline and diesel are phased out by 2038, so that the remaining emissions after 2040 are the result of natural gas combustion in the provincial grid from electric vehicle charging.

Emissions

Energy

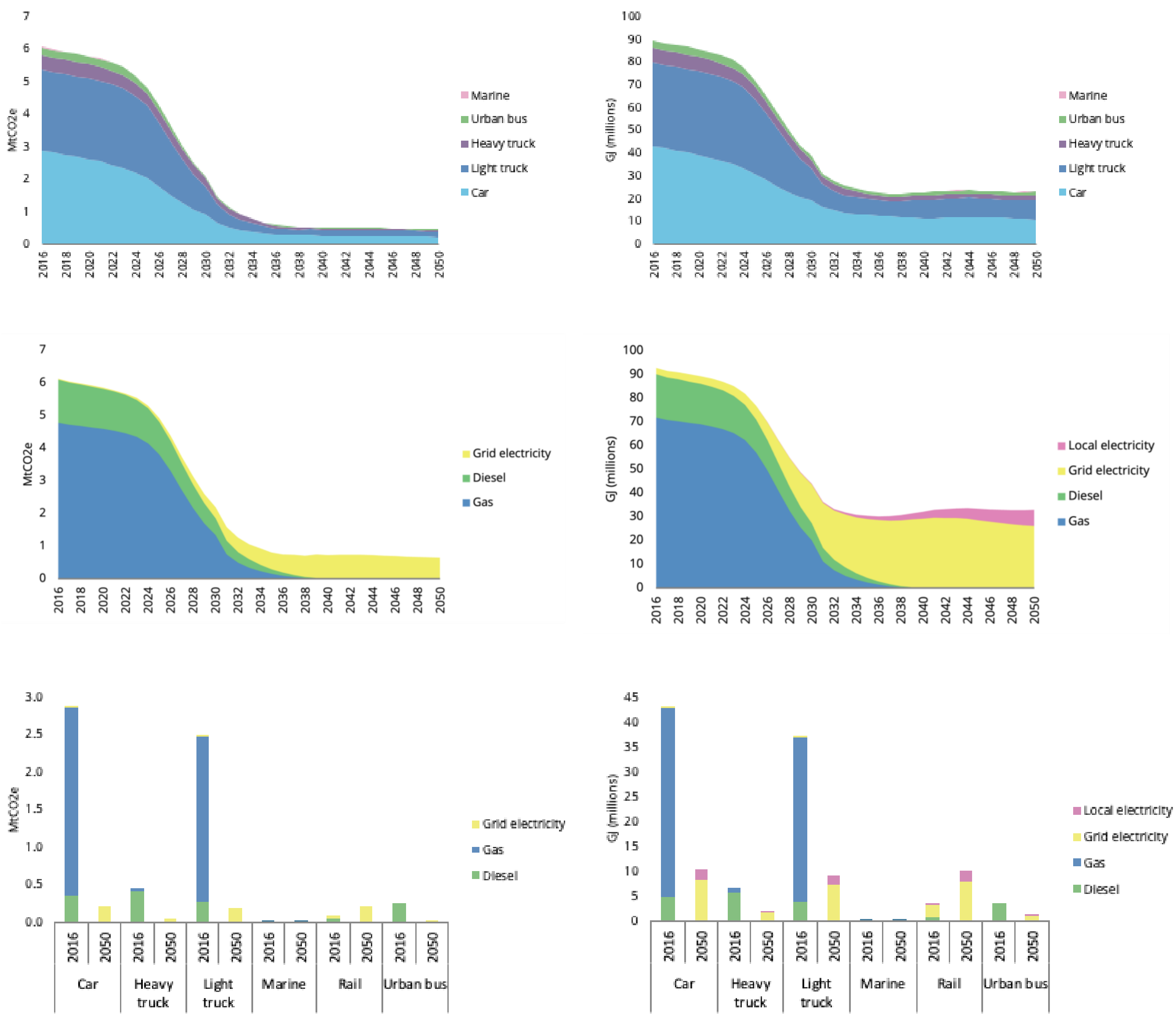

Figure 43. Emissions and energy use from buildings for NZ40, 2016 and 2050.

8. Sustainable Consumption and Zero Waste

8.1 Overview

According to the 2019 GHG Inventory, emissions from waste, water, and wastewater accounted for 7% of Toronto's community GHG emissions, with organic waste being the primary source when it is landfilled. The analysis does not include upstream emissions associated with manufacturing the products.

GHG emissions projections indicate that in 2020 emissions from these sectors were 1.2 MtCO2e (8% of total). Each scenario outcome for the sector in 2050 is illustrated by Figure 44. The Do Nothing scenario results in annual emissions of 0.6 MtCO2e; BAP results in 0.5 MtCO2e; and the NZ40 and NZ50 result in 0.1 and 0.2 MtCO2e, respectively. The cumulative GHG reduction potential between 2020 and 2050 is 10 MtCO2e.

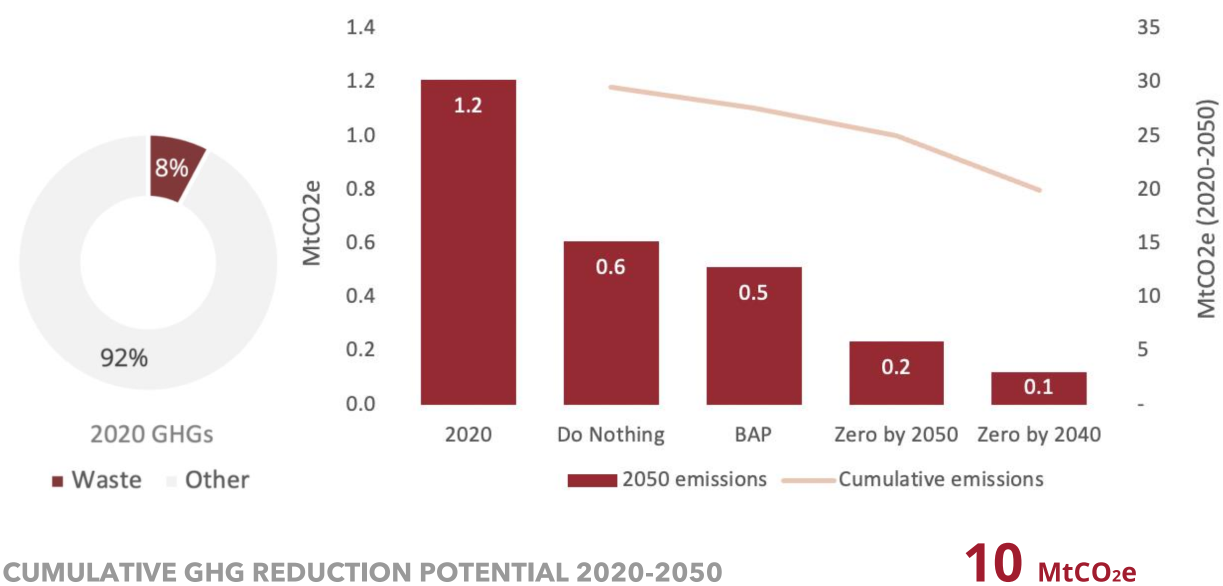

Figure 44. GHG emissions from waste, water, and wastewater.

8.2 Targets

Targets for the waste sector are provided in five year increments for the next decade and then subsequently for each decade until 2050 (Table 12). The targets serve as indicators against which the City can track performance over time.

Table 12. Targets for Waste and Sustainable Consumption Sector Actions, NZ40

	2016	2025	2030	2040	2050
Waste diversion	52%	70%	73%	85%	96%
Waste generation (tonnes per capita)	0.39	0.44	0.45	0.46	0.46
Increase efficiency of water pumps (w.r.t. 2022)	0%	7.5%	20%	20%	20%

8.3 Key Actions

The recommended actions for the waste, water, and wastewater sector are illustrated in the wedge diagram (Figure 45) and in Table 13. The key actions recommended for reaching net zero include:

1. **Waste reduction and diversion**: Increase waste diversion rate beyond 70% by 2025 target to 95% by 2050 (NZ50). Zero organics in landfills by 2025 and zero waste by 2050 (NZ40 target). Results in 4% of cumulative GHG emission reductions.
2. **Increase efficiency of water pumps**: Increase efficiency of water distribution pumps.

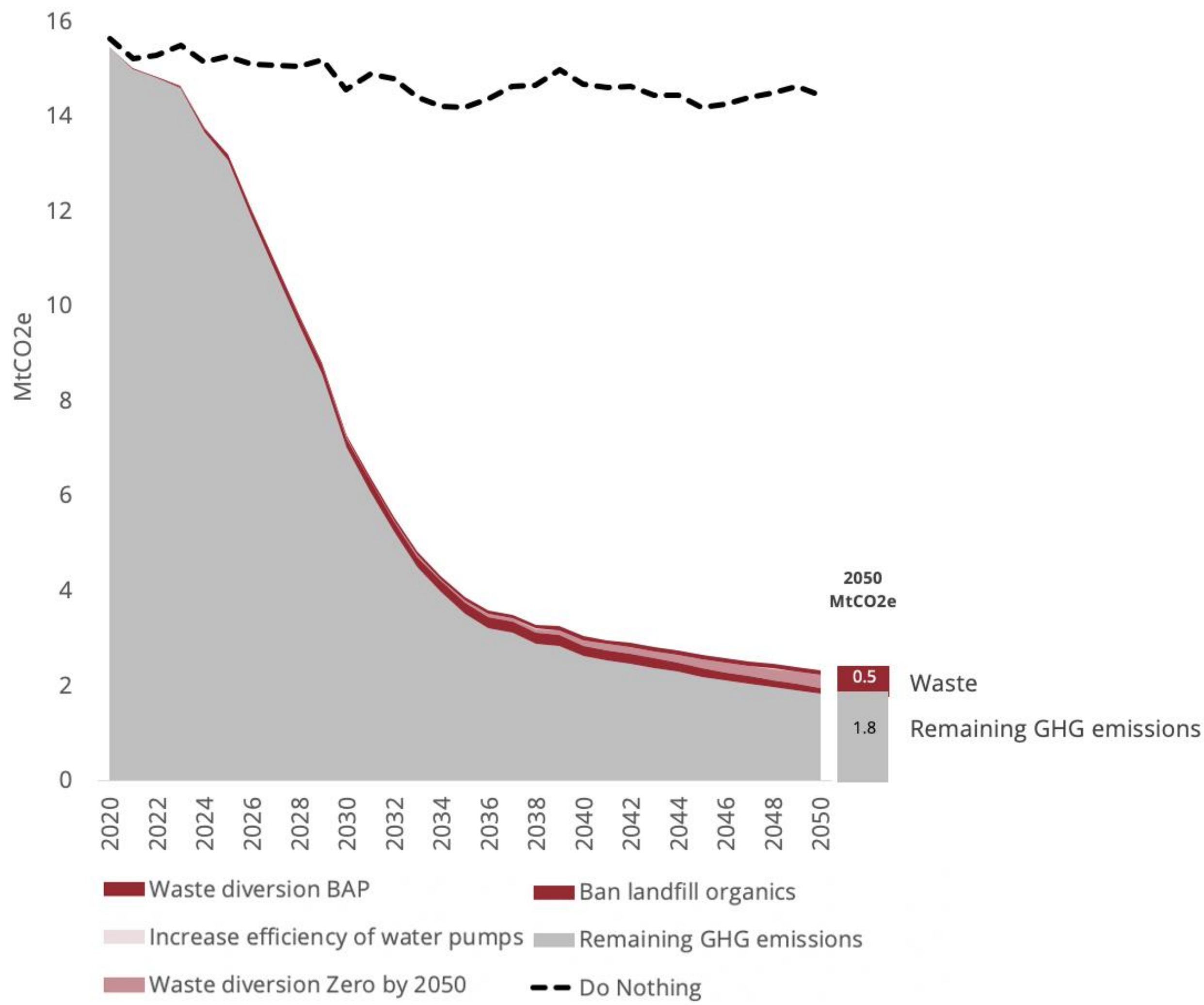

Figure 45. Wedge diagram of waste GHG reduction actions, 2020-2050, NZ40.

Table 13. Description of GHG reduction actions for the waste sector.

Wedge	Wedge Description	Scenario
Waste diversion BAP	Increase waste diversion rate to 70% by 2025.	BAP
Increase efficiency of water pumps	Increase efficiency of water distribution pumps.	
Waste diversion	Increase waste diversion rates beyond the 70% by 2026 target, to 95% by 2050.	Zero by 2050
Ban landfill organics	Zero organics in landfills by 2025.	Zero by 2040

Part 3: The Opportunities

9. Financial analysis

9.1 Financial Concepts

The direct, community-wide, financial impacts of Toronto's net zero pathways provide important context for local decision-makers. However, direct financial impacts should be seen as a secondary benefit of reducing GHG emissions. First and foremost, GHG reductions are a critical response to the global climate emergency. In addition, most measures included in the pathways provide economic and social goods to the community, such as net job creation and positive health outcomes, which are only reflected in this financial analysis as the cost of carbon emitted.[89]

Key concepts that are used to analyze the financial impacts of the pathways are summarized below.[90]

Costs Are Relative to the Do Nothing Scenario

This financial analysis tracks projected costs and savings associated with low-carbon measures that are above and beyond the costs in the Do Nothing scenario.

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, duration of the 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 and, as such, it is inherently uncertain and difficult to determine. Some argue that a very low or even zero discount rate should be applied in the evaluation of climate change mitigation investments. In this project, we evaluate investments in a low-carbon future with a 3% discount rate.[91]

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[89] The Social Cost of Carbon is an estimate of the damage caused to society by climate change including impacts on health and lost jobs.

[90] Detailed financial assumptions are described in the Data, Methods and Assumptions Manual.

[91] Environment and Climate Change Canada. (2016). Technical update to Environment and Climate Change Canada's social cost of greenhouse gas estimates. Retrieved from http://ec.gc.ca/cc/BE705779-0495-4C53-BC29-

Net Present Value

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

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

Abatement Cost

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

Amortization

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

Energy and Carbon Cost Projections

Energy cost projections were derived from[92]:

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

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

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

6A055C7542B7/Technical%20Update%20to%20Environment%20and%20Climate%20Change%20Canadas%20Social%20Cost%20of%20Greenhouse%20Gas%20Estimates.pdf

[92] For more details on the financial assumptions see the TransformTO Data, Methods and Assumptions Manual.

Box: A Prosperous City

Economic prosperity is the capability to flourish, according to a definition developed by the UK Sustainable Development Commission.[93] In articulating this definition, the authors cite broad questions posed by the economist Amartya Sen about how people are able to function: Are they well nourished? Are they free from avoidable morbidity? Do they live long? Can they take part in the life of the community? Can they appear in public without shame and without feeling disgraced? Can they find worthwhile jobs? Can they keep themselves warm? Can they use their school education? Can they visit friends and relations if they choose?[94] The notion of the capability to flourish as a definition of economic prosperity is consistent with the intention of key City documents, such as One Toronto and TO Prosperity: Toronto Poverty Reduction Strategy. It is complementary to the categories on health and social equity discussed elsewhere in this report, and, as the UK Sustainable Development Commission argued, is also consistent with the intention of preventing dangerous levels of climate change.

In considering potential co-benefits and co-harms of efforts to reduce GHG emissions, the aspects of economic prosperity which will be considered include employment, household incomes, enterprises, public finance, environmental capital, and social capital.

9.2 The Big Picture

Table 14. Summary of financial results

	BAP	NZ50	NZ40
Net impacts over the period, *$ billions*			
Total incremental capital investment, 2020-2050	$31.40	$139.63	$145.86
Total savings, 2020-2050[95]	-$32.02	-$107.64	-$114.00
Revenue losses, 2020-2050[96]	$3.35	$25.41	$25.40

[93] Jackson, T. (2009). p.21 *Prosperity without growth: economics for a finite planet*. London ; Sterling, VA: Earthscan.

[94] Nussbaum, M., Sen, A., & Research, W. I. for D. E. (1993). *The Quality of Life*. Oxford University Press.

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

[96] Revenue losses are a result of mode shifts to walking and cycling, and, in the NZ Pathways, from making transit free. See Figure 52 and its description for a more detailed explanation of this.

	BAP	NZ50	NZ40
Net cost, 2020-2050	$2.74	$57.40	$57.26
Financial indicators, $			
Capital cost (undiscounted) to reduce each tonne of GHG	$827	$969	$827
Abatement cost (NPV) per tonne of GHG	$35	$262	$216
Average annual household savings on home energy (undiscounted), 2050 over 2016	$555	$1,258	$1,268
Investment $/person-year of employment			$145,000

The financial impacts of the scenarios were explored in detail. At a high level, the investments in NZ40, which has the highest near-term investments, hover around 5% of annual GDP for a decade prior to declining to 2% in the subsequent decades. Figure 46 illustrates the scale of investments relative to a projection of the annual GDP which is escalated at 1% to illustrate the scale of investments is relatively small in comparison to the overall GDP of the city.

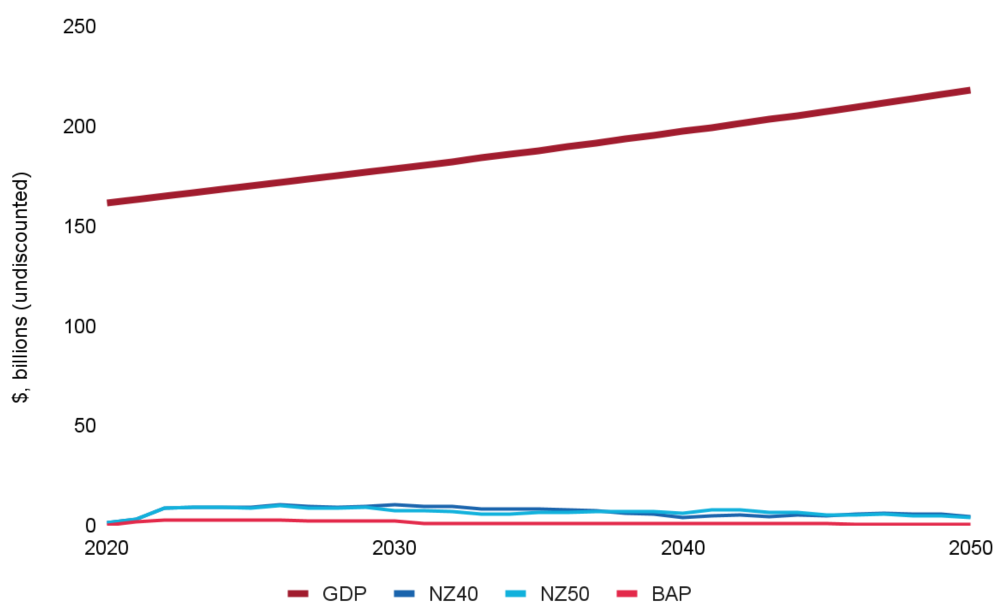

Figure 46. Investments relative to projected GDP (annual growth of 1%).

The investments in the NZ scenarios generate financial returns, the net impact of which is illustrated in Figure 47. Notably, the NZ40 generates financial returns (beginning in 2040) prior to the NZ50 scenario (beginning in 2045), while the BAP generates financial benefits by 2032. The suite of actions in the BAP scenario generate financial returns because investments are low and returns are relatively high, but the BAP is not a viable scenario in terms of achieving the City's GHG targets.

Table 15. Pivot points: Year in which the scenario starts to generate annual savings.

