CHANGE IN YEARLY PROJECTED EMISSIONS FROM LOW CARBON SCENARIO ACTIONS, 2011 - 2050

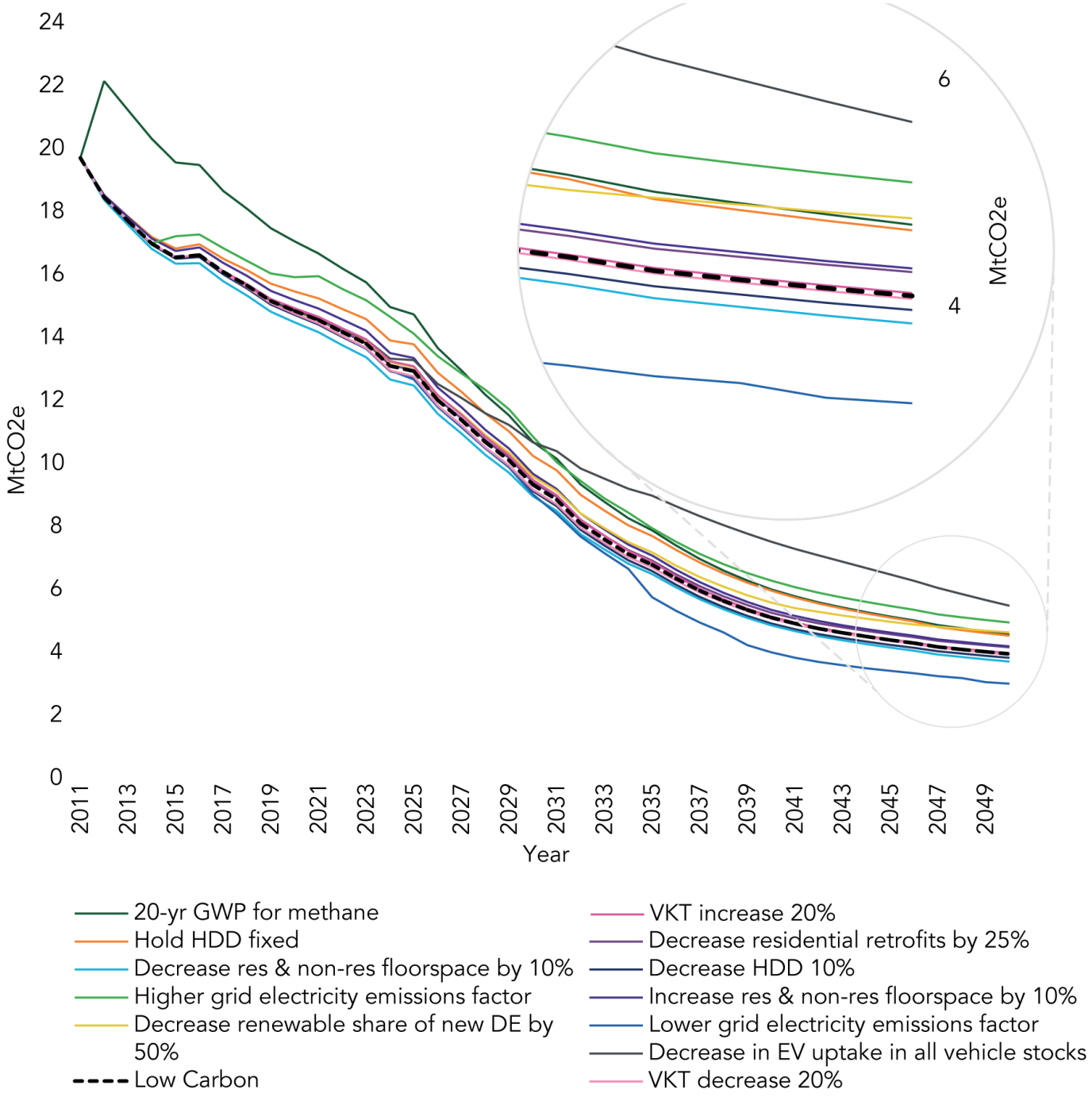

Figure 57. Change in LC projection for modelled variables.

