TransformTO Net Zero Strategy

TECHNICAL REPORT

December 2021

TORONTO

Live green Toronto

SSG SUSTAINABILITY SOLUTIONS GROUP

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 decarbonize 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

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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
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

ACRONYM	DEFINITION
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
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, thus 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

TERM	DEFINITION
Near zero buildings	buildings that are designed to be highly energy efficient but still use 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, including 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 pathways describe detailed transitions 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. The two pathways, alongside two 'reference' scenarios, were analyzed in a finance, energy, and emissions model to understand their impacts. 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 pathways, 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 allows for the evaluation 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 decarbonize 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; and
- 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 policies or incentives required to implement the actions. In many cases policies can be inferred from the actions;
- Use algorithms to optimize 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 optimize for social and economic benefits, prioritizing 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 decarbonization 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; or
- 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 pathways 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% below 2010 levels by 2030 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 an effort 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;
- **Fair phase-out:** Phasing-out existing stockpiles and production of fossil fuels in line with the 1.5°C global climate goal; and
- **Just transition:** Fast-tracking real solutions and a just transition for every worker, community, and country

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

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, set the stage for the Net Zero Pathways presented in this Technical Report, as did important statements such as the Climate Emergency Declaration and the endorsement of the Fossil Fuel Non-Proliferation Treaty.

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.

Figure 1 and Figure 2 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, transportation modelling incorporates consumer choices.

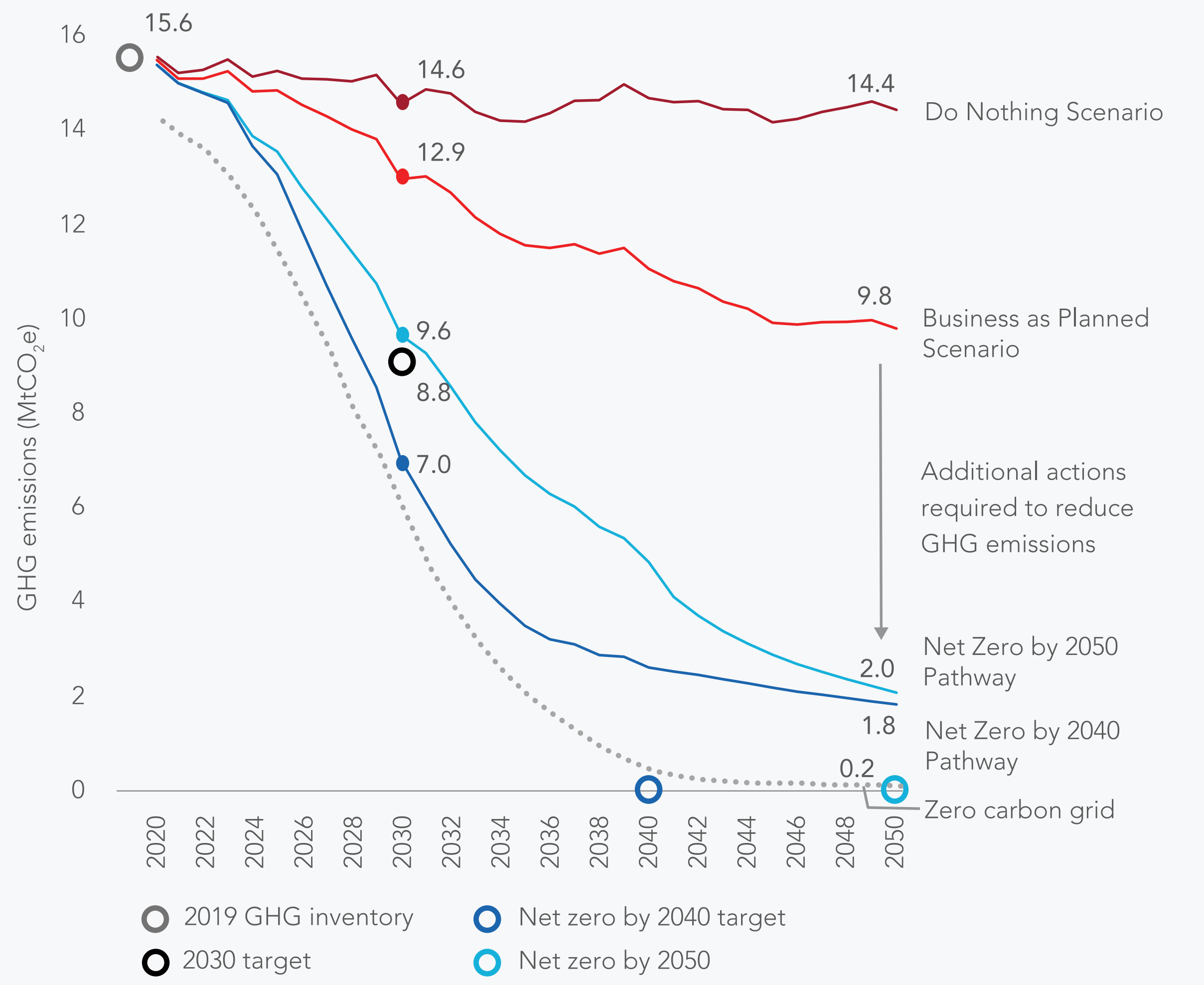


Figure 1. Pathways modelled.

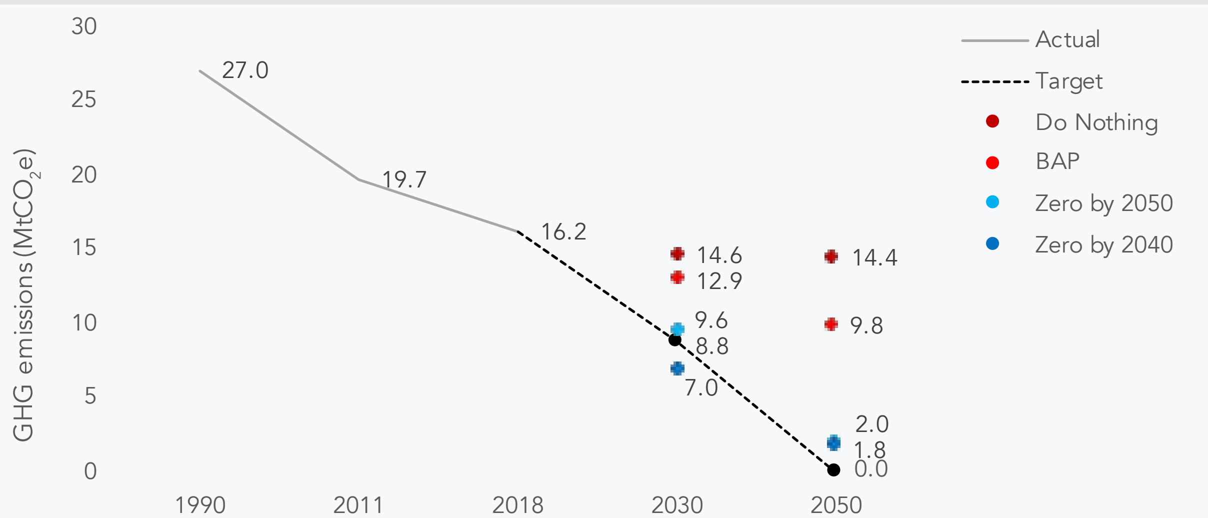


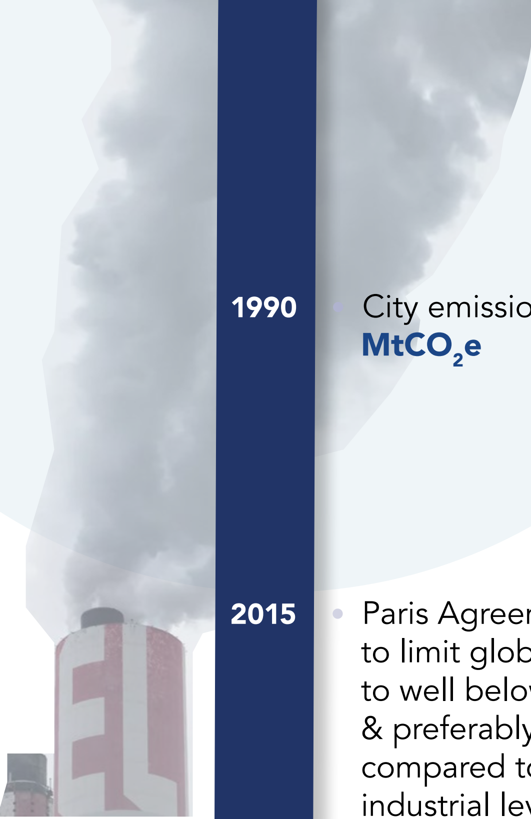
Figure 2. Summary results, GHG emissions (Mt CO_2e).

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.

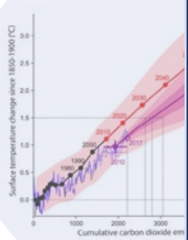


1990 • City emissions are **25 $MtCO_2e$**

2015 • Paris Agreement signed to limit global warming to well below **2°C**, & preferably **1.5°C** compared to pre-industrial levels

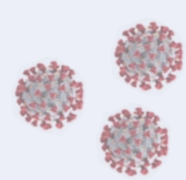
2017 • Council unanimously passes TransformTO with a target of **80%** below 1990 emissions by 2050

2018 • UN scientific body IPCC publishes a report on what is required to limit warming to 1.5°C, indicating the world has **12 years left** at current rates



2019 • City adopts goal to achieve **net-zero emissions by 2050**, updating its previous target set in 2017

2020 • Canada's first **COVID-19** case. Ontario declares a state of emergency in response to the pandemic



2021 • Toronto's updated Net Zero Strategy released with **net zero by 2040 target**

2025 • **Zero organics** are sent to city landfills

• **420,000 new m2** of non-residential building floor area have been hooked up to zero-emissions District energy

2027 • **100% of new residential buildings** are built to Tier4 standards

2030

- **280,000 homes** built before 2016 have been retrofit
- **1,600 MW** of new rooftop solar PV have been installed
- an equivalent of **60,000 full-time jobs** worth of work are carried out as a result of NZS investments

2035

- **$1.8 billion** less is spent on annual energy bills city-wide as a result of NZS actions

2040

- All commercial and residential water and space heating converted to heat pumps and residential natural gas appliances have been phased out
- Nearly **70%** of all trips in the city are taken by either bike, e-bike, walking, or transit
- **All personal and commercial vehicles** are electric

- Hydrogen is used for **100% of process heating** in industrial buildings
- **all transit vehicles** have been electrified

2050

- the city has a total of:
  - **6,300 MW** of solar and wind energy installed
  - **2,000 MW** of storage, and
  - **10.8 million m²** of building floorspace connected to zero-emissions district energy systems

- all new and existing residential and commercial buildings in the city are emissions-free
- city meets its target of **40% tree canopy cover** city-wide
- Toronto's city-wide emissions reach

NET ZERO

Figure 3. Toronto's Roadmap to Net Zero (modelled targets).

Findings

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 $MtCO_2e$, as it drops to 7 $MtCO_2e$ by 2030. 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.

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.

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.

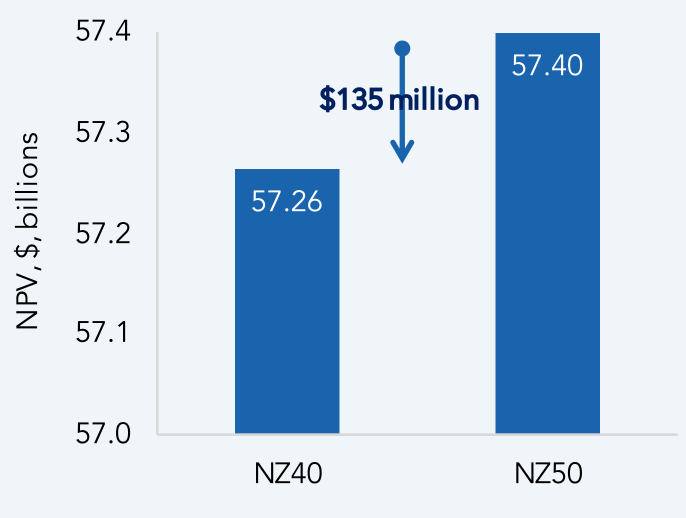


Figure 4. Net present value of the NZ40 and NZ50 scenarios.

THERE ARE MANY BENEFITS THAT GENERATE FINANCIAL RETURNS THAT 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 that go beyond 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 scenario.

THE IMPACT ON EQUITY IS LIKELY POSITIVE, BUT THE IMPLEMENTATION DETAILS MATTER

The net zero 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; however 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 net zero pathway policies.

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 5). These emissions would be eliminated if the province were to decarbonize the grid. 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.

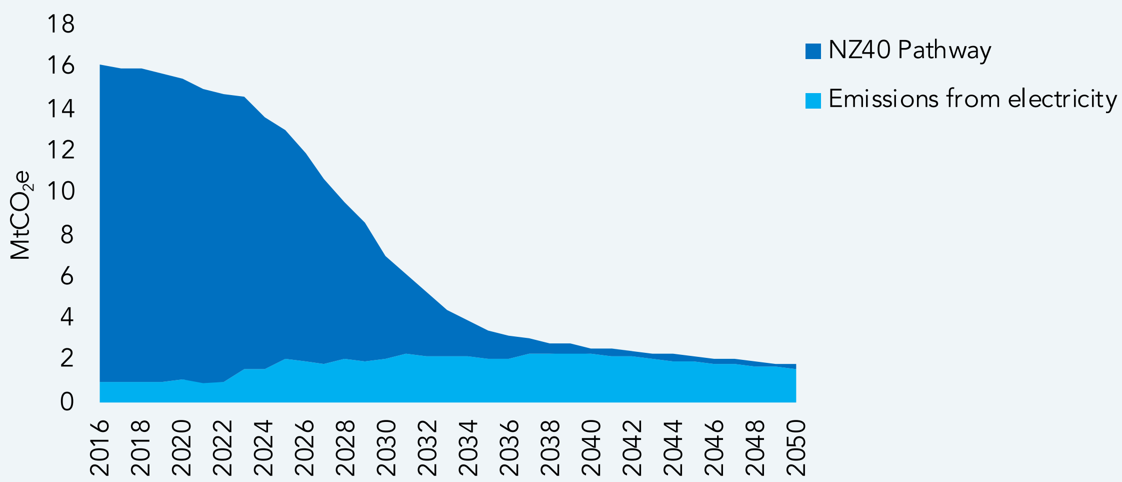


Figure 5. The imperative of eliminating GHG emissions from electricity.

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

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

the efficiency of travel in the city through reduced congestion and car use, amongst many other potential benefits and paybacks.[5]

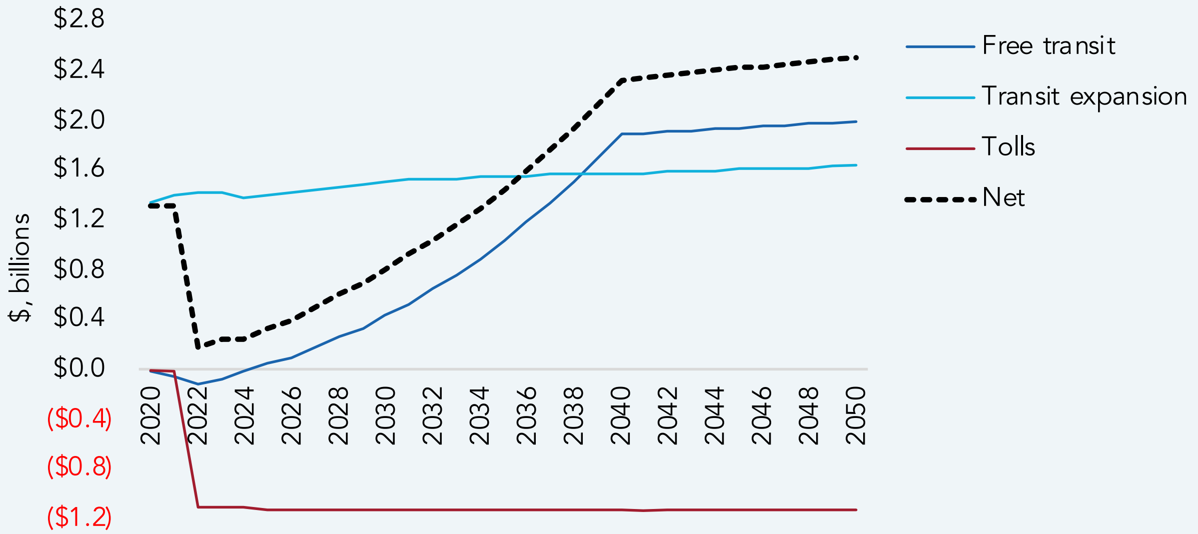


Figure 6. The financial impacts of transit actions.

EFFICIENCY FIRST

Rapidly reducing emissions in buildings and transportation is critical to achieving the net zero pathways. The pathways emphasize 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 that can be used to finance the actions.

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.

5 Štraub, D.; Jaroš, V. Free fare policy as a tool for sustainable development of public transport services.Human Geography Journal of Studies and Research in Human Geography 2019,13, 45–59.

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. This was the largest annual decline since World War II, and 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. 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, and increased emphasis on public spaces and active transportation infrastructure.[13]

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

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.

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.

