TECHNICAL PATHWAY

CLIMATEACTIONWR

BY WALTERFEDY

March 1, 2020

WALTERFEDY

CONTENTS

CONTEXT SETTING

1.0 Climate Change

The main reason for climate change is human activities. Since the beginning of the industrial revolution, humans have burned a significant amount of fossil fuels and converted natural lands from forest to agriculture.

The burning of fossil fuels produces greenhouse gas. Greenhouse gases and the greenhouse gas effect makes the earth warmer. Carbon dioxide is the primary cause of human influenced climate change. Carbon dioxide stays in the earth's atmosphere for a significant period of time.

Climate change has many negative effects including:

- More frequent, longer lasting, and/or more intense extreme weather events which will cause significant adverse effect.
- More intense precipitation events (a warmer atmosphere holds more moisture) followed by long drought periods.
- Decrease in lake levels.
- Negative effects on human health's including temperature related illnesses, the spread of infectious diseases, decrease in water availability, climate anxiety, etc.
- Other adverse effects.

Stabilizing global average temperature, and minimizing climate change and its negative outcomes, can only be accomplished through significantly decreasing and eventually eliminating greenhouse gas emissions by humans.

The Paris Agreement, adopted by 196 parties in December 2015 developed a long-term goal to limit global warming below 2C, with a target of 1.5C compared to pre-industrial levels.

Canada signed onto the Paris Agreement as an active participant.

1.1 Pan Canadian Framework

The Pan Canadian Framework on Clean Growth and Climate Change was developed by the federal government following the Paris Agreement. The Pan Canadian Framework requires Canada and Canadians to significant decrease our greenhouse gas emissions over the next number of decades.

The Pan Canadian Framework both demonstrates Canada's international commitment to the Paris Agreement as well as support Canadians through an actionable climate change plan. The Pan Canadian framework has four primary pillars:

- Pricing carbon pollution
- Complementary measures to further reduce emissions across the economy
- Measures to adapt to the impacts of climate change and build resilience
- Actions to accelerate innovation, support clean technology, and create jobs

The Region of Waterloo's goal of 80by50 is directly inline with the intent of Pan Canadian Framework

1.2 Carbon Budget

Carbon budget is defined as the maximum amount of greenhouse gases that can be emitted world-wide without increasing the global average temperature more than 1.5°C. The anthropogenic emissions cannot exceed more than 2500 GtCO2e to avoid increasing the global average temperature by more than 1.5C. It is estimated that 1900 GtCO2e of these 2500 GtCO2e have already been emitted since industrial revolution to 2011. The balance of 600 GtCO2e is the global carbon budget from 2011 to 2100.

The C40 Cities network, a network of the world's megacities committed to addressing climate change, has created a methodology to distribute the global carbon budget to local communities. Based on this methodology, communities/cities must reach a maximum target emission of 3.2 tCO2e per person by 2030 and reduce those emissions to 0 tCO2e per person by 2050. The curve from 3.2 tCO2e per person to 0 tCO2e per person is a polynomial.

The Region of Waterloo's per capita GHG emissions in 2020 are expected to be approximately 6.58 tCO2e per person. Using this information and the methodology described above, the planned carbon expenditure for the Region of Waterloo from 2020 to 2050 is calculated to be 96.51 MtCO2e.

Refer to the appendix of this report for the detailed calculations on the Region of Waterloo's planned carbon expenditure under both the 80by50 and 100by50 models.

2.0 BASELINE

ClimateActionWR has a clearly established carbon emissions inventory completed for the years of 2010 and 2015, with the baseline year of 2010.

Carbon emissions are often quantified for an individual, business, facility, or otherwise under three primary scopes.

Scope 1 – Direct Emissions. Direct emissions are direct burning of fossil fuel (ex. Burning of natural gas in a homes furnace for space heating).

Scope 2 – Indirect Emissions. Indirect emissions are utilizing an energy source which does not directly produce greenhouse gases at that location, but that energy was generated upstream from fossil-fuel generation (ex. Electricity purchased from the grid which is sourced from various generation sources where some involve the burning of fossil fuels).

Scope 3 – Other Indirect Emissions. Other indirect emissions that are not directly controlled (ex. Fuel and energy related to transportation of products, or the manufacturing of products). This can often include embodied carbon.

Consistent with municipalities and overarching carbon inventory frameworks, the Waterloo Region inventory focused on scope 1 and 2 inventories.

The Waterloo Region carbon inventories have been divided into five primary sectors:

- Homes
- Workplaces
- Transportation
- Agriculture
- Waste

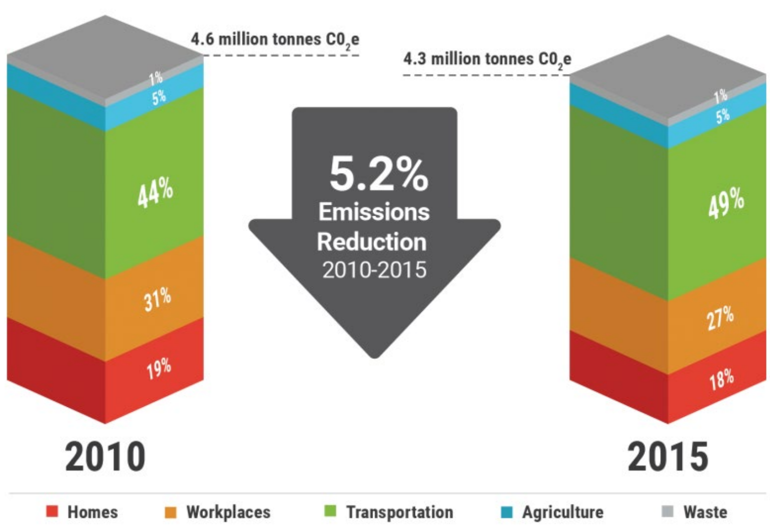


Figure 1: Emissions reduction from 2010 to 2015

For the Homes, Workplaces, and Transportation sector, which represents greater than 90% of the regions carbon baseline inventory, there are six primary energy/fuel sources which contribute to greenhouse gases:

- Electricity
- Natural Gas
- Fuel Oil
- Propane
- Gasoline
- Diesel

Table 1 provides a summary of annual GHG emissions for the baseline (2010) year aggregated by GHG emission source type across all sectors.

Figure 2: Annual GHG emissions for the baseline (2010) year from various sources.

Sources	Annual GHG emissions - 2010 (tCO2e)	Percentage (%)
Electricity	652,881	14
Natural gas	1,376,389	31
Fuel oil	133,952	3
Propane	72,851	2
Gasoline	1,561,598	35
Diesel	450,470	10
Agriculture	213,559	5
Waste	45,774	1
Total	4,507,474	100

Gasoline and Natural Gas are the largest single sources of carbon emissions in the Region of Waterloo. That being said, the primary actions will focus on reducing the direct fossil fuels burned in transportation and at facilities (workplaces and homes).

Now that 2020 is completed, data will be acquired to develop the 2020 inventory and evaluate progress.

3.0 A ROADMAP TO 80BY50

In Waterloo Region we will achieve the goal of 80by50. This goal will be achieved both passively through industry trends where we do not locally drive change (ex. Personal Electric Vehicle adoption) and actively through local initiatives where we are clearly demonstrated leaders.

3.0 Roadmap to 80by50

Through technical engagement efforts over the past year, we have garnered significant input and feedback on our approaches and methodologies to achieve the overarching goal. This engagement and our technical back casting work (working backwards from the overarching goal of 80by50 to our baseline) have allowed us to define a quantifiable vision of our future state. We have defined the vision for each of the primary sectors (Transportation, Homes, Workplaces, Waste and Agriculture). This is defined by the following:

3.0.1 Transportation

- Most trips are active transportation and shorter trips.
    - Less vehicles are on the roadways.
    - Electric vehicles (or alternative fuel source vehicles such as renewable natural gas, hydrogen, etc.) represent the vast majority of vehicles on the roadways.
        - This includes personal, business, and commercial vehicles.
    - A culture of shift away from single occupant driving is clearly evident.
    - The load shift curve is dominated by:
        - Carshare and carpooling.
        - Public Transportation.
        - Biking and Walking.
        - Autonomous vehicles.
    - Connection to the GTA is virtual and/or train based.
    - Public transportation routes, nodes, etc. are enhanced, accessible, and efficient.