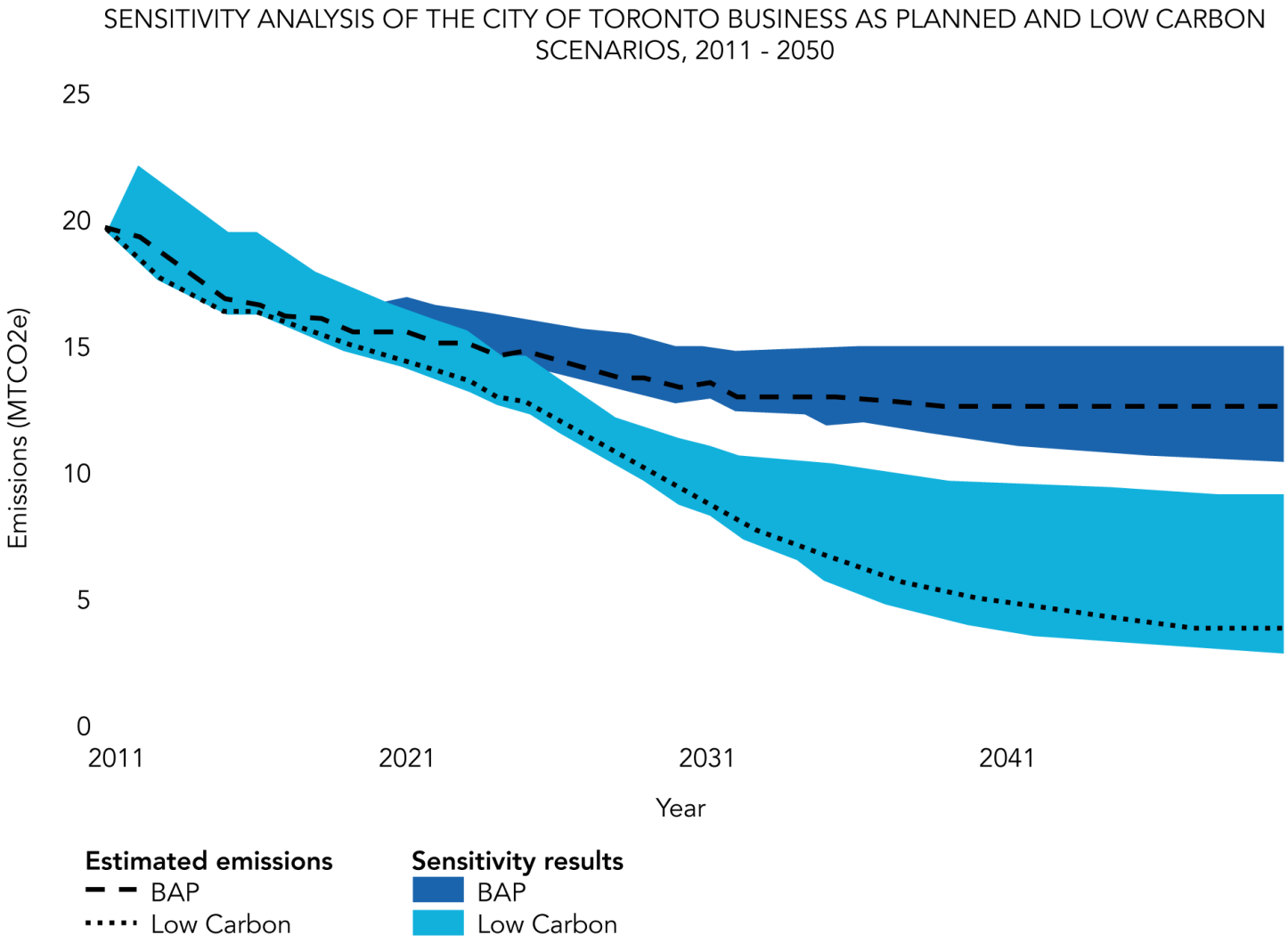

Figure 58. Sensitivity analysis.

Changes in assumptions for HDD, grid electricity emissions factor, uptake of electric vehicles, district energy fuel mix, and the GWP of methane have the most significant impact on the GHG emissions trajectory. Those variables with the least impact include changes in VKT and residential retrofit rates.

Heating degree days appear to be muting the impact of increasing population growth on emissions; if it is assumed that HDD are constant over the time period (i.e. the climate does not change, and winters do not become warmer), the results indicate an increase in emissions (+14.8%), and the impact of the population growth becomes more apparent.

Changes in the grid electricity emissions factor appear to have significant influence; as there is a major shift towards electricity in the low carbon scenario, it is fundamental that the emissions factor of new capacity remain low or the electrification approach is at risk from a GHG emissions perspective.