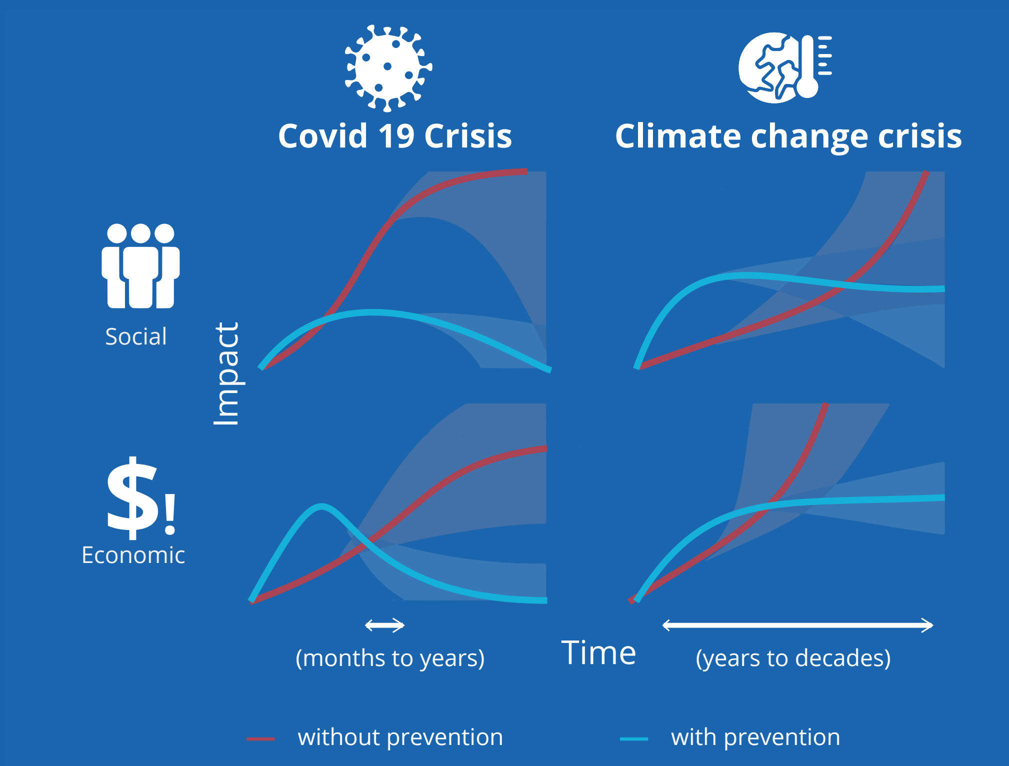


Figure 7. [15] *Illustrative diagram of social and economic impacts of the COVID-19 and climate crises in the presence and absence of preventative measures, with different timescales. In the case of COVID-19 and climate change, there is a social cost of failing to take preventative measures. Without 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.*

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 8).

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

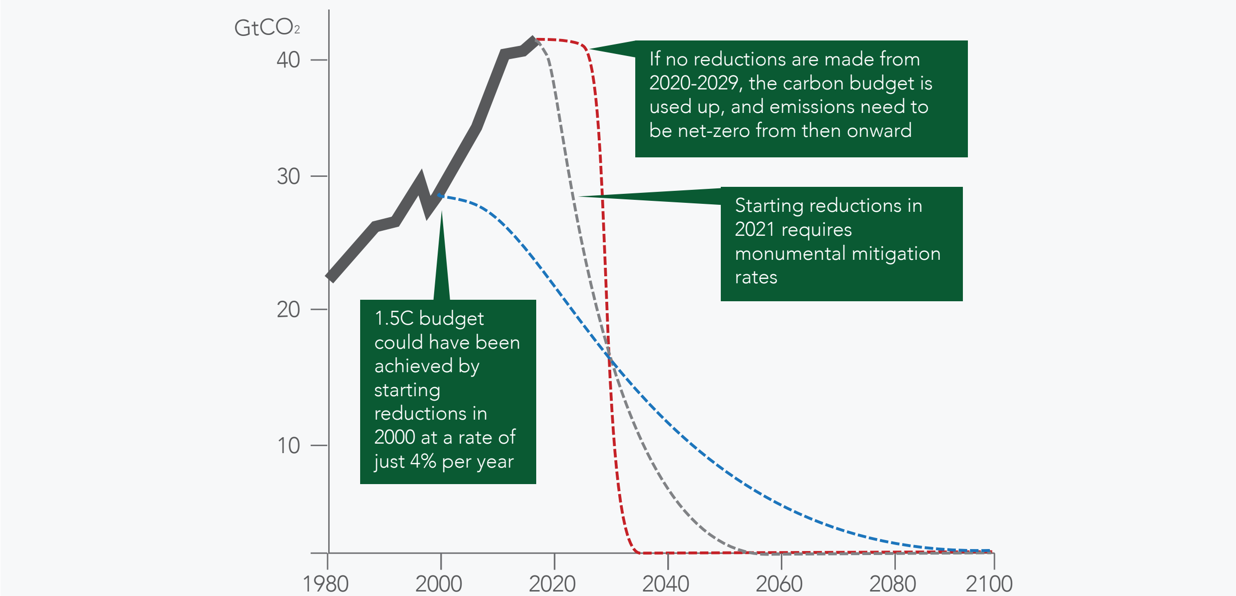


Figure 8. Likelihood of limiting warming to 1.5°C given a global target of achieving net zero by 2040.[17]

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 toward limiting global warming to 1.5°C.

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 9 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 Urgently 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.

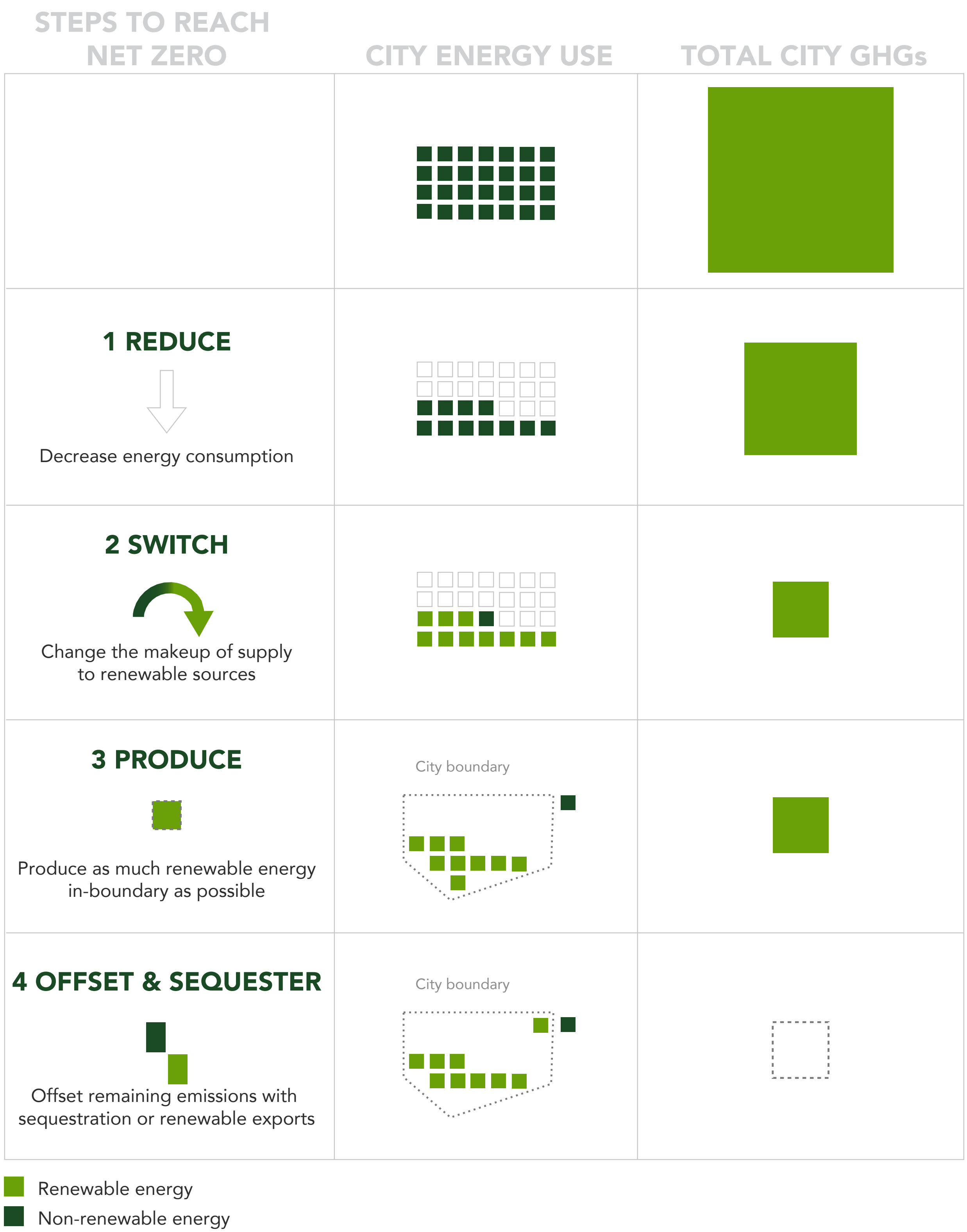


Figure 9. Schematic of net zero emissions.[20]

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.

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.

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

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 human and natural systems.[23] Globally 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]

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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

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 $GtCO_2e$ 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

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 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.

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

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

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.

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]

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/

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

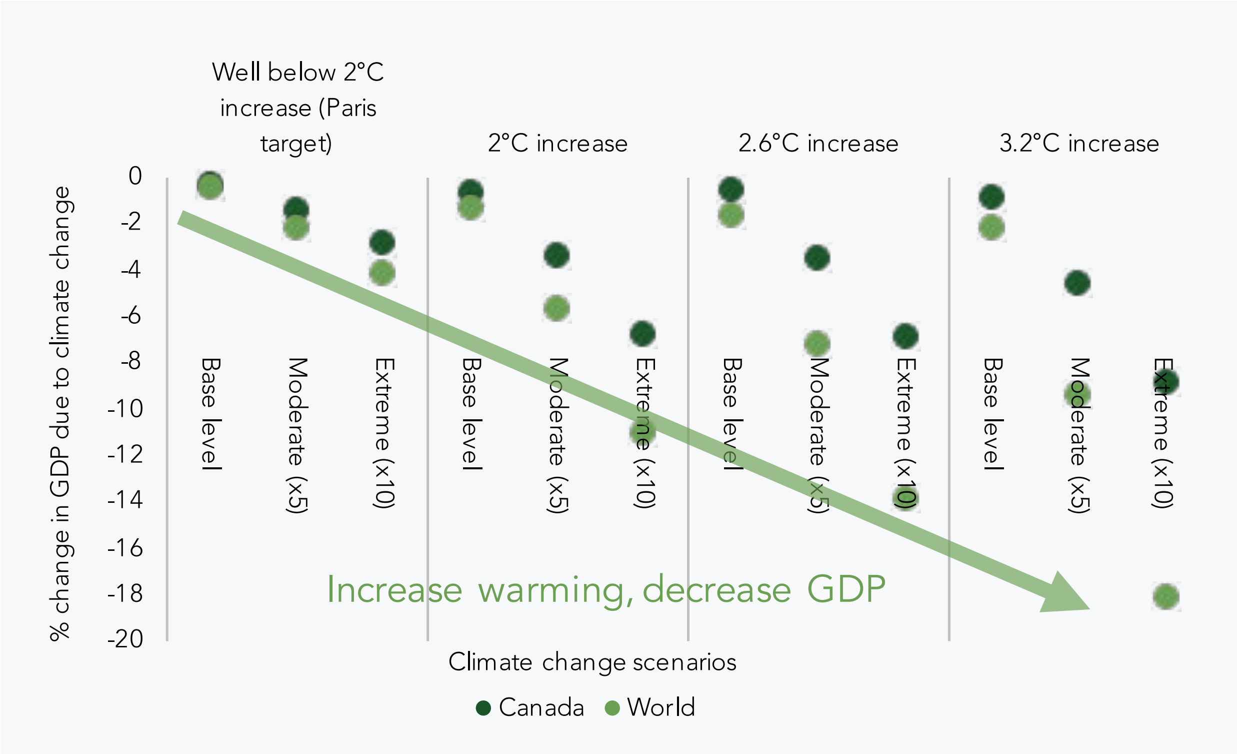

Figure 10. Percent impact on GDP of climate change for different temperature rises relative to a no climate change world.[35]

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 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.

35 Ibid.

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

According to the IPCC, global GHG emissions from buildings will need to be 80–90% lower, energy use for transportation will need to be reduced by about 30%, and renewables will need to supply 70–85% 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.

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:

1. Responsibility is determined on the basis of both historic and current emissions, as well as the capability to act. In other words, wealthy countries that 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 that have access to more resources need to do more than those countries without resources.

2. 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.

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

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 indicated by the IPCC's *Global Warming of 1.5°C* 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]

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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

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 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.

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 analyzed 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, focused 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

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

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.

2.8 A CLIMATE-SAFE CITY

Climate resilience is often an indirect or co-benefit of mitigation actions. Figure 11 illustrates how climate hazards impact infrastructure and 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.

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/

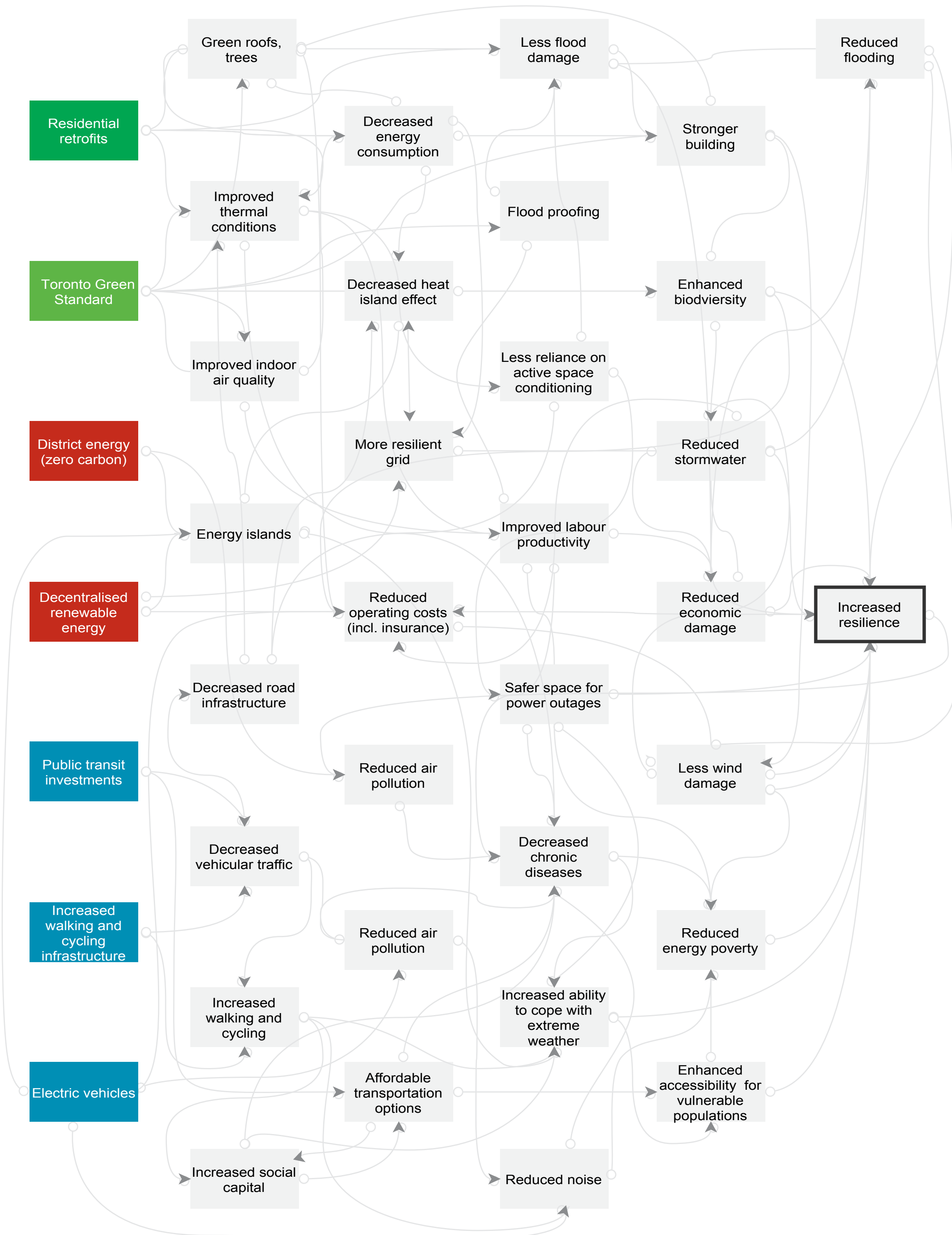

Figure 11. Schematic on the relationships between mitigation actions and increased resilience.[46]

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

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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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: CO_2 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

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 to 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]

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.

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

QUESTIONS	RESPONSE BASED ON THIS ANALYSIS
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
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
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.