	NZ40	NZ50	BAP
Year that annual savings begin	2040	2045	2032

Each of the lines in Figure 47 represent the addition of investments and savings. For illustrative purposes, in an early year in a net zero scenario, investments might total $7 billion, while savings total $1 billion- this results in a net cost of $6 billion (7-1=6). Later in the study period, investments might total $5 billion, while savings total $6 billion, resulting in net savings of -$1 billion (5-6=-1). There are many underlying dynamics at play that result in these curves. Both the NZ40 and NZ50 scenarios have higher initial investments and NZ40 has higher investments in vehicles than NZ50. As a result of the earlier investments in EVs, greater savings occur in NZ40 earlier, pushing the NZ40 line down to zero earlier than the NZ50 line. The investments in NZ40 and NZ50 generate greater savings than the BAP post 2050. In the post-investment period after 2050, the benefits continue for as long as the measures deliver savings.

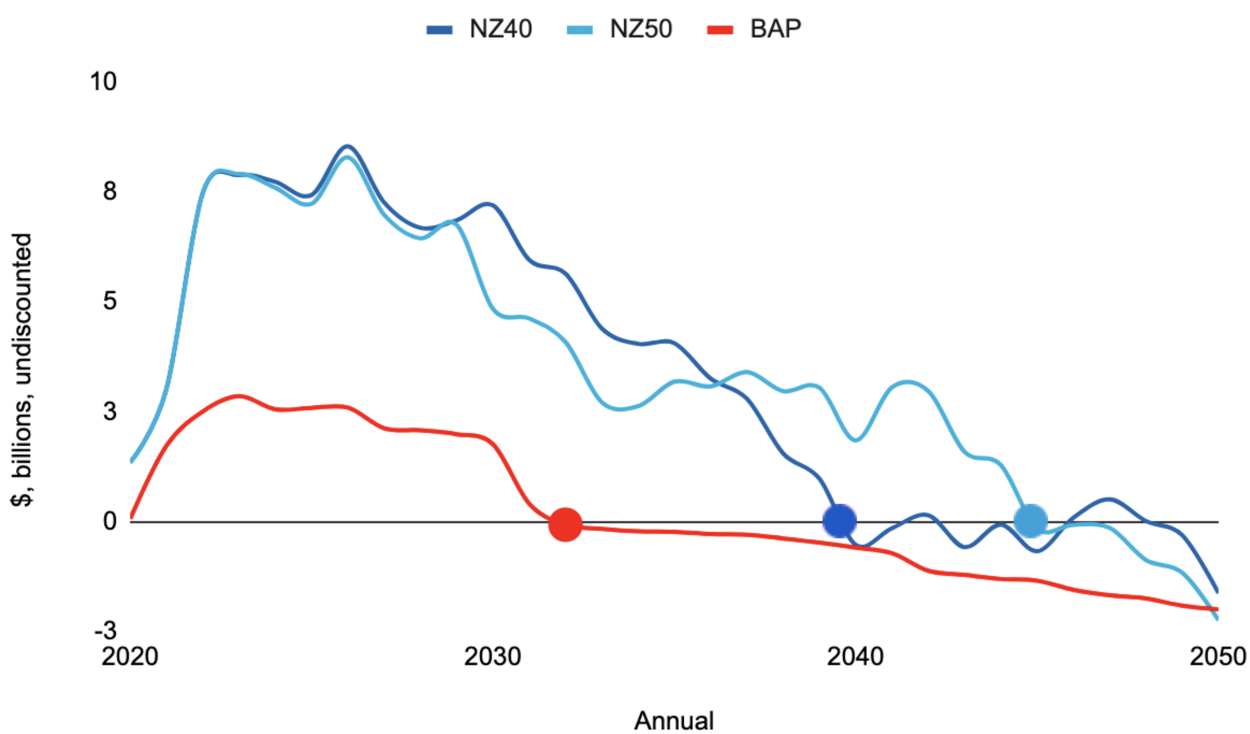

Figure 47. Net annual community-wide costs/savings for the three scenarios (costs are positive, savings are negative).

9.3 A Mix of Abatement Costs and Savings

Abatement costs provide an indication as to whether a measure generates financial returns over its lifetime. A negative abatement cost indicates an action generates financial returns, while a positive abatement cost indicates the cost of an action exceeds financial returns. The width of each bar on the x-axis indicates the amount of GHG emissions that it saves.

The marginal abatement cost for the NZ40 actions are provided in Figure 48. Active transit infrastructure has the highest marginal abatement cost at $14,567 for every tonne of GHG reduced. Increasing tree canopy follows with a marginal abatement cost of $6,506. Both of these are interesting examples because, unlike other actions, GHG emission reductions are not always the primary motivator for these projects. In addition, these actions deliver significant benefits (improved health in the case of active transportation and ecology and shade in the case of trees) that are not factored into the calculation as financial benefits.

More compact buildings have the lowest cost, generating financial returns (savings) $10,474 per tonne of GHG reduced. Electrification of vehicles consistently generate savings including personal vehicles (savings of $205/t), transit (savings of $566/t), and the City fleet (savings of $592/t). These measures deliver a third of the GHG reductions while generating financial savings that could help to pay for building retrofits.

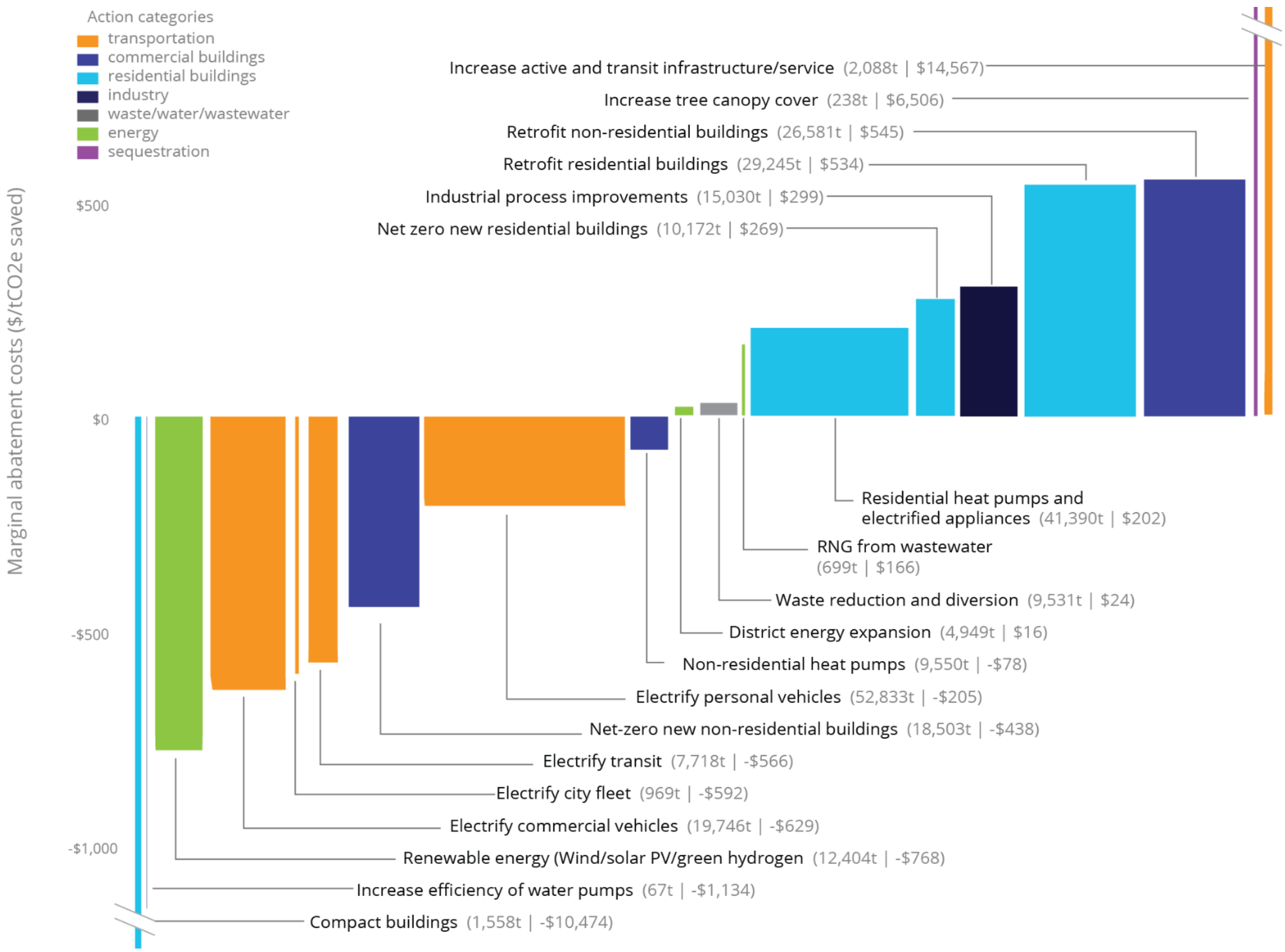

Figure 48. Marginal abatement cost curve (MACC) for the City's net zero by 2040 actions.

Box: The Criticality of a Systems Approach

The abatement costs provide an important insight: the electrification of transportation generates financial savings, which, given the deployment of appropriate financial mechanisms, can be used to finance building retrofits, which are more costly. Building retrofits are critical to minimizing the burden on the grid to enable electrification of transportation.

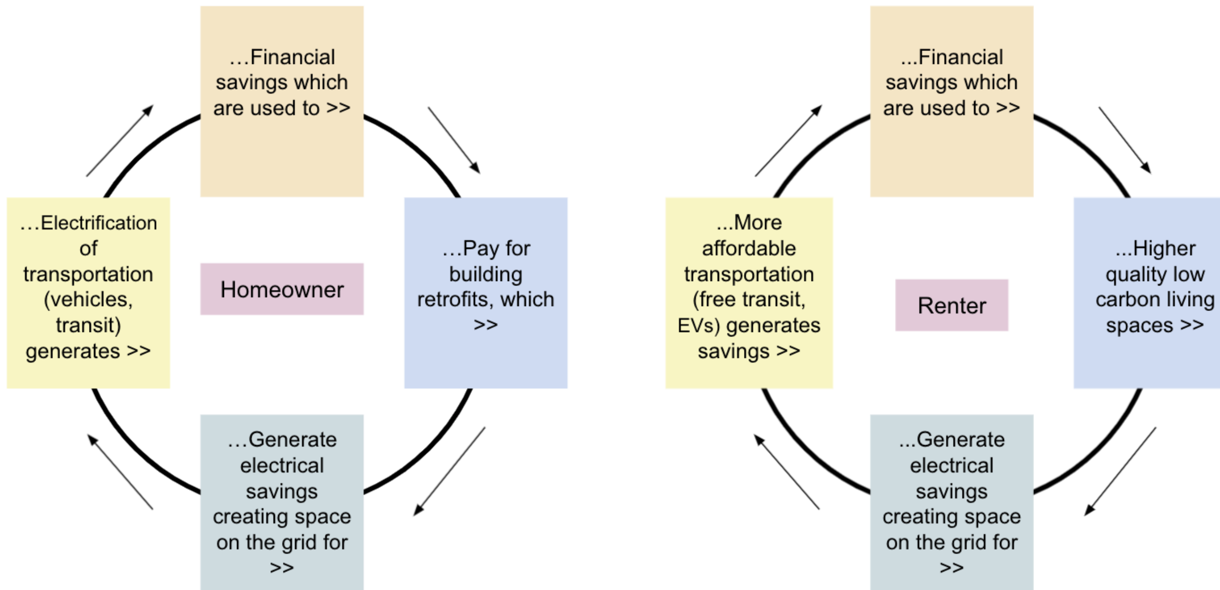

Figure 49. The electrification feedback cycle.

While a marginal abatement cost curve (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 district energy cost increases without retrofits. Another important message is that in order to achieve the City's target all the actions need to be undertaken as soon as possible. While there can be a tendency to wait for technological improvements, this has the effect of reducing the value of the savings that can be achieved for households and businesses, and the new employment opportunities that can be created.

Box: Using Abatement Costs to Guide Policy

Figure 50 illustrates an abatement curve of actions. Actions on the left save money and are therefore financially interesting to investors. Actions in the middle have a net present value that is either slightly negative or slightly positive and may require credit enhancements to be compelling. Finally, on the right, those actions which are NPV negative will require subsidies. A capital-constrained public sector must concentrate on the expensive projects while relying on the private sector for the rest. A capital-rich public sector can invest in projects that are more expensive and those which may generate more interesting financial returns.

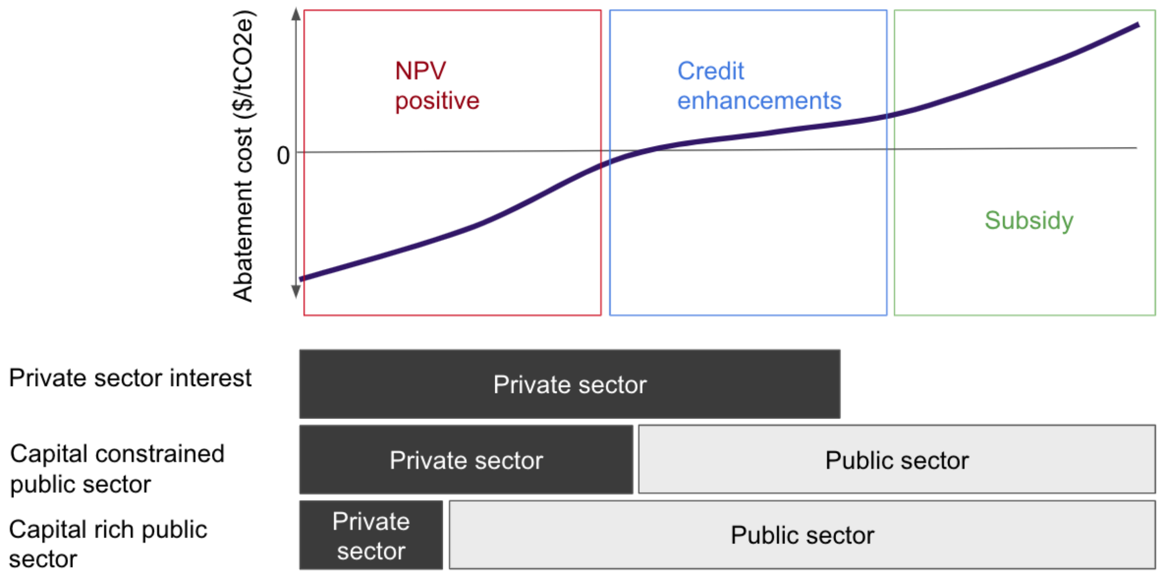

Figure 50. Aligning the abatement costs with investor interest.

Many of the actions in the NZ scenarios have positive net present values. Figure 51 shows the present value of the major components of the three scenarios: 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 both NZ scenarios have a present value of $57 billion (the light green bar), meaning there is no substantial financial difference between these two scenarios. It is important to highlight the fact that capital investment for the plan ends in 2050, however the NPV includes the energy, maintenance, and carbon costs savings as well as revenue projected over the full life of the measure, which, in some cases, extend as far as 2089.

Figure 51. Present values of investments and returns for the three scenarios over the Do Nothing scenario (2021-2050). Costs appear above the x-axis, while revenue and savings appear below it.

The annual costs, savings and revenue associated with fully implementing the actions in the NZ scenarios are shown in detail in Figure 52, with capital expenditures shown in full for the years in which they are incurred. As is characteristic of low-carbon transitions, the capital expenditures in the early years of the transition are significantly greater than the savings and revenues generated, and by 2040 savings are beginning to exceed investments in the NZ40 scenario.

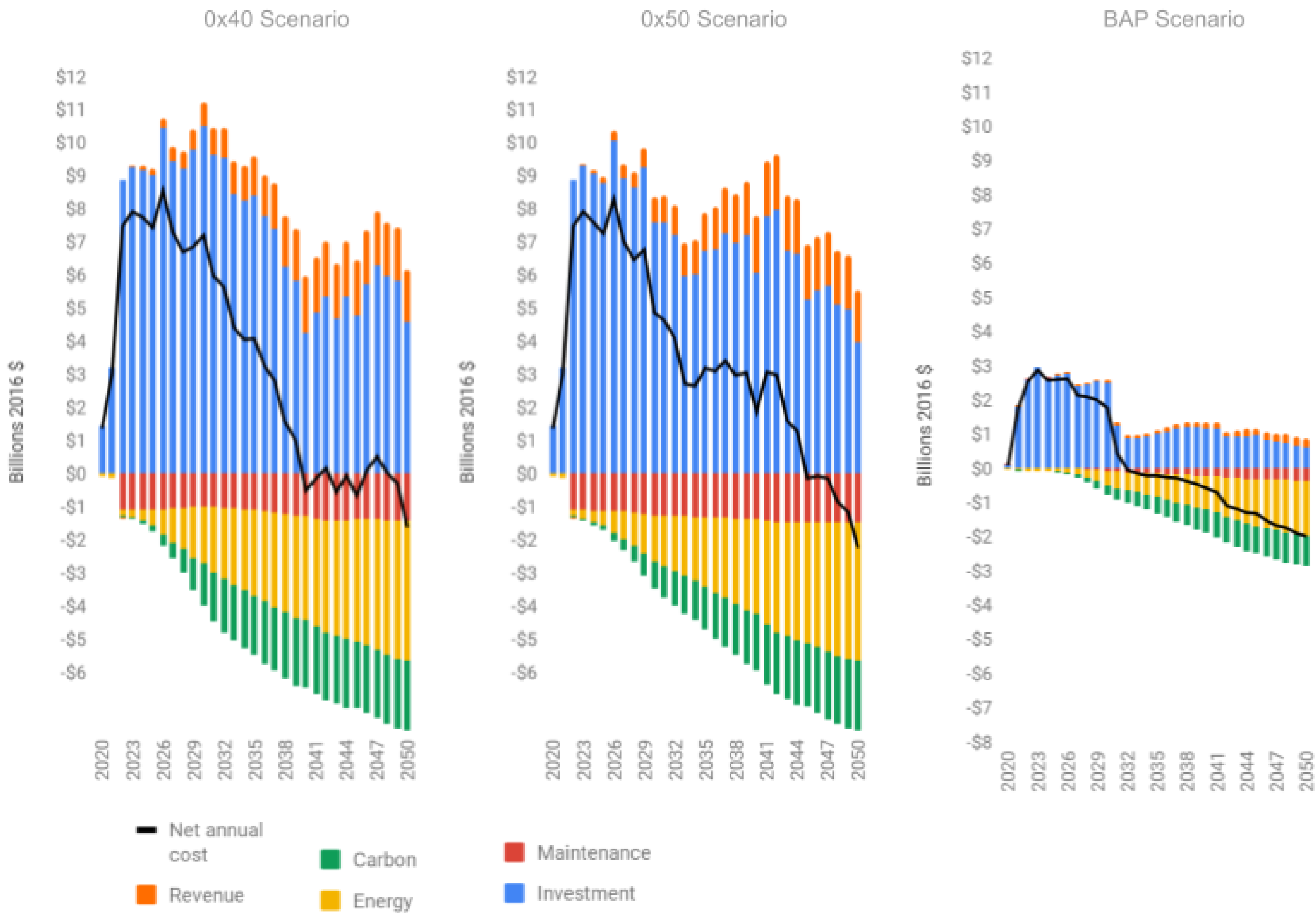

Figure 52. Year-over-year investments and returns over the Do Nothing scenario, 2020 - 2050.

Note that revenues show up as a cost (positive numbers), rather than as savings (negative numbers), contrary to what would be expected with the significant additions of renewable energy and district energy that generate new revenues. This outcome results because the reduction in revenues from transit relative to the Do Nothing scenario (as transit is free) exceeds the new revenues from renewable energy and district energy systems generating a net cost (Figure 53).