Electric vehicle (EV) uptake in the low carbon scenario plays a major role in the decrease of emissions in the transport sector. Reducing the share of EVs in the vehicle stock to 62% in 2050, compared with 100% in LCS, results in an increase in emissions of 1.53 Mt CO2e, which is 39.1% higher than the projected 2050 emissions of the LCS.

Global warming potential (GWP) is a measure of how much energy the emissions of 1 tonne of a gas will absorb over a given period of time, relative to the emissions of 1 tonne of carbon CO2. That time period is generally 100 years. However, certain gases have a much bigger impact over a 20-year period, which is the period of concern in terms of preventing dangerous levels of climate change. Methane for example, has a much shorter lifetime than CO2 and absorbs more energy over a 20-year period than 100-yr; subsequently, its 20-year GWP is much higher at 86, compared with its 100-yr GWP of 34.

Using the 20-yr GWP for methane of 86, compared with 34 in the LCS, results in an increase of 0.63 Mt CO2e in 2050. The immediate spike in emissions in 2012 in Figure 58 is as a result of changing the GWP factor of methane.

In terms of risk to the City of Toronto's 2050 target, increased fossil fuel generation in the Provincial electricity grid is a major risk as this would jeopardize the emissions reduction value of fuel switching efforts in the building and transportation sectors. This risk is difficult to mitigate, unless the City embarks on massive city-owned renewable energy projects to displace the impact of increased emissions from the grid. If the emissions factor of the grid is maintained or decreased, the next most significant risk is if the uptake in electric vehicles is slower than modelled. In this case, the City can focus its efforts on reducing emissions by reducing VKT. However, the modelling has indicated that significant reductions in VKT are difficult to achieve.

Relying on renewable natural gas in the district energy system is also a risk. If the availability of renewable sources, including the anticipated supply of renewable natural gas, are less than anticipated, significant emissions could result from the district energy system.


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8. Discussion items

8.1 Regional emissions

The City of Toronto's GHG emissions are significantly influenced by the activities of people in the surrounding municipalities. Conversely, the GHG emissions of the surrounding municipalities are significantly influenced by the activities of people living within the City's boundaries. The analysis of inbound and outbound external trips highlighted this interdependency; no matter how much the transit lever was pushed in the City of Toronto, the vehicular mode share of the trips beginning or ending outside of the City barely moved.

If the City of Toronto establishes an advanced green building standard that comes with an increased price, there is a risk that this may spur additional- and less efficient housing beyond the boundaries of the City of Toronto. For these and other reasons, collaborating with other municipalities in the City of Toronto's "commutershed" to harmonise approaches and transfer expertise would enhance the ability of the City of Toronto to achieve its emissions targets.

8.2 Carbon budget

The pathway to the 2050 target facilitates the identification of a carbon budget for the city, essentially the total emissions under the curve of the low carbon trajectory. The carbon budget is an important concept in terms of understanding the cumulative impacts of the city's low carbon pathway.

The cumulative emissions reduction of the LCS for the city between 2017 and 2050 is 175 Mt; compared to the total emissions under the BAP of 484 Mt CO2e, this results in a carbon budget of 309 Mt, that is, the cumulative emissions remaining under the LCS. From another perspective, the low carbon budget would be exhausted within 19 years if the level of emissions in 2017 (16.4 Mt CO2e) were continued.