QUESTIONS	RESPONSE BASED ON THIS ANALYSIS
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.
Limitations/Opportunities for Additional Investigation	
Impacts on peak electricity demand	The impacts on peak demand and the required electricity capacity to support peak demand were 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

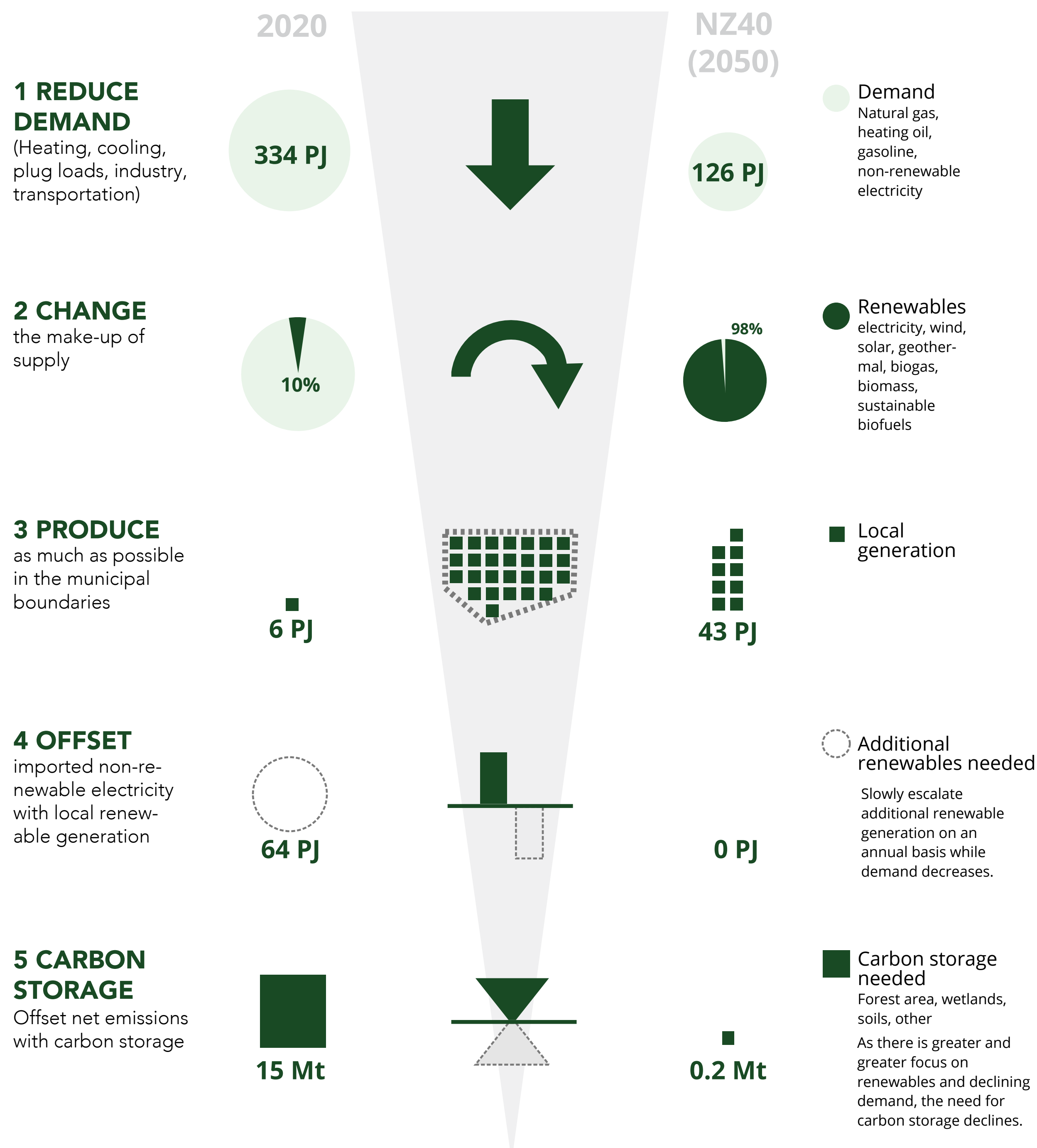


Figure 12. Net zero goals and trajectory. Note that in the image above, it is assumed that the provincial grid is fully decarbonized by 2050 in the NZ40 Scenario.

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.

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

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]

Figure 13. 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

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

in a report titled *Indigenous Climate Action,* prepared by the organization 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.

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 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.

55 Indigenous Climate Action (2018). Indigenous Climate Action Summary Report: Indigenous 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.

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.

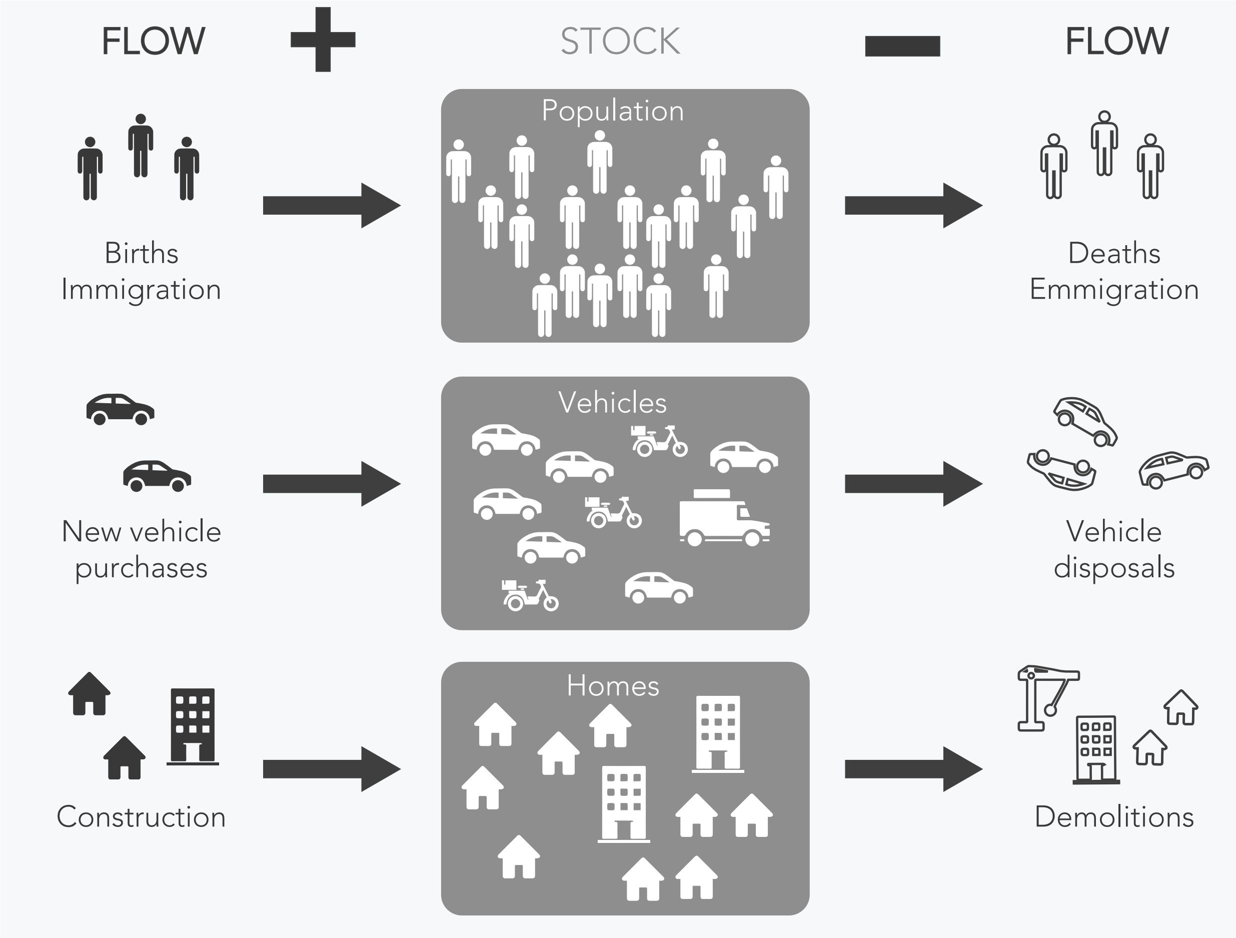


Figure 14. Examples of stocks (light grey) and flows (dark grey).

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 that generates emissions will likely need to be retrofitted 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]

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

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 using 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.

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

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 tCO_2e, less than 0.2% of baseline emissions (Every Tree Counts, City of Toronto, 2013).

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 amount of renewable energy generation that will be needed, a necessary step towards deep decarbonization.

Figure 15 provides a visualization for the steps taken to determine the City's net zero scenarios.

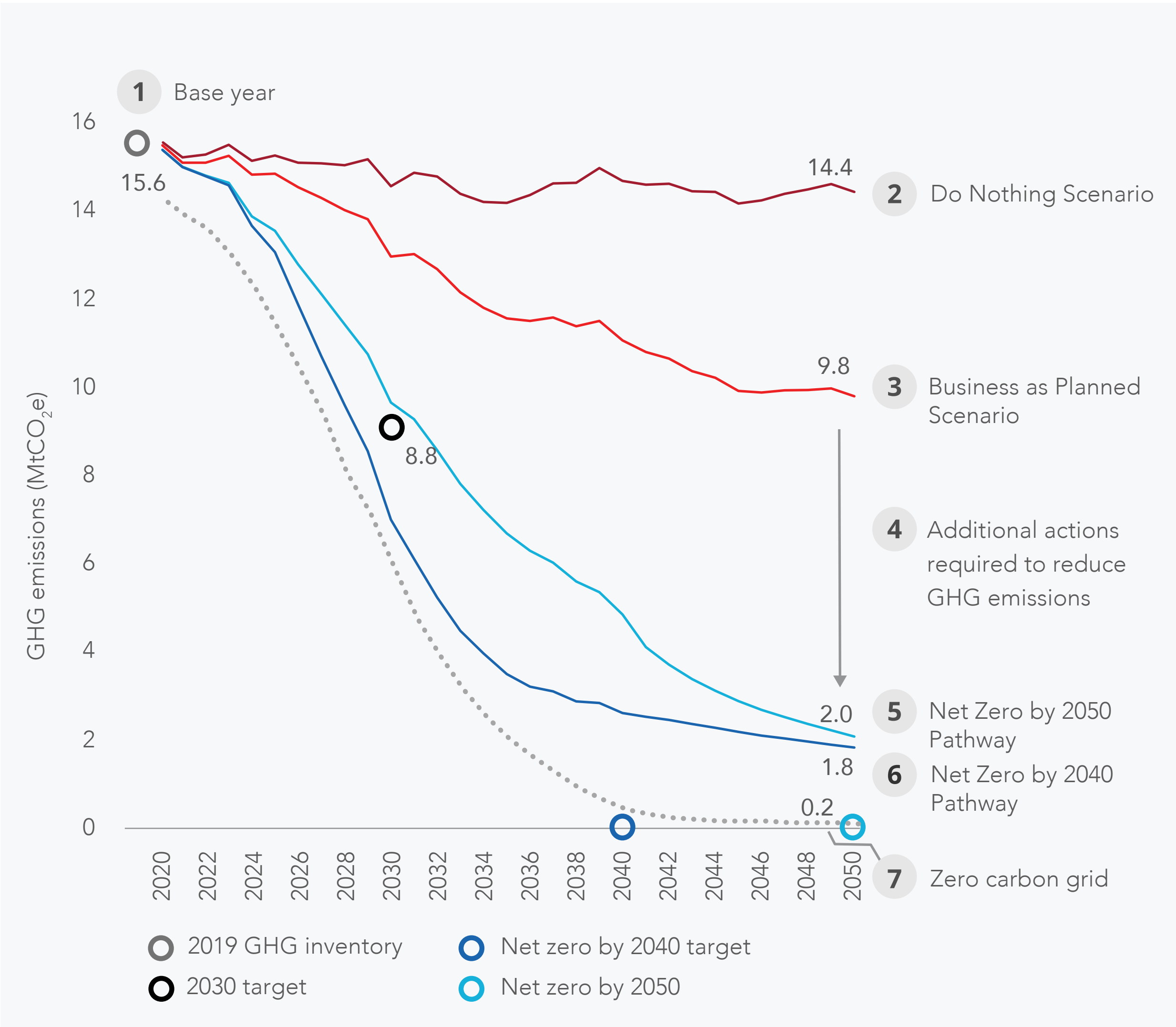


Figure 15. Overview of the net zero scenario development process.

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 rollout 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.

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

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.

Step 5: Net Zero by 2050 Pathway (NZ50): Two net zero pathways were devised to explore potential routes to 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 identified included switching to renewable energy sources, increasing energy efficiency, and reducing or altering emissions-producing activities. Their energy, emissions, and financial impacts were compared to the BAP and Do Nothing scenarios. The design of the two net zero pathways 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 mostly be 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.

63 Ibid.

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

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 today. For example, CarbonCure's technologies currently inject CO_2 into concrete at the rate of 17 $kgCO_2$ per m^3.[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. To ensure comparability, they are held constant across all of the scenarios. The 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

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

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.

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%

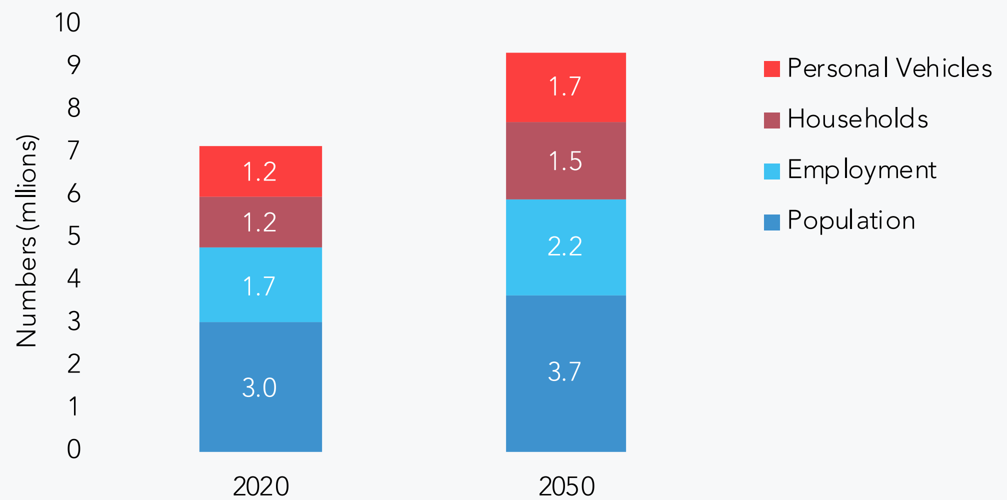


Figure 16. Key drivers of GHG emissions by the numbers.

4.5 A DIRTIER ELECTRICITY GRID

Ontario's electricity system is relatively clean compared to other provinces, but is projected to become more GHG-intensive per unit of electricity generated (Figure 17) 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.

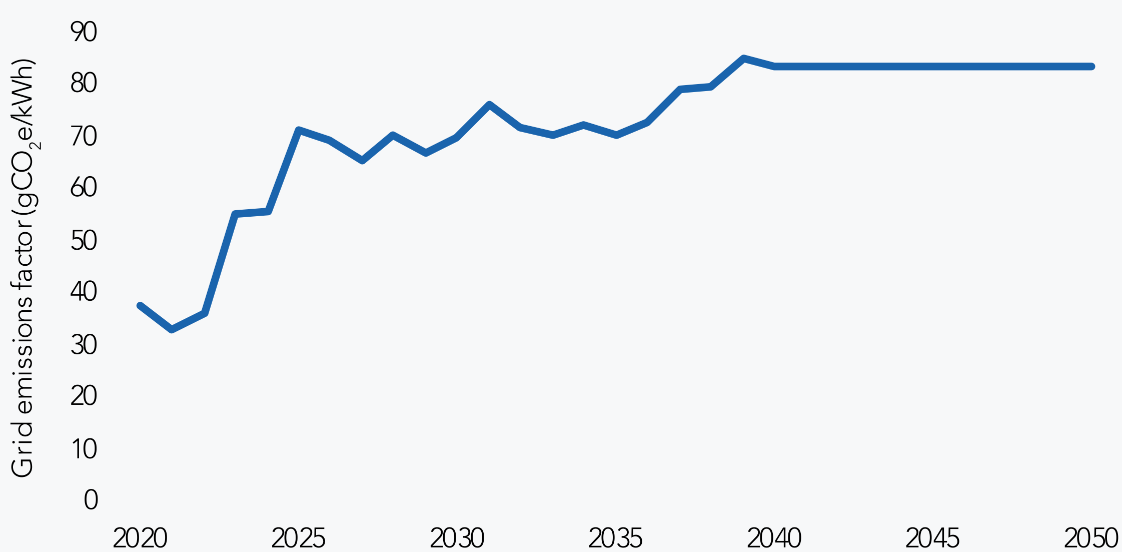


Figure 17. Projection of the GHG emissions intensity of the Ontario grid.

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 18). Emissions from buildings remain the highest contributors, followed by emissions from transportation and waste.[70]

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

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

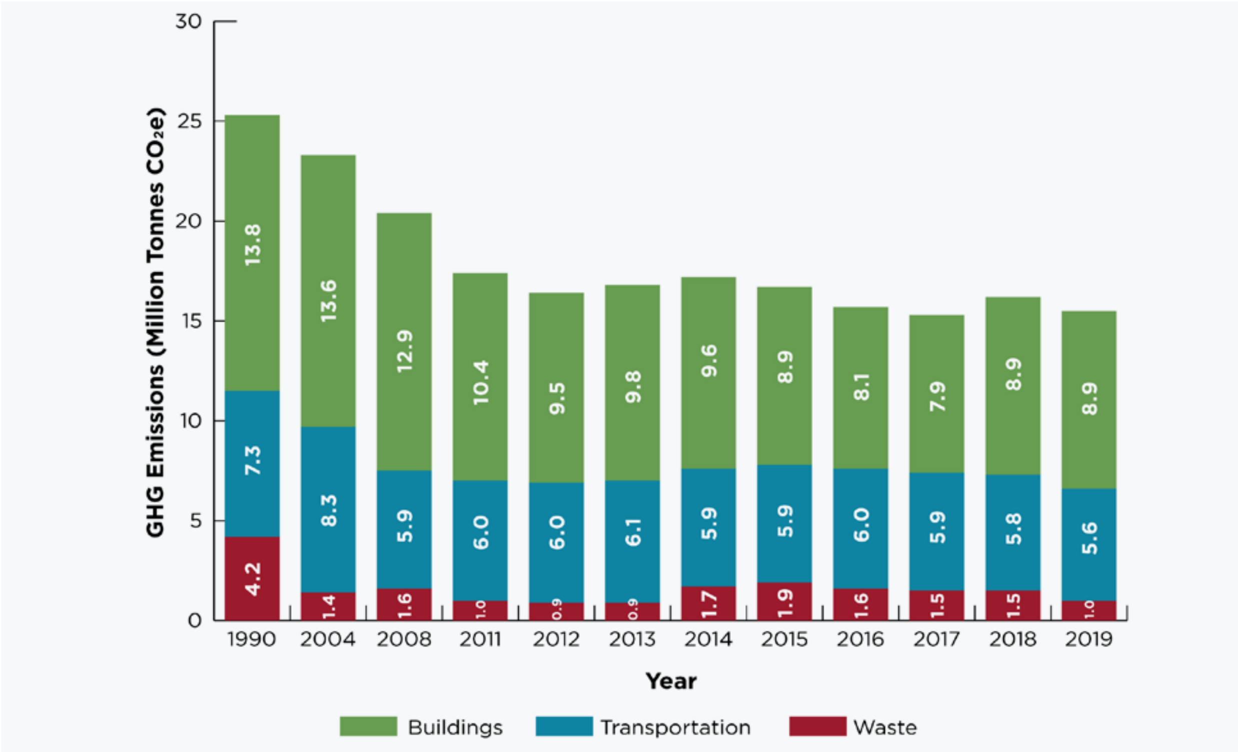


Figure 18. GHG Emissions by Sector, 1990-2019.[71]

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 19 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.