3.0.2 Homes

- New home construction is built to Passive House and/or Carbon Neutral standards. This includes all forms of 'homes':
    - Rural single-family homes
    - Urban single-family homes
    - Townhomes
    - Multi-unit residential

  - etc.

- Non-fossil fuel consuming micro-grids and district energy systems in smart communities are frequent and can be tied into with ease. This is achieved through community energy planning.

- Existing homes have been retrofitted, towards major energy and carbon reduction, with the following hierarchy/priorities:

  - First: Conservation and reduction in energy and carbon profiles.

  - Second: Energy and Carbon systems are efficient and primarily low energy use with a focus on minimizing GHG emissions.

  - Third: On-site or local renewable energy systems provide significant portions of source energy.

- Housing and workplaces are planned around public transportation nodes to support active transportation.

3.0.3 Workplaces

- New workplace construction is built to Passive House and/or Carbon Neutral standards. This includes all industries/sectors:

  - Small business

  - Commercial

  - Post-Secondary

  - Industrial

  - Healthcare

  - etc.

- Non-fossil fuel consuming micro-grids and district energy systems in smart communities are frequent and can be tied into with ease. This is achieved through community energy planning.

- Existing workplaces have been retrofitted, towards major energy and carbon reduction, with the following hierarchy/priorities:

  - Conservation and reduction in energy and carbon profiles.

  - Second: Energy and Carbon systems are efficient and primarily low energy use with a focus on minimizing GHG emissions.

  - On-site or local renewable energy systems provide significant portions of source energy.

- Accessible around efficient public transportation nodes.

3.0.4 Waste

- Circular economy (use items as long as possible, extract maximum value from product, recover, repurpose, regenerate product after end of life) is standard practice.

- We use less and there is significant waste diversion from landfill.
- Wastewater treatment and landfill facilities have been retrofitted to maximize the recovery of waste energy/heat available. These have been integrated into the micro-grids.

3.0.5 Agriculture

- Rural agricultural communities are further integrated with the urban landscape, including a significant increase in the local food supply chain.
- Methane emissions are actively tracked and considered.
- Technology and geographical barriers have been overcome such that waste heat and energy (ex. manure) is captured in an economically and environmentally viable way. This waste energy is transitioned to effective energy production.

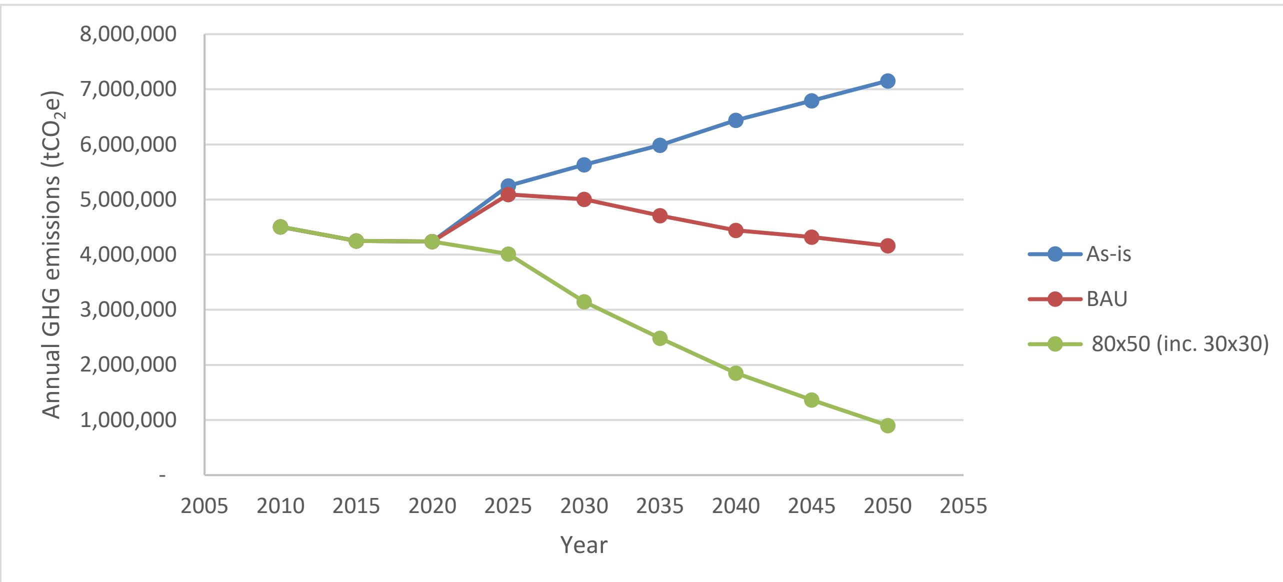


Figure 3: Annual GHG emissions (tCO_2e) for As-is, BAU and 80x50 scenarios.

Figure 3 presents a forecast for the Waterloo Region's expected future emissions for As-is, Business-As-Usual (BAU) and 80x50 scenarios. In the As-is scenario, GHG emissions from the baseline year increase proportionally to the expected changes in the Waterloo Region's population. As such this scenario does not account for any additional changes that might occur during this timeline.

The BAU scenario accounts for expected industry trends such as transition to electric vehicles from gasoline powered vehicles, increase in work from home practices, high efficiency HVAC equipment due to technological improvements etc. This scenario represents the expected GHG emissions for the Waterloo Region in absence of any active GHG reduction strategy. For 2050, annual GHG emissions under this scenario are only marginally lower than the 2010 levels.

The 80x50 scenario is designed to achieve 80% reduction with respect to the baseline (2010) levels by 2050. This scenario explores necessary changes to reduce consumption of high GHG energy sources, switch to alternative low GHG energy sources and generation of carbon neutral energy.

Figure 4 provides a summary of data used in Figure 3.

Figure 4: Annual GHG emissions (tCO2e) for As-is, BAU and 80x50 scenarios.

Scenario	2010	2015	2020	2025	2030	2035	2040	2045	2050
As-is	4,507,474	4,252,462	4,237,026	5,246,106	5,630,822	5,986,167	6,436,653	6,795,336	7,154,019
BAU	4,507,474	4,252,462	4,237,026	5,092,461	5,007,705	4,706,436	4,443,109	4,319,276	4,161,747
80x50 (inc. 30x30)	4,507,474	4,252,462	4,237,026	4,012,068	3,148,788	2,487,037	1,850,823	1,363,479	901,942

Figure 5 provides a detailed summary of annual GHG emissions by GHG emission sources for the 80x50 scenario. Significant reduction in GHG emissions from the combustion of natural gas, gasoline and diesel must be realized to achieve target GHG emissions levels in 2050.

Figure 5: Annual GHG emissions (tCO2e) for 80x50 scenario.

Sources	2010	2015	2020	2025	2030	2035	2040	2045	2050
Electricity	652,881	227,300	204,603	416,179	435,947	413,082	487,607	406,702	301,821
Natural gas	1,376,389	1,458,973	1,614,579	1,438,038	1,256,769	970,037	708,489	510,969	323,511
Fuel oil	133,952	141,989	158,063	-	-	-	-	-	-
Propane	72,851	77,222	85,964	-	-	-	-	-	-
Gasoline	1,561,598	1,655,294	1,398,364	1,440,840	888,167	581,511	255,748	112,598	9,483
Diesel	450,470	477,498	520,923	457,678	308,572	263,074	139,646	73,877	7,793
Agriculture	213,559	213,559	213,559	213,559	213,559	213,559	213,559	213,559	213,559
Waste	45,774	45,774	45,774	45,774	45,774	45,774	45,774	45,774	45,774
Total	4,507,474	4,297,609	4,241,830	4,012,068	3,148,788	2,487,037	1,850,823	1,363,479	901,942
Percent	100%	95%	94%	89%	70%	55%	41%	30%	20%

3.1 Target 30by30 on the Roadmap to 80by50

To better align with global climate goals, we have defined an interim goal of a 30% reduction in carbon by 2030. To achieve this interim goal, significant active action will be required within the region in the coming years.

Technically, we have highlighted the list of largest impact changes which will contribute to achieving this goal, while laying the foundation to achieve the overarching goal of 80by50 (Note: the 30by30 goal will be achieved primarily through the Transportation, Homes, and Workplace sectors).

- Our community will have planned and begun building our transportation system to put walking and cycling first with support from transit.

