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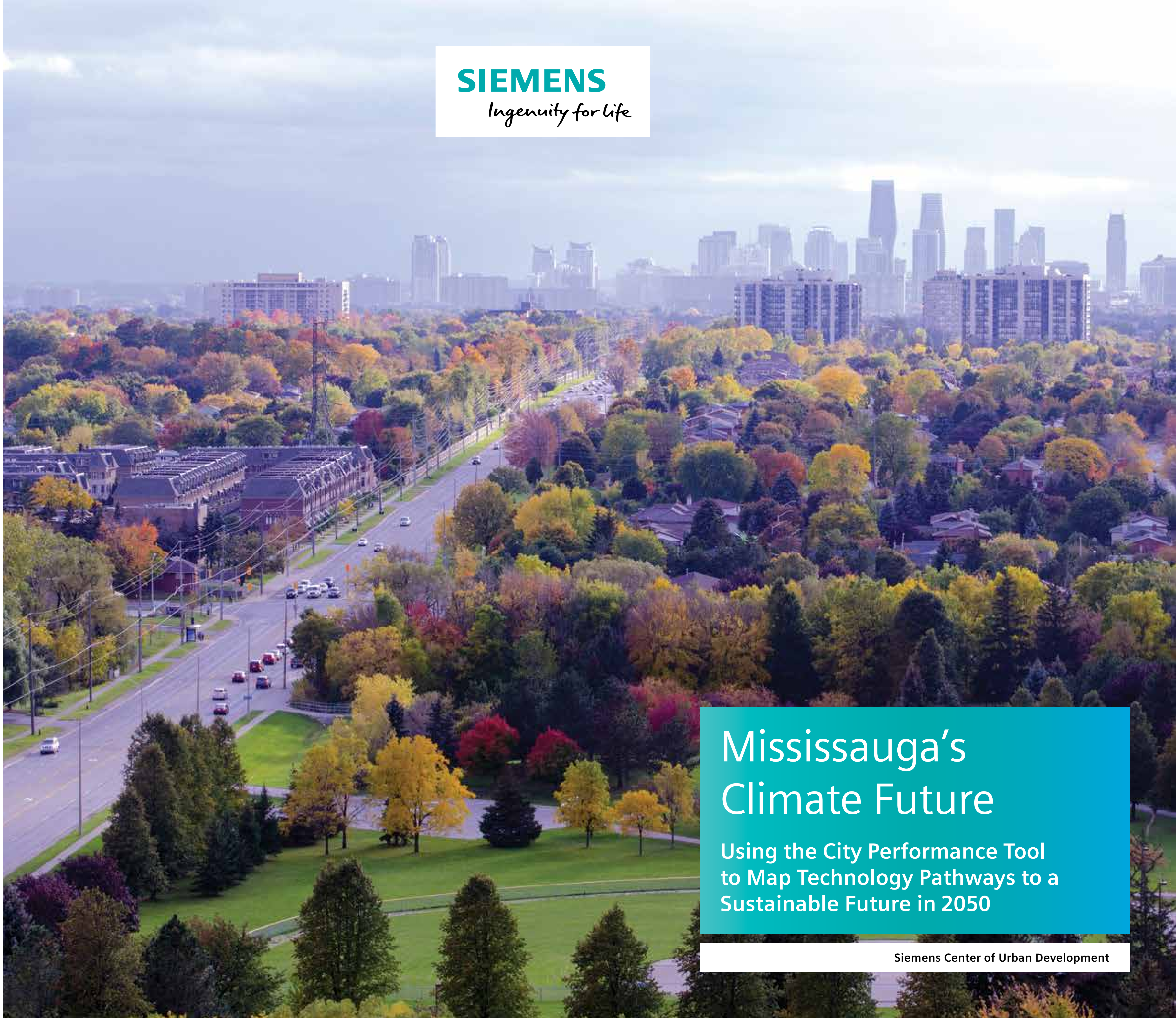

Mississauga's Climate Future

Using the City Performance Tool to Map Technology Pathways to a Sustainable Future in 2050

Siemens Center of Urban Development

About the Report

About Siemens

Infrastructure is the backbone of a city's economy and urban development projects help to create a livable and sustainable smart city. With automated and intelligent infrastructure technologies, Siemens expertise is in integrating hardware and software to improve quality of life, capacity, and efficiency in metropolitan areas. Siemens established the Center for Urban Development, comprised of a dedicated team, to address specifically the needs of city leaders, their staff, and administrative agencies.

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Color and visual guidelines

We have used colors and visual cues in powerful ways to enhance the meaning and clarity of data visualization throughout this report. Please refer to the following as you are browsing:

- **CO_2eq**
- **Transport**
- **Buildings**
- **Energy**

Siemens would like to thank:

The City of Mississauga, Environment Section for their support and guidance during the development of this report. Special thanks to Julius Lindsay (former Supervisor, Climate Change) and Leya Barry (Climate Change Coordinator).

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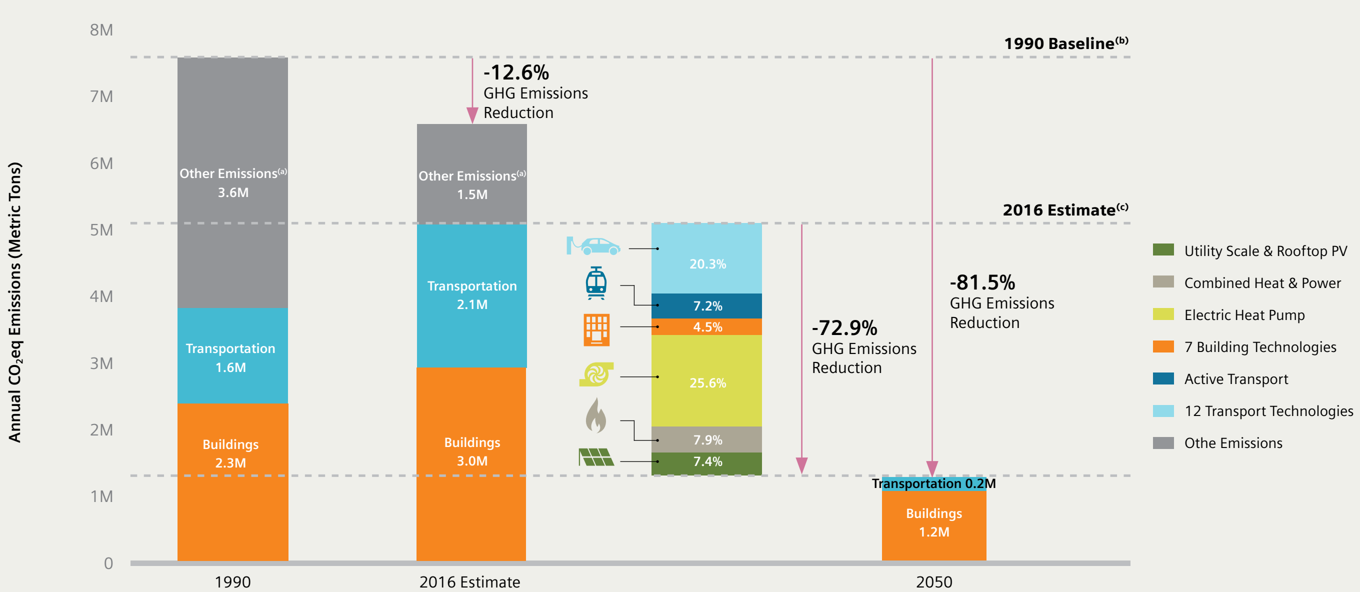
Executive Summary

According to the analysis based on Siemens City Performance Tool (CyPT), deep carbon emissions reductions can be achieved in the City of Mississauga by the year 2050. In order to achieve this, significant commitments to greener energy, including a grid that has additional utility scale wind and solar, and more efficient heating options for residential and commercial buildings (e.g., electric heat pumps and CHP), would be needed. This report analyzes the impact of existing policies, such as the City's Transportation Master Plan's mode share target, which states that half of trips to, from, and within Mississauga will be taken by sustainable modes (those other than driving a car, such as walking, cycling, transit, ridesharing, and ride hailing in a taxi or TNC) and layers on 12 technologies that target public, private, and freight transportation to model achievable reductions in the transportation sector. Similar analysis performed for the building and energy sectors shows a possible pathway to reducing GHG emissions in Mississauga by over 80% while improving air quality and strengthening the local economy. The results and recommendations from this study will serve to inform Mississauga's first Climate Change Action Plan, which is expected to be released in Fall 2019.

Deep Carbon Reduction Can Be Achieved

The "waterfall" chart outlines Mississauga's journey towards 80x50. The City Performance Tool (CyPT) analysis estimates CO_2eq emissions for today (2016) and 2050 for building and transportation energy usage only. The chart illustrates the impact and individual contributions of technologies affecting public and private transit, buildings, electricity generation, and building heating.



(a) Other emissions include GHG emission from water, wastewater, industry, airport, and any other sectors not in scope of CyPT analysis. For Mississauga, these emissions are obtained from Peel Region's inventory as well as Mississauga's Community GHG calculations.
(b) 1990 Baseline GHG emissions are from Peel Climate Change Strategy.
(c) 2016 Estimates for Buildings and Transportation sector are calculated from CyPT analysis by collecting over 350 data points from the City.