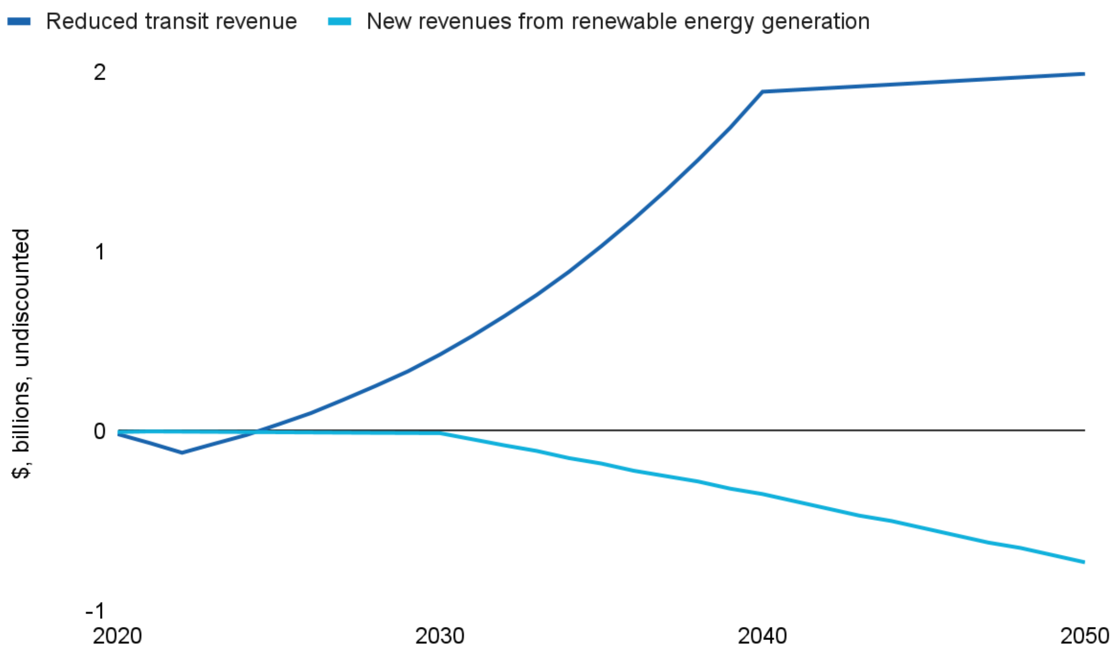

Figure 53. Impact of free transit on avoided annual revenues, relative to revenues from renewable electricity generation, NZ40.

In addition to the reduced revenue as a result of making transit free, transit investments are also one of the three major capital investment areas in the NZ scenarios, totalling $92 billion over the period. Transit plays a similar role to building retrofits by reducing the overall energy demand on the grid resulting from the electrification of transportation, as transit is more efficient than personal vehicles. Residential and non-residential buildings are the other major sources of investment, accounting for $74 and $42 billion, respectively (Figure 54).

The stacked area charts in Figure 54 represent the investments in the year in which they are made, which results in spikes and peaks depending on which actions are implemented in which year. For example, there is a spike in local energy investments in 2027 when renewable energy capacity is added. There is also an incremental capital expenditure relative to the Do Nothing scenario in 2030 when EVs are added reflecting the early retirement of ICE vehicles- expenditures on vehicles are greater in the NZ40 scenario than the background replacement rate in the Do Nothing scenario. Because of the early replacement, fewer vehicles are purchased in the NZ40 scenario than the Do Nothing scenario between 2038 and 2044, resulting in a reduction in capital expenditures in this category. Similar blips can be observed in the NZ50 scenario but later on in the time period. The investment in transit and the building stock in the NZ scenarios is apparent relative to the BAP scenario.

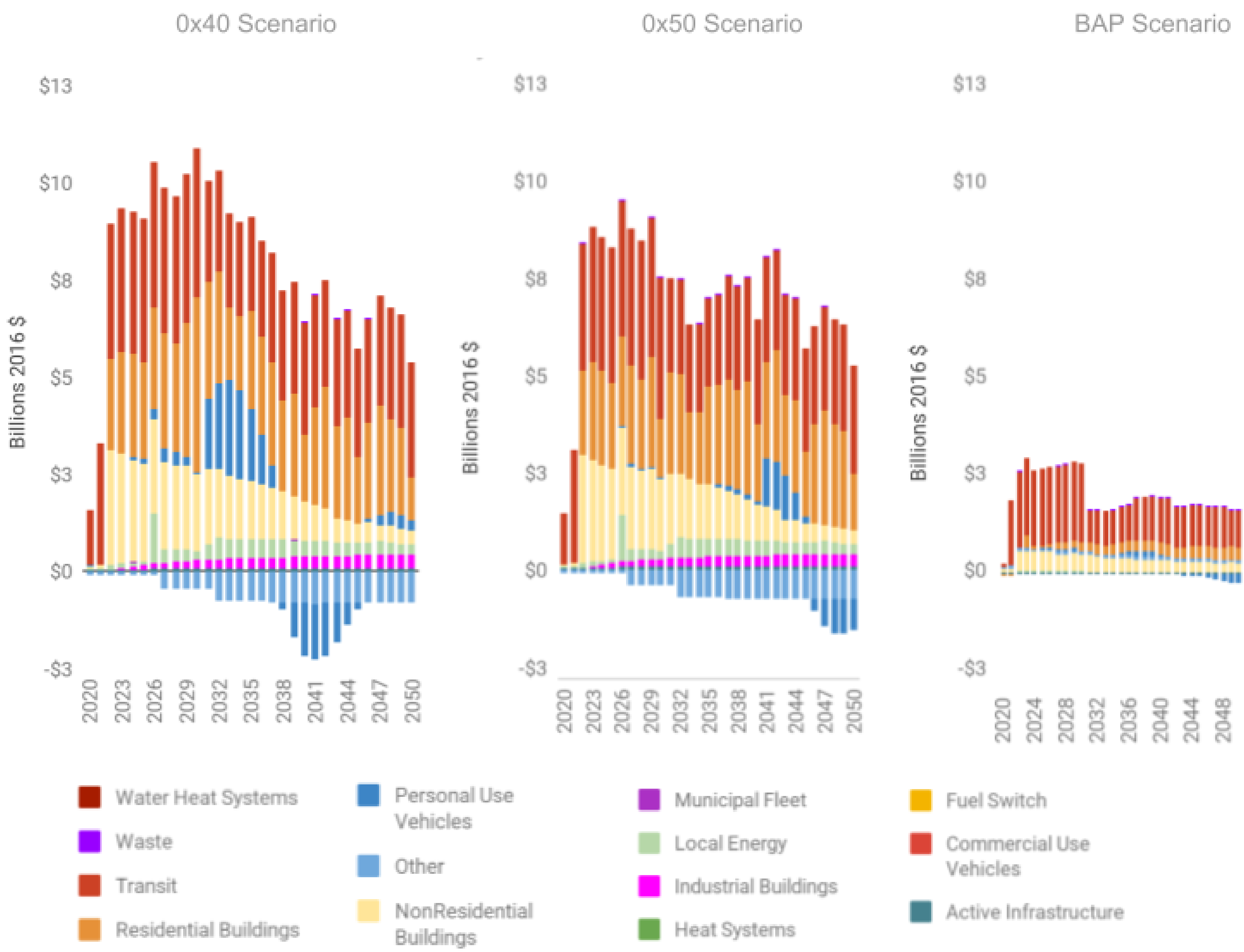

Figure 54. Capital investments over the Do Nothing scenario by action area, undiscounted.

Figure 55 presents costs and revenues, but with the capital expenditures amortized over 25 years with 3% interest. 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, right from the beginning of the program. By 2045 the annualized capital payments begin to decline as the earliest investments are paid off. On an annual basis, the NZ scenarios have an annual deficit and annual savings only exceed annual costs by a small amount after 2070, as illustrated by the black line.

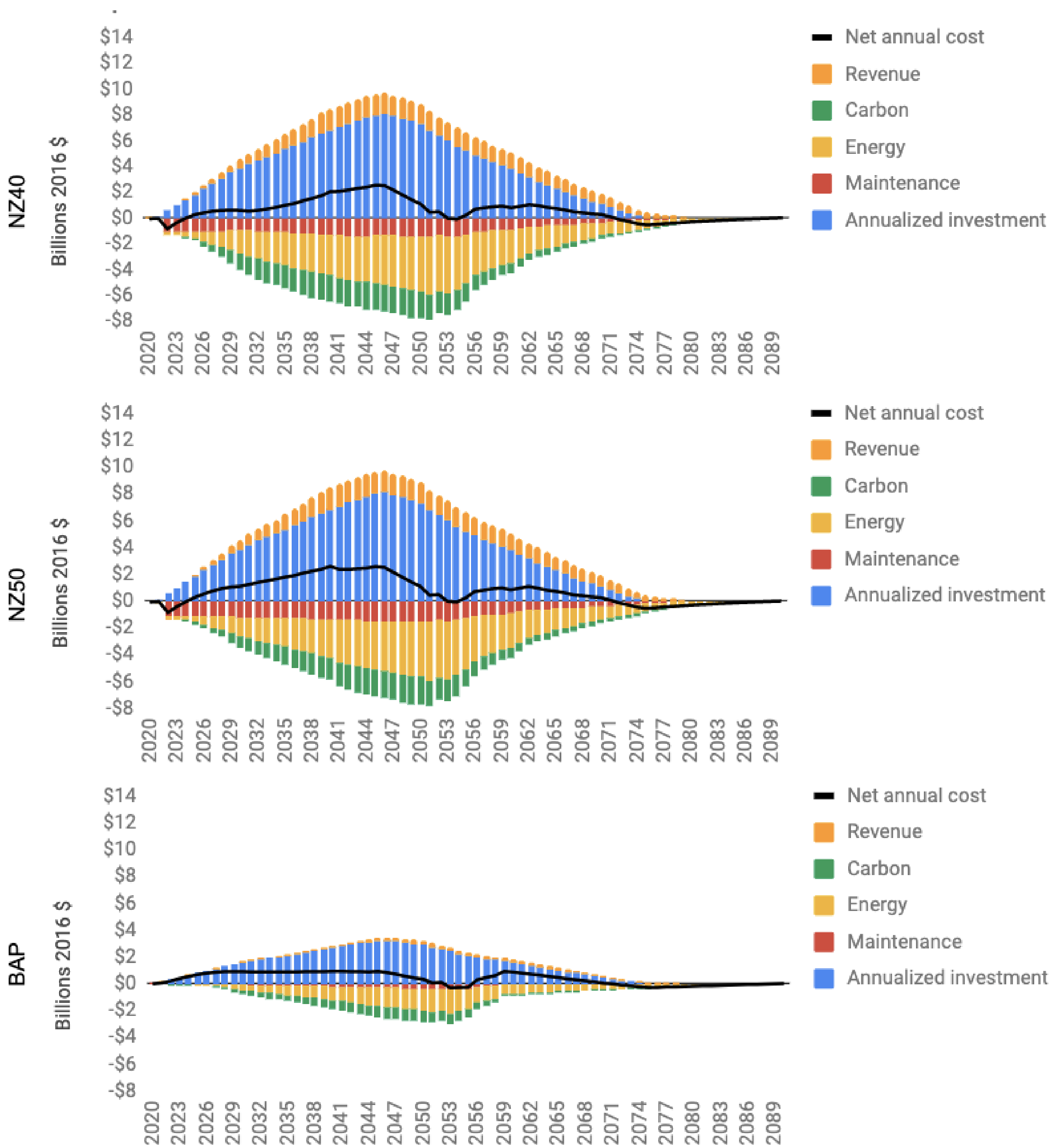

Figure 55. Investments amortized over the period for each of the three scenarios over the Do Nothing scenario.

Amortization reduces the requirement for capital in the short term and smoothes out the trajectory, resulting in a longer tail of payments out until 2070 (Figure 56).

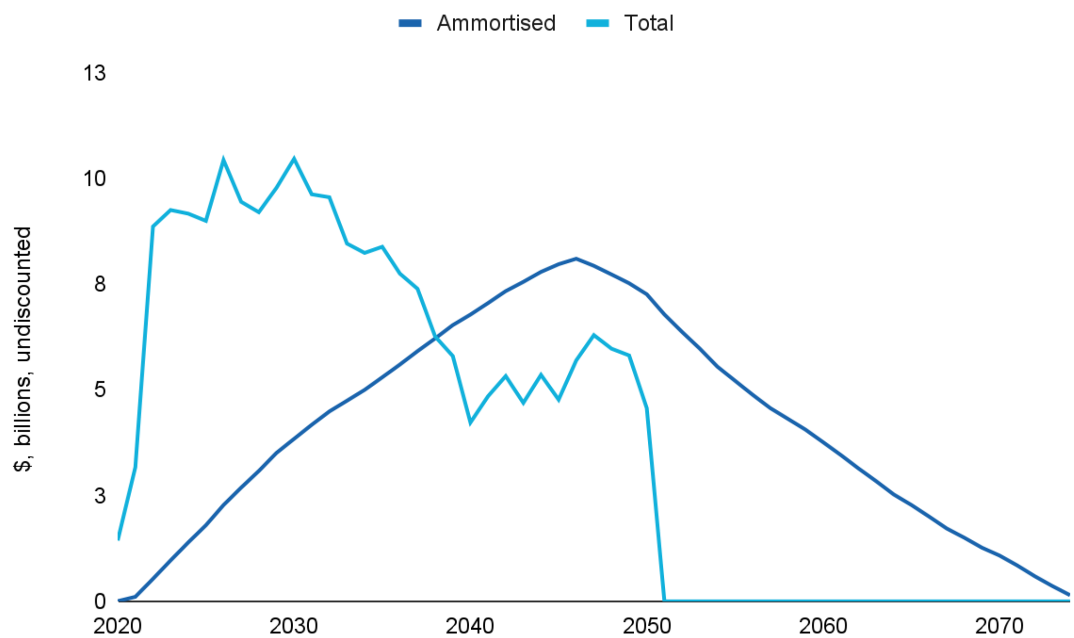

Figure 56. Impact of amortization on capital requirements for the NZ40 scenario.

Household expenditures on energy—natural gas, electricity, gasoline, and diesel—are projected to decline slightly in the BAP and decline significantly in the net zero scenarios (Figure 57). 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 hotter due to climate change. The net zero scenarios involve shifting away from natural gas and gasoline to electricity, a more costly energy source. The increased cost, however, is offset by the increased efficiency of homes as required by building codes and in the case of electric vehicles by the high efficiency of the electric motors as compared to internal combustion engines. The carbon price also adds to the cost of using fossil fuels for heating and transport. In the net zero scenarios, an average household in 2050 spends less on fuel and electricity (household energy and transportation expenditures) than they would have in the Do Nothing scenario. Depending on the business, policy and financing strategies used in the implementation of the actions, these savings will be partly offset by the incremental capital expenditures required.

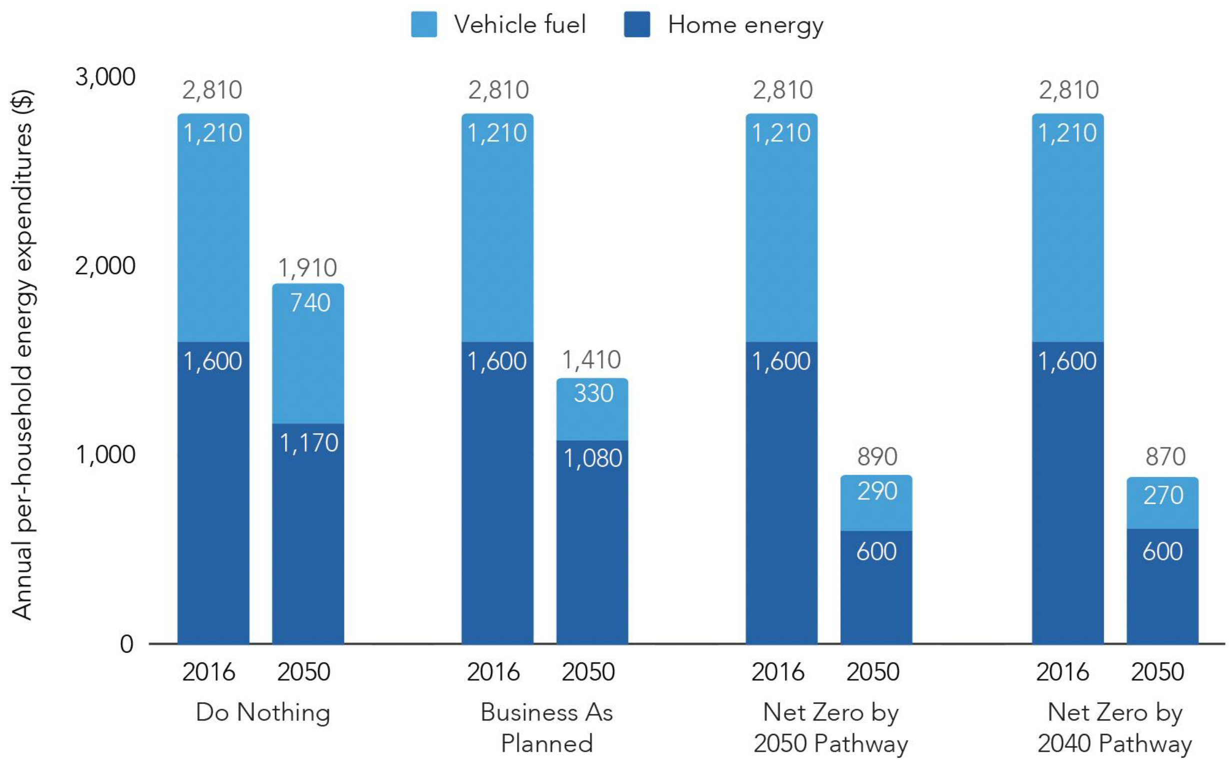

Figure 57. Average annual household expenditures on residential energy for each scenario.

Box: The Impact of the Carbon Tax

The carbon price is currently projected to climb to $170/tCO_2e$ by 2030. This has the impact of increasing the cost of gasoline and natural gas relative to electricity. As a result, gasoline is more expensive than electricity on a per-unit-of-energy basis by 2028 (note that the carbon price has not been factored into the electricity cost as it is negligible). This benefit is compounded by the fact that electric vehicles can go further per unit of energy than gasoline vehicles. Natural gas is still more affordable than electricity on a per unit basis over the period. Heat pumps, however, are three times more efficient than natural gas heating and home heating with an electric heat pump becomes more affordable than heating with natural gas in 2027 (Figure 58).

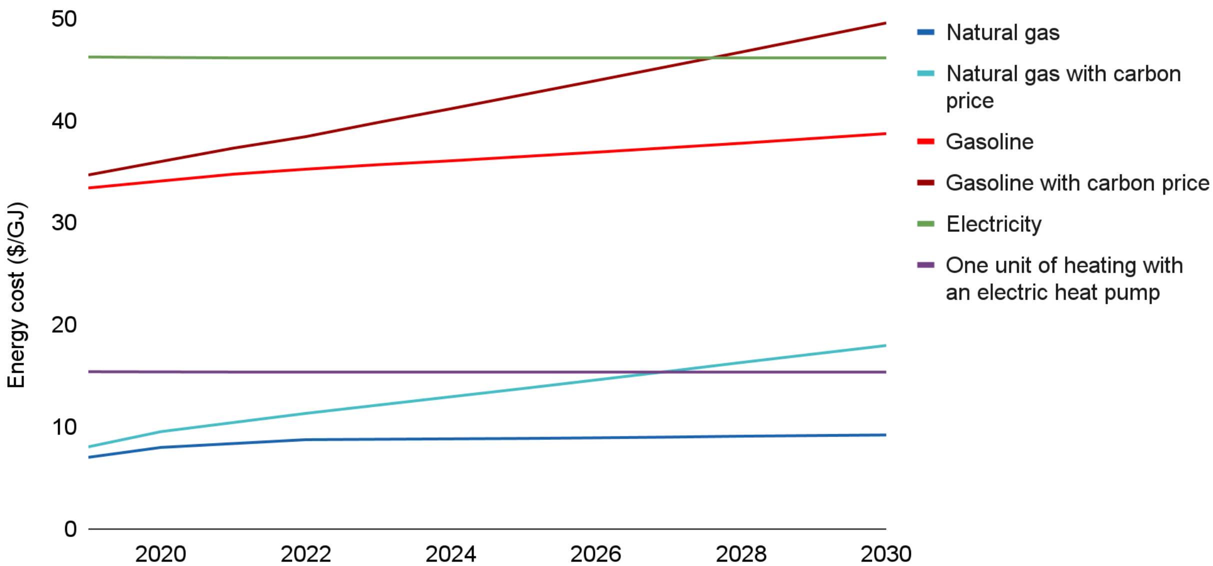

Figure 58. Projections of relative energy costs for gasoline, electricity, and natural gas.