- People are supported to make changes so they can take fewer trips, take shorter trips, and to take more trips by walking, cycling, or taking transit.
- 50% of personal and commercial vehicles are zero-emissions vehicles.
- 20% of Workplace and Home facilities fossil fuel sources of heating have transitioned to low or carbon neutral sources of heating (space, ventilation, water, etc.).
- Fuel oil and propane are no longer used for heating in Workplaces and Homes.
- All workplaces and homeowners have a plan to transition their facilities to low or no carbon.
- 10% of Workplaces and Homes energy is zero-carbon and/or renewable sources of energy.
- All workplaces and homes have a plan to reduce the energy and carbon intensity of their facilities (ex. Increase the energy efficiency of a home by re-insulating the building envelope).
- Local organizations and governments will have provided proactive guidance to provincial and federal governments on the actions they need to take so that we can achieve our 80by50 goal.

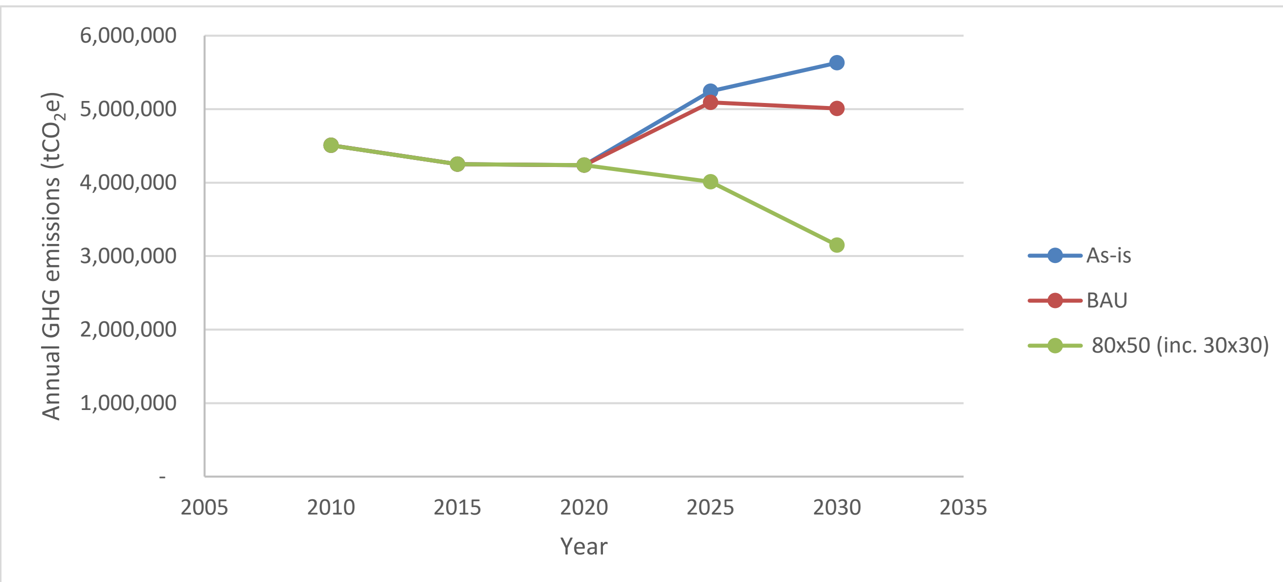


Figure 6: Annual GHG emissions (tCO2e) for As-is, BAU and 80x50 scenarios.

Figure 2 presents a forecast for the Waterloo Region's expected future emissions for As-is, Business-As-Usual (BAU) and 80x50 scenario with an interim goal of 30% reduction in GHG emissions by 2030. Data used in this Figure is summarized in Table 4.

Figure 7: Annual GHG emissions (tCO2e) for As-is, BAU and 80x50 scenarios.

Scenario	2010	2015	2020	2025	2030
As-is	4,507,474	4,252,462	4,237,026	5,246,106	5,630,822

Scenario	2010	2015	2020	2025	2030
BAU	4,507,474	4,252,462	4,237,026	5,092,461	5,007,705
80x50 (inc. 30x30)	4,507,474	4,252,462	4,237,026	4,012,068	3,148,788

4.0 TECHNICAL BREAKDOWN TO 80BY50

4.0 Technical Engagement

A detailed technical engagement program was completed to engage a group of experts across the climate action field. The intent of the engagement was to gain perspective, insights, and potential solutions from a wide-range of subject-matter and technical experts to identify major obstacles, explore mitigation strategies, and identify changes and actions. The big picture was always to achieve the community wide 80by50 goal.

We engaged a group of greater than 40 people had various skillsets including:

- Engineering
- Architecture
- Technical Solution Providers
- Utilities (Gas, Hydro, IESO)
- Internal and External Municipalities (ex. City of Vancouver)
- Universities and Colleges (Facilities and Academia)
- Association of Energy Engineers (AEE)
- Community Technical Groups
- Community Technical Leaders
- Others

Approximately 75% of the group engaged had some connection to Waterloo Region (work, live, previously work or previously live) and 25% had no connection to Waterloo Region. This ratio was advantageous as it garnered both local and broader geographic perspective.

4.0.1 Technical Engagement – Key Outcomes

There were many key outcomes and themes which were observed and retained following the technical engagement summarized by the following:

- Human Motivations (Behaviour change) play a significant role in major carbon reduction change.
- Political landscape can create inherent challenges with short- and long-term perspectives.
- Incentives for all stakeholders are an excellent means to gain carbon initiative adoption.
- Education is essential across all stakeholders.
    - Education on long-term beneficial economics of energy projects.
    - Societal impacts of business as usual.
    - Must be diverse and appeal to all sectors and people.
- Up-front capital cost of replacing existing infrastructure can be a significant roadblock.
- Technology should be embraced in supporting major change.

4.1 Overarching Approach

We have developed an overarching approach to achieving major carbon reduction in Waterloo. This is defined under a priority hierarchy.

This hierarchy has four primary levels:

1. Conservation First. A focus on lowering the overall energy and carbon use intensities.
2. Alternative systems. Transition to no and low carbon systems which are highly energy efficient.
3. Generation. Focus on local, no and low carbon sources of energy generation, with a high priority on renewables.
4. Carbon Offsets. Invest in high impact carbon offset to lower the total carbon profile of the Region.

4.2 Big Changes – Sector Breakdown

With Homes, Workplaces, and Transportation representing approximately 94% of the baseline carbon inventory, we developed a comprehensive approach to achieve major carbon reduction with 31 big changes. These changes were established following the technical engagement within the industry where obstacles were identified, followed by exploration of roadblock themes, mitigation strategies, and actions.

- Homes:
  - Conservation:
    - Improvement of Building Envelope performance to reduce energy load.
    - Improvement in efficiency of plug load equipment and appliances.
    - Improvement in HVAC system efficiencies.
    - Optimize home heating and cooling controls systems including better zonal control, space set-backs, and smart monitoring.
    - Optimize occupied space usage and density.
- Systems:
  - Retrofit fuel oil-based HVAC systems with low energy/carbon systems (ex. Electric - Heat Pump).
  - Retrofit propane-based HVAC systems with low energy/carbon systems (ex. Electric - Heat Pump).
  - Retrofit natural gas-based HVAC systems with low energy/carbon systems (ex. Electric - Heat Pump).
  - Retrofit fossil fuel-based water heating systems with low energy/carbon systems.
- Generation:
  - Integrate carbon neutral energy generation (ex. Solar PV, Solar Thermal, carbon offsets, etc.).
- Workplaces:
  - Conservation:
    - Improvement of Building Envelope performance to reduce energy load.
    - Improvement in efficiency of plug load equipment and appliances.

        - Improvement in HVAC system efficiencies.
        - Optimize heating and cooling controls systems including better zonal control, space set-backs, and smart monitoring.
        - Optimize occupied space usage and density.
        - Optimization of energy and carbon intensity of processes.
    - Systems:
        - Retrofit fuel oil-based HVAC systems with low energy/carbon systems (ex. Electric - Heat Pump).
        - Retrofit propane-based HVAC systems with low energy/carbon systems (ex. Electric - Heat Pump).
        - Retrofit natural gas-based HVAC systems with low energy/carbon systems (ex. Electric - Heat Pump).
        - Retrofit fossil fuel-based water heating systems with low energy/carbon systems.
    - Generation:
        - Integrate carbon neutral energy generation (ex. Solar PV, Solar Thermal, carbon offsets, etc.).
        - Capture waste energy for effective re-use.
- Transportation
    - Conservation:
        - Reduce overall average trip length for mid-long trips (over 5km).
        - Transition to active transportation for short trips (<5km).
        - Reduce work related commuting trips (ex. Transition to working from home).
        - Reduce discretionary trips or transition to active transportation.
        - Right-size vehicle fleet.
        - Significantly increase transit mode share.
        - Optimization of delivery routes.
    - Systems:
        - Transition gasoline vehicles to zero-emission vehicles.
        - Transition diesel vehicles to zero-emission vehicles.