Environmental and Economic Impact

A snapshot of the environmental and economic impact from the buildings, energy, and transportation sectors are shown in this chart. Reaching and partially exceeding the 80x50 goal for the City means reducing 4.2 million metric tons of CO_2 emissions. These GHG reductions would be accompanied by generation of over 290,000 local full-time equivalent jobs and would require investments of $55 billion in capital and operating expenditures between now and 2050.

Mississauga 2050

4.2M
Potential CO_2eq Reduction (in metric tons) as compared to 2035 BAU

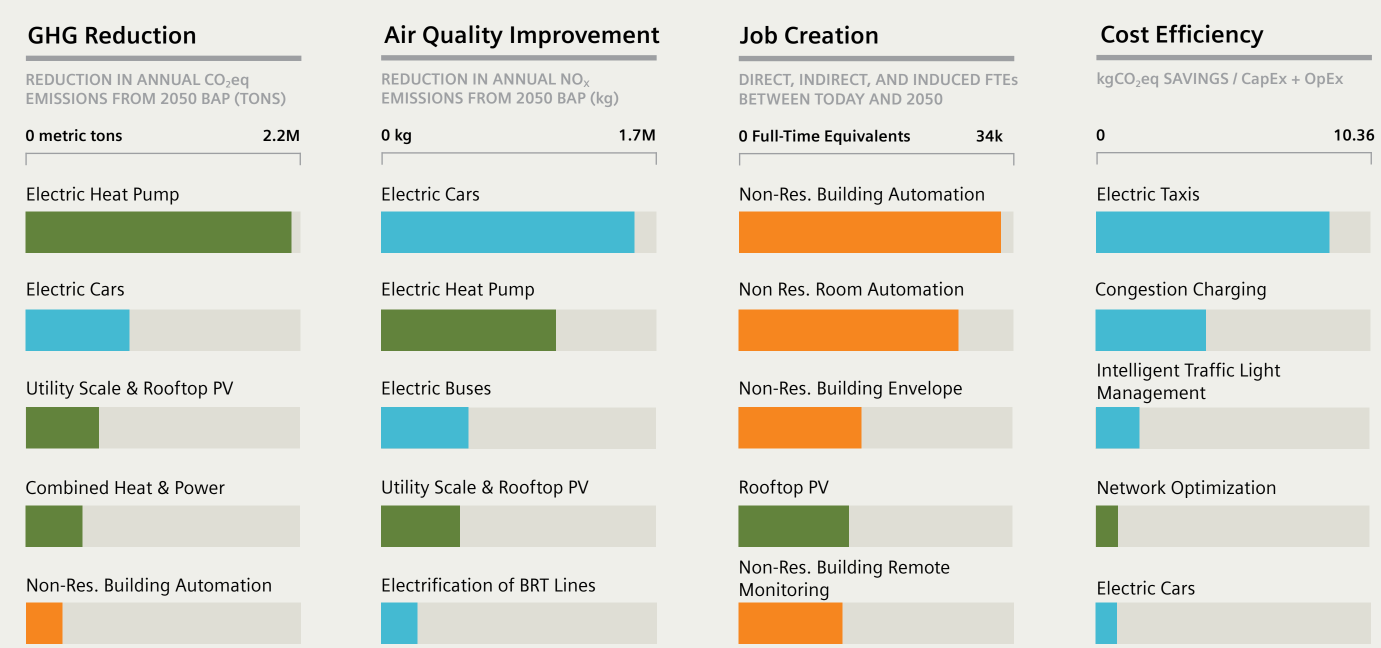
81.5%
Potential CO_2eq Reduction (%) as compared to 1990 Baseline

$55B
Capital and Operating Expenditures between Today and 2050

295,000
Full-time Equivalents Generated between Today and 2035

High-Performing Technologies

The top-performing technologies in terms of GHG reduction are predominantly the result of electricity and heating technologies, with air-source electric heat pumps providing the most significant reduction of over 2 million tons of CO_2 savings. Electric heat pumps also appear in the top five technologies that would improve air quality in the city, followed by 100% transition to electric cars. Various building technologies would be the most significant in creating jobs, with building automation responsible for over 34,000 new FTEs.



Introduction

As the sixth largest city in Canada, Mississauga is quickly growing and with projected population set to be over 900,000 by 2050, the City will remain one of the biggest economic centers in the Greater Toronto Area (GTA). The City is making meaningful progress towards ensuring a sustainable future by reducing greenhouse gas emissions throughout the corporation and in the community. These initiatives include greening the City's fleet, installing rooftop solar photovoltaics, transitioning to LED street lights, planting over 300,000 new trees, and reducing per capita water consumption.

Despite these accomplishments, Mississauga has a long road ahead to achieve its climate goals and targets. Since 2018, Siemens has been working in close collaboration with the Environment Section at the City to evaluate technology pathways for deep carbon reduction that would ensure the City's success in achieving an 80x50 goal. During our joint analysis, we collected data from the City's transportation and buildings and energy sectors to establish an emissions baseline for 2016 and a projected baseline for 2050. Siemens co-hosted a technology workshop with the Environment Section in which stakeholders from six different agencies[d], including multiple departments within the City, identified policy and technology scenarios under which Mississauga could reach its 80x50 target.

The future impact of the recommended policies and technologies are the subject of the rest of this report, which quantifies the performance of these recommendations against five key performance indicators: GHG emissions, nitrogen oxides (NOx), particulate matter (PM10), gross full-time equivalents (FTE)[e], and capital and operating expenses. As Mississauga prepares to release its first comprehensive Climate Change Action Plan later this year, this report serves as an input into the development of the Action Plan as well as a starting point for discussion around policies and actions Mississauga will need to take in order to achieve its climate change goals and targets.

Siemens co-hosted a technology workshop in which stakeholders from six agencies identified policy and technology scenarios under which Mississauga could reach its 80x50 target.

(d) List of agencies and participants can be found in Appendix I.
(e) FTE is a person-year of work, calculated as 2,080 hours of work.

City Performance Tool

The City Performance Tool (CyPT) was developed by Siemens with a goal of helping cities make informed infrastructure investment decisions to achieve ambitious environmental targets. While working with the City of Mississauga on a decarbonization analysis, Siemens used the City Performance Tool (CyPT) to identify how technologies from the transportation, buildings, and energy sectors can mitigate carbon dioxide equivalent (CO_2e) emissions, improve air quality, and create new jobs.

The CyPT model has assessed environmental and economic development opportunities available to cities across the globe, including San Francisco, Copenhagen, London, Mexico City, Seoul, Los Angeles, Washington, DC, and Vienna. Siemens collaborated with each city to identify infrastructure and technological solutions that best fit the city's energy demand and production characteristics. CyPT results help cities drive their sustainability agendas. For example, in Copenhagen, the CyPT analysis revealed that implementing 15 energy efficiency technologies in just 40 building owners' portfolios could reduce annual emissions by 10%. The City of Copenhagen is now discussing ways to act on that recommendation, whether by piloting those energy efficiency technologies in a public building or by creating an incentive program to encourage building owners to retrofit their portfolios. The CyPT analysis for the City of Los Angeles, Climate LA, showed that LA's greenhouse gas reduction targets for 2035 and 2050 are achievable[1]. Success will require transitioning to 100% generation of renewable electricity, increasing transit ridership and active transportation as modes of travel, and an additional 19 infrastructure technology measures. Emissions reductions would be accompanied by 72% improvement in air quality and almost two million local jobs. In addition, CyPT analyses for the cities of Minneapolis and Phoenix supported the adoption of a 100% renewable electricity target citywide and a more aggressive GHG reduction target by 2035, respectively.

Analysis using CyPT starts with more than 350 data inputs from a city's transportation, energy, and buildings sectors, including more general characteristics such as population growth, the supply mix of electricity generation, transportation modalities and travel patterns, building energy use, and the built environment footprint.

Starting with the city's population, energy performance, and emissions baseline, the model estimates the future impact of more than 70 technologies (only 60% of which are sold by Siemens) along the following three drivers:

1. **Cleaner underlying energy mix:** Shifting the energy generation mix from non-renewable to renewable energies (e.g., photovoltaics or wind power) and/or improving the efficiency of the current fossil fuel sources (e.g., combined heat and power cogeneration plant).
2. **Improved energy efficiency in buildings and transport:** Replacing existing technologies with more energy efficient ones. For example, replacing traditional street lighting with LEDs and/or demand-oriented street lighting, or replacing internal combustion cars with electric cars.
3. **Modal shift in transportation**: Modeling changes in the modal split of the city. For example, by creating new BRT lines, a city potentially moves passengers away from single-occupancy cars and into the BRT.