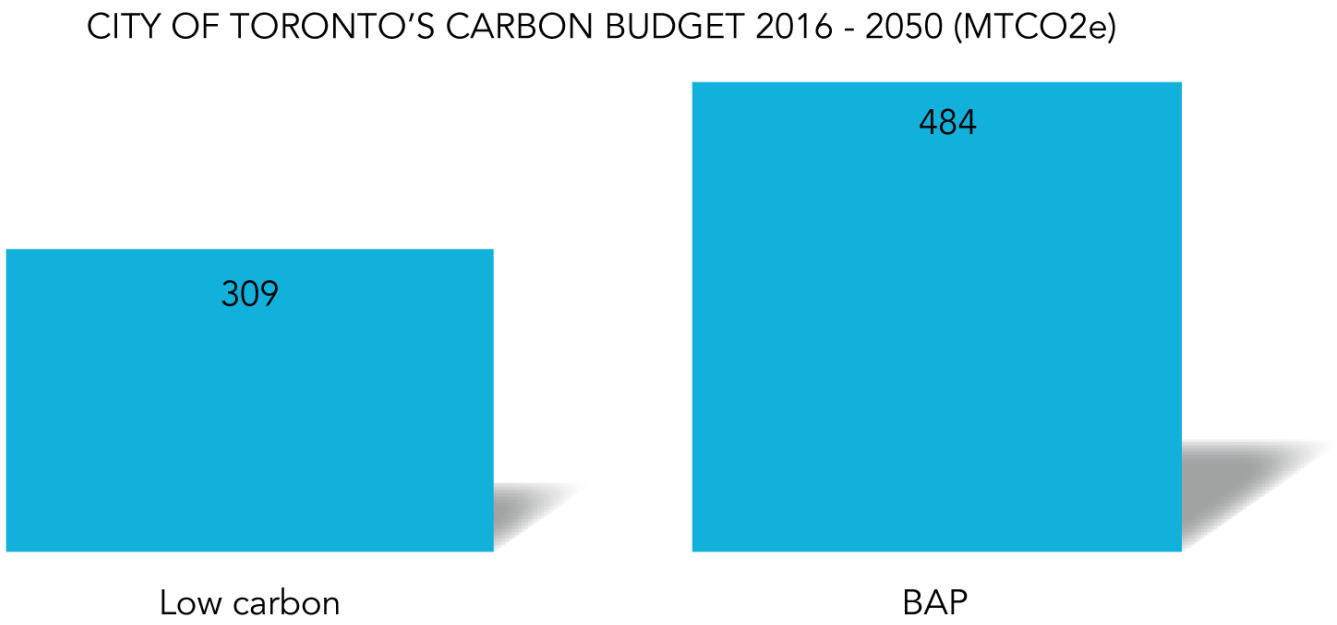

Figure 59. Toronto's carbon budget.

The cumulative carbon budget helps to make the targets real. For example, the City has a total of 309 Mt CO2e of emissions between 2016 and 2050. Each year, the remaining emissions available in the budget decline and the implications of those reductions for the remaining years in the time period are immediately apparent. If more rapid emissions reductions are achieved than anticipated, than the City is on track; if not, then it is immediately apparent that more significant action is required.

8.3 Carbon sinks

Carbon sinks were not included in the GHG analysis within this report, because the potential for emissions reductions was deemed to be low in the context of the City of Toronto. An analysis of the City of Toronto's trees estimated that they sequester 36.5 ktCO2e each year,[129] however, this is a background rate of sequestration and maintaining this rate already requires major tree planting efforts. For this reason, forests were not incorporated as a potential source of additional reductions in the LCS.

In addition to forests, there are other opportunities to reduce emissions using carbon storage, including in green roofs which can be integrated with solar

129 City of Toronto. (2013). Every tree counts: A portrait of Toronto's urban forest. Retrieved from http://www1.toronto.ca/City%20Of%20Toronto/Parks%20Forestry%20&%20Recreation/Urban%20Forestry/Files/pdf/E/every_tree_counts.pdf

panel installations. A green roof can sequester 0.4 kg CO2e per m2.[130] An innovative process by the company CarbonCure embeds 18 kg of CO2 into each cubic metre of concrete, causing the concrete to cure more quickly.[131] This process is already being used by the major concrete masonry suppliers in Toronto. Future investigation into novel approaches to carbon storage is recommended as a seperate analysis in order to better understand the potential scope for Toronto.

8.4 Consumption-based inventories

In the discussions related to the City of Toronto's GHG emissions targets, the idea of a consumption-based GHG inventory was raised, an alternative to tracking emissions by sector using a geographic approach. The analysis completed in this report is guided by the Global Protocol for Community Scale Greenhouse Gas Emissions Inventories, using a geographic approach. This approach accounts for emissions that result from the various sectors within the geographic limits of the city and some GHG emissions, resulting from electricity production outside of the city's boundaries, are also tracked. A consumption-based approach seeks to track all GHG emissions associated with the goods and services consumed by individuals living in the City of Toronto, while excluding goods and services which are exported. This approach typically uses an input-output model, which links consumption patterns and trade flows to energy use and GHG emissions. Consumption-based inventories typically result in higher emissions on a per capita basis than sector-based inventories in 'consumer cities' like Toronto,[132] and the opposite is true for cities in the Global South which are producing goods for consumers in the North. The results, which focus on patterns of consumption, can provide additional insights into sources of emission and create opportunities for new municipal policies.