4.3 Big Change – Methodology

4.3.1 Three drivers

The flow of calculations for greenhouse gas inventories, projections and impacts are subject to three primary drivers. These occur in series with one another and build on one another.

1. Load. There is a load which is being overcomes (ex. A vehicles wheels must turn, a house must be heated or cooled, air must be circulated).

2. Energy. The energy used to power the systems which overcome that load.

3. Greenhouse gas impact of energy source. The greenhouse gas emissions resulting in that energy being used.

As identified in the hierarch of primary levels, if change is made on the first level (load), this will have a positive impact on emissions reductions of load, energy, and greenhouse gases. If change is made on the second level (energy), it will have an impact on energy and greenhouse gases. If change is made on the third level, if will only impact that level.

With this understanding, any big change under a primary driver of 1 or 2 will have an interactive effect with a big change under 2 or 3.

Therefore, the hierarchy was established, with a focus on conservation (load reduction) first.

4.3.2 Backcasting

Our approach to integrate the each of the 31 big changes, quantify their impacts, interactive effects was implemented utilizing the back-casting method.

In back-casting, you start at the goal (80by50, which is 20% of the baseline emissions) and quantify how significant change is required in each of the 31 big changes to achieve this goal. You then work backwards in time, from 2050 to the baseline and current year with interim achievements.

To execute on a back-casting method for long term community action, our model considered and imbedded analysis of the interactive effects that each big change has on one another. The model was developed in a way in which it could be iterated upon and the overall impact of any adjustment to a single big change, in any of the particular 5-year increments, could be seen.

After multiple live stakeholder back-casting technical model meetings, a final roadmap path was developed. This roadmap includes the required metrics of big change required for each of the 31 big changes.

For each of the big changes, a comprehensive analysis was created.

Table 8 provides a summary of the 31 big changes that were developed for the 80x50 scenario. To account for interactive effects, first changes that were aimed at conserving energy were applied, followed by changes aimed at utilizing alternative low GHG energy sources. Lastly, changes aimed at generating carbon neutral energy were applied. This process was carried out for each sector separately..

Figure 8: Summary of required changes as part of the 80x50 pathway

Sector	Changes	2010	2015	2020	2025	2030	2035	2040	2045	2050
Residential	Building envelope improvements (reduce thermal losses)	0	0	2	5	10	15	20	25	30
Residential	Efficient equipment - plug loads (TVs, computers etc.)	0	0	2	15	20	25	30	35	40

Residential	Efficient equipment - HVAC	0	0	0	5	10	15	20	30	40
Residential	Optimized/relaxed heating/cooling setpoints	0	0	0	2	4	6	8	10	12
Residential	Increase people per square foot	0	0	0	2	4	6	8	10	12
Residential	Reduce fuel oil use	0	0	0	100	100	100	100	100	100
Residential	Reduce propane use	0	0	0	100	100	100	100	100	100
Residential	Retrofit NG furnaces to electric heat pumps	0	0	0	10	20	40	60	70	85
Residential	Retrofit NG water heaters to electric heaters	0	0	0	10	20	40	60	70	85
Residential	Carbon neutral electricity generation (ex. solar PV)	0	0	0	0	5	15	20	30	45
ICI	Building envelope improvements (reduce thermal losses)	0	0	0	5	10	15	20	25	30
ICI	Efficient equipment - plug loads (TVs, computers etc.)	0	0	2	15	20	25	30	35	40
ICI	Efficient equipment - HVAC	0	0	0	5	10	15	20	30	40
ICI	Optimized/relaxed heating/cooling setpoints	0	0	0	2	4	6	8	10	12
ICI	Increase people per square foot	0	0	0	2	4	6	8	10	12
ICI	Optimization of processes	0	0	0	5	10	15	20	25	30
ICI	Reduce fuel oil use	0	0	0	100	100	100	100	100	100
ICI	Reduce propane use	0	0	0	100	100	100	100	100	100
ICI	Retrofit NG furnaces to electric heat pumps	0	0	0	10	20	40	60	70	85
ICI	Retrofit NG water heaters to electric heaters	0	0	0	10	20	40	60	70	85
ICI	Carbon neutral electricity generation (ex. solar PV)	0	0	0	0	5	15	20	30	45
ICI	Waste heat recovery	0	0	0	2	4	6	10	20	35
Transportation	Reduce trip length	0	0	0	0	2	4	6	8	10
Transportation	Short trips through active transportation	0	0	0	5	10	20	40	60	80
Transportation	Work from home	0	0	20	5	10	20	30	35	40
Transportation	co-locating errands	0	0	40	2	4	12	14	16	18
Transportation	Vehicle fleet rightsizing	0	0	2	4	6	12	14	16	18
Transportation	Significantly increase transit mode share	0	0	2	4	6	12	14	16	18
Transportation	More efficient delivery routes	0	0	0	2	4	12	14	16	18
Transportation	EV vehicles - gasoline	0	0	2	20	50	60	80	90	99
Transportation	EV vehicles - diesel	0	0	2	20	50	60	80	90	99

Regarding Agriculture and Waste, it was assumed that a similar intensity for each will be maintained over the duration of the plan.

4.4 Plan Implementation – Sample Projects

Within each of the 31 big changes, a sample project(s) has been identified to better understand specific solutions under each of these.

4.4.1 Homes

- Conservation:
  - Improvement of Building Envelope performance to reduce energy load.
    - Replace windows with triple-pane glazing.
    - Re-insulate wall assembly eliminating thermal bridging.
    - Re-insulate roof assembly.
    - Install weather stripping.
  - Improvement in efficiency of plug load equipment and appliances.
    - Replace primary appliances with energy star appliances.
    - Install smart power-bars to reduce phantom loads.
  - Improvement in HVAC system efficiencies.
    - Ensure highest performing equipment is installed.
    - Right-size equipment to actually building loads (which can be reduced through building envelope improvements).
  - Optimize home heating and cooling controls systems including better zonal control, space set-backs, and smart monitoring.
    - Add zonal dampers with actuator and controls in home ductwork.
    - Install thermostats in primary occupied spaces (not just one in the family room).
  - Optimize occupied space usage and density.
    - Consider building or purchasing a smaller home.
    - Effectively utilize home spaces.
    - Build a new home to passive house standards.
- Systems:
  - Retrofit fuel oil-based HVAC systems with low energy/carbon systems (ex. Electric - Heat Pump).
    - Replace fuel-oil boiler with geothermal geo-exchange, water, or air-sourced heat pump.
    - Replace fuel-oil furnace with geothermal geo-exchange, water, or air-sourced heat pump.
  - Retrofit propane-based HVAC systems with low energy/carbon systems (ex. Electric - Heat Pump).
    - Replace propane furnace with geothermal geo-exchange, water, or air-sourced heat pump.
  - Retrofit natural gas-based HVAC systems with low energy/carbon systems (ex. Electric - Heat Pump).
    - Replace natural gas boiler with geothermal geo-exchange, water, or air-sourced heat pump.
    - Replace natural gas furnace with geothermal geo-exchange, water, or air-sourced heat pump.
  - Retrofit fossil fuel-based water heating systems with low energy/carbon systems.
    - Replace natural gas hot water heating tank with electric instantaneous system.
- Generation:
    - Integrate carbon neutral energy generation (ex. Solar PV, Solar Thermal, carbon offsets, etc.).
    - Install Solar photovoltaics on South facing roof exposures.
    - Install solar thermal for outdoor pool heating.
    - Install battery system for electrical energy storage.