71 From the City of Toronto's 2019 GHG Inventory.

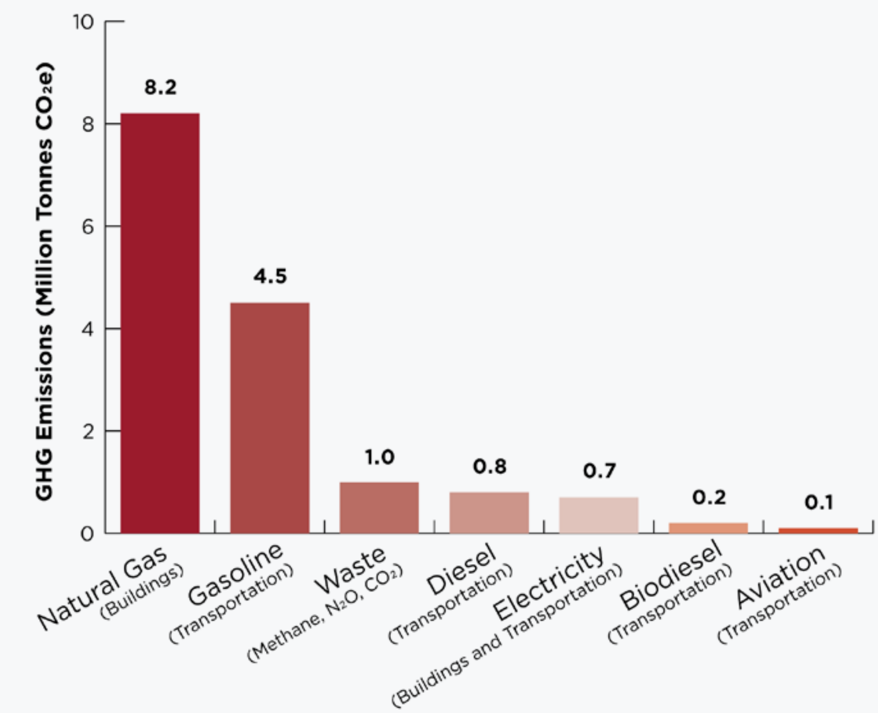


Figure 19. Greenhouse gas emissions by source (2019).[72]

72 From the City of Toronto's 2019 GHG Inventory.

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%
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%

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				
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 improvements 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										
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	1029	-	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%

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				
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 allocate 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/ contracted 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%
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%

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				
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)			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				
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%

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				
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%

GHG EMISSIONS FROM NATURAL GAS

GHG emissions from natural gas are commonly reported based on the carbon dioxide (CO_2) 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 4. 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: the provincial electricity grid.

Figure 20 illustrates curves for the total annual GHG emissions for each scenario between 2020 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.

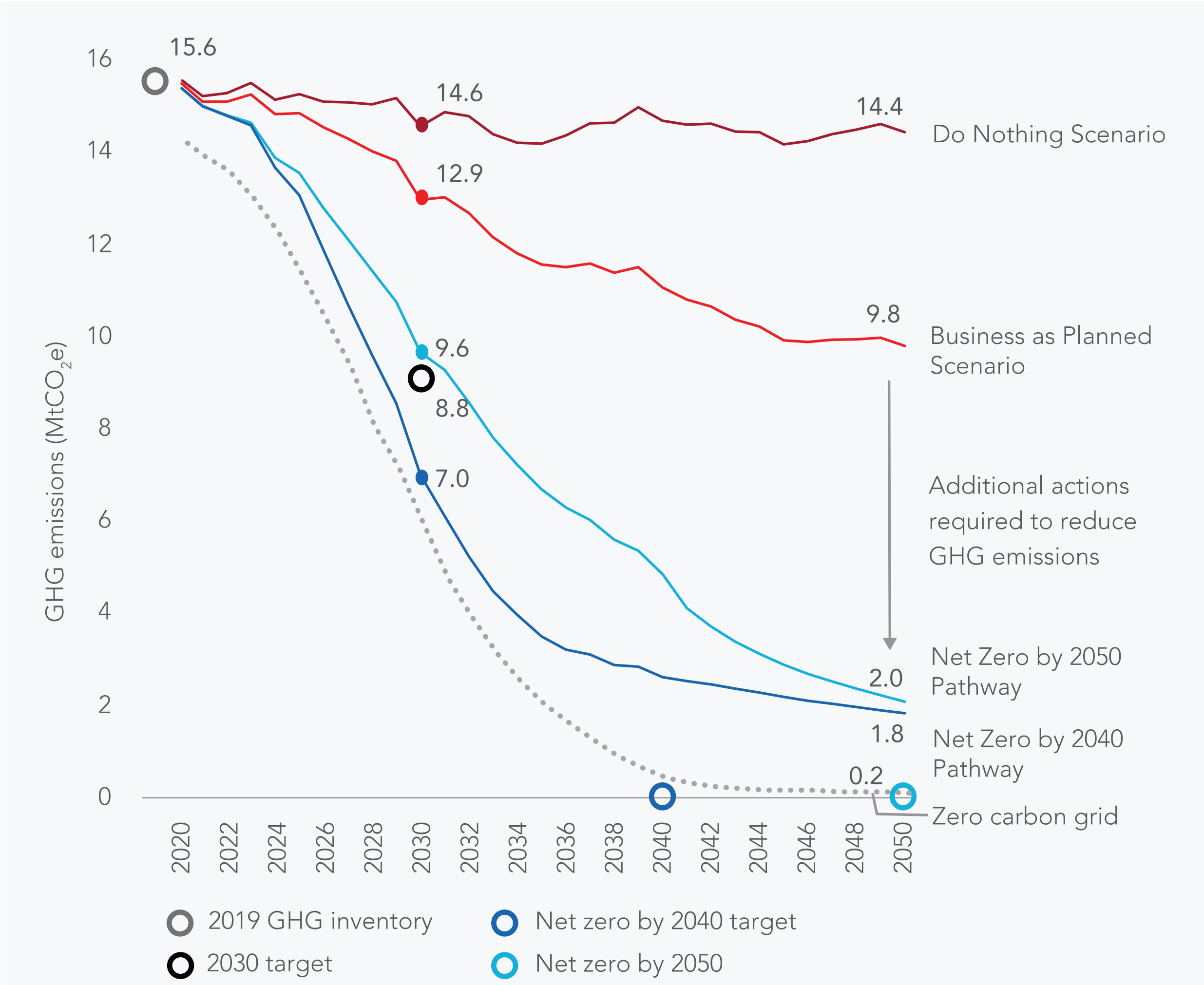


Figure 20. Total GHG emissions for each of the scenarios.

Figure 21 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 (to 2.7 tCO_2e) by 2050, whereas the Do Nothing scenario reduces per capita emissions by 1.6 tCO_2e (to 3.9 tCO_2e) by 2050.

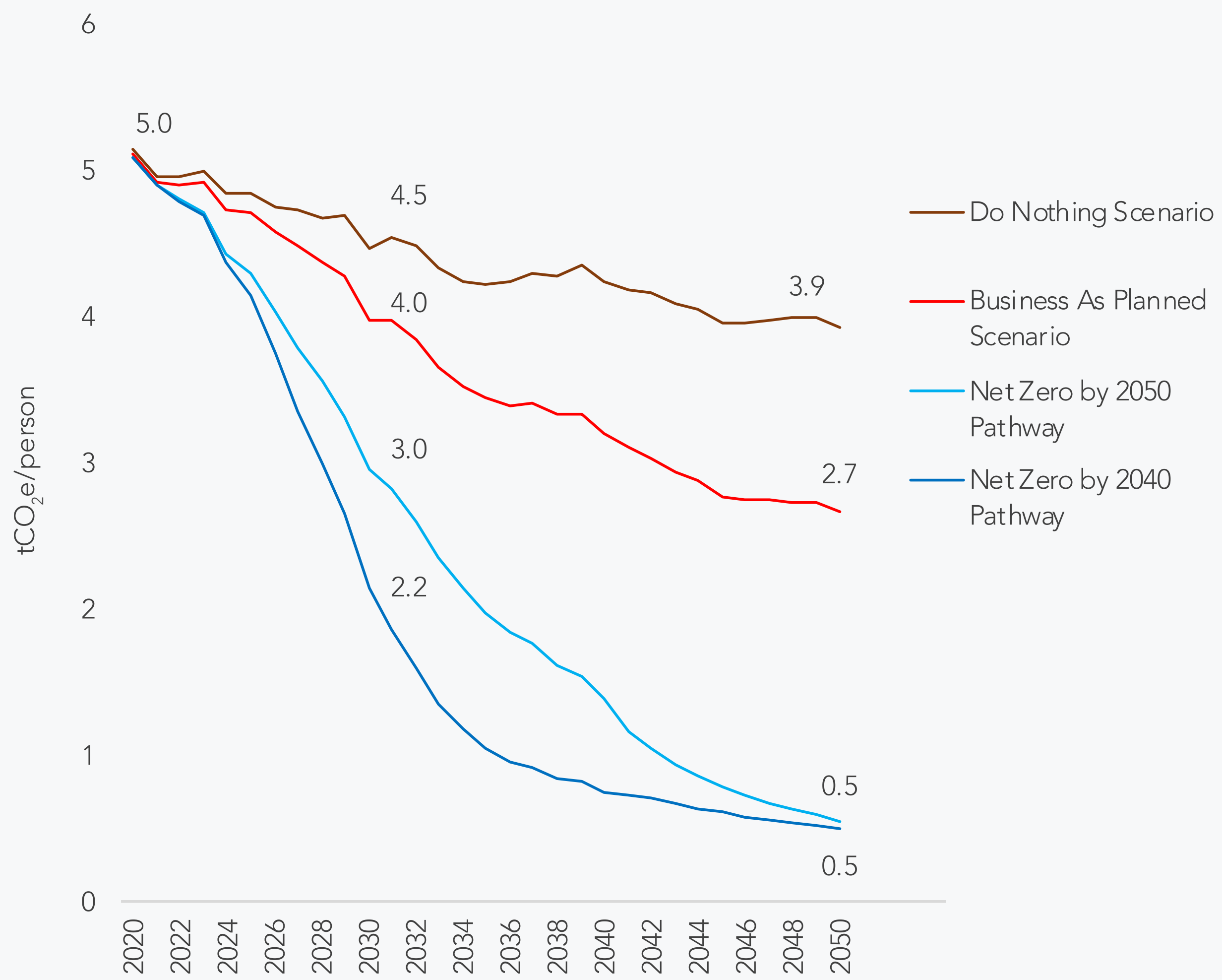


Figure 21. GHG emission per person achieved by the net zero scenarios.

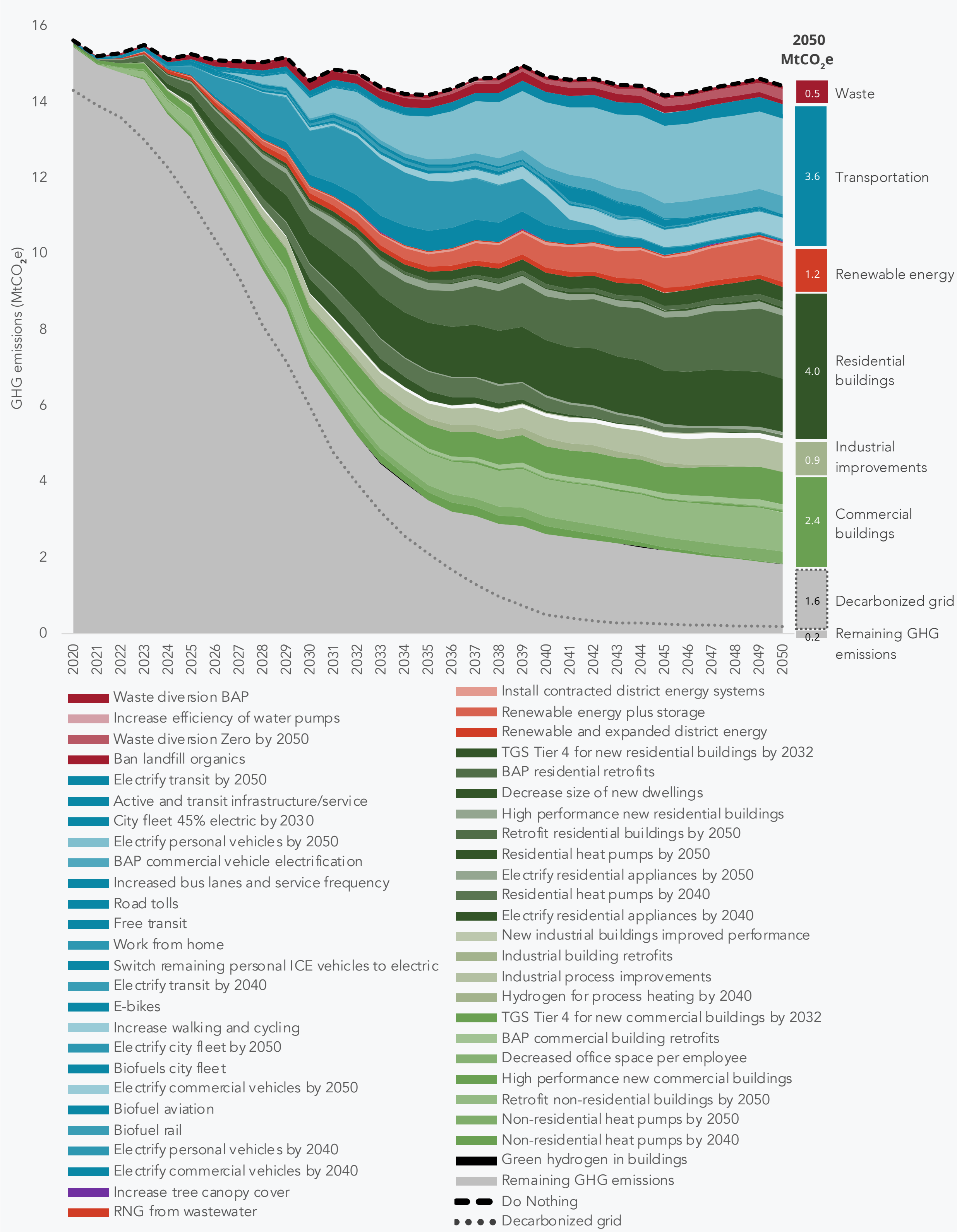


Figure 22. Net Zero Scenario by 2050 Wedge Summary: The relative impact of the key actions modelled.

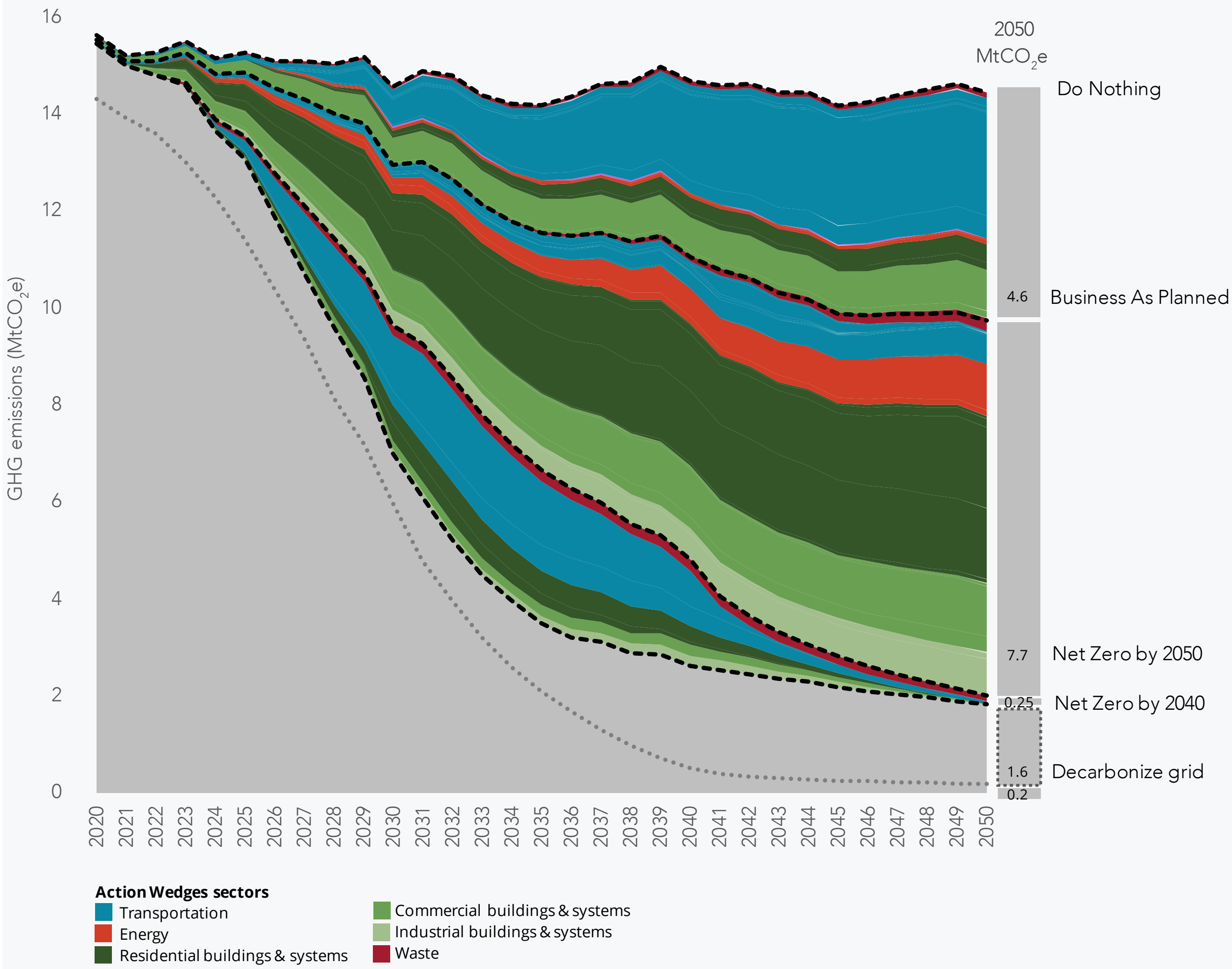


Figure 23. Net Zero Scenarios Wedge Summary: The relative impact of the actions modelled.