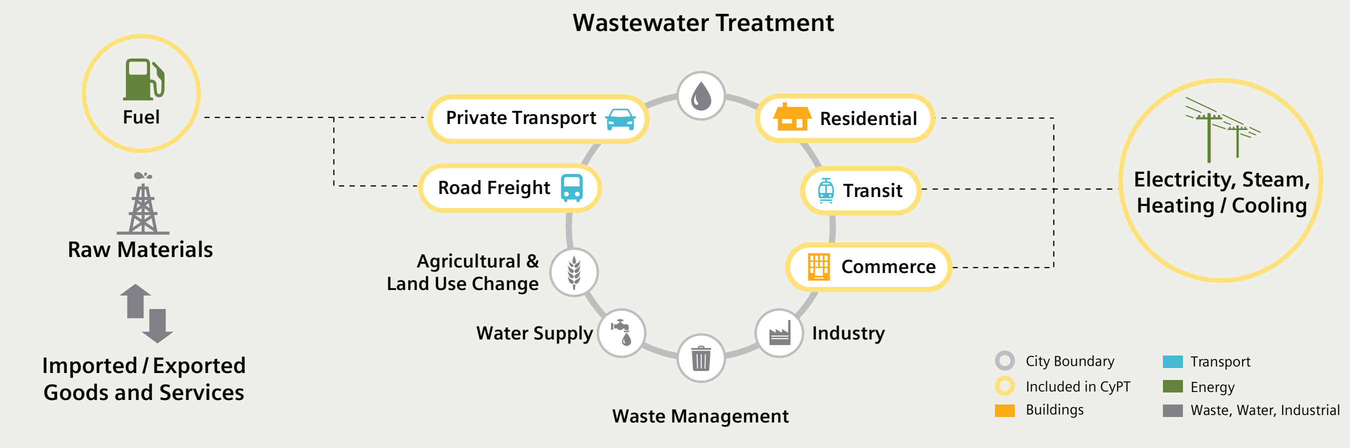
The outputs of the model are CO_2e emissions, nitrogen oxides (NOx), particulate matter 10 (PM10), gross full-time equivalents (FTE), and capital and operating expenses.[f, 2]

CyPT results are helping cities around the world assess their environmental and economic development opportunities and drive their sustainability agendas.

(f) An FTE is a person-year of work, calculated as 2,080 hours of work in the US.

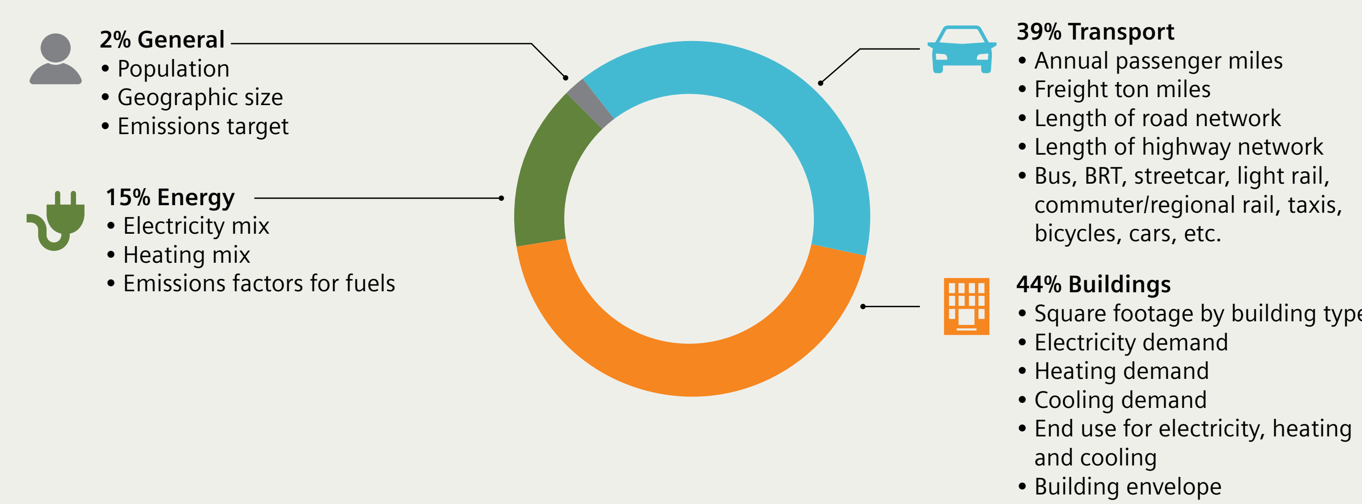
City Performance Tool: Scope of Emissions Model

The CyPT utilizes the 2012 GPC Protocol for Community-Wide Emissions as its methodology for estimating GHG emissions. It covers Scopes 1, 2, and 3 emissions for energy generation and energy use in buildings and transportation. As such, the CyPT takes into consideration both direct emissions occurring within the city boundaries (e.g., exhaust fumes) and indirect emissions from the conversion of chemical energy to power, heat, or steam or purchased energy from outside the city. The included Scope 3 emissions refer to the emissions produced as a result of fuel production and extraction. This also includes the construction and production of renewable power plants.



CyPT Inputs

The CyPT can be customized through more than 350 city-specific data inputs, which when combined, project how a city is expected to grow and change as its population and infrastructure expand. More than half of the inputs that go into the CyPT look at how people move around the city, live, and work.



Mississauga's Emissions Baseline

Accurately projecting Mississauga's emissions for 2050 is the first step in charting out technology pathways that will result in deep carbon reductions for the City. In order to evaluate emissions, we collected over 350 data points from Mississauga's transportation, building, and energy sectors. Through collaboration with the City's Environment Section, data on population and population projections, travel patterns, building footprint, and energy usage, as well as energy mix was collected and analyzed to create a greenhouse gas emissions baseline for today as well as 2050. We also reviewed studies and policies which will shape Mississauga's future and incorporated them into our analysis, including the Peel Climate Change Strategy[3], Mississauga's Living Green Master Plan[4], as well as IESO's[g] planning outlook[5] for Ontario which provides a 20-year look ahead for Ontario's electricity system.

Mississauga is the third most populous city in Ontario and is expected to grow by 27% over the next 30+ years. Assuming a business as usual scenario, this growth translates into an 18% increase in GHG emissions for 2050 as compared to today.

Our analysis for Mississauga considers two baseline scenarios: business-as-usual (BAU) and business-as-planned (BAP). BAP is a more realistic picture of a growing city that considers a 35% reduction in single-occupancy vehicles mode shares as well a 10% increase in renewable fuels in the electricity mix. In contrast to the BAU, the BAP projects a 9% increase in GHG emissions as compared to today.

(g) Independent Electricity System Operator or IESO is the local utility company operating as Independ Electricity Market Operator and supplying electricity to Ontario Province.

Mississauga, Today to 2050

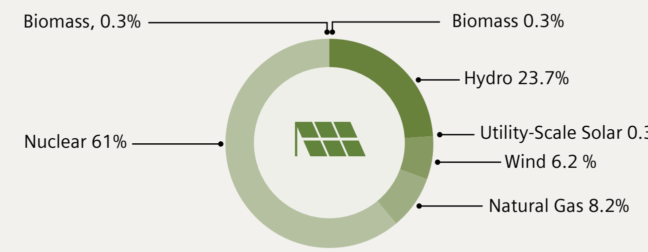
Today

POPULATION

721,599

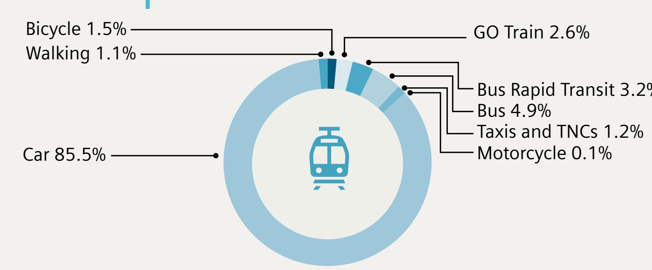
ELECTRICITY MIX

31% Renewable



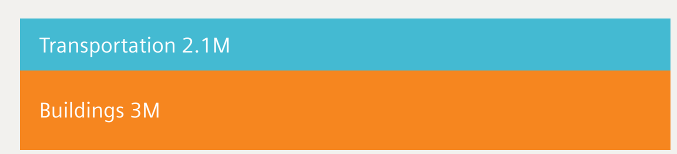
PASSENGER MODE SHARE§

14% Transit and Active Transport



CYPT-ESTIMATED ANNUAL GHG EMISSIONS*

5.1M Metric Tons



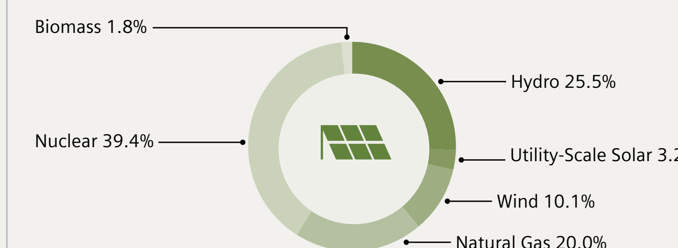
2050 (Business-as-Planned)