8.5 Vehicle efficiency standards: At risk of a rollback

One of the variables that contributed to the downward trend in GHG emissions in the BAP was the fleet wide fuel efficiency standards which the Government of Canada has harmonized with the US Government. The US Government has indicated that it will roll back vehicle efficiency standards, which has the potential to impact this assumption in the modelling results, by approximately 4.5 Mt CO2e per year in reductions by 2050. The rollback is not assured and the state of California has indicated that it will move ahead

130 Getter, K. L., Rowe, D. B., Robertson, G. P., Cregg, B. M., & Andresen, J. A. (2009). Carbon Sequestration Potential of Extensive Green Roofs. Environmental Science & Technology, 43(19), 7564–7570. https://doi.org/10.1021/es901539x

131 Personal communications with CarbonCure, January, 2017

132 Seto, K. C., Dhakal, S., Bigio, A., Blanco, H., Delgado, G. C., Dewar, D., … others. (2014). Human settlements, infrastructure and spatial planning. Retrieved from http://pure.iiasa.ac.at/11114/

with the regulations irrespective of the US Government.[133] Canada has given no indication that it will adjust its direction.[134] Making the case for more aggressive electrification, beyond the current standards is a key aspect of the LCS.

8.6 Discounting

The rate of discounting has a significant impact on the financial performance of the actions in the LCS, particularly since many of the investments require early capital and result in avoided costs at the end of the period considered.

Discounting is based on the idea that future consumption is worth less than present consumption, firstly because if consumption continues to grow into the future, one unit of consumption will be valued less than that same unit of consumption is valued today. Secondly, people prefer consumption today rather than tomorrow.

The issue of climate change challenges both of these assumptions.[135] In the first case, the impacts of climate change pose an existential threat to the prospects of continuing growth into the future. In the second case, discounting future consumption discriminates against future generations, on the basis of birth.

For this reason, a discounting rate recommended by the Government of Canada of 3% was used for this analysis.[136]

8.7 Long-term planning

Directly related to the considerations around discounting and the carbon budget is the importance of long-term planning. City planners and transportation planners are more accustomed to looking thirty or more years into the future than most other professions. The impacts of city infrastructure on GHG emissions require a new emphasis on long-term planning, and therefore on managing uncertainty. The infrastructure that is built now determines trajectories of GHG emissions for thirty years or more. If this infrastructure is retired or replaced prior to the end of its lifetime, costs

133 Mulkern, A, A. (2017). California forges ahead with clean cars rules. Retrieved March 28, 2017, from https://www.scientificamerican.com/article/california-forges-ahead-with-clean-cars-rules/

134 Mccarthy, S., & Keenan, G. (2017, March 15). Trump targets fuel-efficiency standards. *The Globe and Mail.* Retrieved from http://www.theglobeandmail.com/report-on-business/in-victory-for-auto-makers-trump-orders-review-of-vehicle-emissions-rules/article34312126/

135 Stern, N. (2006). The Stern review on the economic effects of climate change. Cambridge University Press. Retrieved from https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull48-2/48205692528.pdf

136 Boardman, A. E., Moore, M. A., & Vining, A. R. (2008). Social discount rates for canada. In John Deutsch Institute Conference: Discount Rates for the Evaluation of Public-Private Partnerships. Kingston, ON. Accessed September (Vol. 22, p. 2011). Retrieved from http://jdi-legacy.econ.queensu.ca/Files/Conferences/PPPpapers/Moore%20conference%20paper.pdf

include the opportunity cost associated with some of the most expensive infrastructure that society builds, the cost of removing or reconfiguring the infrastructure including buildings, roads, water and wastewater pipes and the cost of introducing new low or zero carbon infrastructure. Careful consideration using techniques such as scenario planning and appropriate incentives and regulations that reduce the risk of stranded municipal and private investments will either minimize the upfront cost of the low carbon pathway, while generating new economic opportunities.

8.8 The cost of doing nothing

This report focuses on the benefits of implementing a Low Carbon pathway. Conversely the risk of doing nothing is also significant. Risk is defined as the probability of an event combined with the severity of its impacts. In the context of this analysis, risks include a slower response to mitigation and therefore more severe impacts of climate change, a missed opportunity to transition to low carbon urban systems and therefore an increased burden on the City, households and the private sector to support the transition. It is also a missed opportunity for leadership in the public and private sectors and a missed opportunity to acquire the co-benefits in improved health outcomes, economic development, a more resilient energy system and improved quality of living that are synergistic with the LCS.


