Prepared by Kristin Koetsier **May 22nd 2020**

Greenhouse Gas Inventory: The Municipality of Central Manitoulin

Executive Summary

This document outlines calculations made to estimate the amount of greenhouse gases being released within the geographic boundaries of our municipality. These greenhouse gas emissions fall into two categories: those coming from corporate assets and operations, including the municipal fleet, municipal buildings, water and sewage treatment, and streetlights; and those coming from community activities such as energy use in homes and work spaces, transportation within the municipal boundaries, agriculture, and the decomposition of waste. For a baseline year of 2018, we found our emissions to equal the following:

Corporate Total	**507.9 tCO_2e**	**Community Total**	**34 663.48 tCO_2e**
Municipal Fleet (including outsourced waste haulage)	353.87 tCO_2e	Energy Use at Home and Work	21 701.47 tCO_2e
Municipal Buildings	147.33 tCO_2e	Transportation	8521.05 tCO_2e
Water and Sewage Treatment	4.16 tCO_2e	Agriculture	3895.38 tCO_2e
Streetlights	2.54 tCO_2e	Waste	545.58 tCO_2e

We also found that the forest cover within the municipality may be absorbing approximately 90 768.2 tCO_2 per year, more than what is released within our geographic boundaries. However, this does not relieve us of our obligation to reduce our emissions, as global totals of greenhouse gas emissions are still far higher than what could be absorbed globally—and the atmosphere is not politically bounded. We have the good fortune to be living in a carbon sink, but our carbon-intensive lifestyles are still contributing to the larger problem. Furthermore, what is not included in this inventory are the greenhouse gas emissions released outside our municipal boundaries due to actions taken by Central residents; the shopping, diet, and travel choices of individuals typically contribute to a fair portion of their "carbon footprints", and this portion is not accounted for here.

Through municipal-led actions to both reduce our corporate emissions and to help enable the reduction of community emissions, we can make it easier for community members and visitors alike to reduce the portion of their carbon footprints associated with emissions physically released within our geographic boundaries. It will be up to each individual to address components of their footprints involving emissions released elsewhere. By protecting and enhancing our carbon sink, we can help improve the possibility that the world as a whole could one day be carbon neutral.

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Introduction

The purpose of a greenhouse gas inventory is to define a "starting point" from which emissions can then be reduced. Having a defined starting point allows us to track our progress towards our goals over the years. Without an inventory, taking climate action is a bit like taking a shot in the dark—we wouldn't know whether what we're doing is enough.

Calculating greenhouse gas emissions is a complicated matter, however, and in order to effectively compare emissions from one location to another, it is important to ensure that all locations use the same method for these calculations. Including only those emissions released within a municipality's geographic boundaries also eliminates the possibility of emissions being "double-counted" between different communities. We chose to follow the guidelines developed by the Partners for Climate Protection (PCP) program, outlined in a document known as the PCP Protocol, and also made use of the PCP Tool—an online program that calculates the amount of emissions resulting from a given input to the Tool, such as the amount of fuel burned for a specific use. The PCP program and the PCP Tool were developed by the Federation of Canadian Municipalities (FCM) and the Canadian chapter of ICLEI Local Governments for Sustainability. These resources are being used by many municipalities across Canada.