POPULATION

919,826

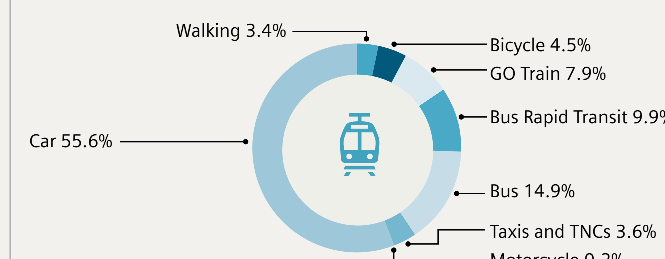
ELECTRICITY MIX

41% Renewable



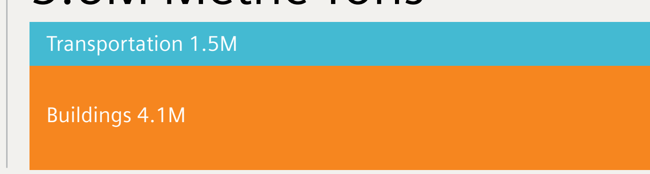
PASSENGER MODE SHARE§

41% Transit and Active Transport§



CYPT-ESTIMATED ANNUAL GHG EMISSIONS*

5.6M Metric Tons



	Today	2050 Business-as-Planned
ESTIMATED % INCREASE IN GHG EMISSIONS AS COMPARED TO TODAY		+9.1%
TARGET GHG EMISSIONS REDUCTION AS COMPARED TO 1990		80%

§ Assumption for transit mode share for 2050 is based on the City's transportation target to ensure 50% of the vehicle kilometers traveled in 2041 come from single occupancy vehicles.

* For energy, buildings, and transport sectors only. See the section on "City Performance Tool" for more information on the methodology and scope of the CyPT.

CyPT Technology Scenarios

Buildings & Energy

Today, buildings in Mississauga cover over 116 million square meters of space, 31% of which are dedicated to homes. The average energy use intensity (EUI) of homes in Mississauga is 0.7 GJ/m², which is consistent with the average EUI of homes in Ontario, according to Natural Resources Canada (NRCan)[6], while the square footage of homes in Mississauga is 2% larger when compared to the provincial average. Non-residential buildings in Mississauga overall are more energy efficient when compared to the provincial average, with the energy use intensity almost three times lower than average. The distribution of energy usage is consistent with what one would expect in Mississauga's cold climate. Over 80% of energy expended in residential buildings goes into heating homes and water, compared to non-residential buildings, which only use 58% of energy expended to provide space heating and water.

Of the 60% emissions attributed to buildings throughout the city, over half come from residential buildings. The City is already making strides towards reducing the emissions footprint of buildings. The City's 5-year Energy Conservation plan[7] targets municipal buildings (20% of the city's built footprint) and the City is seeing increasing uptake of energy efficiency standards such as LEED and BOMA BEST in buildings.

Buildings and Energy Data

Today, buildings in Mississauga cover over 116 million square meters of space, 31% of which are dedicated to homes. The average energy use intensity (EUI) of homes in Mississauga is 0.7 GJ/m², which is consistent with the average EUI of homes in Ontario, according to Natural Resources Canada (NRCan), while the square footage of homes in Mississauga is 2% larger when compared to provincial average.

Residential Data

Share of Residential Building Stock
31%

Average Residential Unit Size
1,626 ft²

Total Electricity Consumption
2,188 GWh

Average Energy Use Intensity
0.7 GJ/m²

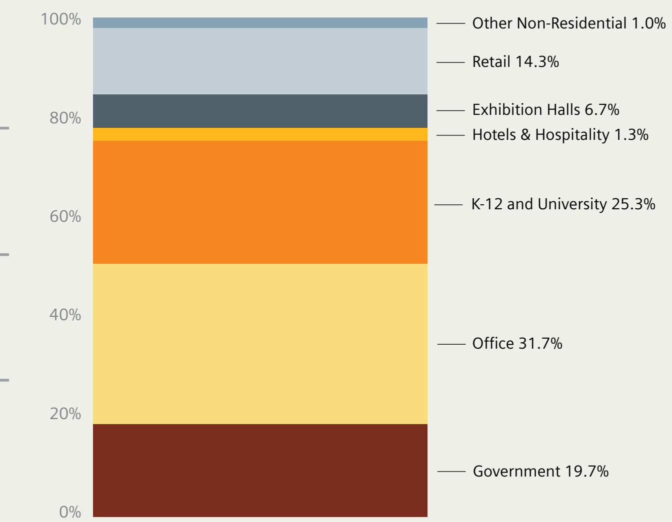
Non-Residential Data

Total Building Footprint
80M m²

Total Electricity Consumption
4,427 GWh

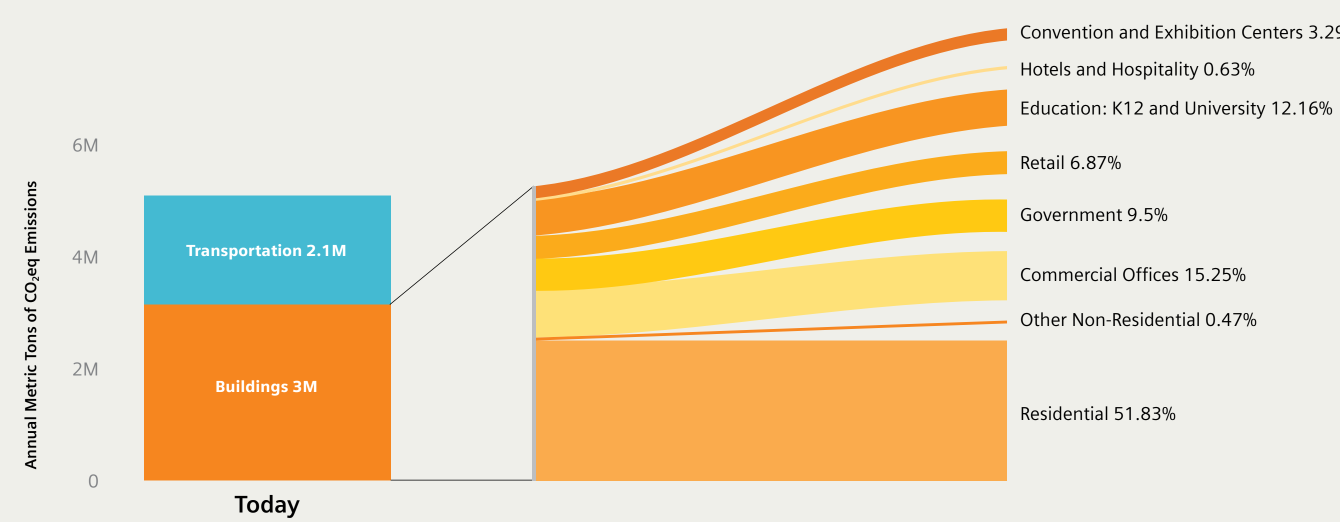
Average Energy Use Intensity
0.4 GJ/m²

Breakdown of Square Footage of Commercial Buildings



GHG Emissions – Buildings and Energy

This CyPT analysis evaluated seven technologies that will impact building energy usage in Mississauga and six technologies that target the electricity, heating generation, and transmission/distribution network. Together, the seven building technologies and six energy technologies could achieve a 57% reduction in GHG emissions by 2050.

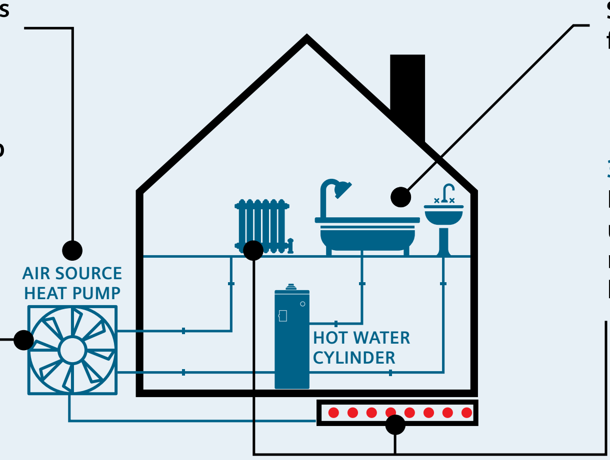


Of the top five high-performing technologies modeled for the buildings and energy sector in the city, the best-performing ones focus on improving the electricity and heating supplied to buildings. In addition to evaluating the impact of 41% renewables in the electricity-generation mix, our analysis also modeled a scenario where 50% of all electricity consumed in the city comes from solar power (10% from rooftop PVs installed on buildings within the city and 40% from utility-scale solar farms that could be located outside the city). This transition alone could help Mississauga save over 670,000 metric tons of CO_2 emissions annually.

Air-source heat pumps, powered by electricity, are the best-performing technology in terms of CO_2 emissions reduction as well as air quality improvements. An adoption rate of 50% across residential and non-residential buildings, combined with 41% renewable fuels used in the electricity-generation mix provides over 2 million metric tons of GHG emissions savings as compared to the 2050 BAP scenario. These emissions savings can be attributed to fuel switching from natural gas to electricity for space and water heating. Our assumption of replacing 50% of natural gas-based heaters with air-source electric heat pumps is in line with other municipal low-carbon scenarios (e.g., Toronto) necessary for achieving an 80x50 emission reduction target[8].