Transitioning to a low- or zero-carbon economy is expected to have four categories of impacts on labour markets: additional jobs will be created in emerging sectors, some employment will be shifted (e.g., from fossil fuels to renewables), certain jobs will be reduced or eliminated (e.g., combustion engine vehicle mechanics), and many existing jobs will be transformed and redefined. The NZ40 scenario adds 1.5 million person-years of employment, over the Do Nothing Scenario between 2020 and 2050 (Figure 59). As seen in the figure, this amounts to approximately 40,000-50,000 jobs annually with the majority in residential and commercial building retrofits and infrastructure investments, averaging 10,000-15,000 in each of these three areas.

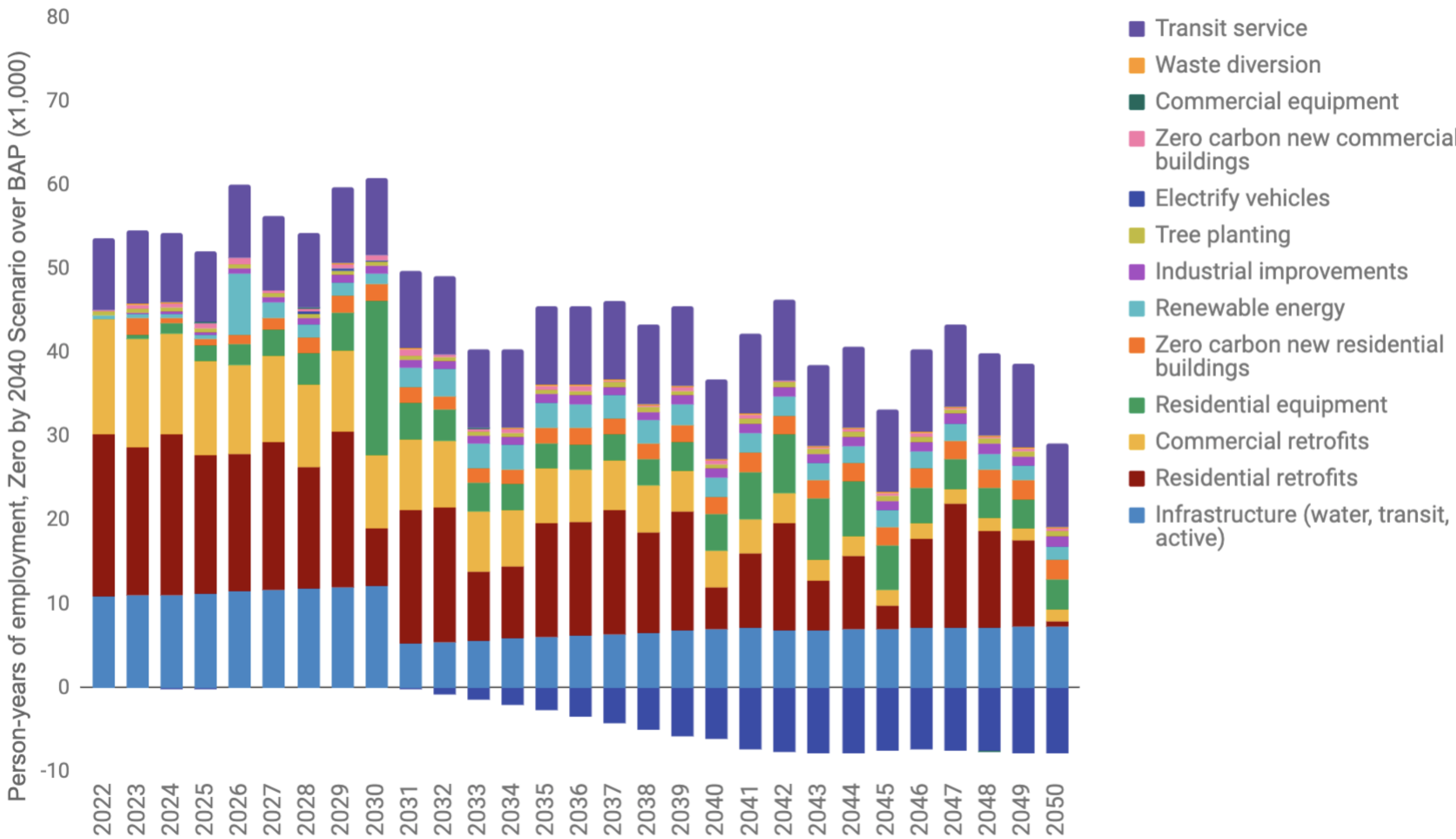

Figure 59. Annual person years of employment generated in the NZ40 scenario.

10. Co-Benefits

As has been discussed, the benefits of GHG mitigation actions go well beyond emissions reductions, also helping to advance City objectives around health, equity, prosperity and climate resilience. Recognizing this, in 2019 the City's Environment and Energy Division commissioned three reports to explore how these benefits from climate actions could be quantified. This section draws on this work, analyzing metrics related to health, equity, and resilience and comparing them across the four scenarios to shed light on the relative impacts of each. The analysis shows that, across the board, the City could expect to see demonstrable improvements in the NZ scenarios over the BAP and Do Nothing scenarios.

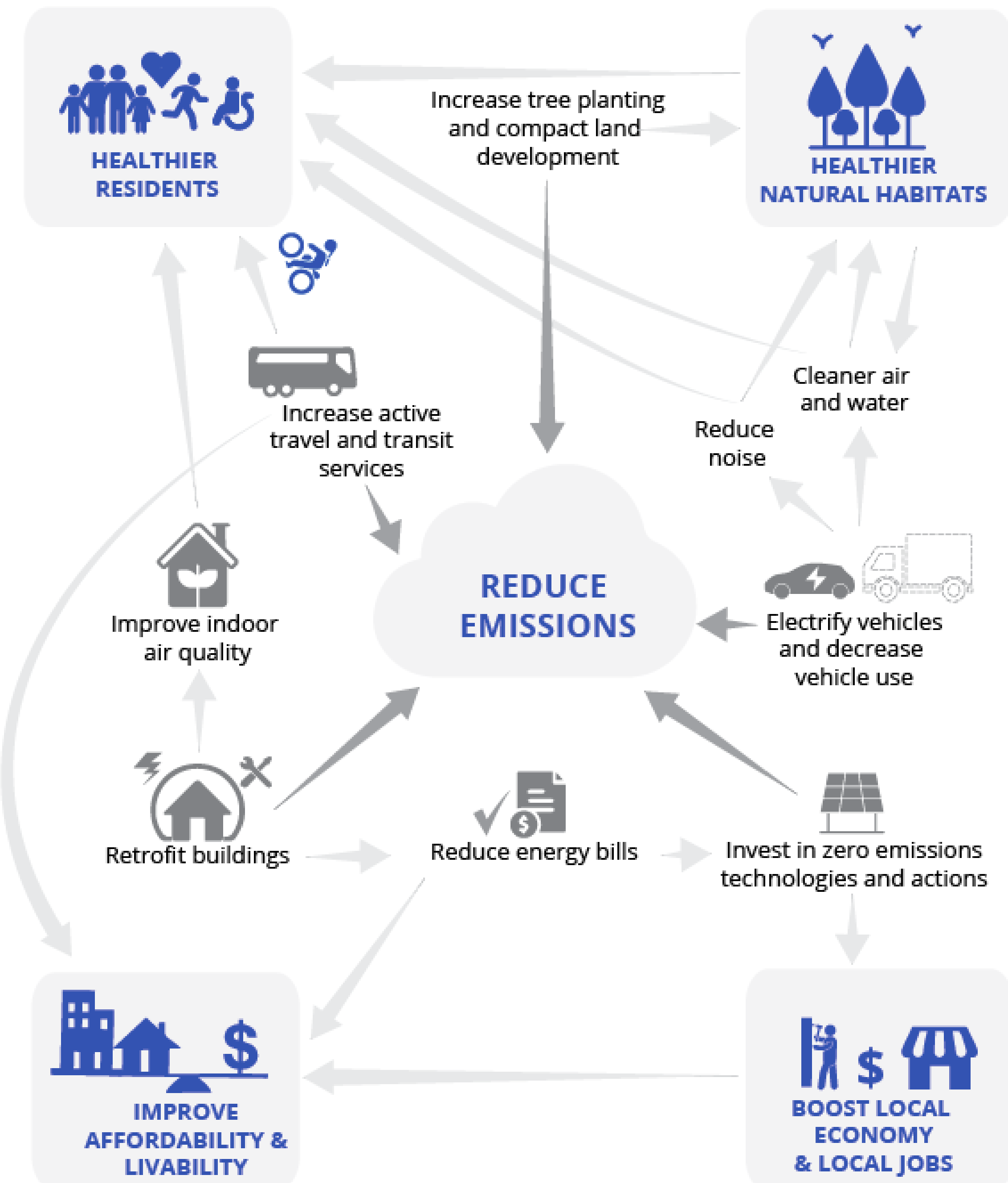

Figure 60. Illustration of some of the key co-benefits of emissions reductions actions.

10.1 Advancing Health

Cleaner Air

In 2020, approximately 232 GJ of fossil fuels were combusted in the City of Toronto. The combustion of these fossil fuels releases air pollutants, such as sulphur dioxide, nitrogen oxides, particulate matter, carbon monoxide, volatile organic compounds, and others, and can create ground-level ozone, all of which have adverse impacts on human health. Air pollution from traffic has resulted in cases of neurological disorders including Parkinson's disease, Alzheimer's disease and other dementias,[97] acute bronchitis in children, asthma, and respiratory illness, among other impacts.[98] In addition, low income residents experience a greater burden of air pollution.[99] Toronto Public Health estimates that 1,300 premature deaths and 3,550 hospitalizations for heart and lung disease in Toronto can be attributed to air pollution each year.[100] According to one study, "eliminating tailpipe emissions, especially in large metropolitan areas, represents a unique opportunity to reduce the health burden of PM2.5 in the U.S."[101] The study quantified the benefit at between US$0.02 and US$0.12 per mile; at $0.056 per mile, the reduced air pollution can be valued at $750 million per year, or $7.5 billion between 2040 and 2050 when ICEs are phased out. The actual value per mile for Toronto would be higher, due the benefits between 2025 and 2040 when EVs are phased in, cleaner electricity to power the vehicles than in the study (less air pollution) and the exposure levels due to the urban environment of Toronto.

There is also increasing evidence about the impacts of using natural gas stoves and fireplaces indoors on health impacts, particularly on children.[102] In the NZ scenarios, natural gas appliances are phased out and replaced with electric appliances. Reducing the combustion of fossil fuels can help alleviate a wide range of air quality health impacts and result in a more livable indoor and outdoor environment in Toronto.

By 2050, the NZ scenarios see a 99% reduction in local fossil fuels combusted compared to the Do Nothing scenario, primarily from switching vehicles and building heating systems to electric sources. NZ40 cumulatively achieves a 10% greater reduction in fossil fuels than NZ50 due to early action.

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[97] Shi, L., Wu, X., Yazdi, M. D., Braun, D., Awad, Y. A., Wei, Y., ... & Zanobetti, A. (2020). Long-term effects of PM2· 5 on neurological disorders in the American Medicare population: a longitudinal cohort study. The Lancet Planetary Health, 4(12), e557-e565.

[98] City of Toronto. (2014). Path to healthier air: Toronto air pollution burden of illness update.

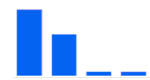
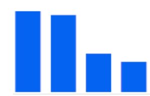
[99] Giang, A., & Castellani, K. (2020). Cumulative air pollution indicators highlight unique patterns of injustice in urban Canada. Environmental Research Letters, 15(12), 124063.

[100] City of Toronto. (2017). Avoiding the TRAP: Traffic-Related Air Pollution in Toronto and Options for Reducing Exposure. Technical Report. Retrieved from: https://www.toronto.ca/legdocs/mmis/2017/pe/bgrd/backgroundfile-108667.pdf

[101] Choma, E. F., Evans, J. S., Hammitt, J. K., Gómez-Ibáñez, J. A., & Spengler, J. D. (2020). Assessing the health impacts of electric vehicles through air pollution in the United States. Environment International, 144, 106015.

[102] Seals, B. and Karasner, A. (2020). Health effects from gas stove pollution. Retrieved from: https://rmi.org/insight/gas-stoves-pollution-health

Table 16. Comparison of fossil fuels combusted in Toronto across the four scenarios

	Do Nothing	BAP	NZ50	NZ40	All scenarios
Local fossil fuels combusted					
GJ fossil fuels combusted in 2050 (millions)	**197**	**120**	**2**	**1**	
% improvement from Do Nothing	-	-39%	-99%	-99%	
Cumulative GJ of fossil fuels combusted (2020-2050) (millions)	**6,445**	**5,130**	**2,855**	**2,095**	
% improvement from Do Nothing	-	-20%	-56%	-67%	

Physical Activity

Actions in both NZ scenarios result in increased active travel by increasing bike lanes and pedestrian infrastructure and by taking transit, achieved through promotional campaigns, and by encouraging alternative forms of travel over vehicle use through road tolls and e-bike programs. With active transportation being the most common form of physical exercise, increasing walking and biking has been identified as one of the most significant ways to improve a city's public physical health.[103] Health benefits from routine physical exercise include reductions in incidence of diabetes[104], cancer, and heart-related illnesses, as well as improvements to mental health.[105]

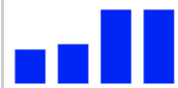
The NZ scenarios result in a doubling of average walking kilometers per person per year and sixfold increase in average yearly cycling kilometers per person annually by 2050 compared to the Do Nothing scenario.

[103] CSEP (2019). Canadian 24-Hour Movement Guidelines. Canadian Society for Exercise Physiology. Retrieved from: https://csepguidelines.ca/

[104] Sampasa-Kanyinga, H., Colman, I., Hamilton, H. A., & Chaput, J. P. (2020). Outdoor physical activity, compliance with the physical activity, screen time, and sleep duration recommendations, and excess weight among adolescents. Obesity science & practice, 6(2), 196-206.

[105] Ruegsegger, G. N., & Booth, F. W. (2018). Health benefits of exercise. Cold Spring Harbor perspectives in medicine, 8(7), a029694.

Table 17. Change in active kilometers travelled in 2050 across the scenarios.

	Do Nothing	BAP	NZ50	NZ40	All scenarios
Active travel per capita					
Yearly walking kms/person (2050) % improvement from Do Nothing	**74** -	**83** +12%	**150** +103%	**150** +103%	
Yearly cycling kms/person (2050) % improvement from Do Nothing	**109** -	**405** +273%	**626** +477%	**626** +477%	

While nearly every neighbourhood experiences increases in active transportation, the increases are not evenly distributed. For example, neighbourhoods in a ring around the downtown experience increases 2-4 times higher than other parts of the city, due to their proximity to services. Large areas of geography experience increases that average 0.5 to 1 km per person per day, while a smaller number of zones experience little or no growth. These walking and cycling deserts require more targeted interventions.

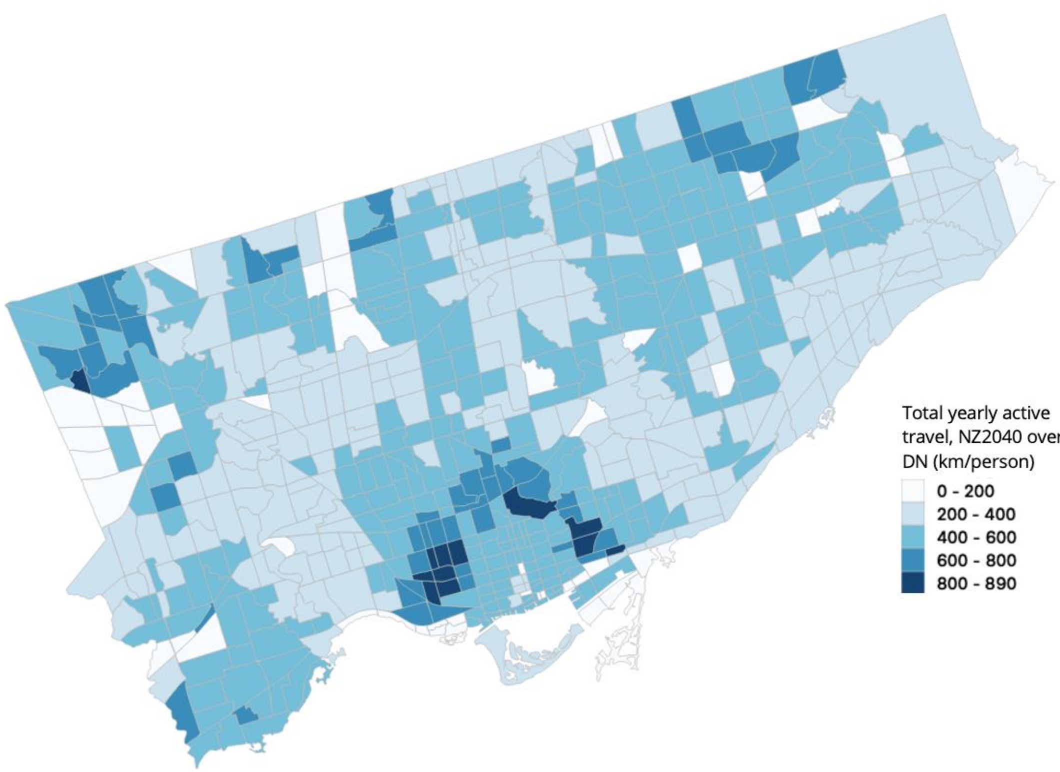
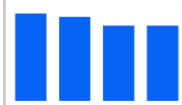
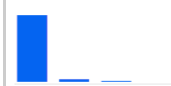


Figure 61. Increase in yearly kilometres per capita of active travel for commuting in the NZ40 scenario compared to the Do Nothing scenario, 2050.

Noise Pollution and Traffic

Noise pollution is reduced in the NZ Scenarios, in part through reduced vehicle kilometers travelled (14% fewer than Do Nothing in 2050), but primarily through conversion of internal combustion engine vehicles to quieter electric vehicles. By 2050, there are approximately 1.3 million fewer internal combustion engine vehicles and 125,000 fewer commercial internal combustion engine vehicles on Toronto's roads in the NZ scenarios compared to Do Nothing. Noise pollution from traffic has been associated with a number of health impacts including cardiovascular disease,[106] annoyance,[107] sleep disturbance, and heart attacks.[108]

Table 18. Change in personal use VKT (vehicle kilometres travelled) in 2050, by scenario.

	Do Nothing	BAP	NZ50	NZ40	All scenarios
Vehicle use					
Yearly personal use VKT (billions) (2050) % improvement from Do Nothing	**20.2** -	**19.4** -4%	**17.3** -14%	**17.3** -14%	
ICE vehicles on roads					
ICE personal use vehicles (2050) % improvement from Do Nothing	**1,272,000** -	**31,000** -98%	**0**[109] -100%	**0** -100%	
ICE commercial vehicles (2050) % improvement from Do Nothing	**125,000** -	**79,000** -37%	**2,000** -98%	**0** -100%	

[106] Biel, R., Danieli, C., Shekarrizfard, M., Minet, L., Abrahamowicz, M., Baumgartner, J., ... & Weichenthal, S. (2020). Acute cardiovascular health effects in a panel study of personal exposure to traffic-related air pollutants and noise in Toronto, Canada. Scientific reports, 10(1), 1-12.