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9. Conclusions

1. The low carbon pathway is technically feasible using current technology.

The modelling demonstrates that by applying existing technologies, the City of Toronto can achieve its GHG target of 80% reductions by 2050 over 1990 levels. The LCS is but one pathway and other pathways that achieve the City of Toronto's target are also possible.

2. The City has a solid foundation

The direction of a number of the City's existing policies, including in land-use and solid waste is congruent with the 80% target. The City also has many of the existing programs in place required to implement the LCS, including in building codes, retrofits, district energy, renewable energy and transit. These programs need to be massively scaled up to achieve the 80% target.

3. The City of Toronto is an urban energy system and all of the pieces need to be considered as an integrated whole.

Considering actions in the context of an urban energy system is critical in order to avoid higher capital costs than necessary or over-inflated expectations for GHG emissions reductions. The results of the integrated GHG emissions scenario are very different than the results of a wedge by wedge implementation. The order in which actions are implemented also matters, influencing both the effectiveness and cost of the action and subsequent actions.

4. Land-use, district energy and transit investments can result in positive feedback cycles.

Using land-use policies to direct future development into particular areas can not only increase the access of the future development to transit and district energy, but that future development can also tip the balance of a neighbourhood from no district energy to district energy and to higher levels of transit service, resulting in

disproportionate GHG emissions reductions. Investments in transit and district energy can attract density, which may support additional investments in transit, resulting in a positive feedback cycle.

5. There are key actions, but the actions work together.

While all of the actions are required to support the LCS, there are certain actions that are non-negotiable in order to achieve the 80% target. Fuel switching via electrification of the personal and commercial vehicle fleet is necessary to reduce gasoline and diesel consumption. The installation of heat pumps and district energy facilitates the transition to renewable heating. Energy retrofits in buildings result in reduced energy consumption but also reduce the capital costs of the transition, by generating a flow of avoided costs. Many of the actions are inter-related and if one action scales back its efforts on GHG emissions, other actions have to scale up their ambition, and given current technologies, there is likely a high cost associated and there may also be physical limits on the potential reductions

6. The low carbon pathway provides societal benefits and achieves multiple objectives.

The Low Carbon pathway as a whole improves health outcomes, provides new economic opportunities, improves quality of life, and depending on the implementation mechanisms, may enhance equity. The most significant co-benefits include reduced air pollution, increased health benefits associated with walking and cycling, avoided damages associated with climate change impacts (represented by the Social Cost of Carbon) and the economic stimuli associated with the LCS, including jobs and new business opportunities.

The alternative, the cost of doing nothing, was not evaluated in full from the perspective of co-harms or co-benefits, but this alternative represents risks in enhanced damage from climate change, avoided economic opportunities, and reduced societal benefits. Notably, the Low Carbon pathway unlocks investments which are not otherwise available, for example, retrofitting most of a building stock within a city and establishing a major district energy system, both of which would be major economic stimuli.

7. The low carbon pathway requires major capital investments, most of which will generate financial returns.

The Low Carbon pathway requires major new investments, totaling $60 billion between the period of 2017 and 2050, using a discounting rate of 3%. The marginal abatement curve showed that 67% of the emissions reductions will save money over their lifetime and that a few actions, totaling 33% of the GHG emissions reductions, will cost money, given current technologies and the financial assumptions used to generate the marginal abatement costs. Actions save money by avoiding capital and maintenance expenditures, energy costs and the cost of carbon.

It is of particular importance to analyze the financial implications in a model that reflects the integrated energy system. Without the full picture, investments could be stranded. For example, district energy systems may be scaled based on buildings prior to energy efficiency retrofits, reducing or eliminating the financial benefit of the action.

Many of the investments are front-loaded and the benefits incur towards the end of the time period. The overall financial benefit is therefore highly sensitive to the rate of discounting. If a higher discounting rate is used, the financial case for some of the actions may be reduced or eliminated. The savings at the end of the period are in part due to the learning effect, as society learns how to undertake building retrofits on a large scale, but the advantages of the learning rate require immediate action.