4.4.2 Workplaces

- Conservation:
  - Improvement of Building Envelope performance to reduce energy load.
    - Replace windows with triple-pane glazing.
    - Re-insulate wall assembly eliminating thermal bridging.
    - Re-insulate roof assembly.
    - Install weather stripping.
  - Improvement in efficiency of plug load equipment and appliances.
    - Replace primary appliances with energy star appliances.
    - Install smart power-bars to reduce phantom loads.
    - Implement an organization phantom load policy.
  - Improvement in HVAC system efficiencies.
    - Ensure highest performing equipment is installed.
    - Right-size equipment to actually building loads (which can be reduced through building envelope improvements).
    - Change HVAC system type to a system with lower energy and carbon profiles.
  - Optimize heating and cooling controls systems including better zonal control, space set-backs, and smart monitoring.
    - Install or upgrade the facilities Building Automation system.
    - Integrate smart building controls with BAS.
    - Install zonal controls systems.
  - Optimize occupied space usage and density.
    - Develop work from home policies.
    - Leverage space usage diversity with work from home.
    - Invest in technologies which optimize workflow.
  - Optimization of energy and carbon intensity of processes.
    - Invest in waste-heat recovery technologies.
    - Complete comprehensive energy and system analysis audits to explore opportunities to reduce energy and carbon.
- Systems:
  - Retrofit fuel oil-based HVAC systems with low energy/carbon systems (ex. Electric - Heat Pump).
    - Replace fuel-oil boiler with geothermal geo-exchange, water, or air-sourced heat pump.
    - Replace fuel-oil furnace with geothermal geo-exchange, water, or air-sourced heat pump.
  - Retrofit propane-based HVAC systems with low energy/carbon systems (ex. Electric - Heat Pump).
    - Replace propane furnace with geothermal geo-exchange, water, or air-sourced heat pump.
  - Retrofit natural gas-based HVAC systems with low energy/carbon systems (ex. Electric - Heat Pump).
    - Replace natural gas boiler with geothermal geo-exchange, water, or air-sourced heat pump.
    - Replace natural gas HVAC systems with geothermal geo-exchange, water, or air-sourced heat pump system and/or variable refrigerant flow.
    - Optimize ventilation within space. Utilize demand-controlled ventilation.
  - Retrofit fossil fuel-based water heating systems with low energy/carbon systems (ex. Electric - Heat Pump).
    - Replace natural gas hot water heating tank with electric instantaneous system.
- Generation:
  - Integrate carbon neutral energy generation (ex. Solar PV, Solar Thermal, carbon offsets, etc.).
    - Install Solar photovoltaics on South facing roof exposures.
    - Install solar thermal for outdoor pool heating.

- Install battery system for electrical energy storage.
- Install thermal energy storage systems (ex. Ice storage chiller plant).
- Invest in high impact carbon offsets.

▪ Capture waste energy for effective re-use.
- Capture waste heat from exhaust stacks and/or engine jackets.

4.4.3 Transportation

- Conservation:
  - Reduce overall average trip length for mid-long trips (over 5km).
    - Optimize when/how trips are completed. Leverage new habits from COVID impacts.
  - Transition to active transportation for short trips (<5km).
    - Purchase a transit pass.
    - Commit to a walking-based regiment.
    - Invest in an all or three season bicycle.
  - Reduce work related commuting trips (ex. Transition to working from home).
    - Invest in and embrace collaboration technologies.
    - Support a hybrid WFH and in-office setting.
  - Reduce discretionary trips or transition to active transportation.
    - Utilize public transit for trips.
    - Consider more local activities.
  - Right-size vehicle fleet.
    - Consider not replacing an ICE vehicle at end of life. (leverage active transportation and WFH if possible).
  - Significantly increase transit mode share.
    - Re-locate to transit nodes.
    - Develop public transit operational habits.
  - Optimization of delivery routes.
    - Utilize machine learning and/or AI to optimize route planning and travel.
- Systems:
  - Transition gasoline vehicles to zero-emission vehicles.
    - Replace aging internal combustion engineer (ICE) gasoline vehicle with zero-emission vehicles.
    - Install EV charging port at homes/workplaces.
  - Transition diesel vehicles to zero-emission vehicles.
    - Replace aging internal combustion engineer diesel vehicle with zero-emission vehicles.

4.5 Plan Implementation – Impacts

To provide insights on overall impact of the big changes towards 80by50, we rolled up the actions into six primary categories. These categories have been defined as follows:

- Building Upgrades
- Building Use Optimization
- Building Fuel Switching
- Net-Zero Electricity Generation
- Reduction in Travel
- Zero-emission vehicles (ex. EVs)

Utilizing the back casting quantified results, the following two plots have been developed to visually represent the impact of each of the six categories with respect to the business as usual (Figure 3) and As-is scenario (Figure 4). In Figure 3, it can be observed that the Building fuel switch and Building upgrades are the two categories with the largest impact on GHG emissions. When compared to the As-is scenario (Figure 4), transitioning to electric vehicles from gasoline powered vehicles has the largest impact on GHG emissions. This indicates that the adoption of EVs is influenced by current trends whereas Building fuel switch and Building upgrades categories require more active role from the local government.

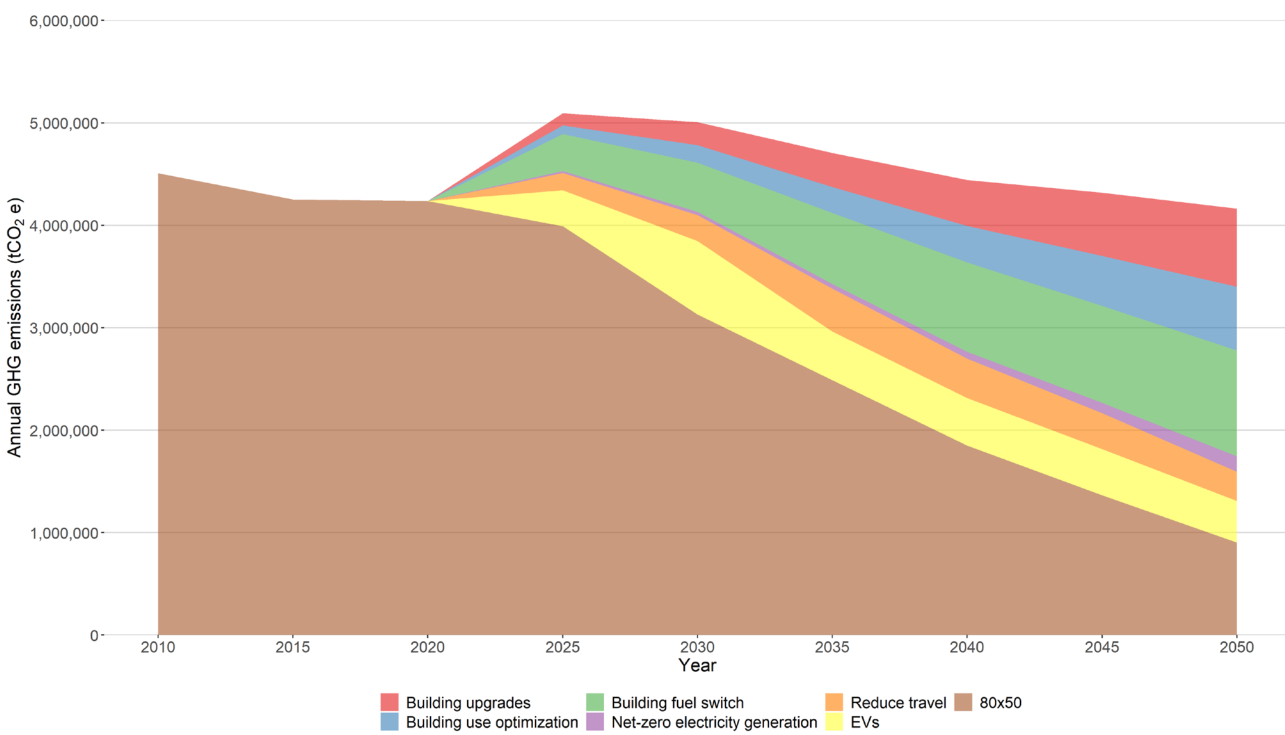


Figure 9: Annual GHG emissions as part of the 80x50 pathway with respect to the BAU scenario.