[107] Miedema, H. M. E., & Oudshoorn, C. G. M. (2001). Annoyance from Transportation Noise: Relationships with Exposure Metrics DNL and DENL and Their Confidence Intervals. Environmental Health Perspectives, 109(4), 409–416.

[108] De Nazelle, A., Nieuwenhuijsen, M. J., Antó, J. M., Brauer, M., Briggs, D., Braun-Fahrlander, C., … Lebret, E. (2011). Improving health through policies that promote active travel: A review of evidence to support integrated health impact assessment. Environment International, 37(4), 766–777.

[109] The actual number of ICE vehicles is not zero but it is negligible, and was therefore represented as 0.

Figure 62 illustrates that the decrease in VKT in the NZ40 scenario due to mode shifting and changing transportation patterns is not concentrated in one area of the City but rather is widespread. Figure 63 shows how VKT is reduced by 30% in some zones, from 50 million VKT per year to 35 million VKT, for example. The benefits are multiple in terms of reduced air pollution, noise, increased safety, reduced social isolation and other factors.

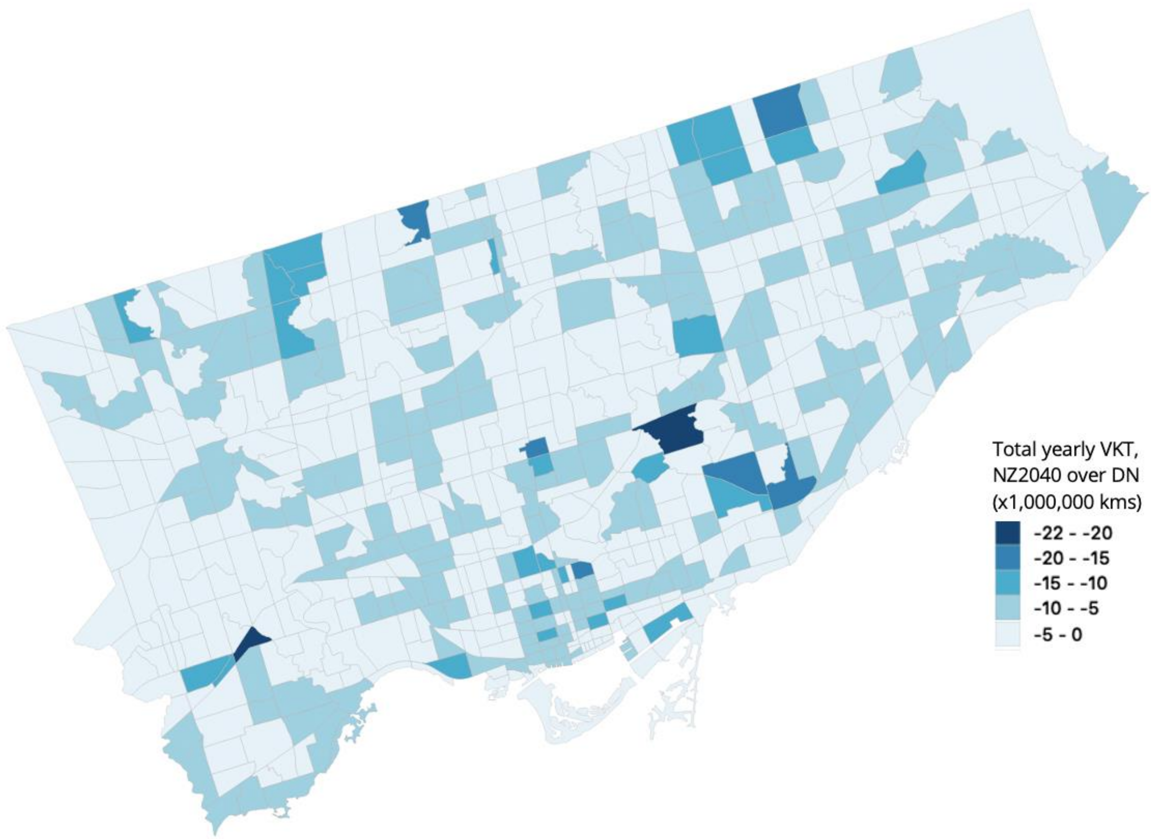


Figure 62. Decrease in total yearly VKTs (for trips within Toronto's boundaries) in the NZ40 scenario compared to Do Nothing, 2050. Darker blue means a greater decrease in VKTs in the NZ40 scenario.

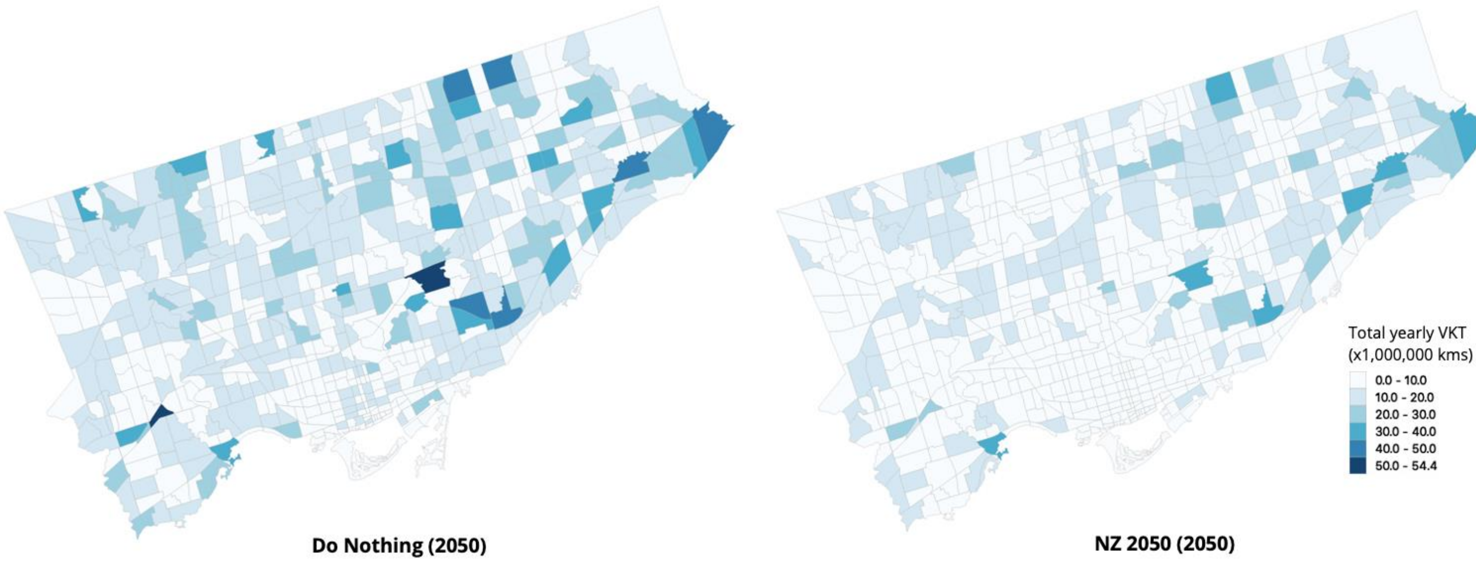


Figure 63. Total yearly VKTs (for trips within Toronto's boundaries) in the NZ40 scenario compared to Do Nothing, 2050.

Indoor Environmental Quality

According to the City's buildings projections, over 80% of the floorspace that will exist in 2050 has already been built. With people typically spending 90% of their time indoors,[110] the condition of these spaces significantly impacts the physical and mental health of residents. Retrofits to reduce GHGs include improvements to building envelopes, as well as to heating, ventilation, and air conditioning systems. These retrofits can reduce indoor air pollutants (i.e., NOx, CO, and VOCs), reduce mould and dampness, and improve thermal comfort of buildings. Health benefits from these changes can include reduced risks of cardiovascular, endocrine, respiratory, cancer, and cardiopulmonary illnesses, as well as decreased mental disorders and improvements to mental health.[111,112,113]

In the NZ Scenarios,100% of buildings are retrofitted by 2050, water and space heating systems are all converted to heat pumps, and all natural gas appliances are phased out. By 2050, approximately 804,000 more dwelling units and 10,000 more square meters of non-residential floor space have been

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[110] U.S. Environmental Protection Agency (EPA). 1989. Report to Congress on Indoor Air Quality – Vol. II: Assessment and Control of Indoor Air Pollution. EPA/400/1-89/001C. Washington, D.C.: US EPA.

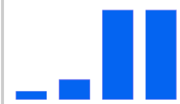
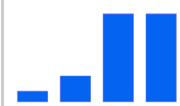
[111] Wu, F., Jacobs, D., Mitchell, C., Miller, D., & Karol, M. H. (2007). Improving Indoor Environmental Quality for Public Health: Impediments and Policy Recommendations. Environmental Health Perspectives, 115(6), 953–957. https://doi.org/10.1289/ehp.8986.

[112] Barton, A., Basham M., Foy C., Buckingham, K., and Somerville, M., on behalf of the Torbay Healthy Housing Group. 2007. The Watcombe Housing Study: the short term effect of improving housing conditions on the health of residents. Journal of Epidemiol Community Health, 61(9):771e7.

[113] Bonnefoy, X. 2007. Inadequate housing and health: An overview. International Journal of Environment and Pollution, 30(3/4), 411. doi: 10.1504/IJEP.2007.014819

retrofitted in the NZ Scenarios compared to Do Nothing. These retrofits result in 93% fewer GJ of fossil fuels being used in residential buildings, and 97% fewer in non-residential buildings.

Table 19. Residential and non-residential buildings retrofit by scenario.

	Do Nothing	BAP	NZ50	NZ40	All scenarios
Dwelling units retrofit					
Dwelling units retrofit (2020-2050) (thousands)	**66**	**182**	**870**	**870**	
% improvement from Do Nothing	-	+175%	+1,200%	+1,200%	
Total GJ of fossil fuels used in residential buildings (2050) (millions)	**78**	**70**	**6**	**6**	
% improvement from Do Nothing	-	-10%	-93%	-93%	
Non-residential buildings retrofit					
Square meters of non-residential building floor space retrofit (2020-2050)	**1,274**	**3,298**	**11,469**	**11,469**	
% improvement from Do Nothing	-	+159%	+800%	+800%	
GJ of fossil fuels used in non-residential buildings (2050) (millions)	**60**	**44**	**2**	**2**	
% improvement from Do Nothing	-	-27%	-97%	-97%	

Social Interactions

In the Net Zero Scenarios, people spend approximately 80 hours walking and cycling annually in 2050.[114] This is just over three times greater than the 26 hours spent in the Do Nothing Scenario in 2050. Time spent outside walking and cycling increases the number of conversations and connections amongst residents, which can increase individuals' mental health, sense of community within a neighbourhood, and neighbourhood safety.[115]

[114] This estimate is calculated based on a walking rate of 4 km/h and a cycling rate of 15 km/h.

[115] Shliselberg, R., & Givoni, M. (2018). Motility as a policy objective. Transport reviews, 38(3), 279-297.

10.2 Economic Prosperity

Local Economy

Economic impacts of the NZ Scenarios have been discussed in detail in the Financial Analysis section. Overall, the NZ Scenarios result in $140 billion (NZ50) and $146 billion (NZ40) in investments over the next 30 years compared to the Do Nothing Scenario. These lead to 1.25 million and 1.26 million new person years of employment, respectively. In addition to this, local businesses see a 32% decrease in fuel costs to heat and cool their buildings due to efficiency improvements, freeing up money for other purposes such as improving business competitiveness or for reinvestment in the economy.

Reduced household costs for energy and transportation also represent opportunities for residents to spend money locally, resulting in more resilient neighbourhoods. Other benefits to the local economy are seen from changing travel patterns and modes in the NZ scenarios, resulting in more visits and spending at local shops.[116] Providing free transit, as is done in the NZ scenarios, has been shown to result in an increase in leisure and shopping trips,[117] while businesses have also seen increased retail sales from the addition of nearby bike lanes.[118]

Table 20. Comparison of local economy metrics across the four scenarios

	Do Nothing	BAP	NZ50	NZ40	All scenarios
Capital investments					
Capital investments over Do Nothing (NPV at 3%) (2020-2050)		**$31 billion**	**$140 billion**	**$146 billion**	
Jobs added					
Person years of employment generated over Do Nothing (2020-2050)		**0.66 million**	**1.25 million**	**1.26 million**	
Non-residential buildings fuel costs					
$/m2 non-residential floor	**$30**	**$26**	**$22**	**$22**	

[116] Klemmer, K., Brandt, T., & Jarvis, S. (2018). Isolating the effect of cycling on local business environments in London. PloS one, 13(12), e0209090.

[117] Bull, O., Muñoz, J. C., & Silva, H. E. (2021). The impact of fare-free public transport on travel behavior: Evidence from a randomized controlled trial. Regional Science and Urban Economics, 86, 103616. https://doi.org/10.1016/j.regsciurbeco.2020.103616

[118] New York City Department of Transportation. 2012. Measuring the Street: New Metrics for 21st Century Streets. Department of Transportation, City of New York, NY. https://nacto.org/wp-content/uploads/2015/04/measuring_the_street_nyc_dot.pdf

	Do Nothing	BAP	NZ50	NZ40	All scenarios
space yearly fuel costs (2050) % improvement from Do Nothing	-	-21%	-32%	-32%	

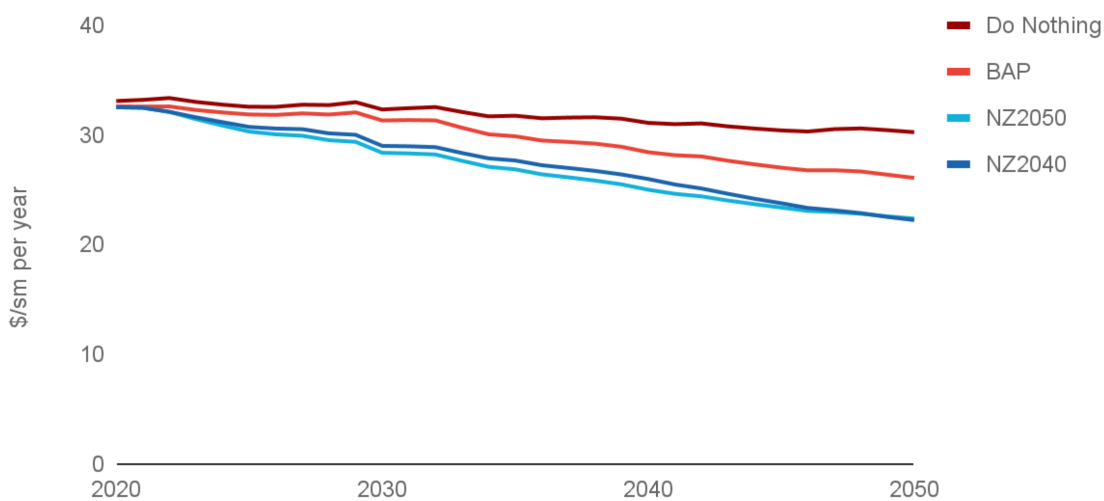


Figure 64. Yearly fuel costs per m2 of floor space for non-residential buildings, 2020-2050.

Cost of Living

GHG reduction measures result in reduced household energy costs as buildings are built and retrofitted to be more energy efficient. NZ Scenario household energy costs are nearly 50% less in 2050 compared to the Do Nothing Scenario. Transportation costs are also reduced in the NZ Scenarios, as more automobile trips are replaced by walking, cycling, and transit trips and as transit becomes free. Transportation costs decrease from $214 per household per month in the Do Nothing Scenario to just $23 per month in the NZ40 Scenario. Taken together, this results in a 77% decrease in household monthly energy expenditures in the NZ Scenarios compared to Do Nothing by 2050, an average reduction of nearly $2,850 per household per year when transit fares are considered, or $1,030 per household per year when transit fares are not considered.

Table 21. Comparison of household fuel expenditures in 2050, across the scenarios.

	Do Nothing	BAP	NZ50	NZ40	All scenarios
Household energy and transportation costs					
Household average monthly energy expenditures (2050) % improvement from Do Nothing	**$97** -	**$90** -8%	**$50** -48%	**$50** -48%	

	Do Nothing	BAP	NZ50	NZ40	All scenarios
Household average monthly travel costs (transit plus vehicle fuel) % improvement from Do Nothing	**$214** -	**$167** -22%	**$24** -89%	**$23** -89%	
Household total monthly travel and energy expenditures % improvement from Do Nothing	**$311** -	**$257** -17%	**$74** -76%	**$73** -77%	

Households across the City experience a reduction in annual household (dwelling) energy costs (home energy and vehicle fuel) of between $500 and $1,000 by 2050, with a small number of zones experiencing reductions between $1,000 and $2,000. Figure 65 indicates that household energy cost reductions (dwelling) are generally between $500 and $1,500 per year by 2050 in the City.

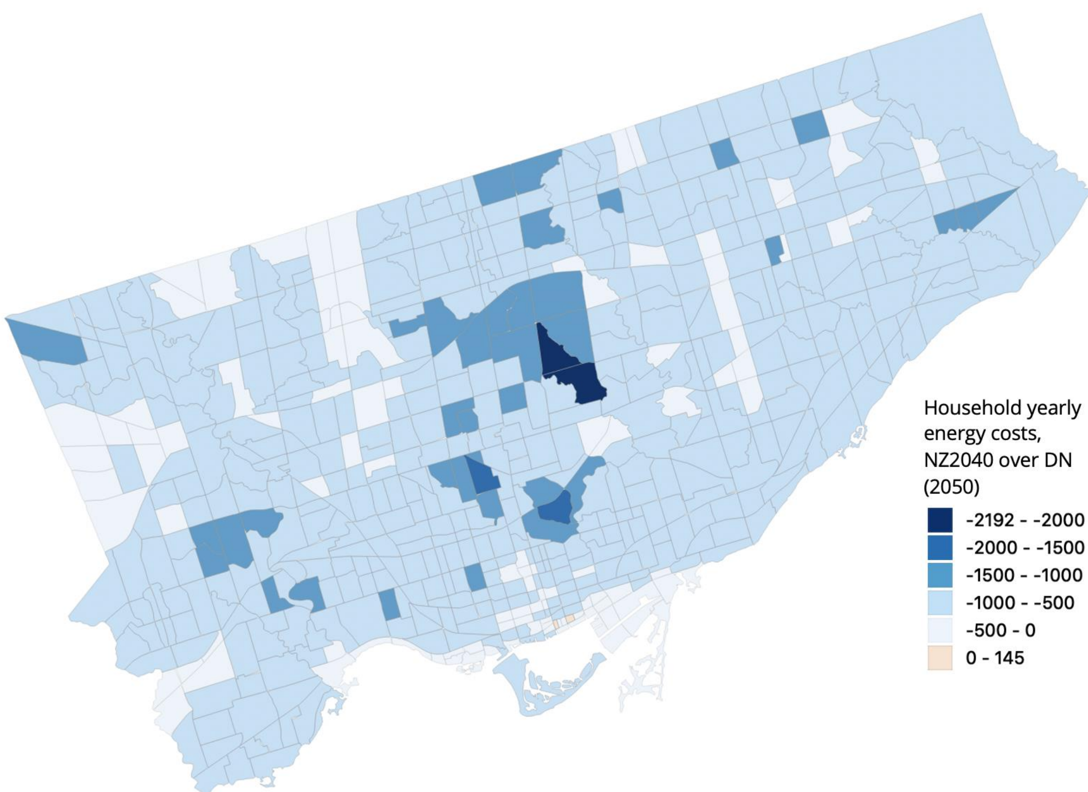


Figure 65. Change in household yearly energy costs (home energy and vehicle fuel) in the NZ40 Scenario over the Do Nothing Scenario (2050). The darkest zones show the greatest decrease.