8. The price of carbon is a key factor in the economic case for many of the actions

In the context of an 80% reduction in GHG emissions, the price of carbon becomes an important variable in contributing to the financial case for particular actions. By 2050, the LCS results in just over $1 billion per year in avoided costs for the price of carbon. It is therefore in the City's interest to advocate for an increasing price of carbon to support the achievement of City Council's 80% GHG reduction target.

9. The prioritization of actions can be determined by three primary factors: the window of opportunity to replace infrastructure at the end of its lifetime, the co-benefits incurring and the cost effectiveness of the measure in reducing emissions.

Hot water heaters will turnover three times between now and 2050, providing three opportunities to upgrade the efficiency or switch to different fuel types. Residential buildings built today, however, will still be around in 2050; decisions on shape, size and energy performance for buildings today therefore have direct implications on the 2050 target. This is not to say that interventions cannot be made midway through the lifetime of an investment, but the societal cost, in terms of finances, materials and energy will be higher. The opportunities for making the lower-cost shift to a low or zero carbon building or technology diminish year over year, so immediate action is crucial to maximizing the financial benefit. If the opportunity is missed, an additional effort and cost is required to undo what was done.

Co-benefits and co-harms are difficult to quantify, because each one involves different considerations. Multi-criteria analysis provides an effective strategy to draw on diverse expertise in order to identify the impact of different actions. The MCA results indicate that there is not a direct correlation between actions which maximizing co-benefits and maximizing GHG reductions. The implication is that in some cases the GHG reduction can be the primary driver for the action, whereas in other cases, a co-benefit may be the primary driver.

10. Ongoing measuring and verification is critical to monitoring progress and making course corrections.

The future is full of uncertainty and the assumptions used to develop the BAP and LCS will change year over year as external conditions change, technologies evolve and the city develops. A key example is autonomous vehicles. The LCS makes certain assumptions around the impact of AVs, but the actual impact is unknown. Monitoring and evaluating progress on an ongoing basis will ensure ongoing adaptation to evolving circumstances. The carbon budget is a useful tool to continually monitor progress towards the 2050 target.


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Glossary

80 x 50 refers to reducing emissions by 80% by 2050 based on 1990 levels.

Autonomous vehicles are also known as self-driving vehicles; vehicles in which at least some aspects of a safety critical control function (e.g., steering, acceleration, or braking) occur without direct driver input.

Baseline is the starting year for the energy or emissions projection.

Biogas is a source of renewable energy, specifically methane, that is derived from the process of bacterial decomposition of sewage, manure, waste, plant crops, or other organic waste products.

Building retrofit refers to changes to the structure or systems of an existing building. Building retrofits allow for reductions in energy and water consumption with the use of more efficient technologies, products, and designs, and can improve amenities for the building's occupants.

Bus rapid transit (BRT) is a bus system that aims to combine the capacity and speed of a metro with the lower cost and flexibility of a bus system. Typically, BRT systems have dedicated right of ways.

Build-as-planned (BAP) is a scenario designed to illustrate energy use and greenhouse gas emissions if no additional plans, policies, programs and projects are implemented.

Capacity factor is the ratio of a power plant's actual output over a period of time to its potential output if it were possible to operate continuously over the same period of time.

Carbon budget is is the maximum amount of carbon that can be released into the atmosphere while keeping a reasonable chance of staying below a given temperature rise.

Carbon dioxide equivalent (CO2e) is a measure for describing the global warming potential a given type and amount of greenhouse gas may cause, using the equivalent amount or concentration of carbon dioxide (CO2) as a reference. CO2e is commonly expressed as million metric tons of carbon dioxide equivalent (MtCO2e).

Cooling degree days (CDD) aret he number of degrees that a day's average temperature is above 18 degrees celsius requiring air conditioning.

Combined Heat and Power (CHP), also known as cogeneration, CHP is the simultaneous production of two or more useful forms of energy from a single device, typically electricity and useful heat.

Corollary benefits (co-benefits) refers to benefits that are additional to the primary objective.

Discount factor is the ratio applied to current values in order to derive a value for future annual revenues and costs; it reflects factors such as perceived future risk and the premium that is placed on immediate revenues and deferred costs.

District energy systems provide heating and/or cooling to multiple buildings from centralised energy provision systems.

Distributed generation refers to technologies that allow consumers to generate electricity on site through solar photovoltaic (PV) systems, combined heat and power (CHP), and/or other technologies.

Economic prosperity is defined as the capability to flourish.