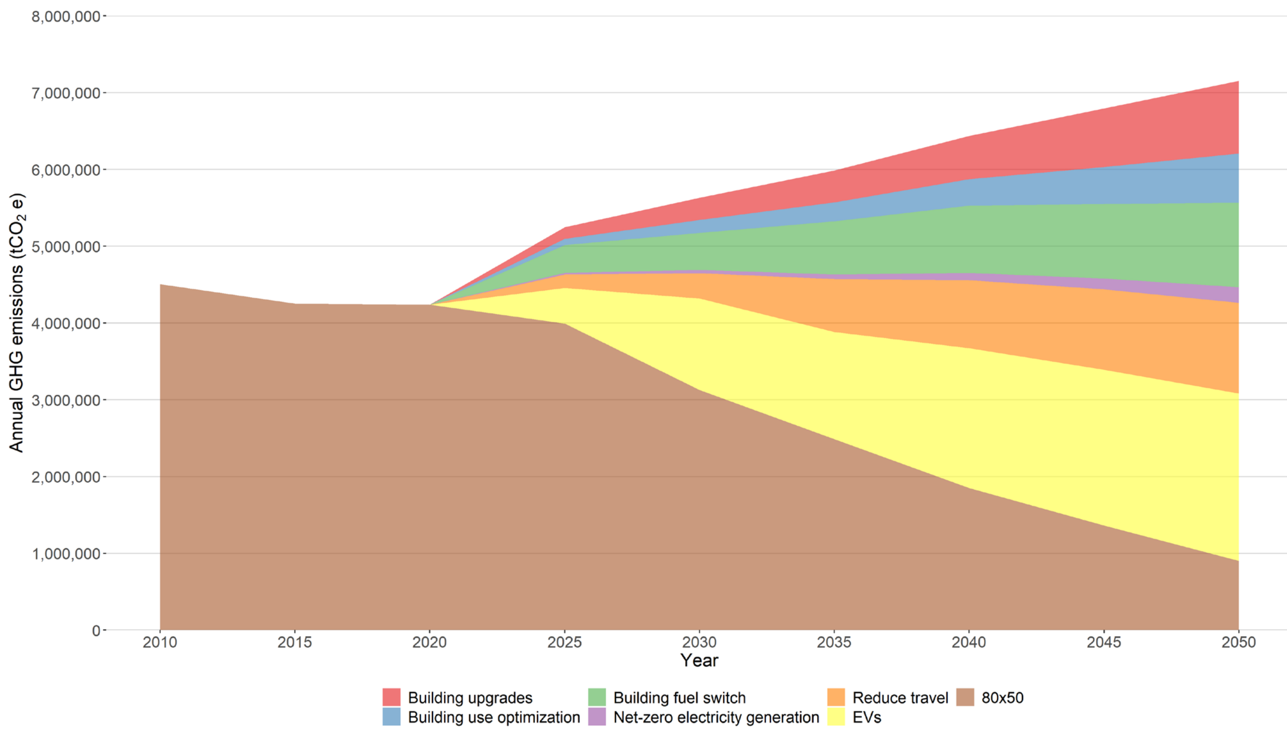


Figure 10: Annual GHG emissions as part of the 80x50 pathway with respect to the As-is scenario.

4.6 Plan Implementation – Commentary on Capital and Operational Costs

In the past, there have been several obstacles and challenges associated with both upfront capital and operational costs in decision making. Often when financial economics have been the primary driver for decisions, it has been more capital expensive and operational to implement the energy efficient or low carbon solutions.

Our industry is changing:

- The traditional operational utility cost 'spark gap' in Ontario. The cost of natural gas (high GHG intensity) for heating is significantly less expensive than the cost of electricity (low GHG intensity) is decreasing. With the cost of carbon increasing significantly now and through the next ten years ($170/tonne by 2030 has been announced by the government), this spark gap will be eliminated (and flipped). It is expected, that making the low carbon solution will have a lower operational utility cost than the fossil fuel option.

- Energy efficiency and low carbon materials and products are becoming more readily available, industry standard, and cost competitive in comparison to traditional systems. This removes the capital cost 'premium' associated with making the decision for low carbon.

- Sustainability, energy efficiency, and low carbon have risen in terms of their importance and weighting in decision making criterion. This recognition, inline with newly established sustainability corporate goals, supports the implementation of low carbon solutions.

- There are more and more federal and provincial funding announcements supporting low carbon projects. These incentive funds support high impact projects which minimize the ratio of capital dollars invested to carbon reduction achieved.

4.7 Plan Implementation – Commentary on Stakeholders

The stakeholders involved in implementing such a wide-reaching plan are far reaching:

- Local Municipal Leaders must be key-drivers of policies, planning, education, and implementation which are inclusive to the entire community.
- Local Sustainability Volunteer groups much be conduits for education and outreach, networking, and supporting low-carbon technology integration.
- Local small, medium, and large business owners and leaders must support the local goals by ensuring alignment with their corporate core values, to the Region of Waterloo. They must also develop, implement and/or consider a similar corporate carbon reduction goal.
- The general public must become engaged in carbon reduction and consider carbon as a high weighting consideration in their day-to-day life as well as when major decisions are made (ex. Personal vehicle purchase, home renovations and retrofits, transit options).
- Product vendors and vendor representatives must support education of their product users and quantify the short- and long-term benefits of the energy efficient and low carbon product offerings.
- Local utilities must both be supportive of the goal and innovative in adjusting their energy sources to low carbon. The utilities must also be supportive braking down barrier (regulatory or otherwise)

One primary recommendation, expanded on in section 6.0, is to develop a comprehensive measurement, monitoring, and verification program. This will require a significant effort of an individual or a group to overcome the diverse barriers associated with accessing good quality data on a recurring basis.

5.0 MEASUREMENT, MONITORING, AND VERIFICATION

Continuous monitoring of Region of Waterloo's GHG emissions across all sectors is essential to measure progress towards achieving our community's GHG emission reduction targets. We cannot quantify the performance outcomes of key actions without measuring them.

Measuring emissions throughout an entire community is extremely difficult. There are situations where data is reliable, accurate and readily available (ex. facilities electricity data) and there is data which is not readily available and requires creative approaches and methodologies to estimate (ex. Personal vehicles in the community).

Even in situations where data is available, regulatory and privacy concerns can make it challenging to obtain data with the appropriate level of detail.

In terms of the primary energy usages within the community, only electricity and natural gas are well tracked by local utility companies.

5.0 Measurement and Verification Plan Recommendations

As technology develops over the next 30 years of this plan execution, a web-based dashboard will be developed in order to automate as much of the data acquisition, analysis, and presentation as possible.

It is recommended to update the overall GHG emissions inventory at a minimum frequency of annually, with a focus on automation. Further, it is recommended to perform isolated analysis of specific measures/projects to monitoring the performance of integrating specific measures.

The International Performance Measurement and Verification Protocol (IPMVP) provides an excellent framework to monitor performance of integrating comprehensive measures at facilities. Although it is designed for facilities and facility systems, there are many strong principles which can be drawn from IPMVP and integrated with community wide GHG monitoring.

The following is a sample list of sector specific metrics that should be monitored to measure progress towards GHG emission targets.

Homes and Workplaces:

- Monitor annual energy consumption from all energy sources such as electricity, natural gas, fuel oil, propane and wood.
- Monitor renewable energy output of all current and new installations.
- Monitor the number of buildings which have undertaken energy retrofits.

Transportation:

- Monitor annual vehicle kilometers traveled and usage type.
- Measure number of people working from home.
- Keep track of number of electric/hybrid vehicles purchased.
- Measure distance travelled using public and active transportation.

Agriculture:

- Track/estimate number of livestock within the region.
- Monitor fuel consumed by farming equipment.

Waste:

- Monitor on volume of organics collected.
- Monitor waste diversion rates.

Ultimately, we recommend a significant and robust plan and effort be put forward to accurately track GHG emissions data for the community through to 2050.

APPENDIX A: KEY TERMS AND ACRONYMS

BAU: Refers to business as usual scenario. It is the projected level of greenhouse gas emissions in future years without any additional efforts to shift or mitigate.

As is: Refers to a scenario with equivalent carbon intensity to the baseline.

Carbon footprint: Refers to the quantity of greenhouse gas emissions emitted.

Carbon neutrality: Refers to a state where any greenhouse gas emissions generated are balanced by either sequestration of emissions elsewhere, or by the purchase of third-party carbon offsets

EF: Refers to emission factor. It is a variable for calculating greenhouse gas emissions from a particular activity, such as burning a fuel, using electricity, or producing waste.

GCO2e: Refers to gigatonnes of carbon dioxide equivalent. It is a metric used to compare the emissions from various greenhouse gases on the basis of their global-warming potential.

GHG: Refers to greenhouse gases. GHGs have an increased warming effect in earth's atmosphere.

HVAC: Refers to mechanical equipment/system utilized within buildings for heating, ventilation, and air conditioning

ICI: Refers to industrial, commercial and institutional sector.