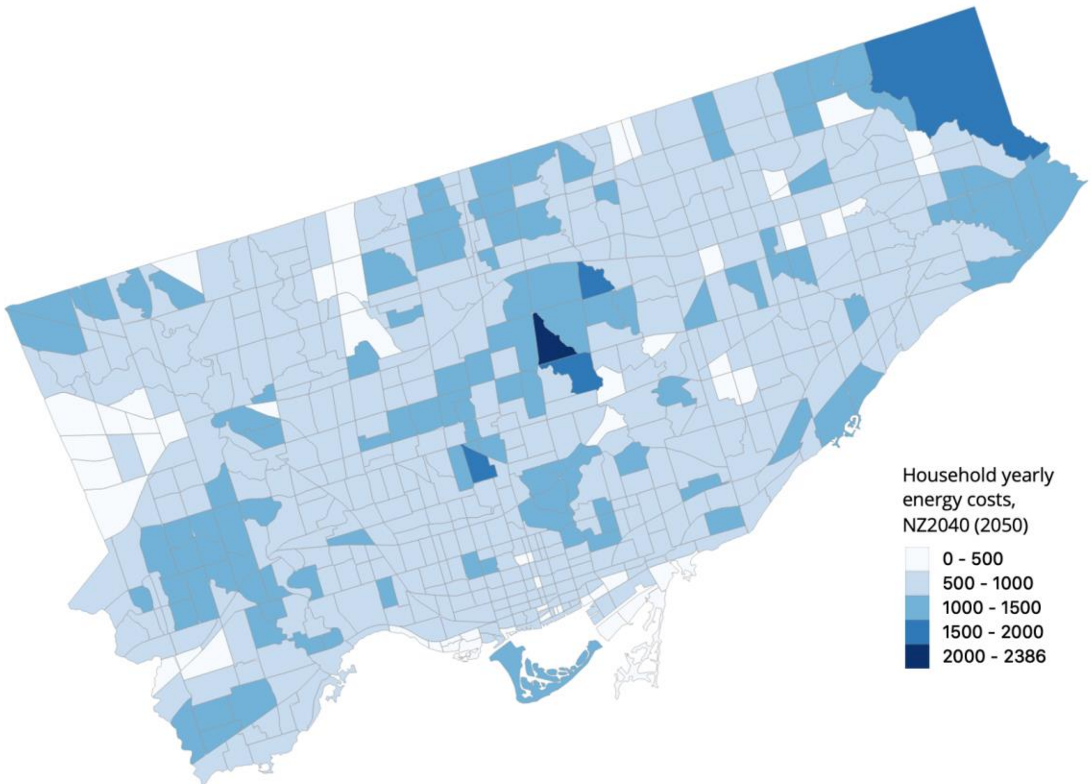


Figure 66. Household yearly energy costs in the NZ40 Scenario (2050).

Municipal Finances

The table below summarizes net municipal costs across the four scenarios. It is important to note that these numbers were drawn from city-wide analysis and thus are broad estimates. A detailed analysis of corporate actions, investments and savings should be undertaken to gain further insights. The costs included in this calculation of municipal finances are: transit infrastructure capital costs (assuming 27% of total investments are incurred by the City, the rest are from Provincial, Federal or other sources), transit bus maintenance and fuel costs, transit revenues, transit vehicle capital costs, wastewater and water treatment, waste management, and road toll revenues. Costs and savings related to: new buildings, building retrofits, renewable energy investments are not included (these are aggregated into the city-wide commercial numbers), nor are costs for staff time for development and deployment of programs to deliver the actions. By 2050, costs increase by approximately $2.2 billion in the Net Zero Scenarios compared to Do Nothing.

Table 22. Comparison of net municipal costs across the scenarios.

	Do Nothing	BAP	NZ50	NZ40	All scenarios
Municipal costs					
Net municipal costs ($billions) (2050)	**-0.08**	**0.8**	**2.16**	**2.16**	
Net municipal costs ($billions) (2020-2050)	**5.3**	**25.6**	**41.3**	**41.0**	

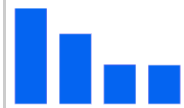
10.3 Biodiversity

Ecosystem Encroachment

All forms of energy generation, including renewables, require land[119] which could otherwise be used to maintain biodiversity or for agriculture or forestry. This land, known as the energy footprint, is required for exploration, fuel extraction, generation, transmission, distribution, and is primarily located outside of Toronto's geographic borders. For example, the energy footprint traces the land use impact of gasoline to the oil sands, or the source of natural gas to shale formations or the source of electricity to wind farms. Through reduced fossil fuel consumption and efficiency gains, the latter of which reduces the capacity required, the NZ scenarios result in an energy footprint 1,392 km2 smaller than that of the Do Nothing scenario—an area more than double the size of the City of Toronto.

[119] Calculated using factors from: *McDonald, R. I., Fargione, J., Kiesecker, J., Miller, W. M., & Powell, J. (2009). Energy Sprawl or Energy Efficiency: Climate Policy Impacts on Natural Habitat for the United States of America. PLoS ONE, 4(8), e6802.*

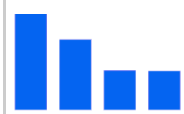
Table 23. Comparison of energy footprint associated with the different scenarios, 2050.[120]

	Do Nothing	BAP	NZ50	NZ40	All scenarios
Energy footprint					
Land area associated with energy production (km2) (2050) % improvement from Do Nothing	**2,292** -	**1,645** -28%	**911** -60%	**900** -61%	

Habitat Connectivity

As development continues throughout the GTA, so too does the importance of preserving and restoring local habitats and biodiversity. The BAP and NZ Scenario targets align with the City's Strategic Forest Management Plan goal of increasing tree canopy cover in the city from 30% to 40%. Additional benefits of increased tree canopy and greenery in cities can include improvements to mental health, reduced heat island effect, improved air quality, and improved stormwater infiltration during extreme rainfall events.[121]

Table 24. Comparison of tree canopy cover across the scenarios.

	Do Nothing	BAP	NZ50	NZ40	All scenarios
Energy footprint					
Tree canopy cover (2050) % improvement from Do Nothing	**30%** -	**40%** +33%	**40%** +33%	**40%** +33%	

10.4 Equity

While consideration of equity is woven through the sections above, this section addresses specific equity considerations.

[120] Note that this is a rough approximation and does not include district energy or hydrogen in the calculation.

[121] Santamouris, M., & Osmond, P. (2020). Increasing green infrastructure in cities: Impact on ambient temperature, air quality and heat-related mortality and morbidity. Buildings, 10(12), 233.

Intergenerational Equity

Climate change represents a burden on future generations, which increases the longer that action is delayed. Recent years have seen increased demand from youth for government action on climate change, including school walk-outs, protests, and lawsuits against their governments for inaction on climate change.[122]

The social cost of carbon (SCC) has been used in regulatory processes in Canada and the US to reflect the impacts of climate change on society. The SCC attempts to add up the quantifiable costs and benefits of a tonne of carbon dioxide on society, incorporating assumptions around future conditions such as population size, economic growth, rate of climate change, and the impact of climate change on these conditions.

The cumulative cost of the Do Nothing Scenario between 2020 and 2050 using the Social Cost of Carbon (SCC) is $94 billion. Under the BAP, this declines to $76 billion. Under the NZ40, it declines to $35 billion, as illustrated in Figure 68.[123]

Impacts on Low-income Population

Climate change is affecting individuals and communities at varying rates and to varying degrees.[124] Climate change is amplifying vulnerability and hindering adaptive capacity of persons with low incomes, Aboriginal Peoples, LGBTQ2S communities, undocumented individuals, immigrants and refugees, diverse women, seniors, children, persons with disabilities, and racialized groups. These groups often lack power as well as access to resources, adequate urban services, and reliable infrastructure. For example, poverty and marginalization not only leave people vulnerable to rising food, water, and energy prices, but also limit their ability to invest in resources and prepare for the impacts of climate change. Following a disaster, it is much harder for low-income and marginalized communities to rebuild, as these groups are less likely to have the social capital and resources to do so.

The figure below shows the decrease in household energy costs, which occurs in nearly every zone across the city. Neighbourhoods with the greatest populations of low-income individuals are highlighted. These areas see reductions of up to $2,000 in yearly household energy costs in the NZ40 Scenario compared to Do Nothing Scenario. Ensuring that the benefits of these savings reach low-income populations (for example, renters rather than building owners), however, is dependent on policies to ensure that this occurs. Similarly, programs to provide or assist with capital for renewable energy and energy efficient construction and retrofits for low-income earners and housing will also be important to ensure that they can participate in and reap the benefits of the low-carbon transition.

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[122] Our Children's Trust. (2016). Landmark US federal climate lawsuit. Retrieved November 14, 2016, from https://www.ourchildrenstrust.org/us/federal-lawsuit/

[123] All values used the 3% discounting rate, 95th percentile which reflects higher than expected economic damages from climate change. Interagency Working Group on Social Cost of Greenhouse Gases, United States Government, 2021. Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990. Retrieved from: https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

[124] Rudolph, L., Gould, S., and Berko, J. "Climate Change, Health and Equity: Opportunities for Action." Oakland, CA: Public Health Institute, 2015. https://www.phi.org/uploads/application/files/h7fjouo1i38v3tu427p9s9kcmhs3oxsi7tsg1fovh3yesd5hxu.pdf.

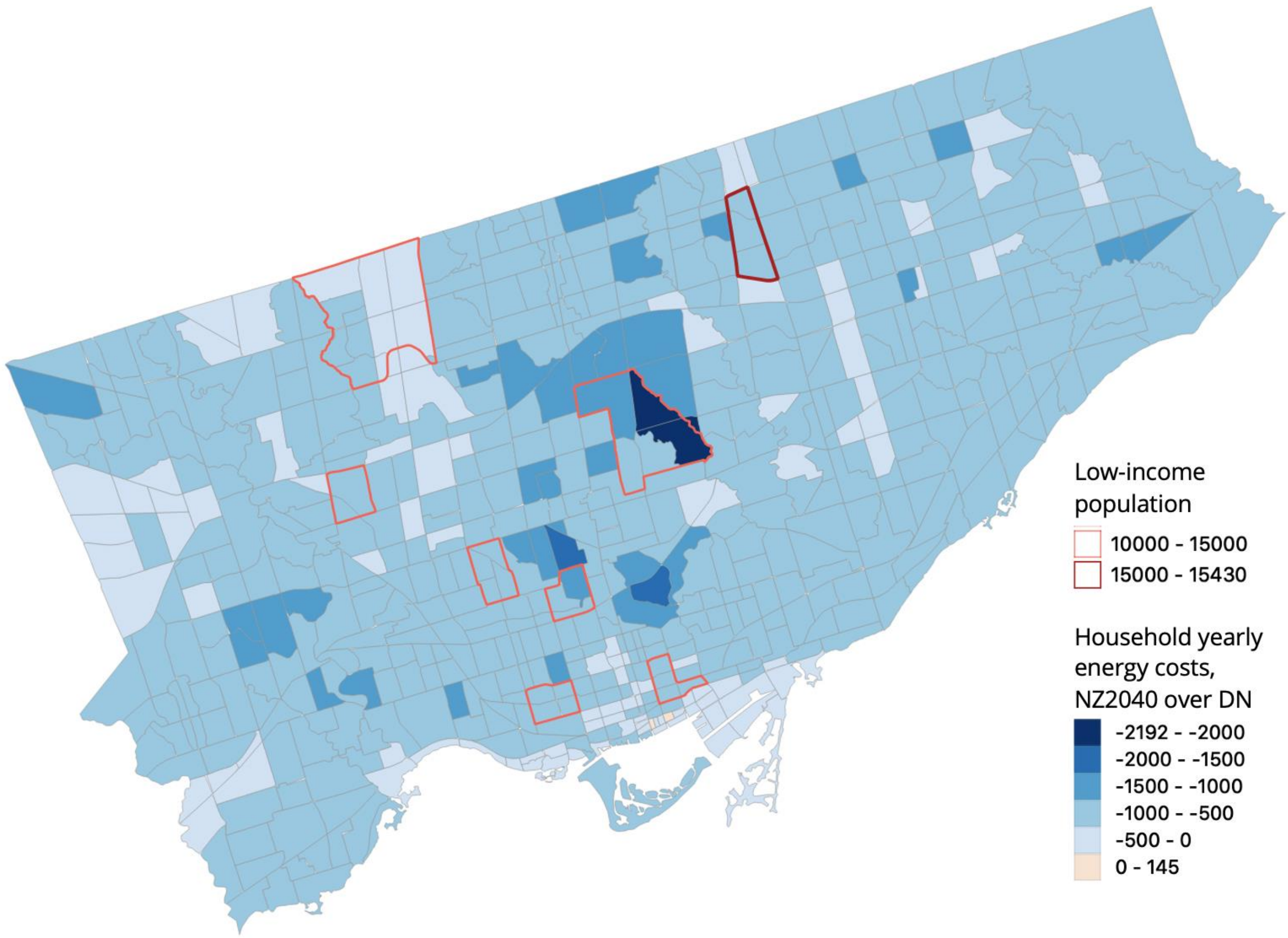


Figure 67. Change in yearly household energy costs (vehicle fuel and home energy) in the NZ40 scenario compared to Do Nothing in 2050. Neighbourhoods housing low-income populations greater than 10,000 people are highlighted. In nearly every zone, energy costs decrease, to a maximum of $2,192/year saved, which occurs in a low-income neighbourhood. Savings are even greater when the impact of free transit is also considered.

Transit and Active Travel Accessibility

The NZ Scenarios call for significant investments in transit, including converting one lane of traffic to exclusive bus lanes on all arterials, increased service frequency on all transit routes (bus by 70%, streetcar by 50%, subway off-peak service to every 3 minutes), and expanding the rapid transit network. The cost of making transit free in the NZ Scenarios is partially offset by tolls of $0.66/km on all arterial roads. As a result, alongside increases in active transportation (see the previous section on physical activity), per-household transportation costs decrease by 76%. This is even more significant for people who do not own a car and for whom costs are reduced by 100%. From an equity perspective, this is significant, as it frees up money for low-income populations to meet other needs and provides them with access to services and job opportunities that might have otherwise been out of reach. Infrastructure investments need to be distributed and directed to low-income areas to ensure that these benefits do in fact reach low-income residents.

Quality Affordable Housing

In 2010, 44% of renter households and 28% of owner households faced affordability issues in the City of Toronto.[125] Households facing energy poverty or energy insecurity face challenges such as "pay the rent or feed the kids", "heat or eat", or "cool or eat".[126] Low-income households stand to benefit greatly from the improved housing quality and energy cost savings resulting from the NZ Scenario actions. Affordable housing units and units occupied by low-income earners in Toronto are more likely to be in need of repair,[127,128] with these buildings often being older, less energy efficient, and lacking proper ventilation.

In the NZ Scenarios, 100% of dwelling units are retrofit to net zero standards, presenting opportunities for improved health and living conditions for residents, and energy savings for households. Prioritizing retrofit of affordable and low-income housing, particularly that which is in need of repair, can help to improve the living conditions of Torontonians who need this most. Energy retrofits can result in improved thermal satisfaction, fewer reported financial difficulties, increased satisfaction among participants with the repair of their homes, fewer reported housing-related problems and more social interactions.[129] Care will need to be taken to ensure that adverse impacts from these efforts, such as increased housing costs or rents, are managed or avoided. Focussing retrofit initiatives on low-income households will mean the financial and health benefits from the NZ actions are seen sooner for those in need.

Retrofits can also increase the resilience of affordable housing by incorporating measures for extreme heat and power outages. Relative death rates can begin to increase at temperatures as low as 20°C, rates which are influenced by pre-existing health conditions, social isolation, living conditions and other factors.[130] A 2010 survey found that 15% of Toronto residents do not have air conditioning, and for those with low incomes, 33% did not have air conditioning.[131] Deep retrofits can increase the passive survivability of the dwelling while the installation of electric heat pumps provides cooling.

[125] City of Toronto. (2016). Housing and health: Unlocking opportunity.

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

[127] Pagliaro, J, 2017. Half of Toronto Community Housing homes to hit 'critical' status within five years. Toronto Star. https://www.thestar.com/news/city_hall/2017/05/23/half-of-toronto-community-housing-homes-to-hit-critical-status-within-five-years.html

[128] Paradis, E., Wilson, R., Logan, J., 2014: Nowhere Else to Go: Inadequate Housing & Risk of Homelessness Among Families in Toronto's Aging Rental Buildings. University of Toronto Cities Centre. https://www.homelesshub.ca/sites/default/files/Paradis%20Homelessness%20Executive%20summary.pdf

[129] Poortinga, W., Rodgers, S. E., Lyons, R. A., Anderson, P., Tweed, C., Grey, C., … Winfield, T. G. (2018). The health impacts of energy performance investments in low-income areas: a mixed-methods approach. Public Health Research, 6(5), 1–182. https://doi.org/10.3310/phr06050

[130] Health Canada. (2012). Extreme heat events guidelines: technical guide for health care workers. Ottawa.

[131] City of Toronto. (2015). Reducing health risk from extreme heat in apartment buildings.

Global Equity

Climate change is directly killing people.[132] A recent paper in Nature developed a new metric, the mortality cost of carbon (MCC), which quantifies the number of deaths per ton of GHG emissions released in 2020.[133] Adding 4,434 tons of carbon dioxide in 2020 causes one excess death globally in expectation between 2020-2100. Using this number, the NZ40 scenario results in 59,539 fewer deaths globally than the Do Nothing scenario. As the authors point out, not all people have an equal impact- the lifetime emissions of 3.5 Americans cause one excess death globally in expectation between 2020 and 2100, the same impact that results from the lifetime emissions of 100 Indians.

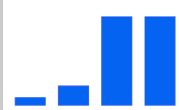
10.5 Safety & Resilience

Resilience to Outages and Climate Impacts

Many GHG mitigation efforts have been shown to increase adaptive capacity to the impacts of climate change. These synergies exist at many levels.[134] While all these benefits are not captured here, some key improvements to resilience in the city from the NZ scenarios include:

- safer buildings during extreme weather events (flooding, extreme heat/cold) from older buildings having been retrofitted,
- decreased impacts of power outages from homes having been fitted with renewable energy and storage systems,
- decreased impacts of power outages for homes that are connected to district energy systems,
- decreased stress on water and wastewater systems from retrofits and more stringent efficiency standards for new buildings,
- decreased heat island effect and flood stress from greater tree canopy cover, and
- increased back-up power from EVs.

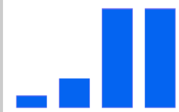
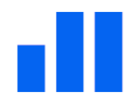
Table 25. Residential and non-residential buildings retrofit by scenario

	Do Nothing	BAP	NZ50	NZ40	All scenarios
Dwelling units retrofit					
Dwelling units retrofit (2020-2050) (millions)	**0.39**	**0.99**	**4.6**	**4.6**	
% improvement from Do Nothing	-	+156%	+1,090%	+1,090%	

[132] Mitchell, D. (2021). Climate attribution of heat mortality. Nature Climate Change, 11(6), 467-468.

[133] Bressler, R. D. (2021). The mortality cost of carbon. Nature Communications, 12(1), 1-12.

[134] Klein, R.J.T., S. Huq, F. Denton, T.E. Downing, R.G. Richels, J.B. Robinson, F.L. Toth, 2007: Inter-relationships between adaptation and mitigation. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 745-777.