Air-Source Heat Pumps

Air-source heat pumps draw heat from the outside air during the heating season and reject heat outside during the summer cooling season. Essentially, the outdoor air serves as the heat source in winter and heat sink in summer. Heat is moved in and out of the building using electricity with help of a low-boiling point refrigerant through a compression cycle – much like the one in a refrigerator. At first glance, one would assume a colder climate might not make air-source heat pumps a suitable heating option. However, Natural Resources Canada (NRCan) has identified three regions within Canada where air-source heat pumps are an economically viable option, southern Ontario being one of these regions[9]. Heating efficiency is measured in terms of HSPF, or heating seasonal performance factor, and is calculated by dividing total heating output by electricity input. According to NRCan for southern Ontario, HSPF would be in the range of 5.9 to 8.6 based on the manufacturer. For this analysis, we've chosen an average value of 7.2, which means for every kWh of heating output, 0.47 kWh of electricity would be required to operate the heat pump. Higher efficiency of electric air-source heat pumps could result in cost savings for homeowners upwards of 50%[9] when compared to an electric furnace. However, the savings are less significant when switching from a natural gas-based heating furnace since the cost savings depend on the price of natural gas versus electricity in Ontario. According to a 2012 study by NRCan[10] comparing life cycle costs of various heat pump options, the capital costs of installing a cold-climate air-source heat pump can be twice that of a natural gas-based heating furnace but can provide roughly 26% utility savings over a 20-year lifetime. The emissions reduction potential from switching to all electric heat pumps is significant, especially as the electricity generated in Ontario is predominately renewable. In Mississauga, this analysis shows that even with 41% of renewables in the baseline, an adoption rate of 50% air-source heat pumps in the city's residential and commercial buildings has the potential to save over two million metric tons of CO_2.



CyPT Levers for Buildings and Energy

Residential + Non-Residential (NR) Buildings		Adoption Today	Adoption 2050
LEVER	UNIT		
Wall Insulation (Residential)	% of building stock w/lever	40%	100%
Home Automation (Residential)	% of building stock w/lever	5%	70%
Building Performance Optimization (NR)	% of building stock w/lever	2%	70%
Building Envelope (NR)	% of building stock w/lever	35%	100%
Building Automation (NR)	% of building stock w/lever	15%	75%
Room Automation – Lighting + HVAC (NR)	% of building stock w/lever	5%	70%
Building Remote Monitoring	% of building stock w/lever	0%	60%

Energy		Adoption Today	Adoption 2050
LEVER	UNIT		
Rooftop & Utility-Scale PV	% of total electricity generation	0%	50%
Utility-Scale Wind Power	% of total electricity generation	6.2%	21.2%
Combined Heat & Power	% of total heating demand	0%	30%
Electric Heat Pumps	% of total heating demand	2.9%	50%
Network Optimization	% of electric grid optimized	0%	100%
Smart Grid for Monitoring & Control	% of electric grid replaced with smart grid	0%	100%

It is important to note that the manufacturing and installation of rooftop PV panels does come with an environmental and economic cost. CyPT analysis includes Scope 3 emissions[h], which accounts for the emissions produced during construction and transportation of photovoltaic panels and results in an increase in PM10 emissions by 85,000 kg. In the context of power production, this means 30 grams of PM10 per MWh electricity produced using PV. By comparison, one MWh of coal-powered electricity would emit roughly twice this amount of PM10. Installation of these rooftop panels would also end up creating 30,000 direct, indirect, and induced jobs between today and 2050.

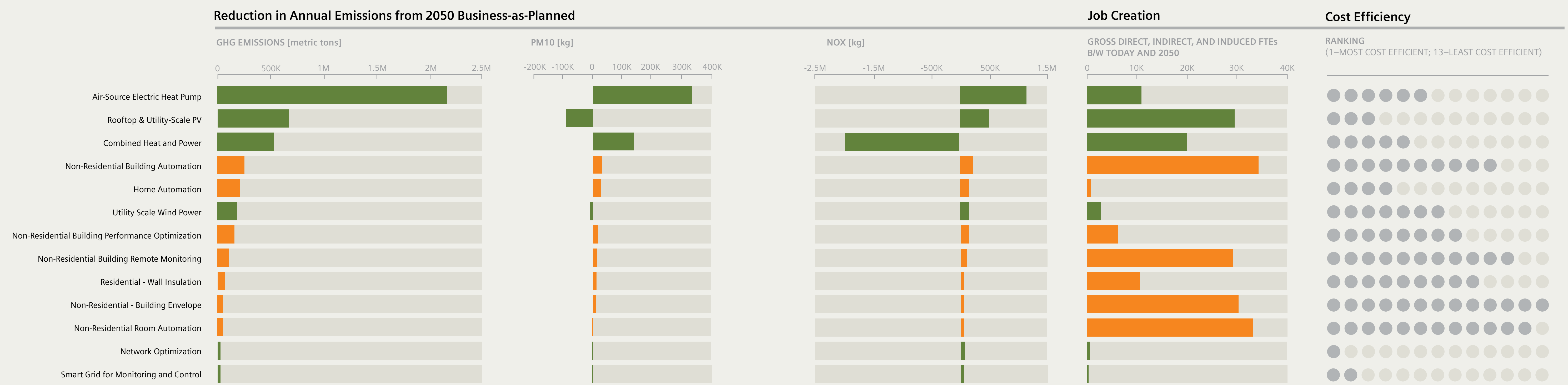
Combined heat and power (CHP) technology has the potential to increase the efficiency of heating while continuing to use natural gas as a fuel. Diverting 30% of the natural gas from traditional heating furnaces to CHP has the potential to save 526,000 million metric tons of CO_2 emissions, but at the same time will increase NOx emissions by 1.9 million kg due to the combustion of natural gas.

(h) Although CyPT utilizes the 2012 GPC Protocol for Community-Wide Emissions methodology while creating the baseline GHG inventory, there are a few key differences, especially when it comes to Scope 3 emissions. For most cities, Scope 3 means only T&D losses; for CyPT, it means indirect emissions including T&D losses as well as upstream emissions from production of fuel (both feedstock and fuel stages). This also includes the construction and production of renewable power plants, e.g., rooftop PV.

Combined Heat and Power

Combined heat and power (CHP) is a highly efficient method of providing power and useful thermal energy (heating or cooling) at the point of use with a single fuel source. By employing waste heat recovery technology to capture a significant portion of the heat created as a by-product of fuel combustion, CHP systems typically achieve total system efficiencies of 60 to 80%, which is a vast improvement as compared to current system efficiencies of 30 to 45% of traditional power generation systems[11]. An industrial or commercial entity can use CHP to produce electricity and thermal energy instead of obtaining electricity from the grid and producing thermal energy in an on-site furnace or boiler. By producing electricity on site, CHP also avoids transmission and distribution (T&D) losses that occur when electricity travels over power lines. Increase in the efficiency of electricity and heat generation by using CHP can also lead to lower energy costs. The amount of savings that CHP represents depends on the difference in costs between displaced electricity purchased and fuel used by the CHP system. For this analysis in Mississauga, we assumed that a natural gas-based CHP system is displacing purchased electricity produced from natural gas, hence the savings come solely from an increase in the efficiency of a CHP system.

CyPT Lever Impacts – Buildings and Energy



Transportation

Even with a 26% growth in bus ridership in Mississauga between 2011 and 2016[12], traffic and congestion is still a concern in Mississauga[13]. With approximately 200,000 additional residents set to call Mississauga home by 2050, the need for infrastructure and investments in public transit are becoming more apparent. The City is proactive in tackling this transportation challenge by developing its first Transportation Master Plan[14]. This plan, which was built on two years of stakeholder engagement as well as research and learnings from current transportation options, hopes to shape how people will move around the city over the next 20+ years.

Currently, Mississauga residents travel an average of 44 km per person per day. 85% of these passenger kilometers traveled are in single-occupancy vehicles. Freight also represents a significant source of emissions in Mississauga. In 2016, 218 million vehicle kilometers were traveled by trucks within the city's boundary, which translates to 4.8 ton-km per person per day.

A little over 40% of Mississauga's CO_2 emissions come from the transportation sector. Our CyPT analysis for most North American cities in colder climates (e.g., Boston, Washington, DC, and Portland) has shown that, on average, transportation contributes to approximately 25% of a city's community-wide GHG emissions. This departure for Mississauga can be explained by two key characteristics. First, its unusually low energy use intensity in commercial buildings (it's three times lower than the provincial average). Second, inclusion of freight transport in the footprint adds an additional 10% of emissions that were excluded in the previously mentioned cities (Boston, Washington, DC, and Portland). Mississauga has the second highest local transit ridership per capita in the GTHA (after Toronto) and accounts for less than 3% of the total emissions from transportation. Contributing over 195,000 metric tons of CO_2, freight emissions are also an important topic for consideration in the city. Freight not only contributes to emission but also to congestion, especially for the section of highway 401 going through the city, which is considered to be one of the busiest highways in Canada and North America.

Public, Private and Freight in Mississauga

Currently, Mississauga residents travel an average of 44 km per person per day. 85% of these passenger kilometers traveled are using single occupancy vehicles.