Table 5. Net Zero by 2040 Scenario (NZ40): the numbers in 2016, 2030, and 2050.

INDICATOR	RESULT 2016	2030	2050	UNITS
Annual GHG emissions	16.2	7.0	1.	$MtCO_2e$
Annual GHG per person	5.5	2.2	0.5	tCO_2e
Average floor area per dwelling	123	118	109	m^2

INDICATOR	RESULT 2016	2030	2050	UNITS
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 6. Net Zero by 2050 Scenario (NZ50): the numbers in 2016, 2030, and 2050.

INDICATOR	RESULT 2016	2030	2050	UNITS
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	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	$1,760	$880	$/year
Annual solid waste to landfill per person	190	93	15	kg

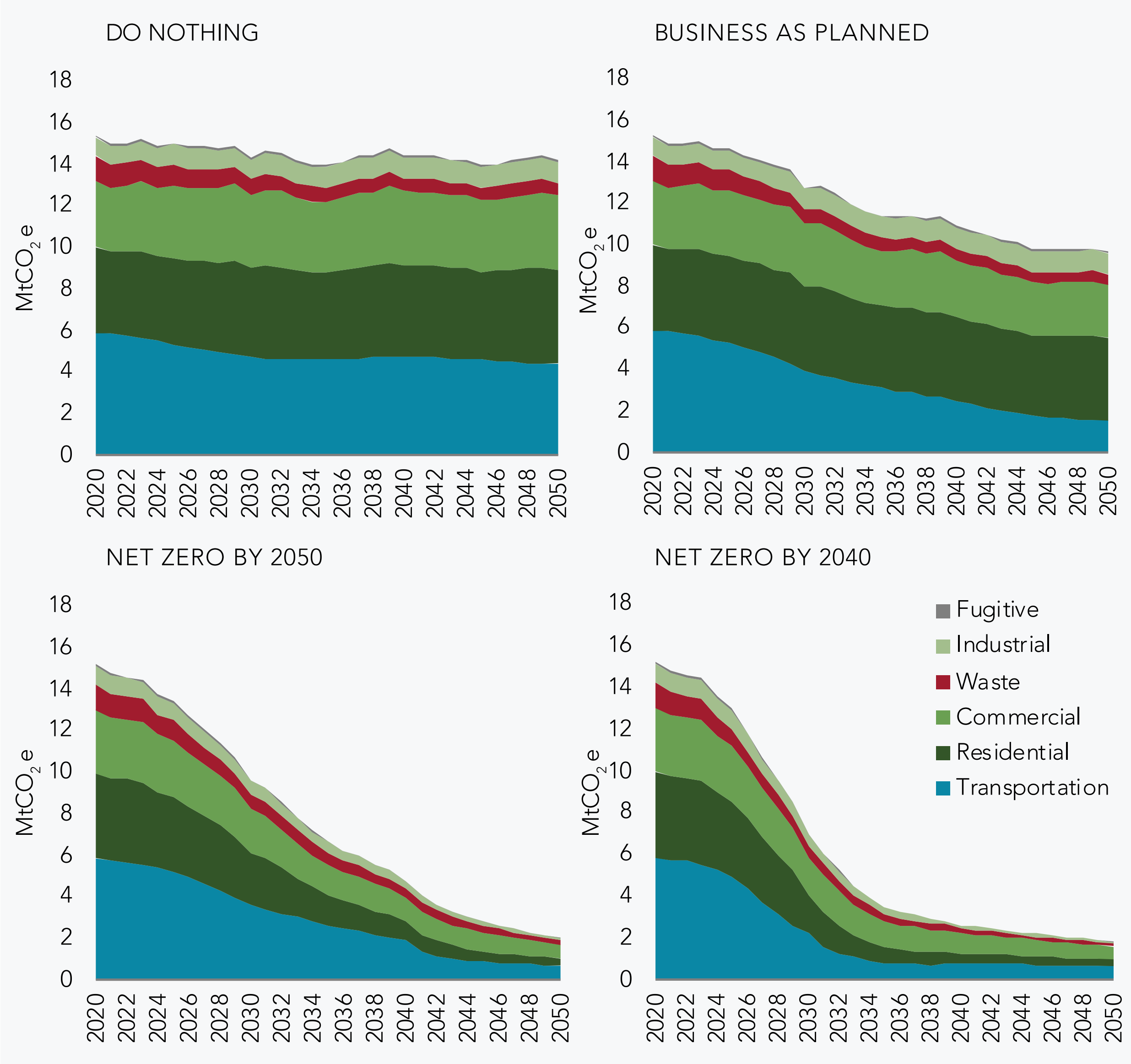


Figure 24. GHG emissions by scenario and sector, 2016-2050.

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.[73] Figure 25 illustrates four different ways in which this scenario could play out.

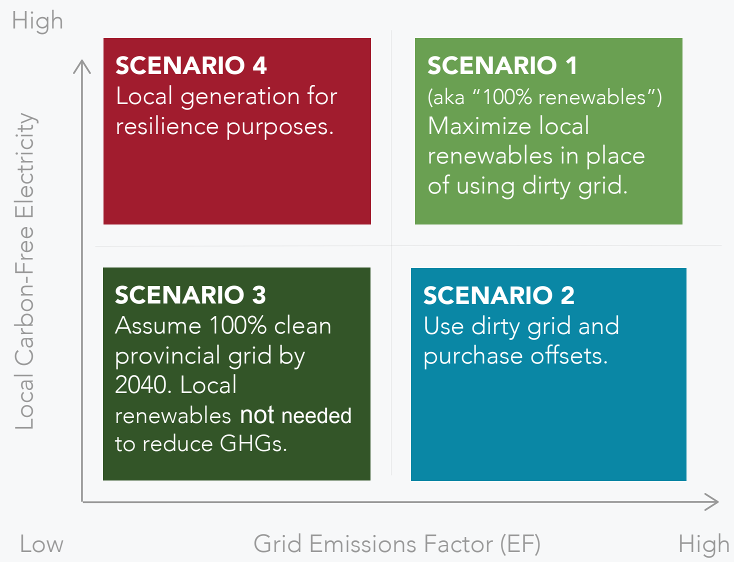


Figure 25. Descriptions of scenarios for reaching net zero emissions based on variations in the provincial grid emissions factor and extent of deployment of local renewable energy.

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)[74] 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

73 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

74 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

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 26). 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, local generation is a major contributor to the decarbonizing of the grid.

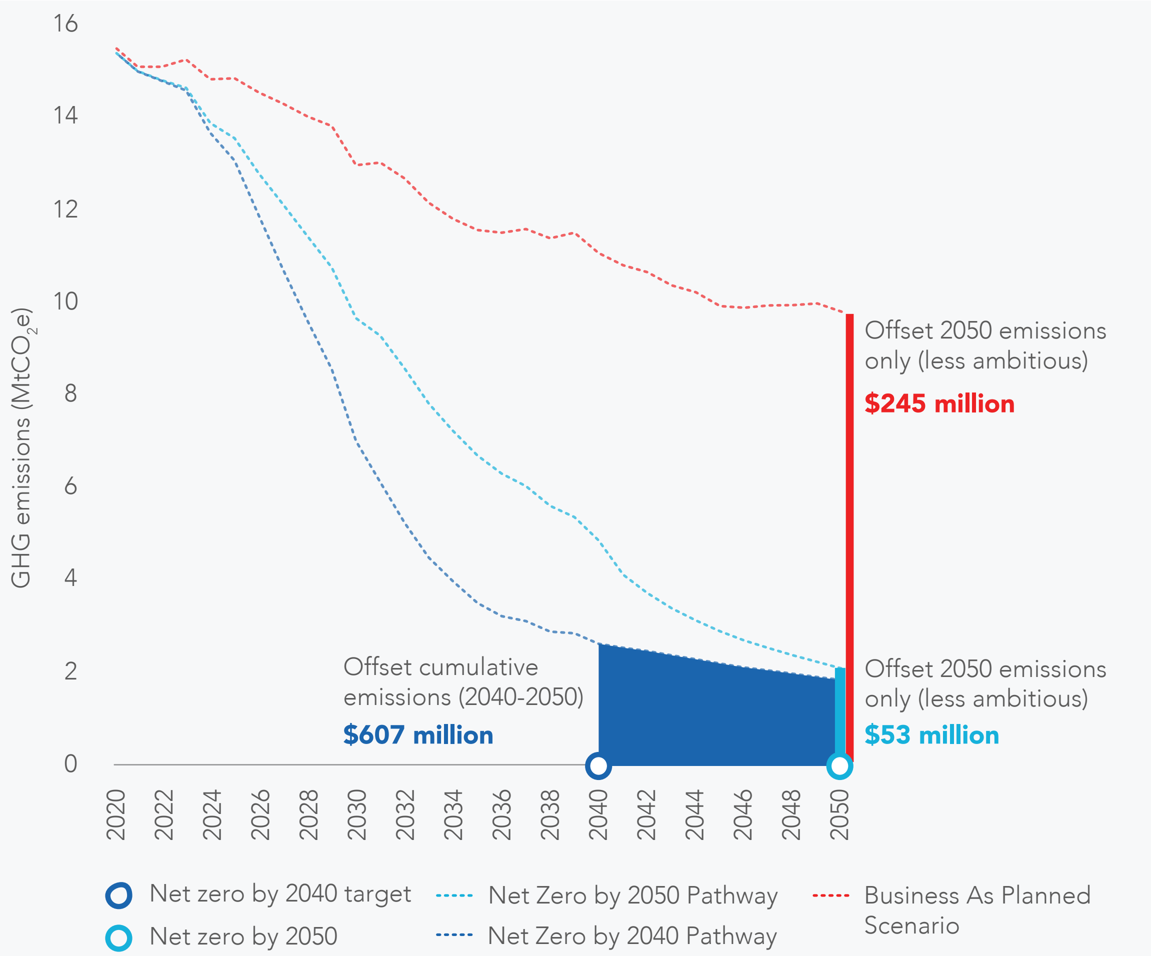


Figure 26. Carbon offset costs for the NZ40, NZ50, and BAP scenarios.

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 net zero scenarios, particularly for sectors such as industries in which electrification is difficult (Figure 27). 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 use of 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."[75]

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

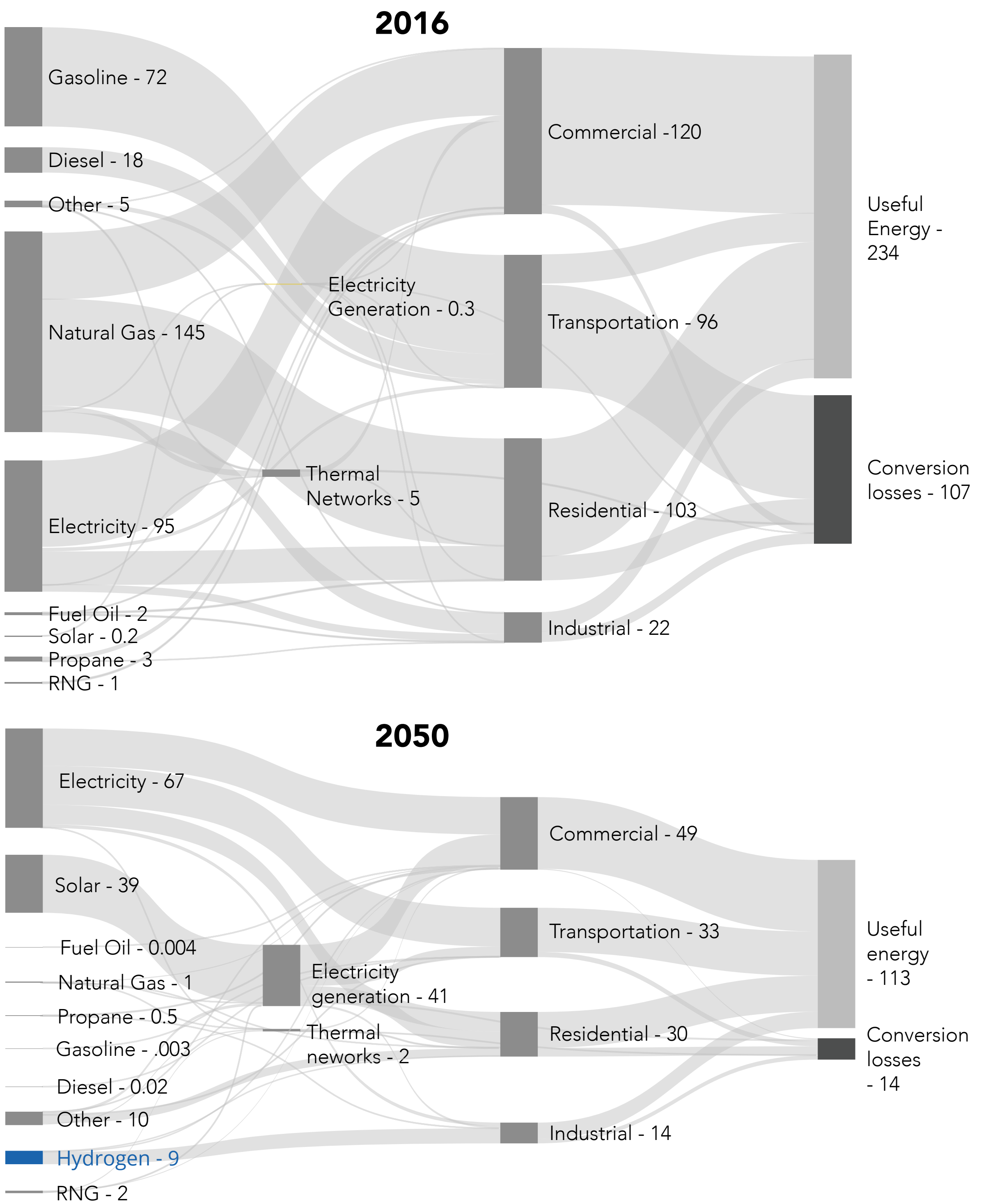


Figure 27. Illustration of the energy system flows in 2016 (top) and NZ40 in 2050 (bottom). The dark grey bars show the amounts of energy with their values indicated in PJ, and the thickness of the light grey flowing lines show the quantities of energy that are distributed for different uses. Hydrogen 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 28). 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 must be taken to achieve the 2030 target. These actions are summarized in Table 3 and in the following sections and include, amongst others, electrifying vehicles sooner, retrofitting buildings sooner, and eliminating organic materials from landfills sooner.