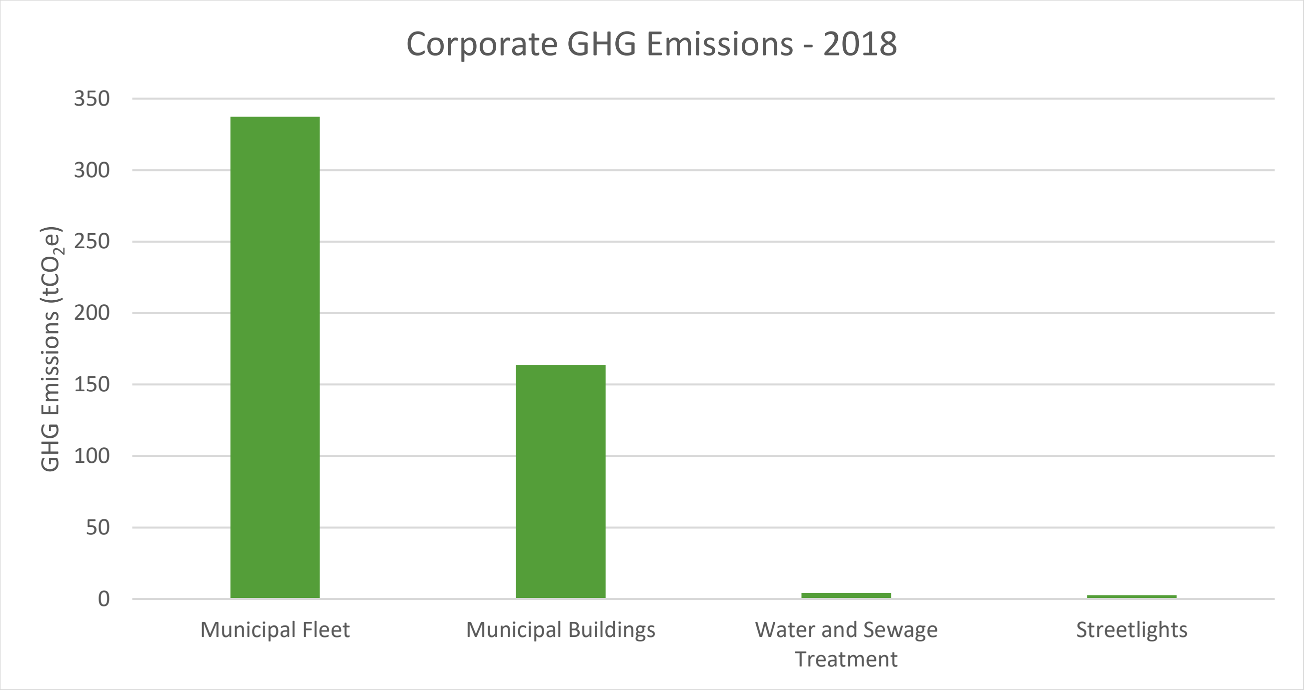
A note on units*: In this report you will see frequent use of the unit "tCO_2e". This is a unit of measurement used by climate scientists to represent tonnes of different greenhouse gases, equalized in terms of their warming potential, as compared to carbon dioxide (CO_2). Some greenhouse gases last* *longer in the atmosphere than others, and warm the atmosphere by varying degrees. Since carbon dioxide is the most abundant and well-known greenhouse gas, scientists often report amounts of other greenhouse gases in terms of how much CO_2 their warming effect is equivalent to, over a given time period. For simplicity's sake, we will only report the total amount of CO_2 equivalent (CO_2e) produced in each category, with amounts of CO_2 and other greenhouse gases having been added together.*

A note on baseline year*: All inventories aim to calculate the amount of greenhouse gases that were produced within a "baseline year", in other words a year with sufficient data available, against which progress can be tracked as years go by. For our inventory we chose the baseline year of 2018, as it was the most recent complete year when the work on the inventory started, though for some categories data was only available as recently as 2016. It is assumed that emissions in these categories did not change significantly over those two years.*

The following sections provide more detail as to where our greenhouse gas emissions are coming from within each category and how these emissions were calculated. The Appendices include still further notes on calculation details and data collection.