Passenger Transportation

Average Distance Traveled, Per Person, Per Day

44 km / person / day

No. of Cars on the Road (Cars Per Household)

437,971 (1.8)

Average Fuel Economy

9.8 Liters/100km

Freight Transportation

Annual Freight Ton Kilometers (Vehicle km Traveled)

4.8 ton-km/person/day

(218 million travelled within Mississauga)

Mode Share

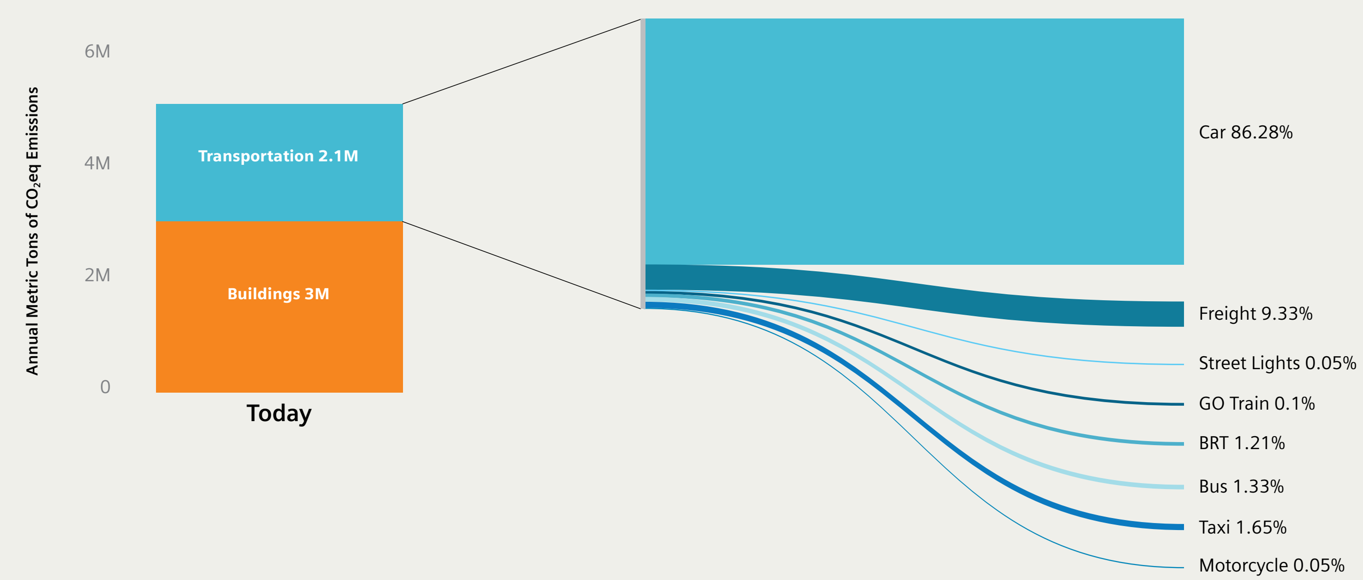
100% by Trucks

Average Fuel Economy

8 miles per gallon

GHG Emissions – Transportation

40% of Mississauga's GHG emissions come from the transportation sector including freight. Less than 3% of these emissions currently come from public transit.



GHG Emissions – Transportation

Our CyPT analysis looks at 12 public and private transportation modes and infrastructure technologies that will target transportation in Mississauga in 2050 and is aggressive in its assumption of adoption rates. For example, 100% electrification of private cars and taxis would require serious commitment not only from the City and its citizens but also from the utility provider, which will have to add over one million MWh of additional electricity to support this transition. According to our analysis, this transition would also require significant investment in charging infrastructure for personal and transit vehicles, including 35,000 additional charging stations for cars, with an additional 80 needed for buses by 2050.

Other transportation levers included in the study tackle infrastructure within the city. For example, the eHighway lever simulates the impact of electrifying 75% of the freight corridors, which would include installation of overhead catenary lines along corridors to allow hybrid electric or fully electric trucks to charge as they are driving, enabling long-haul transportation, and reducing local CO_2 and NOx emissions to close to zero. Congestion charging is another lever that was explored, which looks at instituting a charge for driving into the city and would eventually force a behavior towards public transit usage.

CyPT Levers for Transportation

The technology that would produce the highest impact on GHG emissions by far is the 100% transition to electric cars, with potential savings of over 970,000 metric tons of CO_2. Electric cars would also significantly improve air quality and could generate up to 18,000 local jobs. Comparatively lower performance of other public transit levers is a direct indication of lower usage and availability of these modes. For example, even with the City's ambitious targets of reducing vehicle kilometers travelled by single-occupancy vehicles, the electrification of the entire MiWay bus fleet would only reduce CO_2 emissions by 46,000 metric tons, which is 3% of total emission reductions from all modeled transportation technologies in this study.

CyPT Levers – Transportation

Public Transit

LEVER	UNIT	Today	2050
eBuses	% of public bus fleet	0%	100%
eBRT – New Lines	Total no. of lines	0	5
BRT – Electrification	% of existing BRT lines electrified	0%	100%
Tram – New Lines	Total no. of lines	0	2

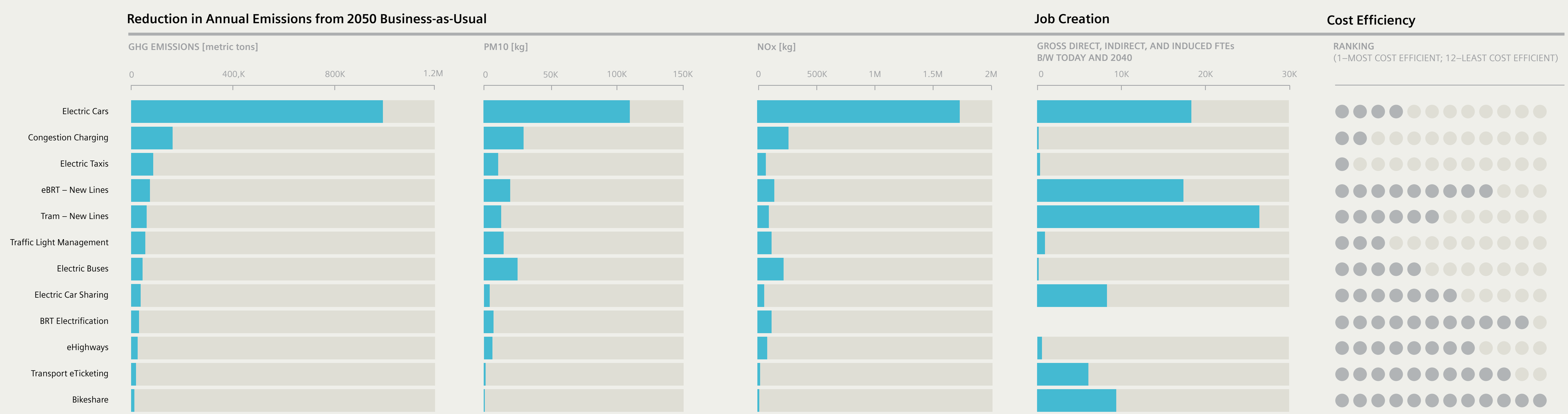
Private Transportation

LEVER	UNIT	Today	2050
Electric Cars	% of cars on the road	0.4%	100%
Electric Taxis	% of taxis on the road	0%	100%
Electric Car Sharing	No. of car sharing cars	0	1,000
Bikeshare	Total no. of sharing bikes	0	5,000

Infrastructure

LEVER	UNIT	Today	2050
Intelligent Traffic Light Management	% of traffic lights w/coordinated fixed time, rules-based, or adaptive control	0%	100%
Congestion Charging	% reduction in road traffic	N/A	15%
Public Transport – eTicketing	% of users as share of travelers	67%	100%
eHighway	% of freight corridors electrified	0%	75%

CyPT Lever Impact Results – Transportation



Conclusion

Pathway to 80% GHG reduction by 2050

By pulling all this information and data together, we present a potential pathway for Mississauga to achieve an 80% reduction in greenhouse gas emissions by 2050. In addition to the technologies outlined, we have identified the policies, behaviors, as well as some market forces that need to work together to make this a reality for the city.

A) 1990 Baseline

We used the 1990 baseline emissions for the City of Mississauga that were presented in the 2006 Community GHG inventory[15] for the Region of Peel as the baseline value for this analysis.

B) 2016 Estimate

The CyPT model estimates 2016 annual GHG emissions, which includes only the energy usage in the buildings and transportation sectors, to be 5.1 million metric tons. When we consider other emissions[i] out of scope for CyPT but included in Mississauga's Community GHG calculations, the 2016 emissions are 12.6% lower than the 1990 baseline[j].

C) 2050 BAU

The business-as-usual or BAU scenario simulates the increase in emissions based on population growth as expected and everything else remaining the same in terms of transportation and building energy usage as well the sources of energy production. In Mississauga, this scenario produces a 13.4% increase in GHG emissions as compared to today.