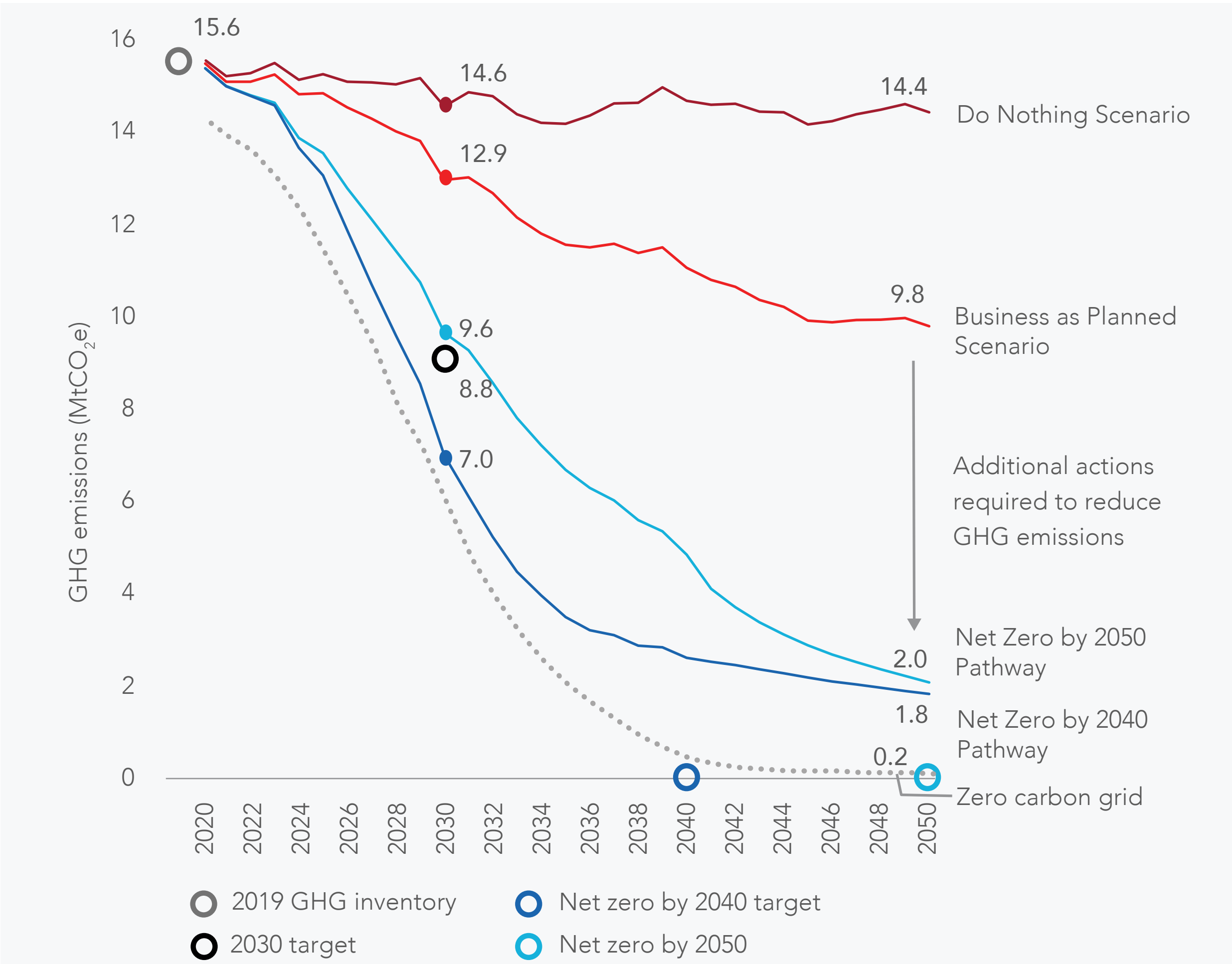


Figure 28. Total GHG emissions for each of the scenarios, 2020-2050.

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 29. 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 $MtCO_2e$.

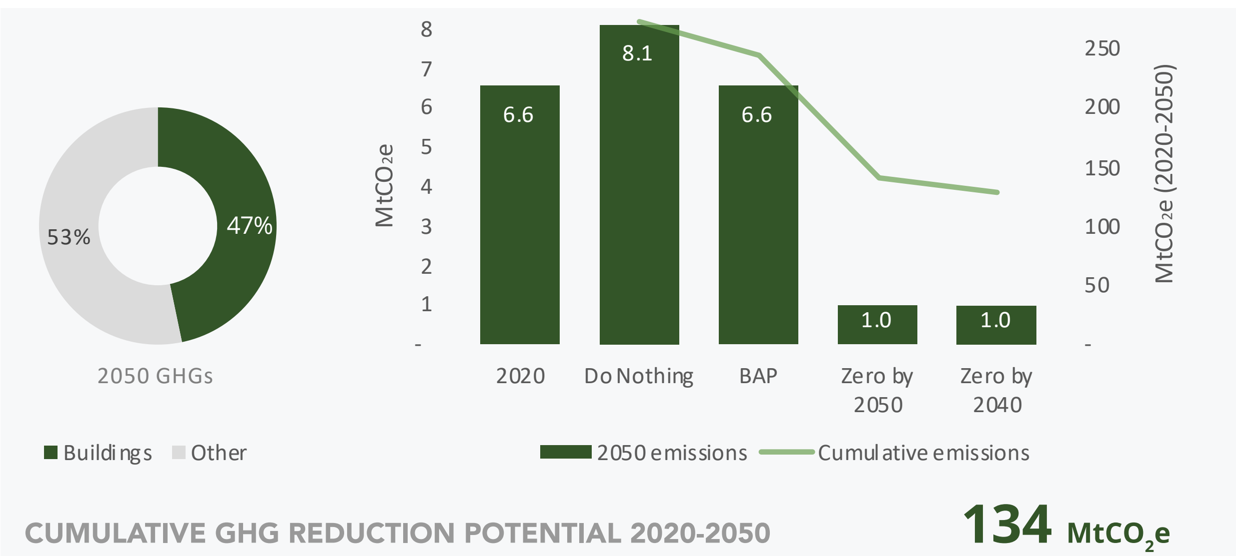


Figure 29. GHG emissions from buildings in 2050, by scenario.

The GHG reduction actions for the buildings sector by scenario are provided in Table 7. This section details the interventions needed to increase the efficiency of the building stock and fuel switch from fossil fuels to renewables.

Table 7. 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
	BAP residential retrofits	Retrofit 6,000 units per year. Annual electricity percent 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.	

SECTOR	WEDGE	WEDGE DESCRIPTION	SCENARIO
	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
Buildings-commercial	TGS version Tier 4 for new commercial buildings by 2032	TGS version 3 Tier 4 for new commercial buildings by 2032.	BAP
	BAP commercial building retrofits	Retrofit 4,500 buildings by 2050.	
	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
	High performance new commercial buildings	100% TGS version 3 Tier 2 by 2021. 100% Tier 3 by 2022. 100% Tier 4 by 2027.	
	Retrofit non-residential buildings by 2050	Retrofit 100% of existing buildings by 2050. Savings of 15% electricity, and 75% thermal energy consumption annually.	
	Non-residential heat pumps by 2050	100% electric heat pumps for space and water heating in non-residential buildings by 2050.	
	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; and
- 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.

WHAT CONSTITUTES A DEEP RETROFIT?

Toronto's Net Zero Existing Buildings Strategy defines a GHG reduction retrofit as meeting two criteria:[76]

1. A minimum upgrade package performance of 50% reduction in GHG emissions, reflecting established best practice in retrofit activities.

2. 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".[77]

76 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

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

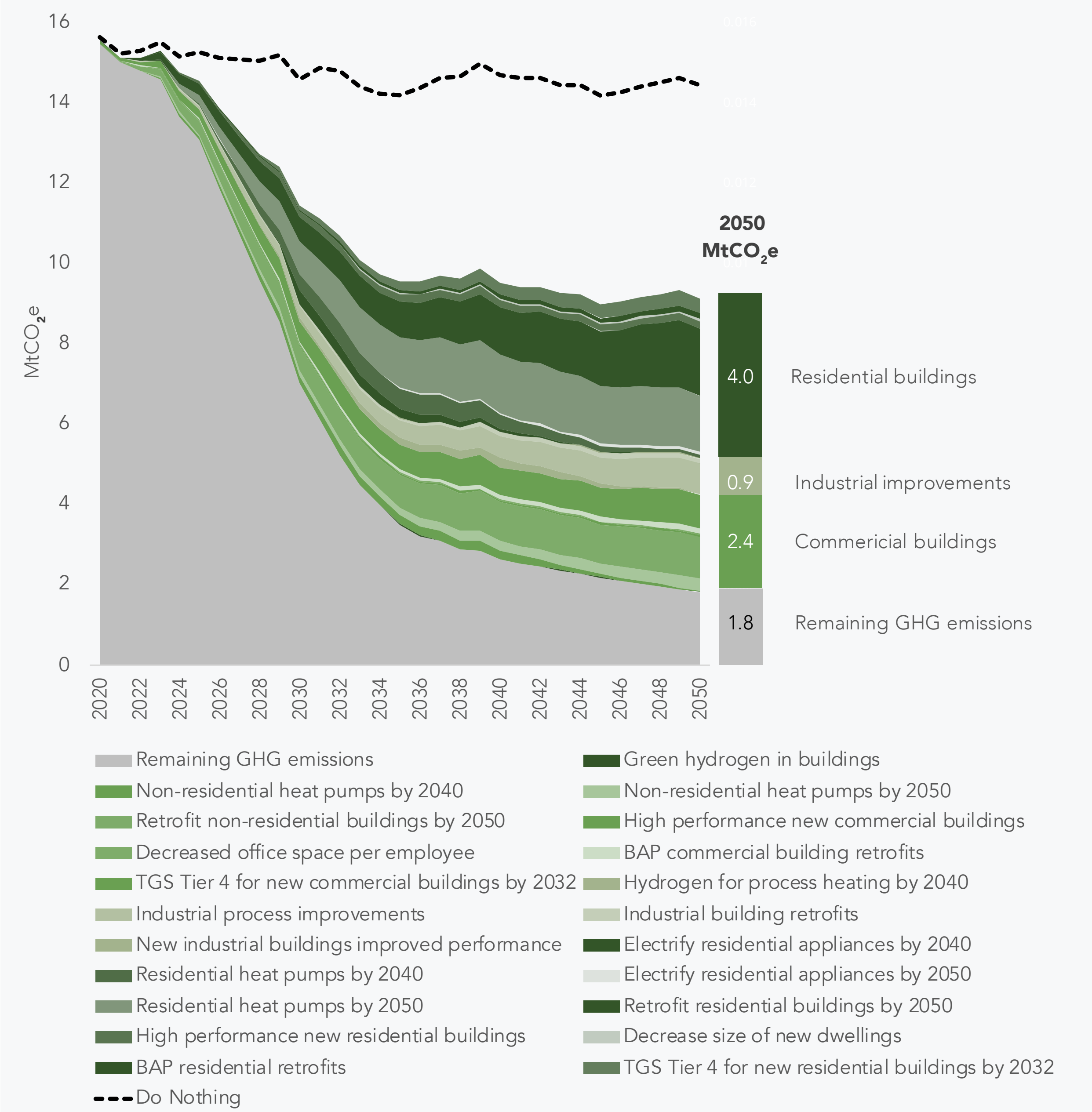


Figure 30. Wedge diagram of buildings GHG reduction actions.

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 decarbonize 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.

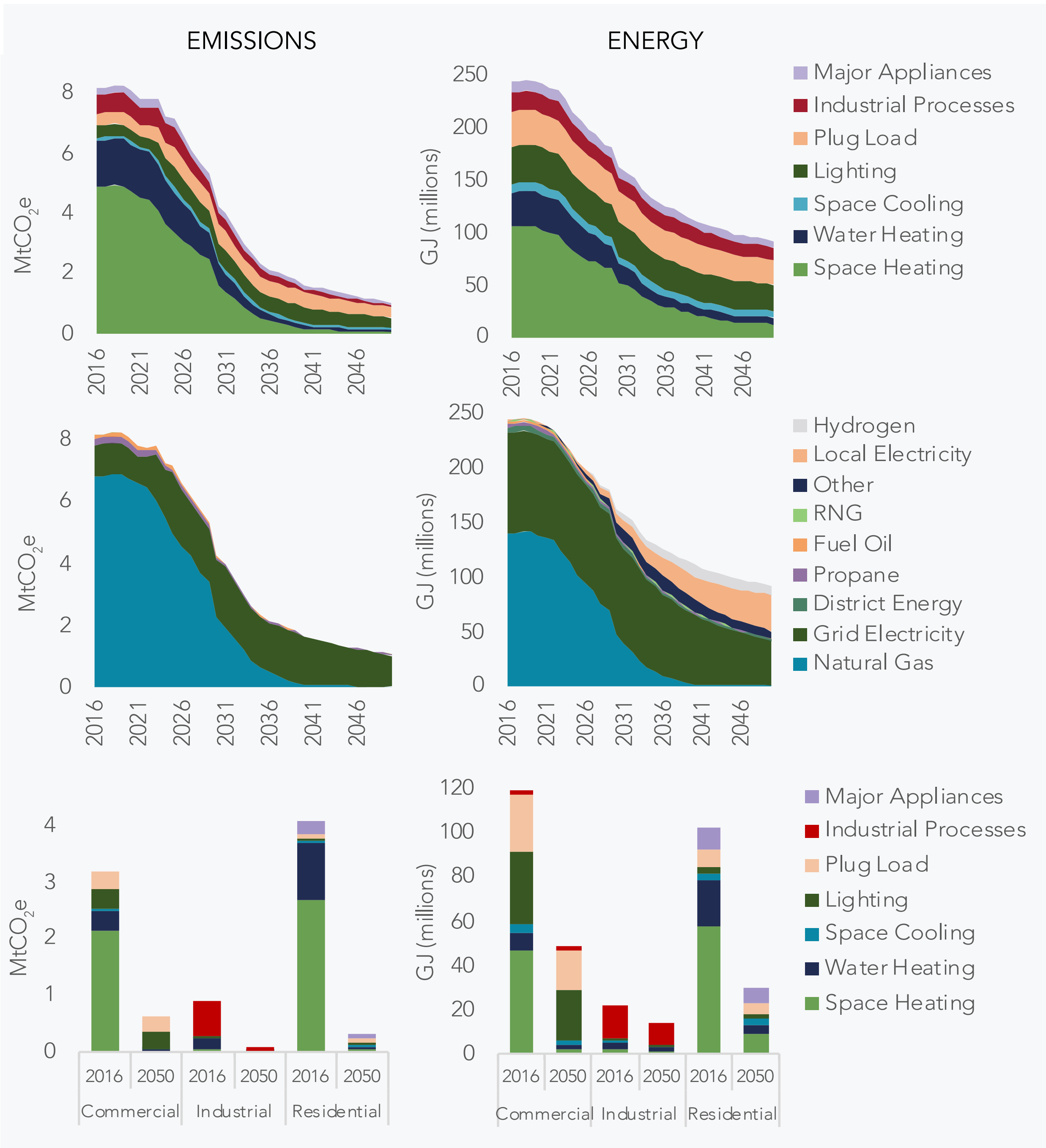


Figure 31. Emissions and energy use from buildings for NZ40.

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 8). The targets serve as indicators against which the City can track performance over time.

Table 8. Targets for Buildings Sector

	2021-2025	2026-2030	2031-2040	2041-2050
Percent 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 (m^2)	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 Retrofit existing buildings, listed above.

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

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.[78] Similar projects are under development in New York State, California, and Massachusetts.[79] The EU has advanced retrofit industrialization programs underway.[80] 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.[81] 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.[82]

6. Energy

6.1 OVERVIEW

Municipalities have a persistent 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 32 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

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

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

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

81 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/

82 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

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.

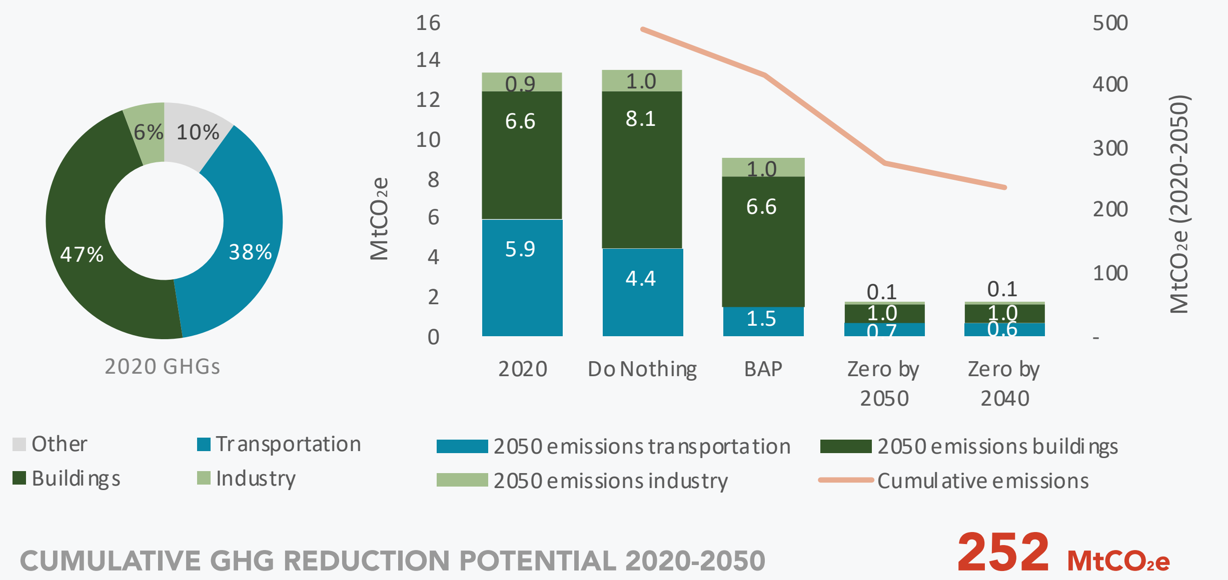


Figure 32. GHG emissions from energy.

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[83] (Table 9).

Table 9. 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.	

83 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 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
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.	

CLIMATE ACTION PLANNING

A key aspect of community energy planning includes prioritizing interventions in terms of a hierarchy based on what lasts longest.[84] 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.

84 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.