	Do Nothing	BAP	NZ50	NZ40	All scenarios
Non-residential buildings retrofit					
Non-residential buildings retrofit (2020-2050) % improvement from Do Nothing	**1,274** -	**3,298** +159%	**11,469** +800%	**11,469** +800%	
Backup power					
MW of storage with solar PV (2050) % improvement from Do Nothing	**0.1** -	**0.1** 0%	**2,000** >1,000%	**2,000** >1,000%	
# of EVs (2050) % improvement from Do Nothing	**0.35 million** -	**1.62 million** +363%	**1.65 million** +371%	**1.65 million** +371%	
Decentralized energy					
#of district energy systems / m2 of floor space served by DE (2050) % improvement from Do Nothing	**6** **9.5M m²** -	**8** **9.8M m²** +33% +3%	**8** **10.8M m²** +33% +14%	**8** **10.8M m²** +33% +14%	

Cycling and Pedestrian Safety

Cycling and pedestrian safety is improved in the NZ Scenarios by:

- increasing cycling and pedestrian infrastructure to provide safer travel and crossings,
- fewer opportunities for collisions with vehicles as VKT decrease, and
- a "safety in numbers" effect from a greater prevalence of pedestrians and cyclists on roads.[135]

The table below shows that the NZ Scenarios result in 2,140 more kilometers of cycling/multi-use trails and 108 more kilometers of sidewalks compared to the Do Nothing Scenario.

[135] Fyhri, A., Sundfør, H., Bjørnskau, T., & Laureshyn, A. (2017). Safety in numbers for cyclists—conclusions from a multidisciplinary study of seasonal change in interplay and conflicts. Accident Analysis & Prevention, 105, 124–133. https://doi.org/10.1016/j.aap.2016.04.039

Table 26. Kilometers of cycling lanes and sidewalks added by scenario, 2020-2050.

	Do Nothing	BAP	NZ50	NZ40	All scenarios
Cycling lane kilometers added					
Kilometers of cycling/multi-use paths added (2020-2050)	-	**1,200**	**2,140**	**2,140**	
Kilometers of sidewalks added					
Kilometers of sidewalks added (2020-2050)	-	**90**	**108**	**108**	

11. Implementation

This section provides key insights for the City as it begins implementing its Net Zero Strategy. These insights have been used in the development of the Net Zero Strategy, which details the City's key implementation actions and targets over the next decade.

11.1 The Question of Feasibility

The City has posed the question as to whether or not achieving net zero by 2040 is feasible. Broadly speaking, feasibility is defined as whether something can be made, done, or achieved. The modelling demonstrates that there is a pathway for Toronto to achieve NZ40 in physical terms. The pathway also provides a number of insights with respect to feasibility:

1. **The pathway is technologically feasible:** The core of the actions evaluated rely on current technologies; in other words, there are no magic or untested solutions that contribute to the NZ40 pathway. Note that we did include some emerging technologies, such as green hydrogen, but they are not critical to the pathway, and technological developments could speed up the pathway even more.
2. **The financial resources can be mobilized:** The investment required is approximately 5% of the City's GDP for a decade, or significantly less if the investments are amortized. In addition, many of these investments generate returns. The mechanisms for mobilizing these investments and which entity makes the investment will influence the timing and scale of funds that can be raised.
3. **Political will is required:** The implementation of the NZ40 pathway will require new and innovative policies which will disrupt the status quo. Given the lag time to develop and deliver policies, there is no time to delay

4. **The grid needs to decarbonize:** The emissions intensity of the provincial electricity grid is currently projected to increase. For the city to get to zero, the grid needs to become clean by 2040. Failing this, the city can rely on the "net" part of the target and purchase carbon offsets or renewable energy certificates, both of which add to the costs of the pathway and deliver limited co-benefits.

There are other conditions that will need to be satisfied in order to implement the NZ40 pathway:

1. **Action must begin now**: The NZ40 pathway requires ambitious action to begin as early as 2021. Swift action not only allows financial benefits to accrue sooner and results in fewer GHG emissions released in the long run, but also sets the stage for actions' ambition to ramp up as the target year approaches and for the City to ultimately meet it by 2040.
2. **The electricity system needs to be adapted:** In addition to decarbonizing the grid, the electricity system needs to be able to adapt to new loads as heating and transportation are electrified. At a high level, the NZ40 scenario mitigates this challenge by emphasizing efficiency first to minimise the increase in annual electricity consumption; however, hourly peaks will vary.
3. **The labour market must shift:** The skills mix and capacity of the labour force will need to scale up rapidly in order to deliver the actions in NZ40.
4. **New and innovative delivery mechanisms must be adopted:** Conventional delivery mechanisms are likely too slow and costly to deliver the transformation envisioned in NZ40. For example, the model of delivering retrofits one house at a time will need to be replaced by a bulk retrofit program.
5. **Impacts on material and land resources should be accounted for:** The economy will need to produce large numbers of electric vehicles and deliver building retrofits and renewable energy in short order. In addition to supplying or manufacturing these resources, there are also material requirements for concrete, wood, insulation, batteries, and land. The environmental, social, and economic implications will need to be carefully considered to ensure that there is not a negative feedback that stimulates additional GHG emissions.

11.2 A Carbon Budget for the City of Toronto

The historical practice of carbon management has been to identify GHG emissions reduction targets for specific years, such as targets set for 2030 and 2050. The more recent emerging paradigm, however, indicates that every tonne of GHG matters and, therefore, the trajectory of GHG emissions, not just the end point, needs to be managed. The City of Toronto's Climate Emergency Declaration (2019.MM10.3) also includes direction to investigate and report back on the feasibility of creating a carbon budget for the City of Toronto to aid in the implementation of TransformTO.[136]

A carbon budget provides a theoretical limit to the total GHG emissions that a community or organization can produce; the budget is directly aligned with the remaining global carbon budget for

[136] Declaring a Climate Emergency and Accelerating Toronto's Climate Action Plan. MM10.3. October 2, 2019. Retrieved from: http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2019.MM10.3

1.5°C of warming. Governments and cities around the world, such as the United Kingdom, the City of Oslo, and several Canadian cities, are implementing self-imposed carbon budgets.

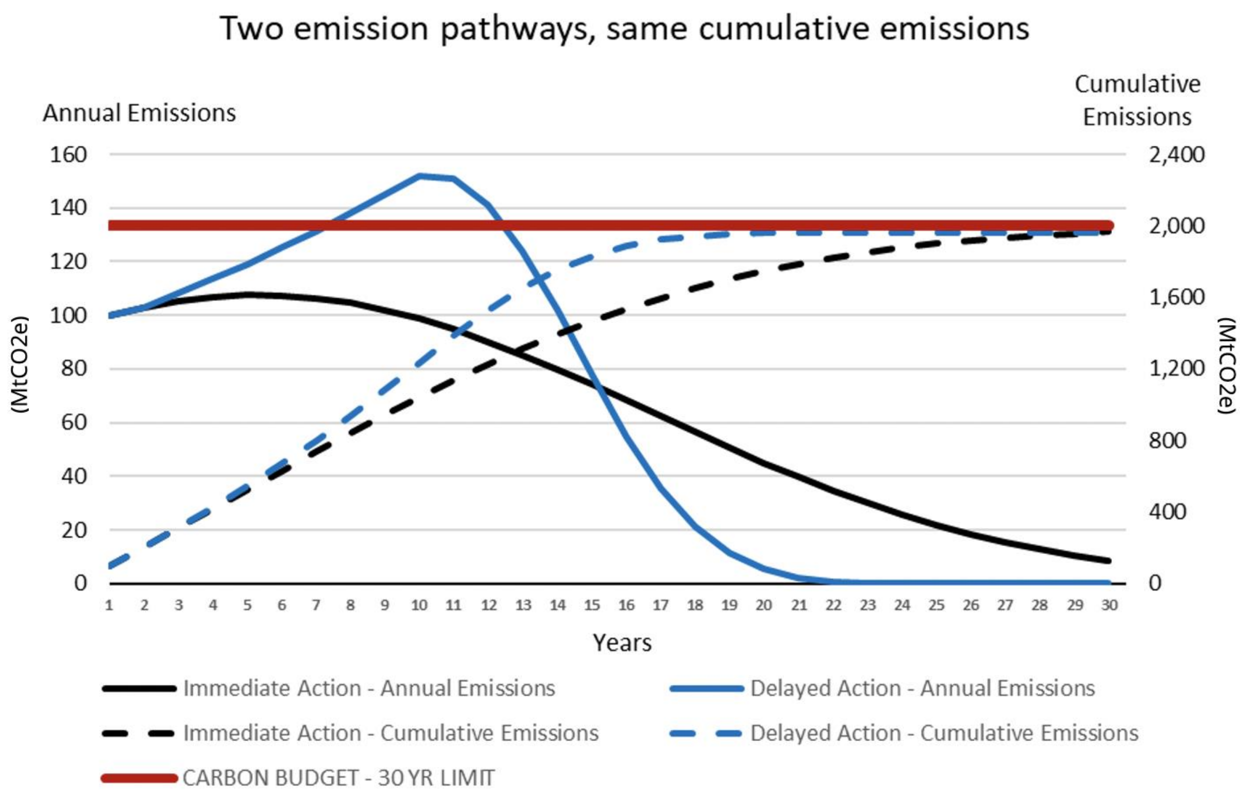


Figure 68. Hypothetical illustration for delayed versus immediate GHG mitigation reductions towards meeting a carbon budget.

Figure 68 demonstrates how a carbon budget can act as a key climate action planning tool. Both pathways result in the same cumulative emissions over the 30-year period; however, by year 15, the delayed action pathway has spent 90% of the carbon budget compared to only 70% for the pathway with immediate action. The delayed mitigation scenario results in GHG emissions continuing to grow until they peak around Year 11, at which time steep reductions are required to stay within the carbon budget. The scenario with significant immediate mitigation action, on the other hand, results in a more gradual transition.

Toronto's Carbon Budget

While Council has set 1.5C aligned targets and directed for the investigation into a similarly aligned carbon budget, the City of Toronto has not yet quantified a carbon budget for itself.

There are different methods for quantifying local and global carbon budgets and there is not yet consensus on a single one that should be used. There is consensus, however, that there is a finite amount of GHG emissions that can be released into the atmosphere to avoid catastrophic climate change, and, as discussed above, a carbon budget allows for accountability and transparency in efforts to reach net zero emissions. The NZ40 scenario results in 178 $MtCO_2e$, which can be used as a proxy for the city's carbon budget. At 2019 levels of emissions, this total would be exceeded in 12 years. The total remaining consumption of gasoline and natural gas ("gasoline and natural gas budgets") can also be quantified in the NZ40 scenario. Remaining natural gas and gasoline equals less than 9 years of consumption of gasoline and natural gas at current rates.

Table 27: Carbon and energy budgets.

Budgets (2021-2050)	Total cumulative emissions	Number of years left at current rates	Natural gas	Gasoline
Do Nothing	442 $MtCO_2e$		4.01 billion GJ	1,616 million GJ
Business as Planned	364 $MtCO_2e$		3.50 billion GJ	972 million GJ
Carbon (NZ50 scenario)	224 $MtCO_2e$		1.49 billion GJ	856 million GJ
Carbon (NZ40 scenario)	178 $MtCO_2e$	12.5	1.15 billion GJ	520 million GJ
Remaining natural gas	1.15 billion GJ	8.3		
Remaining gasoline	520 million GJ	8.8		

11.3 Integrating Climate Resilience

The City's 2019 Resilience Strategy recommended that future TransformTO updates bring together climate mitigation and adaptation more systematically to maximize efficiencies and cost effectiveness. Climate resilience is often used interchangeably with adaptation; however, the City's framework views climate resilience as a state, ability, or capacity to anticipate, reduce, accommodate, or recover from the effects of climate-related events, stresses, and acute shocks. Adaptation is the process by which the City can build climate resilience.

Climate adaptation and mitigation are inherently integrated in the sense that mitigation efforts to reduce emissions will help moderate climate impacts now and into the future. As such, investing in mitigation today lowers the costs and extent of adaptation and resilience in the future. Immediate and near-term policy decisions will determine the level of climate risk that the City of Toronto and jurisdictions around the globe will be exposed to. Similarly, planning and investing in adaptation action now will reduce further impacts and costs as the City's climate changes.

The City can integrate climate mitigation and adaptation efforts and investments to maximize effectiveness and minimize overall risks. There are four types of adaptation-mitigation interactions:

1. **Mal-Investments:** Actions that can be undone or are made less effective by the impacts of climate change if they do not create sufficient resilience (e.g., building new infrastructure in an area prone to flooding).

2. **Trade-offs:** Actions with conflicting effects on mitigation and adaptation (e.g., diesel back-up power or increased air-conditioning units).

3. **Piggybacking:** Actions that are complementary when designed and implemented together (e.g., adding adaptation measures to a mitigation initiative).

4. **Synergies:** Actions that reduce both GHG emissions and climate risk (e.g., investments in new and enhanced green or natural infrastructure).

There are many opportunities for linking the City's Net Zero Strategy and the Resiliency Strategy, including investments in green infrastructure and resilient local energy systems. For example, diversified community energy planning not only reduces GHG emissions, it can also reduce the risk of system failure during extreme storm events.

Toronto's Resilience Strategy recommendations should be integrated into the planning and implementation of its Net Zero Strategy as follows:

1. **Neighbourhood resilience, community energy systems, and energy efficiency:** Develop a bottom-up community resilience approach to enhance and build the capacity of communities to become more resilient to climate impacts and more energy efficient. This approach should include an equity lens that identifies the City's most climate vulnerable neighbourhoods.

2. **Emergency management and infrastructure planning:** Emergency management and risk reduction strategies should be implemented into infrastructure planning during the implementation of new climate mitigation actions.

3. **Climate resilience and retrofitting initiatives:** Integrate climate resilience into ongoing building and tower retrofitting by including resilience to heat, flooding, and extreme events as core components of retrofit objectives.

4. **Critical infrastructure risk and vulnerability:** The City depends upon a complex network of urban infrastructure, including energy, telecommunications, transportation, water supply, wastewater treatment, solid waste management, buildings, and food systems. This complex network will be transformed as the City implements the Net Zero Strategy. At the same time, investment will be required to ensure that these networks can withstand the impacts of the growing frequency of extreme climate events, as well as the impacts of longer-term climate change.

5. **Codes and standards:** Update existing codes and standards for buildings and infrastructure with climate mitigation and adaptation considerations. These updates can be based on the City of Toronto's Future Weather and Climate Drivers Study and the more recent Climate Atlas of Canada, which provides an updated and common set of future climate projections.

6. **Land-use planning:** Integrate climate mitigation actions, such as energy efficiency and active transportation, as well as actions to build climate resilience, such as restricting development in high-risk areas and enhancing natural land cover, into land-use planning policies and processes. Adapting land-use planning tools for climate mitigation and resilience is one of the most effective ways to enhance climate resilience and implement GHG reductions in the urban landscape.

7. **Asset management:** Integrate climate resilience and mitigation measures into the City's corporate wide Asset Management Framework and Integrated Asset Management Plan to align with Ontario Regulation 588/17. This regulation requires that municipalities consider climate change in the development of asset management policies and planning.

8. **Climate mitigation and resilience lens for capital planning:** Develop and apply a comprehensive guideline for applying a climate lens for capital planning that demonstrates how to implement a climate mitigation and adaptation lens for all City capital projects. The lens could include spatial risk and vulnerability mapping, climate resilience design considerations, equitable distribution of infrastructure, and full lifecycle assessment for GHGs and costs.

9. **Green and blue infrastructure city-wide strategy for climate mitigation and resilience:** develop a coordinated and comprehensive city-wide strategy, that builds on current City efforts and plans, to significantly expand green and blue infrastructure. Green and blue infrastructure play a significant role in reducing heat and flooding impacts by increasing infiltration, reducing runoff, reducing the heat island effect, and providing shading. They also contribute other social and environmental benefits, such as improved air and water quality, space for recreation, physical activity and social interaction, reduce noise pollution, reduce energy demand for cooling, and provide habitat, biodiversity, beauty, and in some cases can provide food. Significant expansion of green and blue infrastructure is needed to address heat and flooding, as well as outdoor spaces for the City's growing population.

10. **Indigenous knowledge:** Integrate Indigenous knowledge systems and collaborate with Indigenous peoples to ensure diverse perspectives and approaches are included in climate action planning.

In 2010, the City developed the Toronto Climate Change Risk Assessment Tool to prioritize actions across the City's divisions with a consistent and robust approach. This was followed by a streamlined version used by the City for a High-Level Risk Assessment exercise undertaken in 2016. According to the City's Resilience Strategy, this process was successful in identifying a preliminary list of risk reduction activities. The Strategy recommended the City undertake a more detailed, spatial risk and vulnerability assessment that would include an interdependencies analysis for critical infrastructure systems. This would be ideally undertaken as soon as possible so it can be integrated into the implementation of the Net Zero Strategy actions. For example, Table 28 provides a preliminary list of potential considerations and actions for the NZ40 scenario actions.

Table 28. Examples of climate resilience considerations for NZ40 scenario actions

Wedge	Wedge description	Climate resilience actions and considerations
Buildings- residential		
Decrease size of new dwellings	30% increase in floorspace intensity from 2016 by 2040 (for all new dwellings).	Integrate climate resilience into policies, codes, and standards for new residential buildings. Integrate climate adaptation actions into land-use planning.
High-performance	100% Tier 2 by 2021. 100% Tier 3 by 2022. 100% tier 4 by 2027.	

Wedge	Wedge description	Climate resilience actions and considerations
new residential buildings		Ensure that policies and codes for retrofits of existing buildings include measures for climate resilience based on the impacts of the changing climate.
Retrofit residential buildings by 2040	Retrofit 100% of existing buildings by 2040. Savings of 15% electricity and 75% thermal energy consumption.	
Residential heat pumps by 2040	Convert 100% of residential water and space heating to heat pumps by 2040.	Appliances and water and space heating should be located in low-risk areas within buildings
Electrify residential appliances by 2040	Phase out residential natural gas appliances by 2040.	
Buildings- industrial		
New industrial buildings improved performance	Industrial new build energy intensity reduction (45% from base year) reached by 2031 and applies to lighting, space heating, and water heating end uses.	New industrial buildings should be located in low-risk areas. Retrofits and new building performance standards should include climate adaptation and resilience measures.
Industrial building retrofits	Retrofit all industrial buildings by 2040 to achieve 50% reduction of industrial energy use intensities for lighting and space and water heating end uses.	
Hydrogen for process heating by 2040	Reduce natural gas consumption by 30% by 2030 and 60% by 2050. Convert 100% of remaining natural gas for process heat to hydrogen by 2040. Capture 90% of waste heat from industry.	
Buildings- commercial		
Decreased office space per employee	Reduced office floorspace per employee by a "mobility factor" of 1.7 (i.e., 20 people per 12 desks), then allocated new commercial floorspace along lines of employment projection. Results in reduced growth in commercial/office floorspace (for new office).	New commercial buildings should be located in low-risk areas. Retrofits and new building performance standards should include climate adaptation and resilience measures.
High performance	100% Tier 2 by 2021. 100% Tier 3 by 2022. 100% tier 4 by 2027.	