D) 2050 BAP

The business-as-planned or BAP scenario is a more realistic picture of a growing city. It postulates a 35% reduction in passenger kilometers travelled by single-occupancy vehicles and increases the amount of renewable fuels in the electricity mix to 47% (including 15% more wind power), which results in only a 9% increase in GHG emissions as compared to today.

E) Utility Scale & Rooftop PV

In addition to the assuming 47% renewable energy in the generation mix, the BAP scenario adds 50% more solar to the electricity grid, which means that the city could be powered almost entirely by renewables. Only 10% of this added solar would be generated from panels on the rooftops of Mississauga buildings.

F) CHP

In addition to the renewable grid, we also modeled a 30% increase in combined heat and power in the city. This technology, while continuing to use natural gas as heating fuel, would increase the efficiency of heating and would be able to reduce GHG emissions by 9% as compared to the 2050 BAP scenario.

G) Electric Heat pumps

The next step in reducing the impact of building heating is heating electrification. Installing air-source electric heat pumps in 50% of the residential and commercial buildings could reduce GHG emissions by almost 30% as compared to the 2050 BAP scenario.

H) 7 Building Technologies

Together with a significantly greener electricity grid and more efficient heating, we modeled seven building technologies that target energy reduction in buildings in Mississauga that would reduce emissions by an additional 5%.

I) 12 Transport Technologies

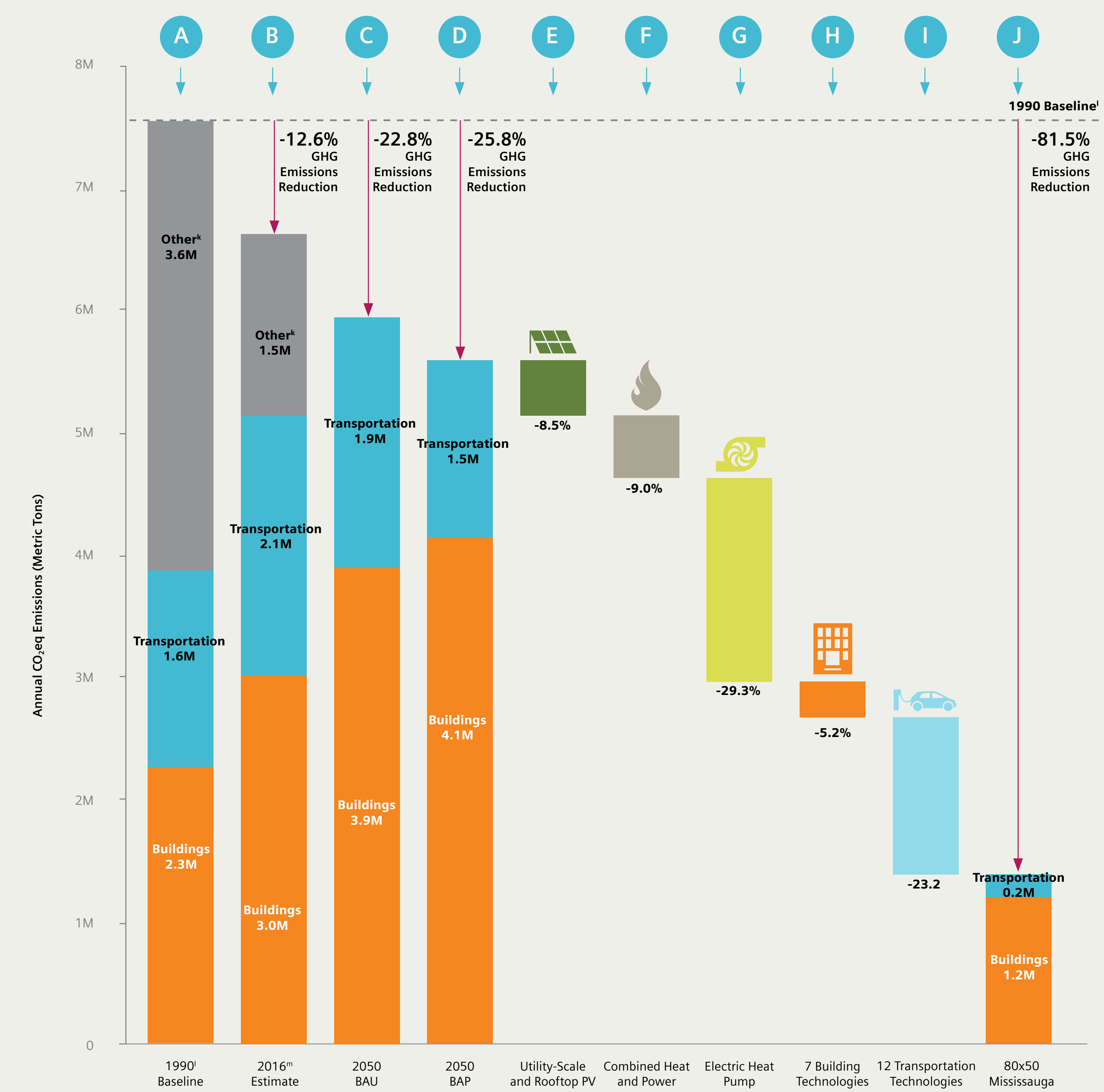
Finally, 12 transportation technologies reduce emissions by just over 23%. These technologies include 100% electrification of the private fleet, taxis, buses, and BRTs. With the potential of 970,000 metric tons of CO_2 reduction, 100% electrification of private cars is the most impactful of these technologies.

J) 80x50 Mississauga

The combination of the 25 energy, buildings, and transportation technologies; market forces; policy changes; and behavioral changes has the potential to reduce the City's annual CO_2e emissions by 81.5% from the 1990 baseline – achieving the 80x50 goal.

(i) Other emissions include GHG emission from water, wastewater, industry, airport and any other sectors not in scope of CyPT analysis. For Mississauga, these emissions are obtained from Community GHG calculations for 2016.
(j) 1990 Baseline GHG emissions are from Peel Climate Change Strategy.

Pathway to 80x50



(k) Other emissions include GHG emission from water, wastewater, industry, airport and any other sectors not in scope of CyPT analysis. For Mississauga, these emissions are obtained from Peel Region's inventory as well as Mississauga's Community GHG calculations.
(l) 1990 Baseline GHG emissions are from Peel Climate Change Strategy.
(m) 2016 Estimates for Buildings and Transportation sector are calculated from CyPT analysis by collecting over 350 data points from the City.

Our CyPT analysis shows that it is possible for the City of Mississauga to achieve an 80% reduction in GHGs by 2050 by creating a greener, smarter, and more prosperous city by 2050. The path forward will require a great commitment from residents, local government, as well as all private and public stakeholders that call Mississauga home.

In addition to creating a greener grid, addressing the heating demands of buildings should also be a priority for the City. Currently in Mississauga, space and water heating consumes 83% of the total energy usage in residential buildings and 58% in commercial and municipal buildings. This provides a huge opportunity for emissions reduction, which has been addressed by modeling two solutions in this analysis – combined heat and power (CHP) and air-source heat pumps. These solutions combined have the potential to reduce GHG emissions by over 2.6 million metric tons.

We also modeled 12 transportation technologies that could have a significant impact on the emissions baseline. In addition to reducing CO_2 emissions by over 1.5 million metric tons, these technologies would significantly improve air quality by reducing NOx emissions by 3.2 million kg and PM10 emissions by 200,000 kg by 2050.

Commitment to Renewable Energy

Cities around the world are embracing renewable energy. As of January 2018, according to CDP[16], over 100 cities get at least 70% of their electricity from renewable sources such as hydro, geothermal, solar and wind. Nine of these cities are in North America, including Burlington, VT; Prince George, BC; and Winnipeg, MB, which are already powered by 100% renewable energy. In the United States, 36 cities have committed to 100% renewable electricity, with over 100 mayors supporting their city's transition to 100% renewable in the future[17].

The City of Minneapolis recently passed a resolution establishing a 100% renewable electricity goal for municipal operations by 2022 and citywide by 2030[18]. This goal is in response to the City's aggressive greenhouse gas emissions reduction strategy outlined in the Climate Action Plan, which seeks to reduce GHG emissions by 80% by 2050 and is based on the recommendations from our 2015 CyPT analysis[19]. Our analysis showed that it is possible for Minneapolis to achieve its 80 by 50 target if the City, its utilities, and its inhabitants work aggressively to clean the local energy supply, adopt electric transport and public transit, and improve energy efficiency in buildings.

Appendices

I – CyPT Technology Workshop Participants

We would like to thank all the participants in the Technology Workshop held in the City of Mississauga for their contribution in developing deep de-carbonization scenarios for the City.