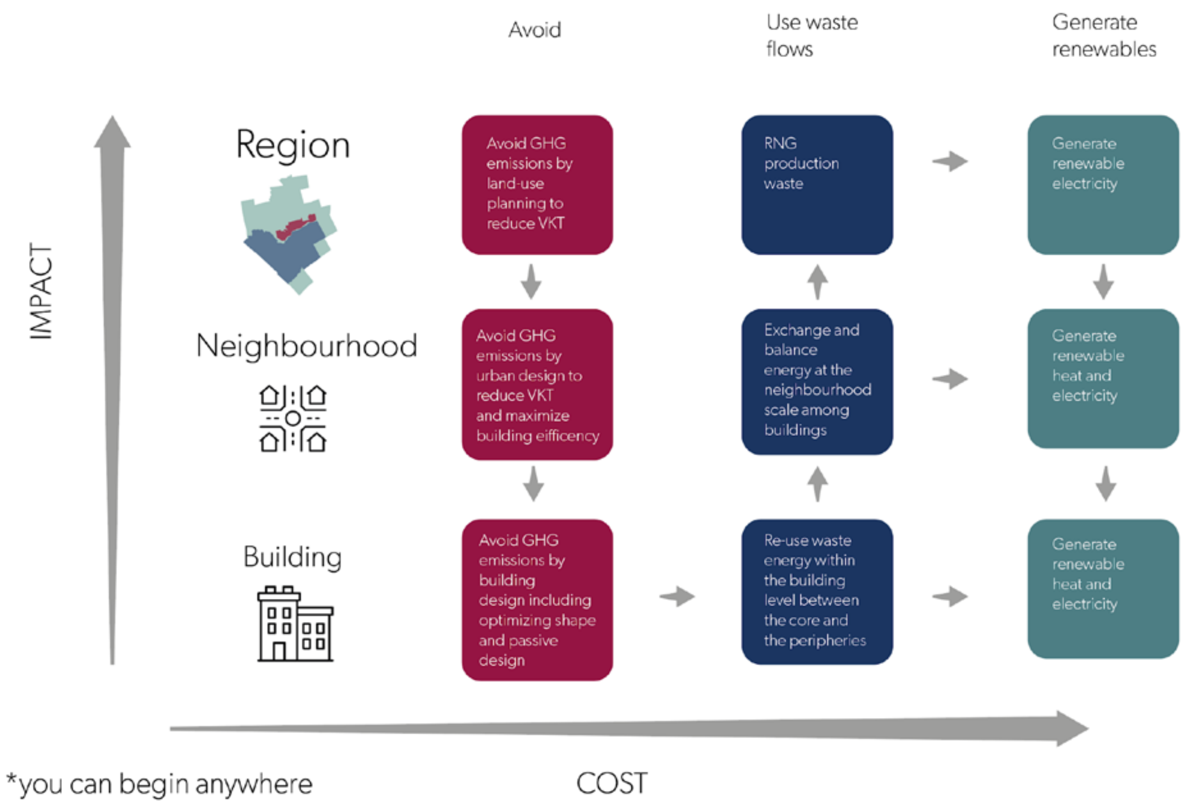


Figure 33. Reducing GHG emissions from a systems perspective.[85]

The hierarchy of climate action interventions shown in Figure 33 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,[86] 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 has been adapted from similar well-known approaches such as Reduce-Reuse-

85 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

86 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.

Recycle (from the waste sector) and Avoid-Shift-Improve[87] (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 34 illustrates the transformation of the energy system in Toronto across the relevant sectors, while Figure 35 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.

87 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

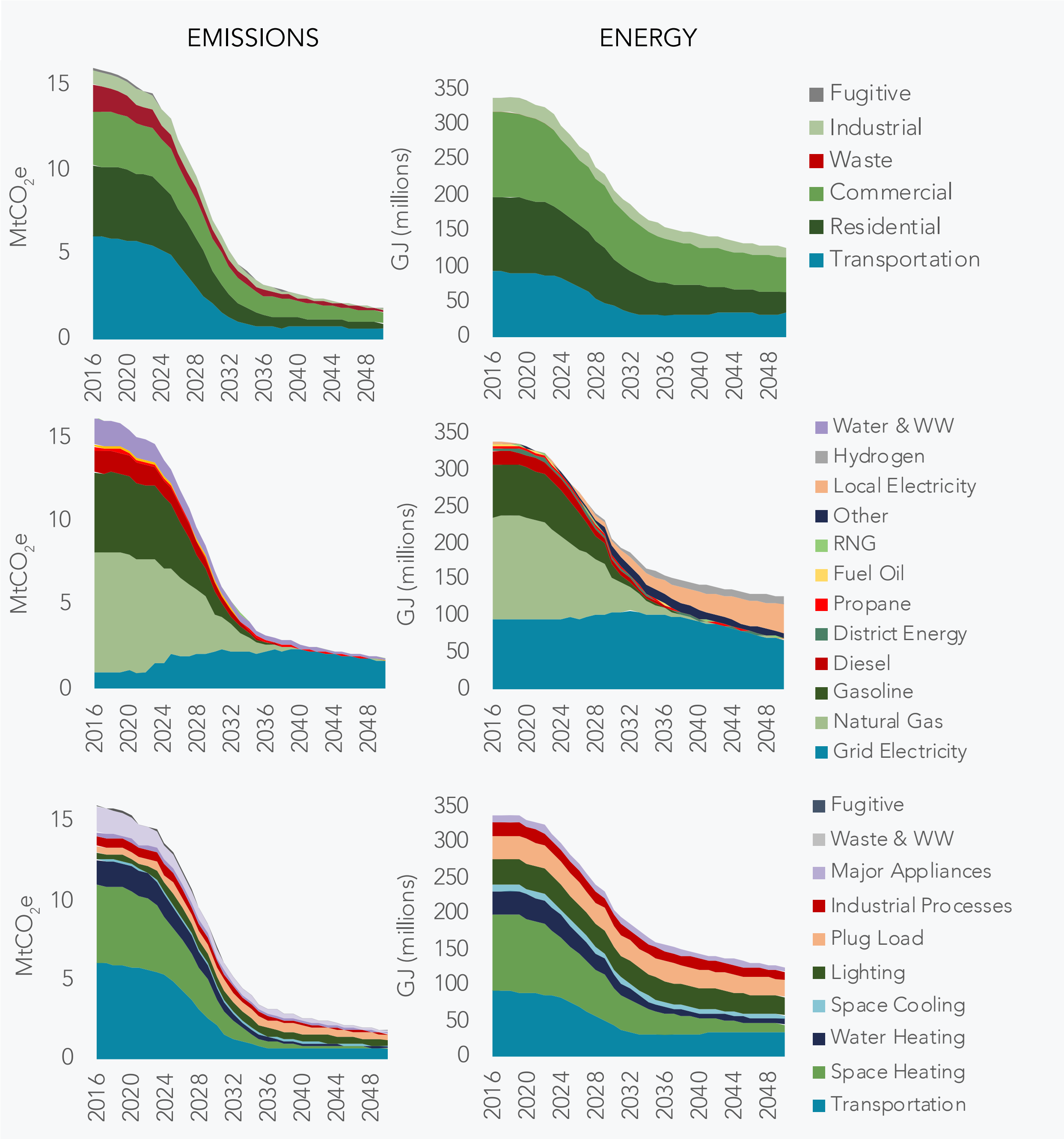


Figure 34. GHG emissions and energy reductions by energy type, sector, and action type (2016 to 2050), NZ40.

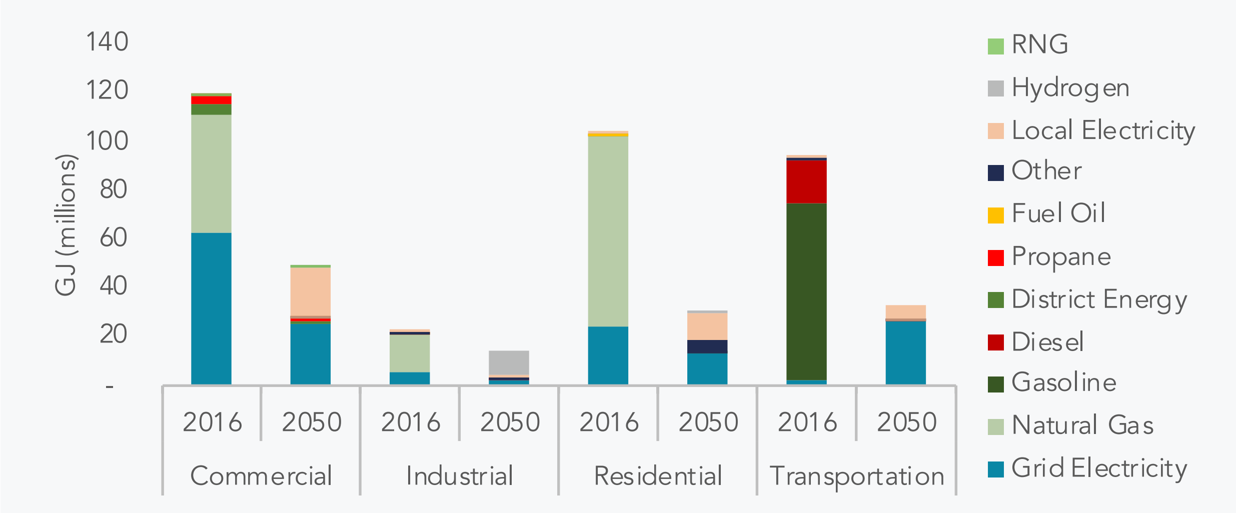


Figure 35. Total energy for NZ40, 2016 and 2050.

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 10). The targets serve as indicators against which the City can track performance over time.

Table 10. 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 (m^2))	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

	2016	2017-2025	2026-2030	2031-2040	2041-2050
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 36 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; for this effort to reduce GHG emissions to nearly zero, the system needs a source of clean electricity. The provincial grid is the most likely candidate.

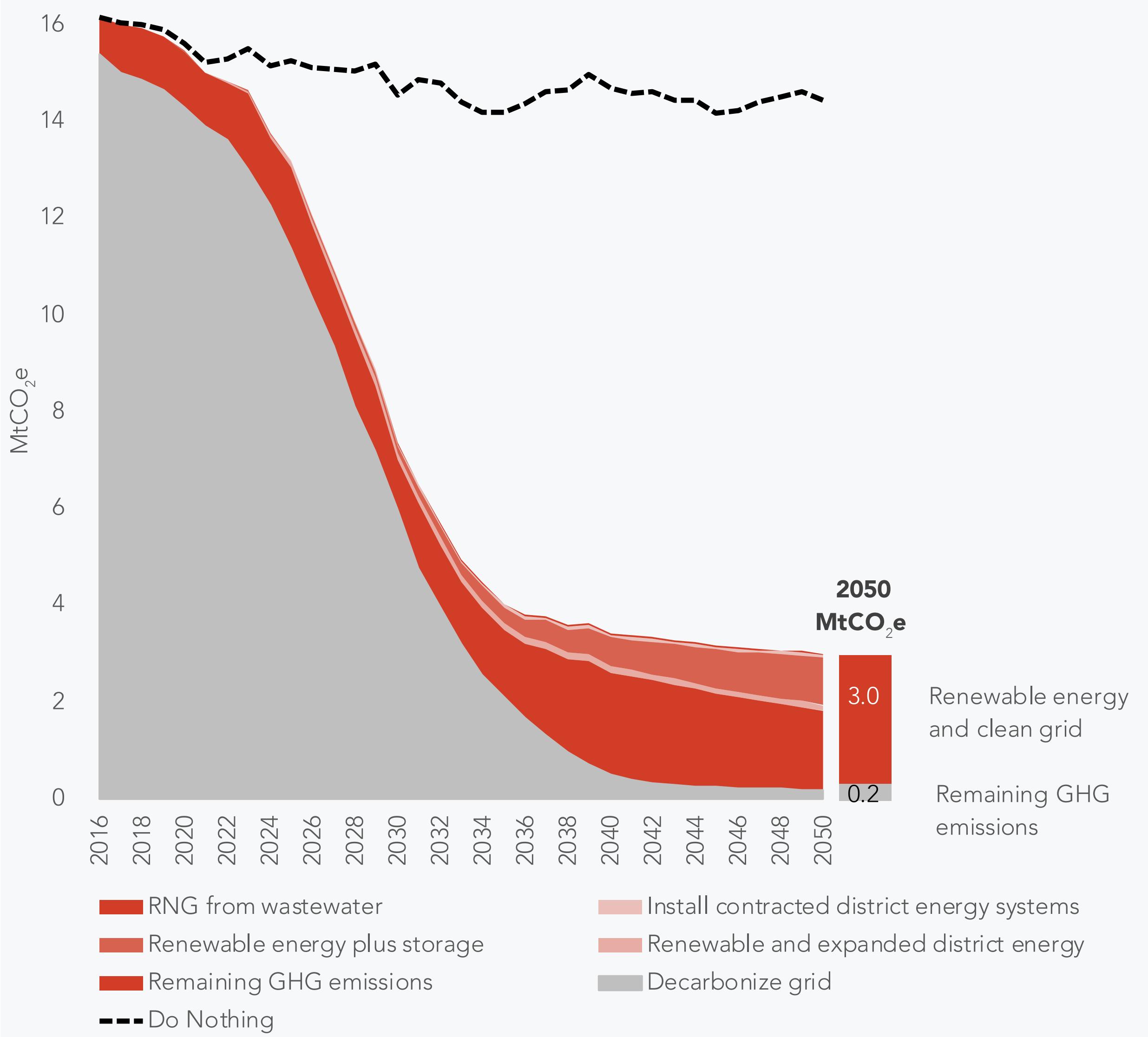


Figure 36. Wedge diagram of energy GHG reduction actions, NZ40, 2020-2050.

DECARBONIZATION AND PEAK ELECTRICITY DEMAND

Electrifying two of the most significant energy consuming activities in society—heating and transportation—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.[88] 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.

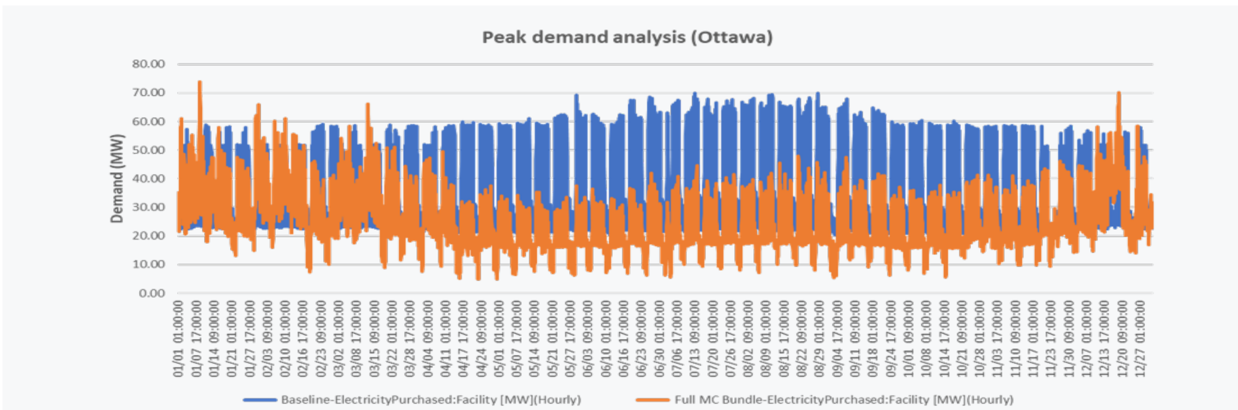


Figure 37. Daily peak demand of simulated natural gas heated buildings, baseline (blue) and post-retrofit and heat pump conversions (orange).

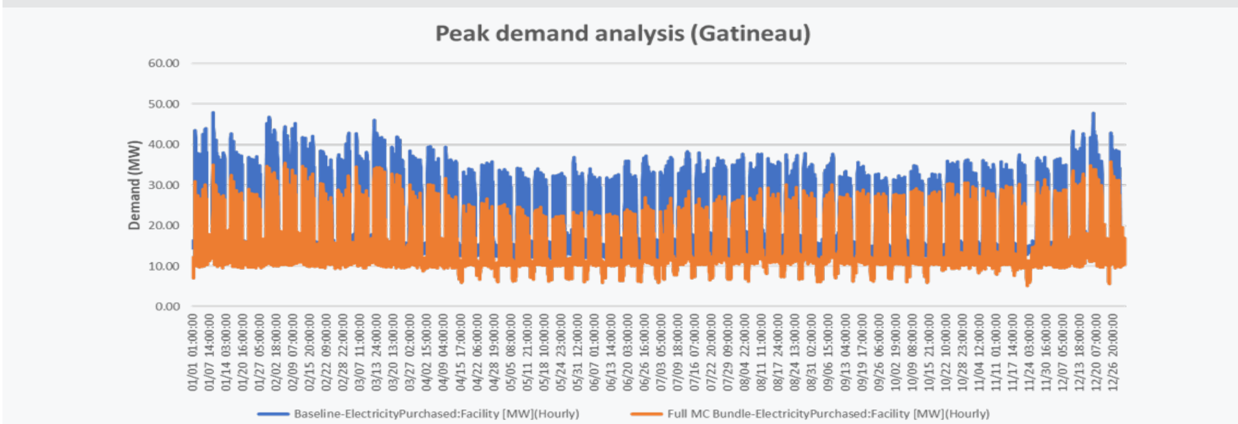


Figure 38. Daily peak demand of simulated electrically heated buildings, baseline (blue) and post-retrofit and heat pump conversions (orange).

88 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

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 39. 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

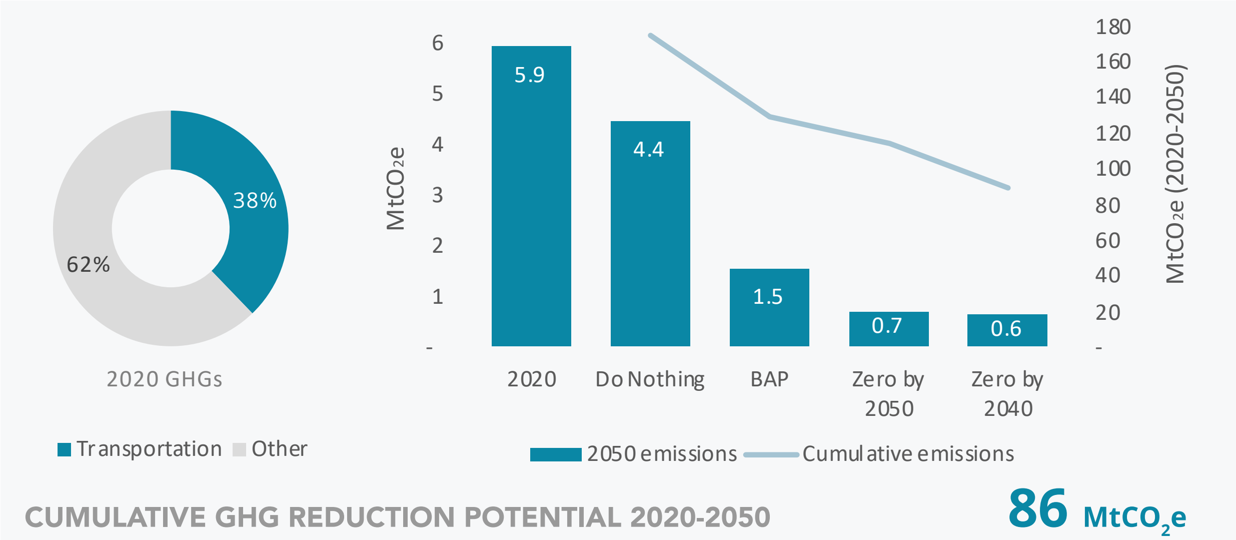


Figure 39. GHG emissions from transportation.