MCO2e: Refers to megatonnes of carbon dioxide equivalent. It is a metric used to compare the emissions from various greenhouse gases on the basis of their global-warming potential.

tCO2e: Refers to tonnes of carbon dioxide equivalent. It is a metric used to compare the emissions from various greenhouse gases on the basis of their global-warming potential.

APPENDIX B: COMMENTARY ON A ROADMAP TO CARBON NEUTRAL BY 2050

We recognize there has been significant momentum towards carbon neutrality since the goal of 80by50 was set by the Region of Waterloo. With that being said, we developed a secondary analysis and approach to achieve a goal of Carbon Neutral by 2050 (100by50), with a more significant interim goal of 50% reduction in carbon by 2030 (50by30).

Technically, we have highlighted the list of largest impact changes which would contribute to achieving the 50by30 goal, while laying the foundation to achieve the overarching goal of carbon neutral by 2050.

To reach a 50% reduction by 2050:

- Our community will have planned and begun building our transportation system to put walking and cycling first with support from transit
- People are supported to make changes so they can take fewer trips, take shorter trips, and to take more trips by walking, cycling, or taking transit
- 50% of personal and commercial vehicles are zero-emissions vehicles
- 60% of Workplace and Home facilities fossil fuel sources of heating have transitioned to low or carbon neutral sources of heating (space, ventilation, water, etc.)
- Fuel oil and propane are no longer used for heating in Workplaces and Homes
- All workplaces and homeowners have a plan to transition their facilities to low or no carbon
- 20% of Workplaces and Homes energy is zero-carbon and/or renewable sources of energy
- All workplaces and homes have a plan to reduce the energy and carbon intensity of their facilities. (ex. Increase the energy efficiency of a home by re-insulating the building envelope)

Further, to achieve the long-term carbon neutral goal, the following key changes are required:

- There is a significant reduction in trips and vehicle travel
- 100% of personal and commercial vehicles are zero-emissions vehicles
- 100% of Workplace and Home facilities fossil fuel sources of heating have transitioned to low or carbon neutral sources of heating (space, ventilation, water, etc.)
- All workplaces and homeowners have significantly reduced the energy and carbon intensity of their facility through deep energy and carbon retrofits
- Building spaces are optimized from all perspective (systems, controls, density, etc.)
- 100% of electricity generation is from zero-carbon sources (predominately renewable sources)
- There is a significant investment in carbon offset projects to offset the remaining carbon profile of the region.

The following three figures demonstrate a visual representation and quantitative tonnes of carbon through 2050.

Figure 5 presents a forecast for the Waterloo Region's expected future emissions for As-is, Business-As-Usual (BAU) and 100x50 scenarios. In the As-is scenario, GHG emissions from the baseline year increase proportionally to the expected changes in the Waterloo Region's population. As such this scenario does not account for any additional changes that might occur during this timeline.

The BAU scenario accounts for expected industry trends such as transition to electric vehicles from gasoline powered vehicles, increase in work from home practices, high efficiency HVAC equipment due to technological improvements etc. This scenario represents the expected GHG emissions for the Waterloo Region in absence of any active GHG reduction strategy. For 2050, annual GHG emissions under this scenario are only marginally lower than the 2010 levels.

The 100x50 scenario is designed to achieve 100% reduction with respect to the baseline (2010) levels by 2050. This scenario explores necessary changes to reduce consumption of high GHG energy sources, switch to alternative low GHG energy sources and generation of carbon neutral energy.

Figure 12 provides a summary of data used in Figure 11.

Figure 11: Annual GHG emissions for As-is, BAU and 100x50 scenarios.

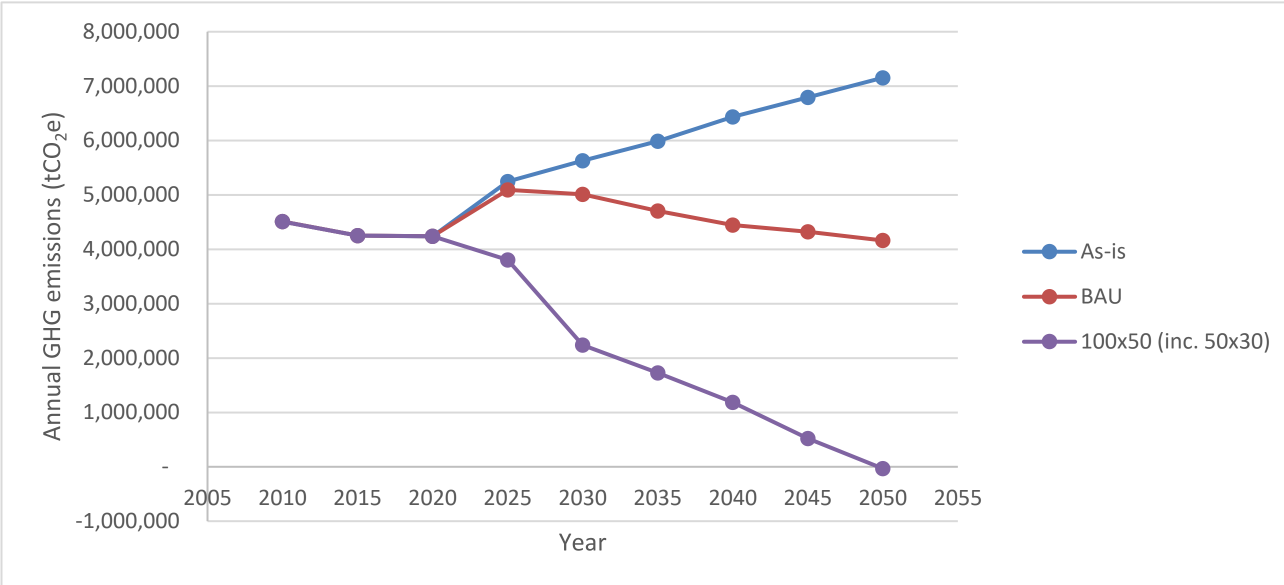


Figure 12: Annual GHG emissions for As-is, BAU and 100x50 scenarios.

Scenario	2010	2015	2020	2025	2030	2035	2040	2045	2050
As-is	4,507,474	4,252,462	4,237,026	5,246,106	5,630,822	5,986,167	6,436,653	6,795,336	7,154,019
BAU	4,507,474	4,252,462	4,237,026	5,092,461	5,007,705	4,706,436	4,443,109	4,319,276	4,161,747
100x50 (inc. 50x30)	4,507,474	4,252,462	4,237,026	3,806,302	2,237,825	1,729,073	1,186,715	523,182	0

Figure 13 provides a detailed summary of annual GHG emissions by GHG emission sources for the 100x50 scenario. Significant reduction in GHG emissions from the combustion of natural gas, gasoline and diesel must be realized to achieve 100% reduction in GHG emissions by 2050. Additionally, some of the GHG emissions must be offset through generation of carbon neutral electricity. This implies that the Waterloo Region would be generating carbon neutral electricity in excess to balance emissions generated through other sources such as agriculture and waste.

Figure 13: Annual GHG emissions (tCO2e) for 100x50 scenario.

Sources	2010	2015	2020	2025	2030	2035	2040	2045	2050
Electricity	652,881	227,300	200,361	402,161	406,219	287,515	67,331	298,263	-489,163
Natural gas	1,376,389	1,458,973	1,614,579	1,246,290	786,404	646,664	518,683	397,073	197,334
Fuel oil	133,952	141,989	158,063	-	-	-	-	-	-
Propane	72,851	77,222	85,964	-	-	-	-	-	-
Gasoline	1,561,598	1,655,294	1,398,364	1,440,840	477,298	338,255	201,723	91,162	-
Diesel	450,470	477,498	520,923	457,678	308,572	197,306	139,646	73,877	-

Sources	2010	2015	2020	2025	2030	2035	2040	2045	2050
Agriculture	213,559	213,559	213,559	213,559	213,559	213,559	213,559	213,559	213,559
Waste	45,774	45,774	45,774	45,774	45,774	45,774	45,774	45,774	45,774
Total	4,507,474	4,297,609	4,237,588	3,806,302	2,237,825	1,729,073	1,186,715	523,182	-32,495
Percent	100%	95%	94%	84%	50%	38%	26%	12%	-1%