Affiliations	Participants
Alectra Utilities	Navneet Budhia; Jon Golin; Caroline Karvonen; Daniel Carr
City of Caledon	Katelyn McFayden
City of Mississauga	Michelle Berquist; Eniber Cabrera; Geoff Marinoff; Angela Dietrich; Edward Nicolucci; Marianne Cassin; Michael Cleland; Julius Lindsay; Leya Barry
Dillon Consulting	Ravi Mahabir
Enbridge	Bruce Manwaring; Vitha Krishnamurthy; Erika Lontoc; Chris Wray
Siemens Canada	Lucy Casacia; Geoff Newman; Sofya Goldkey

II – CyPT Technologies for Mississauga

Building Levers		
Residential and Non-Residential Building Square Footage	Wall Insulation	Solid wall insulation, e.g., made of expanded polystyrene (EPS), can be applied to already existing buildings. Applying the rigid foams to exterior side of walls raises thermal resistance. The insulation reduces the heat gain/loss through the walls and thus minimizes the heating/cooling energy needed. Reduction of CO_2e, PM10, and NOx related due to energy savings.
Residential	Home Automation	Home automation allows the automatic adjustment of heating, cooling, ventilation, and lighting depending on the environmental conditions and the room occupancy by applying sensors and actuators as well as control units. This reduces the energy demand of heating, cooling, ventilation, and lighting.
Residential / Non-Residential	Building Envelope	A high-performance building envelope can be part of the initial building design or it can be created through the renovation of an existing building. A high-performance building envelope would include insulation, high-performing glazing and airtight construction. Energy-efficient solutions can be applied to every part of the building envelope, including floors, roofs, walls, and facades, and it can also be used to reduce the energy loss of a building's technical installations (e.g., pipes and boilers).
Non-Residential	Building Performance Optimization (BPO)	Building Performance Optimization (BPO) is a range of services designed to increase the energy efficiency of an EXISTING building by implementing proven building control strategies otherwise known as facility improvement measures (or FIMs). BPO can improve THERMAL and ELECTRICAL energy efficiency in a building in many ways, typically via improved HVAC technology, by adapting the building to suit usage profiles, or providing information and analytics for operational personnel. Reduction of CO_2e, PM10, and NOx related due to energy savings.
Non-Residential	Building Automation (BACS Class B)	Energy-efficient building automation and control functions save building operating costs. The thermal and electrical energy usage is kept to a minimum. It is possible to estimate the efficiency of a building based on the type of operation and the efficiency class of the building automation and control systems (BACS) installed. Energy Class B includes advanced building automation and controls strategies, such as demand-based operation of HVAC plant, optimized control of motors and dedicated energy management reporting. Reduction of CO_2e, PM10, NOx are related to thermal and electrical energy savings.
Non-Residential	Room Automation	Room Automation provides control and monitoring of heating, ventilation, and air conditioning within individual zones based upon demand, with options for automatic lighting. An in-built energy efficiency function identifies unnecessary energy usage at the room operating units, encouraging room users to become involved in energy saving, and different lighting scenarios can be programmed. Reduction of CO_2e, PM10, NOx are related to electrical power utilized in the heating, ventilation, and air-conditioning and lighting of a building.
Non-Residential	Building Remote Monitoring	Remote monitoring allows individual building performance to be measured and compared against benchmark values for similar building types or sizes. Energy experts can remotely analyze building energy usage, to detect problems and make proposals for improvements. Reduction of CO_2e, PM10, and NOx related due to energy savings.

Transport Levers		
Public	Electric Buses	Share of the vehicle fleet that is battery-electric vehicles. Battery-electric vehicles are "zero" exhaust gas emission vehicles. Significant reduction of local emissions PM10, NOx. A charging infrastructure is set up. The electricity used for charging is generated according to the general local electricity mix.
Public	Tram – New Lines	Light rail systems (LRT) are lighter and shorter than conventional rail and rapid transit trains. They are flexible and can run on shared roadways or along dedicated tracks. These systems can be configured to meet a range of passenger capacity levels and performance characteristics, can operate with high or low platforms, and can have one or multiple carriages. Trams can be equipped with braking energy storage systems to reduce energy demand.
Private	Electric Cars	Share of conventional combustion vehicles replaced by battery-electric vehicles. Battery-electric cars are "zero" exhaust gas emissions vehicles. Significant reduction of local emissions PM10, NOx. A charging infrastructure is set up. The electricity used for charging is generated according to the general local electricity mix.

Private	Electric Taxis	Share of conventional combustion vehicles replaced by battery-electric vehicles. Battery electric cars are "zero" exhaust gas emissions vehicles. Significant reduction of local emissions. A fast-charging infrastructure is set up. The electricity used for charging is generated according to the general local electricity mix.
Private	Electric Car Sharing	Number of sharing cars/1000 inhabitants at target year: model of car rental where people rent eCars for short periods of time, on a self-service basis. It is a complement to existing public transport systems by providing the first or last leg of a journey. Resulting in fewer driving emissions due to eCar and shift to non-vehicle travel, such as walking, cycling, and public transport.
Public	Bikesharing	Number of sharing bikes/1000 inhabitants offered at target year, resulting in a shift from all transport mode equally and lower energy demand per person kilometer together with related emissions.
Public	eBus Rapid Transit New Lines (eBRT)	eBRT provides a high-performance public transport combining dedicated bus lanes with bus stations, and electrical vehicles providing faster, more efficient service than ordinary bus lines. Results in modal shift from private transport to public transport, shift from combustion engines, and reduce energy demand per person km together with related emissions.
Passenger	BRT-Electrification	Share of the vehicle fleet operated by battery electric vehicles. Battery electric vehicles are "zero "exhaust gas emissions vehicles. Significant reduction of local emissions PM10, NOx. A charging infrastructure is set up. Electricity, used for charging, is generated according to the general local electricity mix.
Infrastructure	Congestion Charging	Congestion charging is a form of road pricing applied to a city perimeter and could include a charge levied against use of roads, travel within a certain area, or distance/time-based fees. Charges could also be used to discourage use of certain classes of polluting vehicle or vehicles that use a particular fuel.
Infrastructure	eTicketing	This technology provides simple, affordable, competitive, and integrated ticketing. Electronic tickets offer a one-payment system for all forms of transport and simplify public transport use. Passengers can transfer seamlessly between different transportation modes and fees are calculated at the end of the trip. Passengers pay only for the services they use – automatically, electronically, transparently, and securely. Benefits are achieved through increased revenues, reduced operational costs and improved reliability.
Infrastructure	Intelligent traffic light management	Smart traffic management systems utilize sensors to monitor traffic speed and density. These systems can optimize traffic signal timings, impose speed limits, and open hard shoulders as required to maintain flow.
Freight	eHighways	Share of hybrid diesel-electric trucks and highways with overhead power lines at target year. As soon as trucks join the eHighway, they connect to the overhead power lines and switch into pure-electric mode. Leaving the eHighway, the trucks switch back to using hybrid mode. Energy demand is reduced due to shift of transport to hybrid electric truck and electric transport together with related emissions.

Energy Levers		
Generation	Wind Power	Share of electricity provided by wind power at target year changing the energy mix and its related emissions provides cleaner electricity for buildings and electric-powered transport modes.
Generation	Photovoltaic	Share of electricity provided by photovoltaic at target year changing the energy mix and its related emissions provides cleaner electricity for buildings and electric-powered transport modes.
Generation	Combined Heat and Power	Combined heat and power (CHP) is a highly efficient method of generating electrical and thermal power (heating or cooling), from a single fuel source at the point of use. CHP utilizes both the electrical energy and the heat generated through the combustion process. The heat is essentially a by-product that in other systems may be disregarded as waste. Utilization of the waste heat is a key reason why a CHP system is so efficient. CHP is the type of generation used in district heating.
Generation	Electric Air-Source Heat Pumps	Share of heating supplied to the City buildings coming from air-source heat pumps that run on electricity.
Transmission	Network Optimization	A well-structured, secure, and highly available electricity supply infrastructure reduces grid losses, resulting in less energy generation and related emissions to provide the energy demanded at customer side.
Distribution	Smart Grid for Monitoring and Automation	Increased network performance with intelligent control – optimization of decentralized energy resources – economically and ecologically. Possibility for bidirectional energy flow, reduces technical and non-technical grid losses in distribution and corresponding reduced energy generation and related emissions.

Endnotes

End Notes

1 CyPT analysis for Los Angeles: "Climate LA, Technology Pathways for LA to Achieve 80x50 in Buildings and Transportation", https://w3.siemens.com/topics/global/en/intelligent-infrastructure/cypt-reports/Pages/LA-technology-pathways.aspx

2 The CyPT utilizes the 2012 GPC Protocol for Community-Wide Emissions as its methodology for estimating GHG emissions. It covers Scopes 1, 2, and 3 emissions for energy generation and energy use in buildings and transportation. Essentially, this means that the CyPT takes into consideration both direct emissions occurring within the city boundaries (such as from exhaust fumes) and indirect emissions from the conversion of chemical energy to power, heat, or steam of purchased energy from outside the city. The included Scope 3 emissions refer to the emissions produced as a result of fuel production and extraction. This also includes the construction and production of renewable power plants.

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18 Resolution By Gordon, Fletcher and Schroeder: Establishing a 100% renewable electricity goal for Minneapolis. https://lims.minneapolismn.gov/Download/RCA/4338/100%20renewables%20resolution%20final.pdf

19 Using the City Performance Tool (CyPT) to Test City Sustainability Targets - Minneapolis: 80 by 50? https://w3.siemens.com/topics/global/en/intelligent-infrastructure/cypt-reports/Pages/minneapolis-80-by-50.aspx