Wedge	Wedge description	Climate resilience actions and considerations
new commercial buildings		
Retrofit non-residential buildings by 2050	Retrofit 100% of existing buildings by 2040. Electricity consumption decreases by 15% while thermal energy consumption decreases by 75% compared to 2016 performance.	
Non-residential heat pumps by 2040	100% electric heat pumps for space and water heating in non-residential buildings by 2040.	
Energy		
District Energy	All DE systems are 100% renewable by 2030- natural gas and electric cooling are replaced by RNG and cold water. All of the City's currently planned DE expansions are installed.	District energy systems should incorporate redundancy so they can continue to operate in the event of grid disruptions.
Renewable energy	Wind capacity scaled up to 200 MW by 2050 Onsite battery storage scaled up to 2000 MW by 2050 Ground mount PV on 50% of parking lots 100% of buildings have solar PV installed by 2050, where feasible	Energy storage should be integrated with renewable energy generation to provide localised resilient grids.
Transportation		
Electrify transit by 2040	50% of fleet electric by 2030; 100% by 2040. 100% electrification of GO by 2025.	Develop and apply a climate lens for capital planning that includes spatial risk and vulnerability mapping, climate resilience design considerations, equitable distribution of infrastructure investments that prioritize climate-vulnerable populations, and full lifecycle assessment for GHGs and costs. Develop a bottom-up community resilience approach to enhance and
City fleet 45% electric by 2030	Transition 45% of City-owned fleet to low-carbon vehicles by 2030; 65% GHG reduction by 2030 (from 1990 levels).	
Electrify personal vehicles by 2040	Electrify 100% of personal vehicles by 2040.	
Electrify commercial vehicles by 2040	Electrify 100% of commercial vehicles by 2040.	

Wedge	Wedge description	Climate resilience actions and considerations
Increased bus lanes and service frequency	Convert one lane of traffic to exclusive bus lanes on all arterials. Increase service frequency on all transit routes: bus by 70%, streetcar by 50%, subway off-peak service increased to every 3 mins.	build the capacity of communities to become more resilient to climate impacts and more energy efficient. This approach should include an equity lens that identifies the City's most climate vulnerable neighbourhoods. Integrate climate mitigation actions, such as energy efficiency and active transportation, as well as actions to build climate resilience, such as restricting development in high-risk areas and enhancing natural land cover, into land-use planning policies and processes. Ensure climate risk and vulnerability assessment is integrated into transportation policies, GHG mitigation, and planning.
Road tolls	Tolls of $0.66/km on all arterial roads.	
Free transit	No transit fares.	
Work from home	50% of professional/management/technical and general office/clerical workers in the GTHA work from home on any given day.	
E-bikes	Shift 75% of car and transit trips under 5km to ebikes by 2040.	
Increase walking and cycling	Shift 75% of trips under 2km to walking by 2040.	
Biofuels city fleet	In 2025, begin purchasing renewable diesel for diesel vehicles and equipment (30% renewable diesel for city fleet).	
Biofuel aviation	Aviation runs on 100% low emissions fuels by 2040.	
Biofuel rail	Rail runs on 100% biofuel by 2040.	
Waste/water/ wastewater		
Increase efficiency of water pumps	Increase efficiency of water distribution pumps.	Emergency management and risk reduction strategies should be integrated into infrastructure planning during the implementation of new climate mitigation actions. Ensure climate risk and vulnerability assessment is integrated into waste/water and wastewater management.
Waste diversion Zero by 2050	Increase waste diversion rates beyond the 70% by 2026 target to 95% by 2040.	
Ban landfill organics	Zero organics in landfills by 2025.	

Wedge	Wedge description	Climate resilience actions and considerations
Nature-based solutions/ carbon sequestration		
Increase tree canopy cover	Increase city-wide tree canopy cover to 40% by 2040.	Develop a coordinated and comprehensive city-wide strategy to significantly expand green and blue infrastructure that builds on current City efforts and plans.

11.4 The Cost of Inaction

The impacts and costs of climate change will be determined by how quickly actions are implemented and by how deeply GHG emissions are reduced over the next few years prior to 2030. This is because the cumulative GHGs emitted to the atmosphere determine the degree of global average temperature increase. Over the past several decades, the cost of inaction to address climate change by limiting and reducing GHG emissions has now locked the world into at least 1.5 to 2.0°C temperature increase.

Already, the costs of weather-related disasters, such as floods, storms, and wildfires, have risen in Canada from an average of $8.3 million per event in the 1970s to $112 million per event between 2010-2019. This change represents a staggering 1,250% increase.[137] During the latter time period (2010-2019), total insured losses for catastrophic weather events totalled over $18 billion.

Climate change is driving more extreme weather patterns, resulting in more frequent and more expensive impacts than previous decades. For example, in the last decade, disaster costs have grown from about the equivalent of one per cent of Canada's gross domestic product (GDP) growth to between five and six per cent of annual GDP growth.[138]

These costs demonstrate some of the impacts that previous decades of inaction are now placing on economic growth and well-being today and into the future.

The cumulative cost of the Do Nothing Scenario between 2020 and 2050 is $94 billion based on the Social Cost of Carbon (SCC) . In comparison, the SCC declines to $76 billion in the BAP scenario and to $35 billion in the NZ40 scenario, as illustrated in Figure 69.[139]

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[137] Canadian Institute for Climate Choices. 2020. Tip of the Iceberg: Navigating the Known and Unknown Costs of Climate Change for Canada. Retrieved from: https://climatechoices.ca/wp-content/uploads/2020/12/Tip-of-the-Iceberg-_-CoCC_-Institute_-Full.pdf

[138] Ibid.

[139] All values used the 3% discounting rate, 95th percentile which reflects higher than expected economic damages from climate change. Interagency Working Group on Social Cost of Greenhouse Gases, United States Government (2021). Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990. Retrieved from: https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

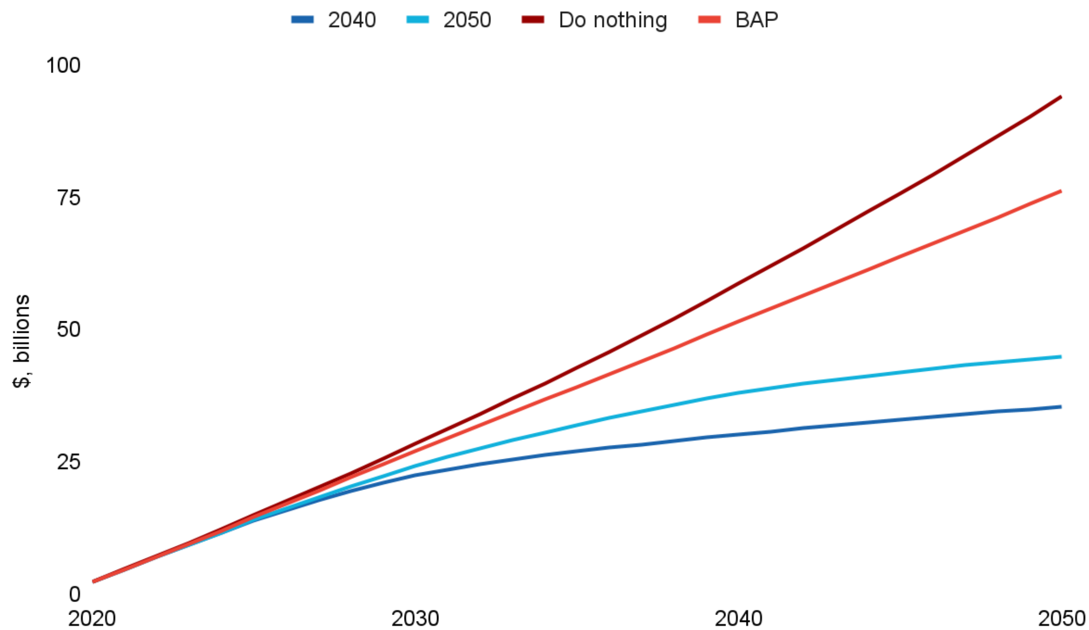

Figure 69. The Social Cost of Carbon (SCC) for all four scenarios, 2020-2050.

The cumulative financial benefits of implementing the NZ40 scenario, with regard to the avoided damage costs of climate change, total $41 billion in comparison to the BAP scenario. And, the cumulative benefits of implementing the NZ40 scenario rather than the NZ50 scenario result in savings of $9 billion in avoided damage costs (Figure 70).

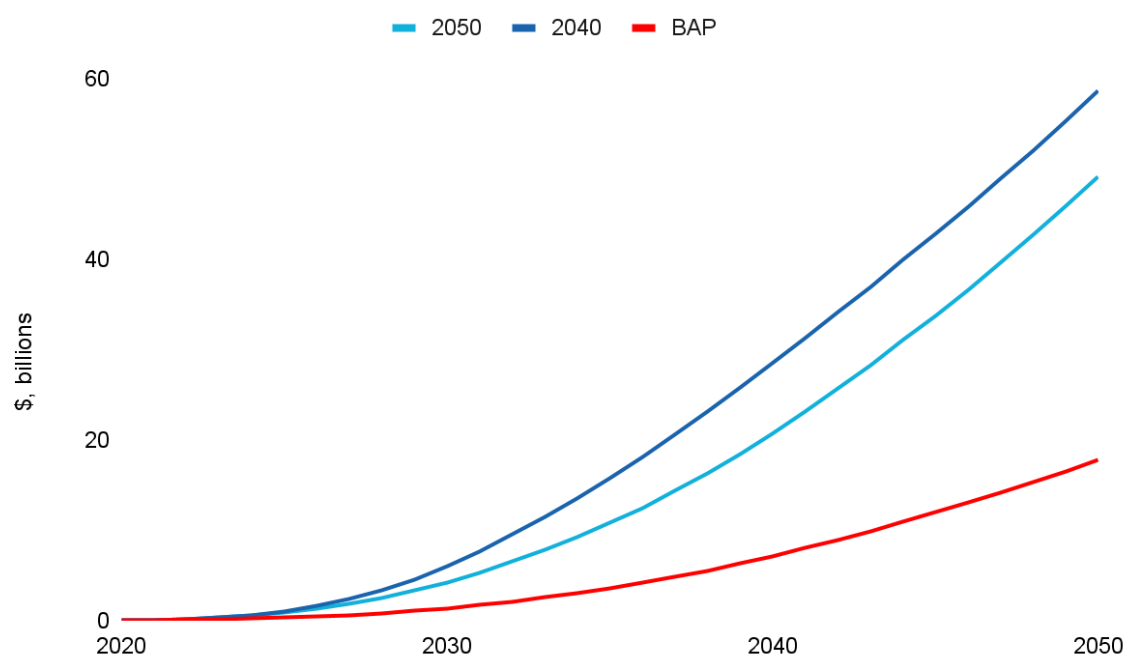

Figure 70. Cumulative benefit of Social Cost of Carbon (SCC), as an indicator of avoided damages of climate change for BAP, NZ40, and NZ50.

Box: The Social Cost of Carbon

The social cost of carbon (SCC) has been used in regulatory processes in Canada and the US to reflect the impacts of climate change on society. The SCC attempts to add up the quantifiable costs and benefits of a tonne of carbon dioxide. While the estimates of SCC are highly uncertain, it is one of the best ways to reflect future damages to ensure that decision-making which has implications for future emissions accounts for those implications. The SCC includes assumptions around future conditions including population size, economic growth, rate of climate change and the impact of climate change on those conditions, drawing on the results of integrated assessment models. The discount rate is a significant assumption within the models. Discounting reflects the idea that people would rather have $100 now than $100 in ten years. From an ethical perspective, a higher discount rate indicates that future generations are worth less than current generations; for this reason, the Stern Review recommended a discount rate of 1.4%, well below traditional discount rates. As Stern pointed out in a subsequent article "A 2% pure-time discount rate means that the life of someone born 35 years from now (with given consumption patterns) is deemed half as valuable as that of someone born now (with the same patterns)." The Government of Canada recommends 3% in circumstances where environmental and human health impacts are involved and 3% was used for Toronto's NZ modelling. In addition, the Government of Canada reports on estimated damage associated with lower probability, high-cost damages, again using a 3% discounting rate. The SCC in this analysis reflects less likely impacts of increased temperatures that result in greater damage, as described within the 95th percentile of the SCC frequency distribution

11.5 Sensitivity

The NZ pathways illustrate how the City of Toronto could achieve its GHG targets; and are built on the assumptions described above in this report. In that light, they reflect what is anticipated to occur in the future if the actions are implemented as described.

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

The process applied a judgement-based "one-at-a-time" exploration of variables within the NZ50 scenario. The results should not be viewed as an evaluation of fully considered alternative futures, rather, it is an exploration revealing how a selected output (i.e. emissions) responds to changes in selected inputs (e.g. VKT).

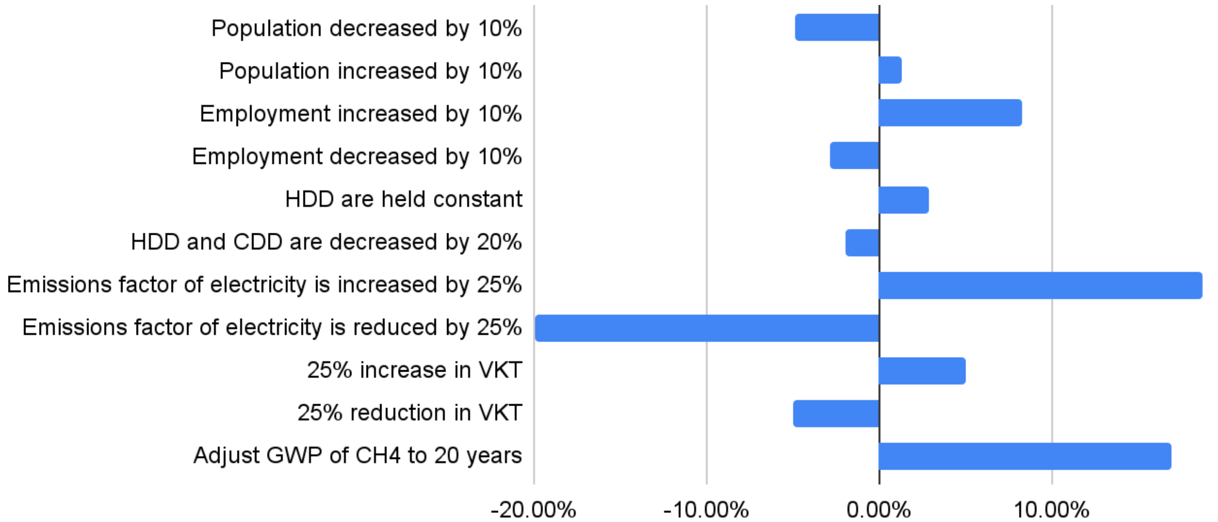

Figure 71. % change in 2050 emissions as a result of adjustments to the variables.

Applying a GWP to methane for 20 years instead of 100 years increases total GHG emissions by more than 1 $MtCO_2e$ per year, while decreasing the emissions factor of electricity reduces emissions by 400 $kTCO_2e$ by 2050. Variation in the emissions factor of electricity defines the outer limits of the variation evaluated, resulting in an overall uncertainty of 37 MtCO23, or 15% of the cumulative 241 $MtCO_2e$ emissions under the NZ50 pathway.

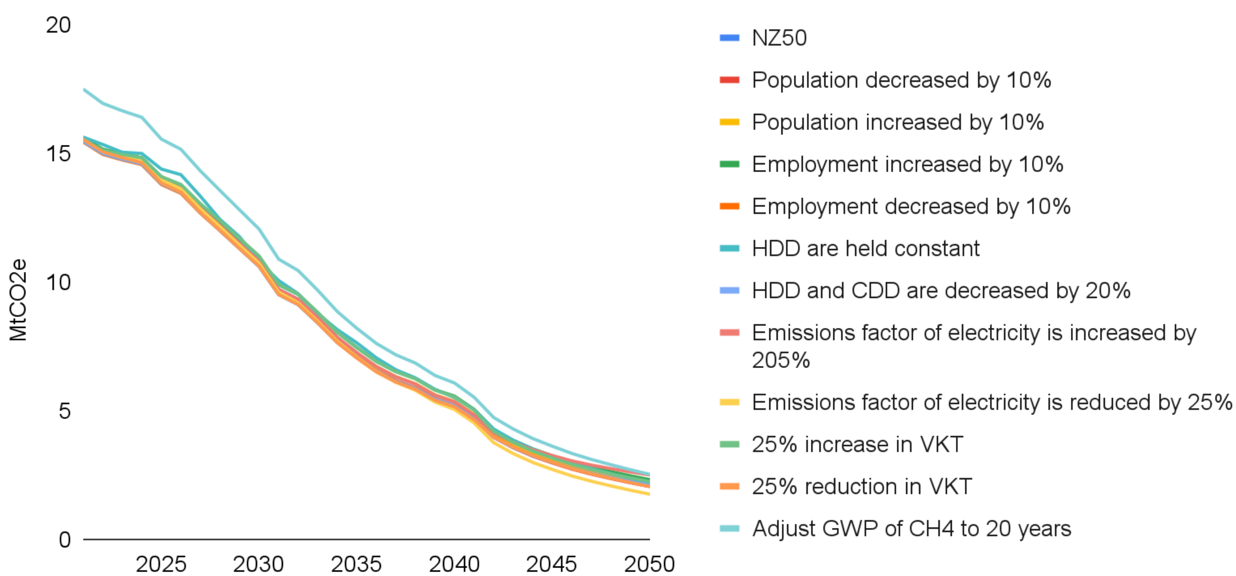

Figure 72. Impact on the NZ40 pathway of adjusting each of the key variables.

Based on this investigation the pathway is sensitive to methane emissions, particularly if a 20 year GWP is applied. The emissions factor of electricity is also critical to accelerating the reduction in GHG emissions, which follows from the electrification of heating and transportation.

12. Conclusion: Time is of Essence

"We basically have three choices: mitigation, adaptation and suffering. We're going to do some of each. The question is what the mix is going to be. The more mitigation we do, the less adaptation will be required and the less suffering there will be."

John Holdren, Professor of Environmental Policy and former Director of the White House Office of Science and Technology Policy

In May 2021, the International Energy Agency (IEA) released a milestone report titled **Net Zero by 2050.**[140] Globally the IEA found that the path to net-zero is narrow, requiring the massive deployment of all available clean energy technologies, including renewables, EVs and energy efficiency building retrofits between now and 2030. IEA's key finding echo those of the TransformTO analysis, notably:

The net zero pathway can bring jobs and growth, we need huge leaps in clean energy innovation and a rapid shift away from fossil fuels, electricity becomes the core of the energy system and new low emissions industries flourish. Similar to the IEA, the Technical Report describes a pathway to completely transform the energy system.

As a viable pathway to substantively address climate change, TransformTO is a beacon of hope. The urgency to act on climate change grows every day, and the technologies and processes required to decarbonize become more accessible and affordable. Decarbonizing sooner rather than later is compelling in order to maximize societal benefits that include reducing GHG emissions more quickly, delivering health benefits, enhancing resilience, enabling a green recovery from COVID, and improving quality of life. From this perspective, delay constitutes forfeited opportunities.

Every new investment which advances decarbonization of the energy system is additional infrastructure which doesn't need to be retrofit down the road, decreasing the cost of transformation. Investments in fossil fuel equipment, on the other hand, are likely to become stranded assets, resulting in financial and social liabilities, which will be prematurely replaced in order to limit climate change.

The NZ pathways modelled in this analysis reduce household transportation and energy costs, which, depending on how these actions are implemented, can benefit lower-income households. In particular, the expanded and free transit modelling in the NZ pathways advances equity objectives by improving accessibility.

The financial industry will play a key role in enabling the NZ scenarios, first by avoiding investments which result in increased emissions and second by facilitating access to the capital for emissions reduction investments. Given access to capital, governments and other organizations will need to

[140] IEA (2021). Net Zero by 2050. Retrieved from: https://www.iea.org/reports/net-zero-by-2050

coordinate their efforts in order to mobilize the workforce that can rapidly deliver retrofits and renewable energy and related actions.

The NZ scenarios represent a transformation of the energy system and the built environment, which will require a coordinated mobilisation of the City and society at large for which there are few precedents. This analysis demonstrates that the technology is available, the financials are viable and the broader societal benefits are extensive. The pathway to net zero by 2040 has no downsides for the current and in particular future generations of the residents of Toronto, and of the world.