APPENDIX C: CARBON BUDGET ANALYSIS

80by50 Carbon Budget

In adherence to the C40 Cities network carbon budget methodology, a network of the world's megacities committed to addressing climate change, the carbon budget for Waterloo Region based on the 80by50 technical roadmap was developed. To adhere to C40 a maximum target emission of 3.2 tCO2e per person by 2030 and reduce those emissions to 0 tCO2e per person by 2050 is required. The curve from 3.2 tCO2e per person to 0 tCO2e per person is a polynomial shaped as follows:

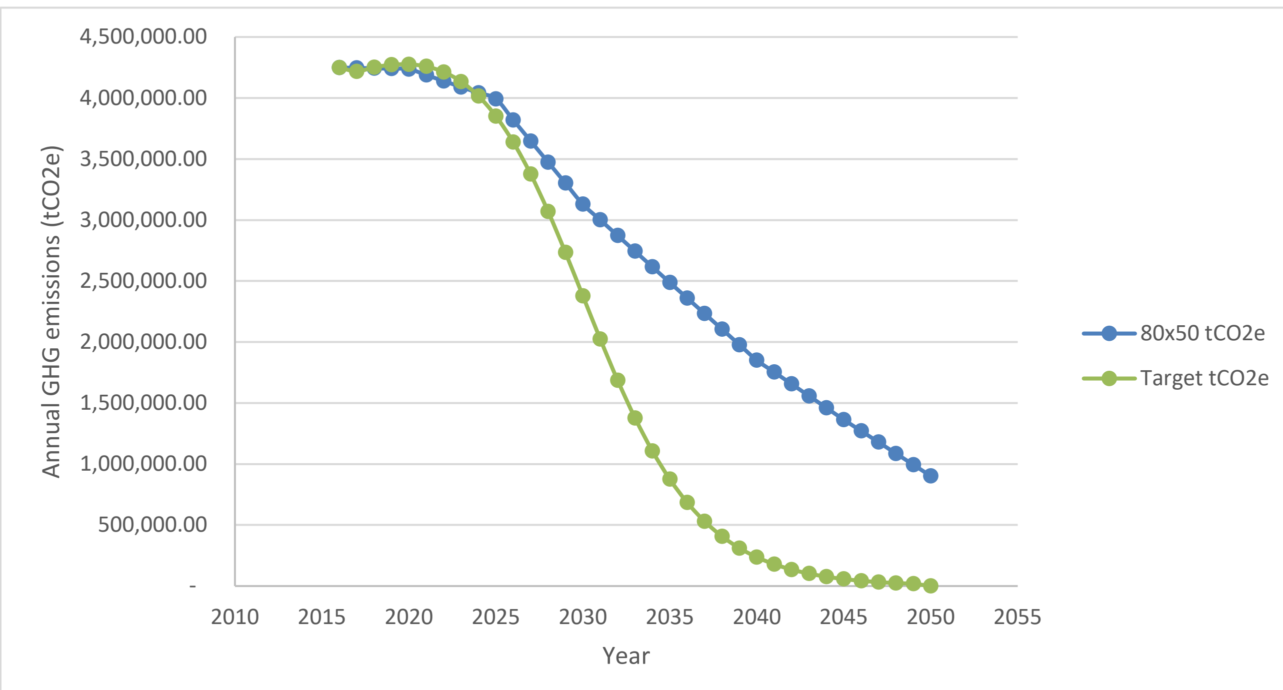
Region of Waterloo's per capita GHG emissions in 2020 are expected to be approximately 6.58 tCO2e per person. By the pure natural of the 80by50 goal, it is not possible for this plan to achieve the C40 recommendations on carbon budget. The primary reason for this is that the carbon emissions do not track to zero. If they do not track to zero by 2050, there is still 'area under the curve' or emissions beyond 2050.

That being said, the C40 methodology is an important benchmark for comparison.

Using this methodology, based on the 80by50 plan with a 30by30 interim goal:

- The planned carbon expenditure for the Region of Waterloo from 2020 to 2050 is calculated to be 96.51 MtCO2e.
- The emissions achieved by 2030 is 4.21 tCO2e per person.
- The C40 carbon budget for the Region of Waterloo from 2020 to 2050 is calculated to be 66.84 MtCO2e.

Figure 14: Annual GHG emissions as part of 80x50 pathway and C40 carbon budget for Waterloo Region.



As you can visually see in the plots, although the 80by50 plan does not adhere to the C40 carbon budget methodology, it still maintains a similar trend.

Under 80by50, it is essential to clearly define the goal beyond 2050. (ex. Carbon Neutral by 2055 or 2060) such that the final planned carbon expenditure for Waterloo Region can be established.

Carbon Neutral by 2050 Carbon Budget

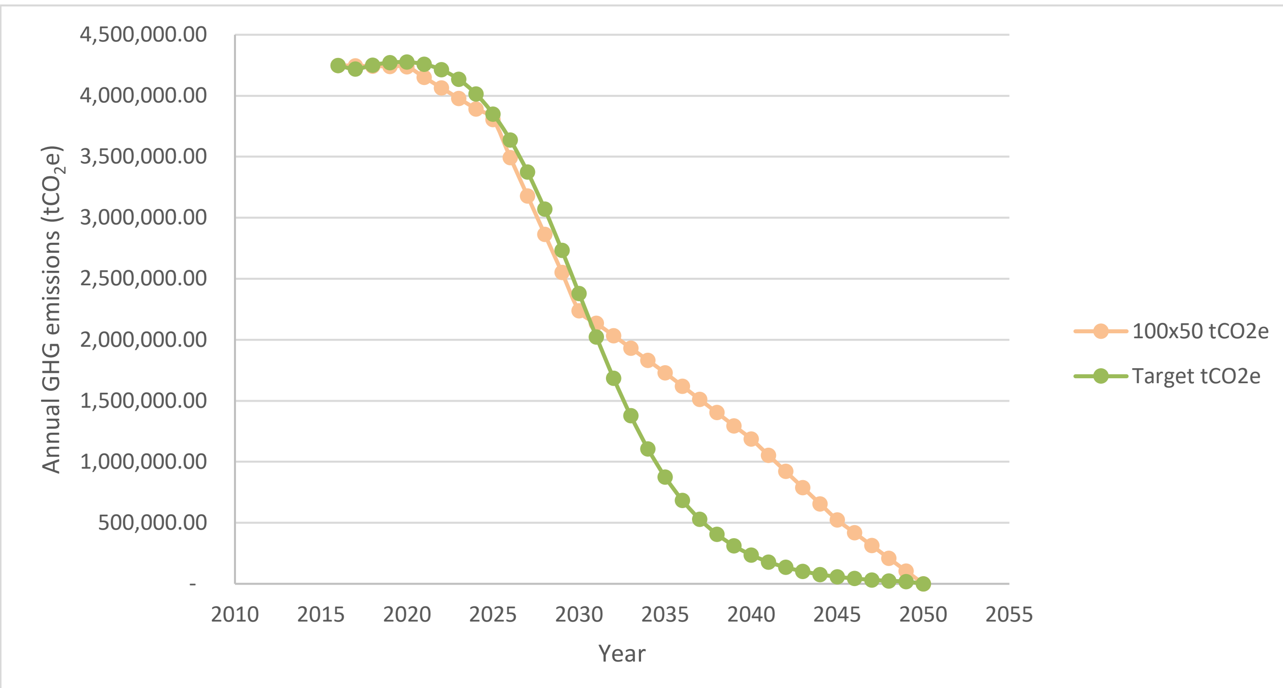
In addition to the 80by50 plan, the carbon budget was calculated for the carbon neutral by 2050 with an interim goal of 50% reduction in carbon by 2030 (100by50 with 50by30)

A carbon neutral plan for the Region of Waterloo was calculated and the planned carbon expenditure under this model was found to more closely follow the C40 model.

Using this methodology, based on the 100by50 plan with a 50by30 interim goal:

- The planned carbon expenditure for the Region of Waterloo from 2020 to 2050 is calculated to be 77.1 MtCO2e.
- The emissions achieved by 2030 is 3.0 tCO2e per person.
- The C40 carbon budget for the Region of Waterloo from 2020 to 2050 is calculated to be 66.84 MtCO2e.

Figure 15: Annual GHG emissions as part of 100x50 pathway and C40 carbon budget for Waterloo Region.



As you can visually see in the plots, although the 100by50 plan does not adhere to the C40 carbon budget methodology, it still maintains a strong trend. It should be noted that from 2030 to 2050, the plan is fairly linear, and there is more planned carbon expenditure during those years than the ideal C40 path.