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 11). 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 11. 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)[89]	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 40) and in Table 12. 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.

89 Mode share targets are the same in NZ50 and NZ40 scenarios.

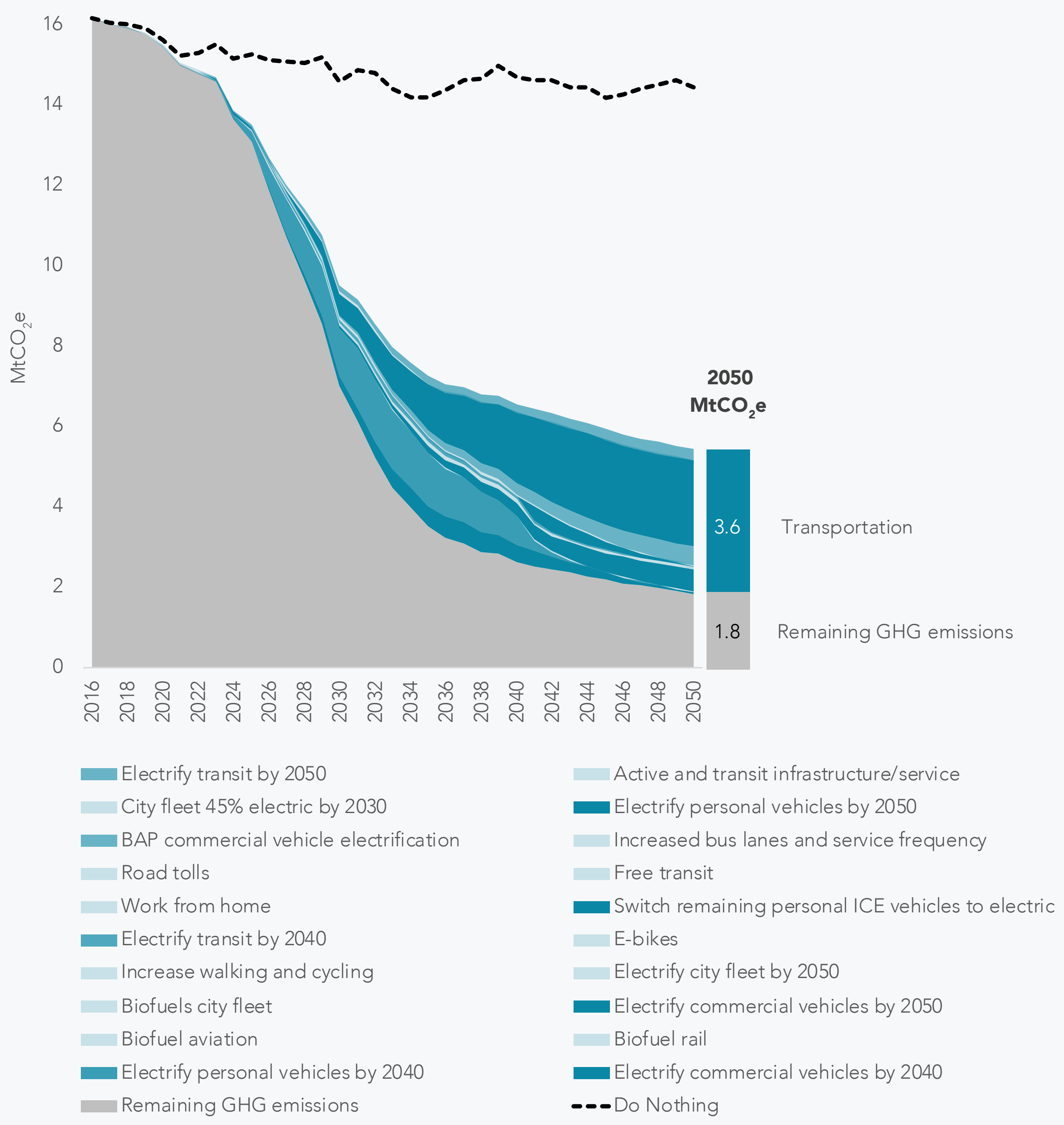


Figure 40. Wedge diagram of transportation GHG reduction actions, NZ scenarios.

Table 12. 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.	

WEDGE	WEDGE DESCRIPTION	SCENARIO
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.	
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 42 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 41). S-curves describe the diffusion of innovations[90] 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.

90 Rogers, E. M. (2010). Diffusion of innovations. Simon and Schuster.

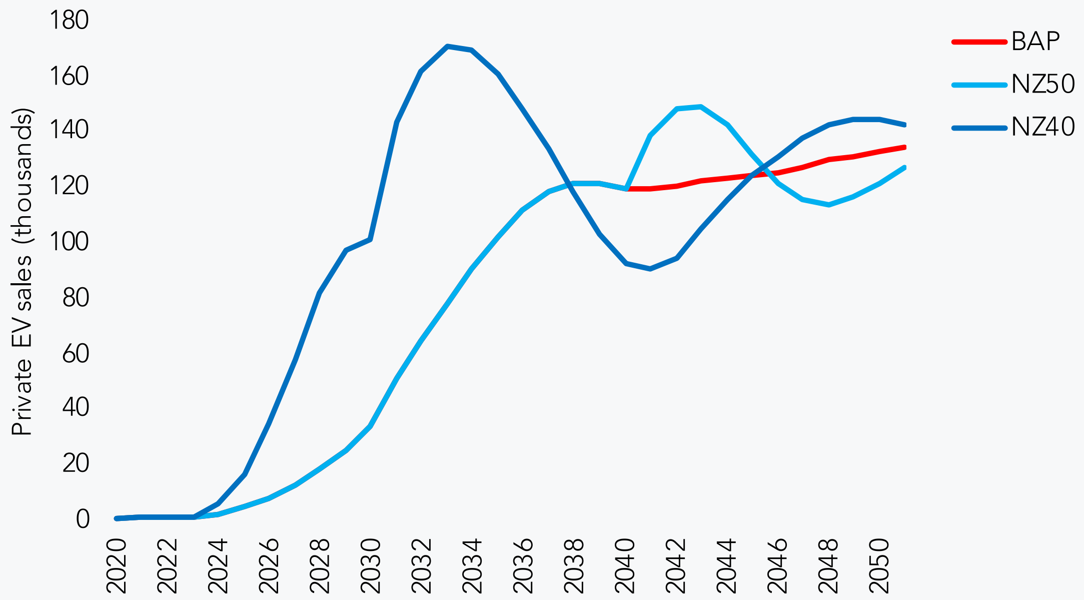


Figure 41. Private EV sales in each of the scenarios, using S-curves.

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.

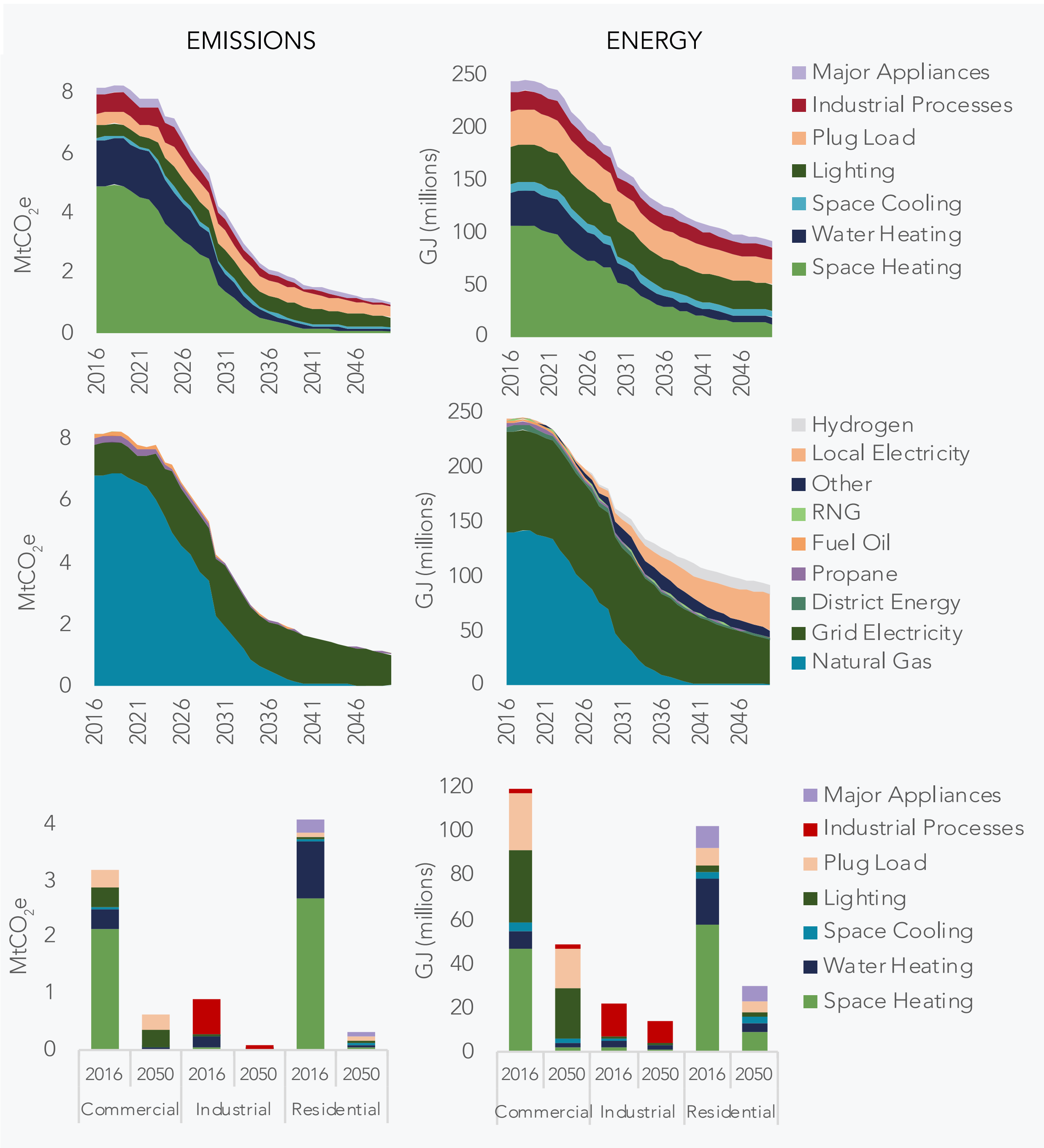


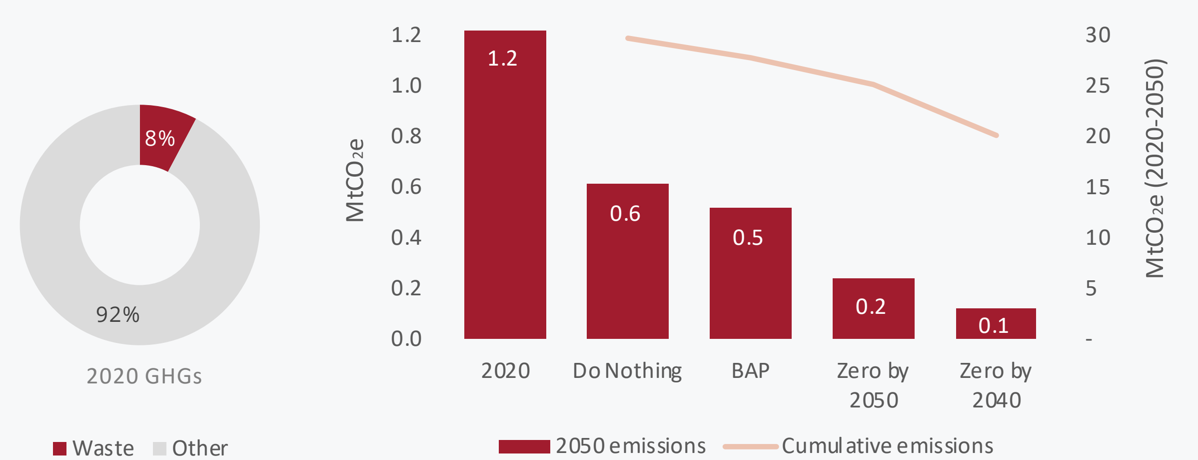
Figure 42. Emissions and energy use from buildings for NZ40, 2016 and 2050.

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 $MtCO_2e$ (8% of total). Each scenario outcome for the sector in 2050 is illustrated by Figure 43. The Do Nothing scenario results in annual emissions of 0.6 $MtCO_2e$; BAP results in 0.5 $MtCO_2e$; and the NZ40 and NZ50 result in 0.1 and 0.2 $MtCO_2e$, respectively. The cumulative GHG reduction potential between 2020 and 2050 is 10 $MtCO_2e$.



CUMULATIVE GHG REDUCTION POTENTIAL 2020-2050 **10** $MtCO_2e$

Figure 43. 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 13). The targets serve as indicators against which the City can track performance over time.

Table 13. 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 44) and in Table 14. 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.

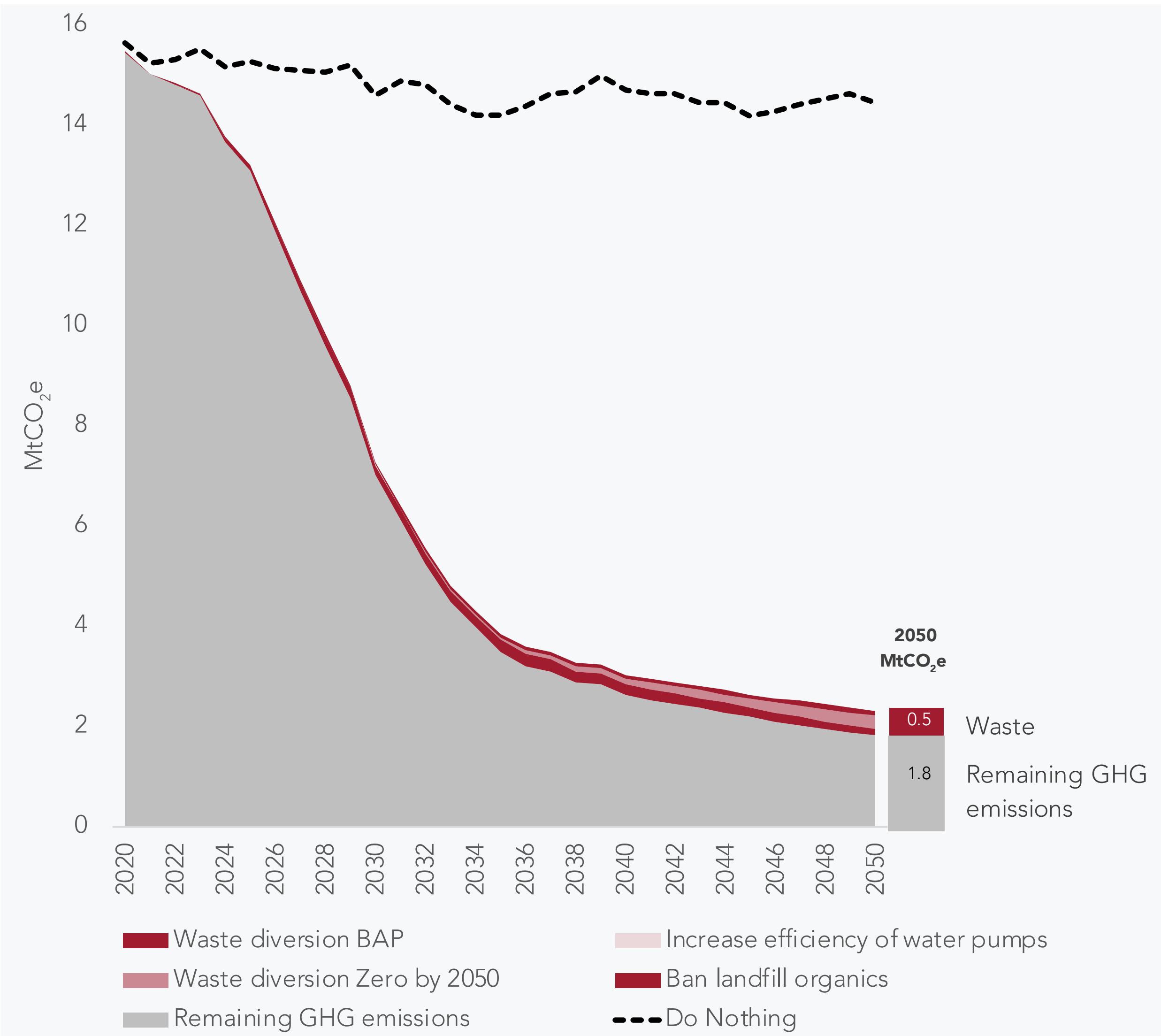


Figure 44. Wedge diagram of waste GHG reduction actions, 2020-2050, NZ40.

Table 14. 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