Energy efficiency improvement is an improvement in the ratio of energy consumed to the output produced or service performed. This improvement results in the delivery of more services for the same energy inputs or the same level of services from less energy input.

Equity is the absence of avoidable or remediable differences among groups of people, whether those groups are defined socially, economically, demographically, or geographically.

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

Energy storage refers to technologies that save generated energy and use it at another time. Energy storage includes electric systems such as batteries as well as thermal systems such as hot and cold water storage tanks.

Fuel poverty refers to a situation in which a household technically has access to energy but cannot afford adequate energy services to meet their basic needs (see Box 4.1).

Impact is any kind of result from an action or measure. In this publication, impact is used to describe any result, positive or negative, arising from an

energy efficiency measure. In this context, the impact could be reduced energy consumption, for example, or increased economic activity (which may drive up energy consumption overall).

Geothermal is heat from the earth that can be used as a renewable source of energy.

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

Heat density threshold is a concentration of heat demand above which district energy systems are considered viable.

Health is defined as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity

Heat pump is a device that transfers heat energy from a source of heat to a target area by using mechanical energy.

Heating Degree Days (HDD) are calculated as how much colder the mean temperature at a location is than 18°C on a given day. For example, if a location experiences a mean temperature of 8°C on a certain day, there were 10 HDD (Heating Degree Days) that day because 18 - 8 = 10.

HVAC is heating, ventilation and air conditioning systems; referred to in the context of a building.

Indicator is an observable or measurable result that shows evidence of whether an impact has occurred and the nature of that impact. It provides a metric by which one can quantify and define the scale of a resulting change.

Induced impacts refer to impacts that arise further down the causal chain, as a result of indirect impacts (see definition above); examples might include additional spending by the people employed as a result of direct or indirect benefits.

Light rail transit (LRT) is a type of rapid transit that typically runs at street level in lanes that are separate from regular traffic.

Marginal abatement cost (MAC) curves are a visual (graphic) illustration of the results of model-based scenarios that convey both the economic

co-benefits (costs or savings) of an action or policy and the potential GHG reduction that can be achieved with the action or policy.

Monetisation is the attribution of financial value to phenomena, usually by relating a change in status of a good or service to the relevant market value of the good or service.

Multi-criteria analysis describes any structured approach used to determine overall preferences among alternative options. The actual measurement of indicators need not be in monetary terms, but are often based on the quantitative analysis (through scoring, ranking and weighting) of a wide range of qualitative impact categories and criteria. Explicit recognition is given to the fact that a variety of both monetary and nonmonetary objectives may influence policy decisions.

Multiplier effect is a further extension of an induced impact, referring to ripple effects arising across the wider economy from the original energy efficiency policy. For example, a multiplier effect would be that stores, restaurants or other service providers benefit from the spending of people who are newly employed (directly or indirectly) because of an energy efficiency policy and have greater capacity to spend or invest their earnings.

Net benefit is the measure of the value of an outcome after the cost of delivering the outcome has been accounted for and deducted.

Re-commissioning is a process of examining how a building's operating and maintenance systems are functioning and optimising these systems after a building has been fully operational for a period of time.

Renewable natural gas is natural gas that is generated from resources which are naturally replenished on a human timescale, such as solid waste.

Renewable energy is energy that comes from resources which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat.

Sankey is a type of diagram that illustrates the flow of materials, often energy, through a system.

Sick building syndrome is a situation in which the occupants of a building experience acute health- or comfort-related effects that seem to be linked directly to the time spent in the building.

Social capital is the links, shared values and understandings in society that enable individuals and groups to trust each other and so work together

Social equity implies fair access to livelihood, education, and resources; full participation in the political and cultural life of the community; and self-determination in meeting fundamental needs.

Solar photovoltaic, also known as solar electric systems or solar panels, these are systems that convert sunlight into electricity. Any excess electricity produced that a building does not use can be sold to the utility through a process called net-metering.

Solar thermal is a system that uses solar energy to generate hot water that can be used for domestic hot water and/or space heating in buildings. The system can be paired with thermal energy storage that can store heat until it is needed to meet demand.

Wedge is a representation of GHG emissions reductions resulting from a particular action or policy measured against a business as usual curve.

Well-being refers to the integrated physiological, psychological and mental state of an individual, a household or group of people. It is broader than health, which typically refers to the physical state of an individual, family or group of people (public health).

Vehicle kilometres travelled is a measurement of kilometres traveled by vehicles within a specified region for a specified time period.

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