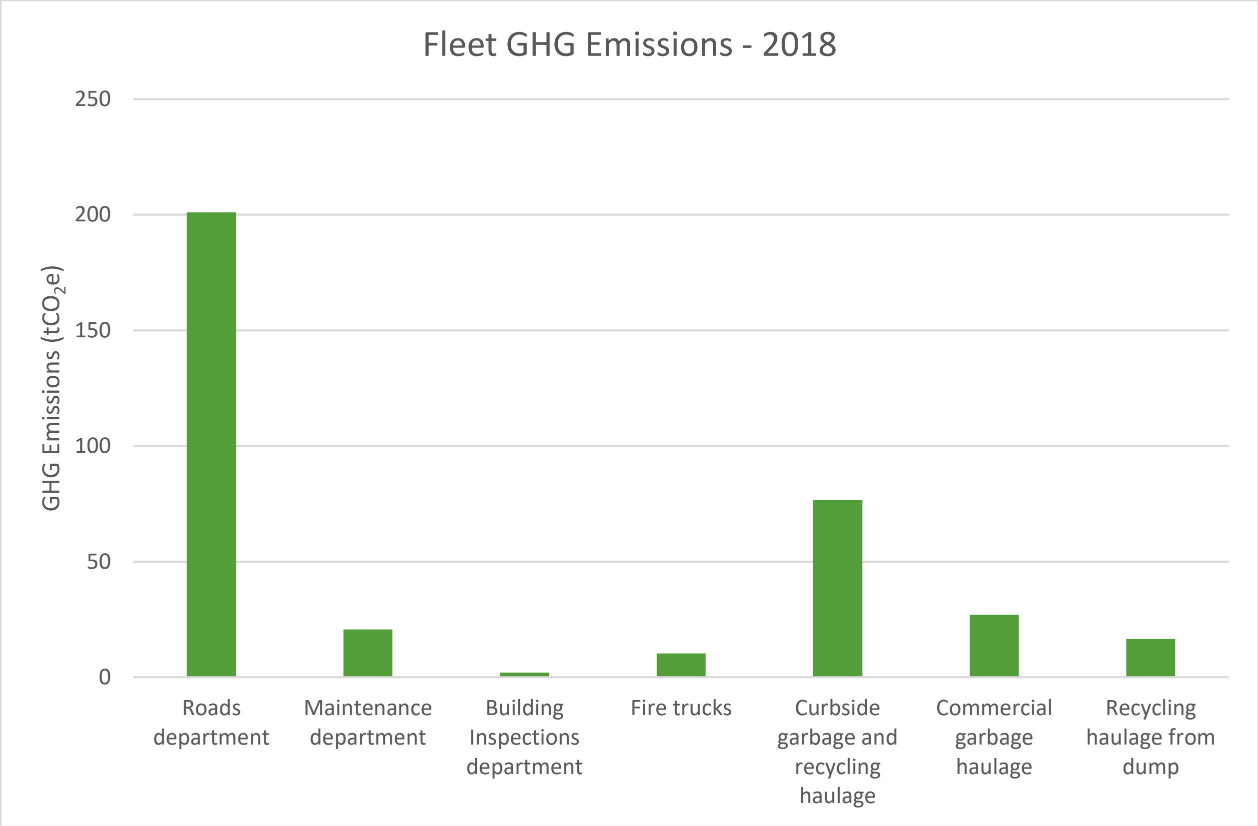
Corporate Emissions

In total our corporate emissions amounted to **507.9 tCO_2e** for 2018, with municipal fleet being the biggest category, followed by municipal buildings, then water and sewage treatment, and lastly streetlights.



Municipal Fleet

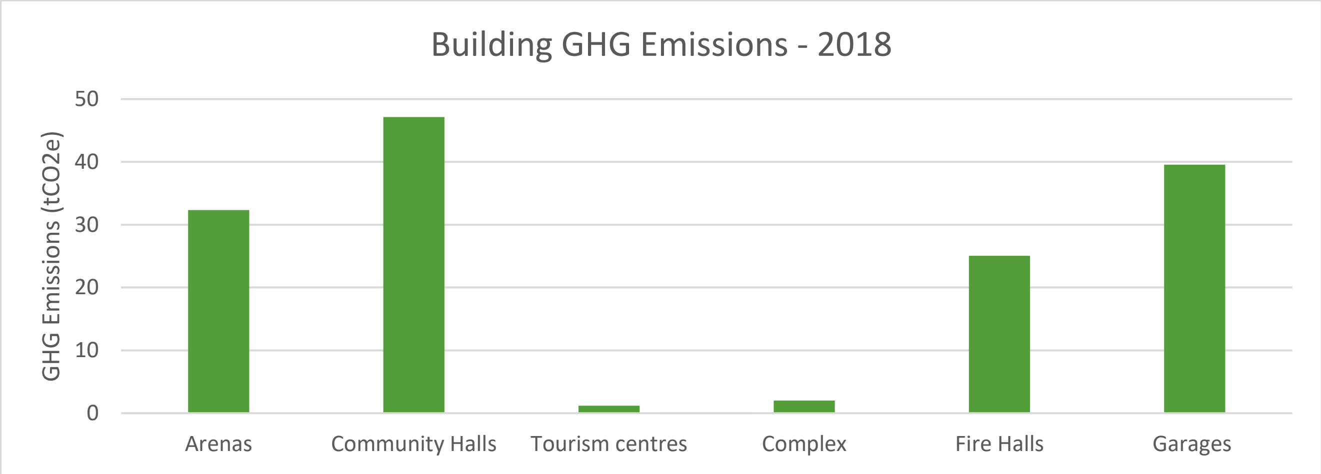
For municipal fleet, we included the emissions from transportation fuel burned by our own roads, maintenance, building inspections, and fire crews, which added up to **233.83 tCO_2e.** Since some municipalities provide trucking of waste as part of their fleet services, we included emissions from this activity as well, even though in our case that service is outsourced to GFL Environmental. In Central Manitoulin, one large truck comes from Espanola each week to collect commercial waste and deliver it to the Dodge landfill in Espanola; this emits **26.96 tCO_2e** in a year. Three smaller trucks also come all the way from Blind River each week to collect both curbside garbage and recycling, taking the garbage to our own landfill; this emits **76.62 tCO_2e** in a year. The recycling at Central's dump is also picked up once a week by two larger front-end trucks, one for cardboard and one for plastic, taking the recycling all the way to Blind River. These two trucks also pick up recycling from at least half a dozen other communities on the Island as part of the same trip, therefore we have calculated Central's share of the emissions to be 1/6 of the total, emitting **16.46 tCO_2e** in a year. **In total, all these fleet emissions add up 353.87 tCO_2e**.

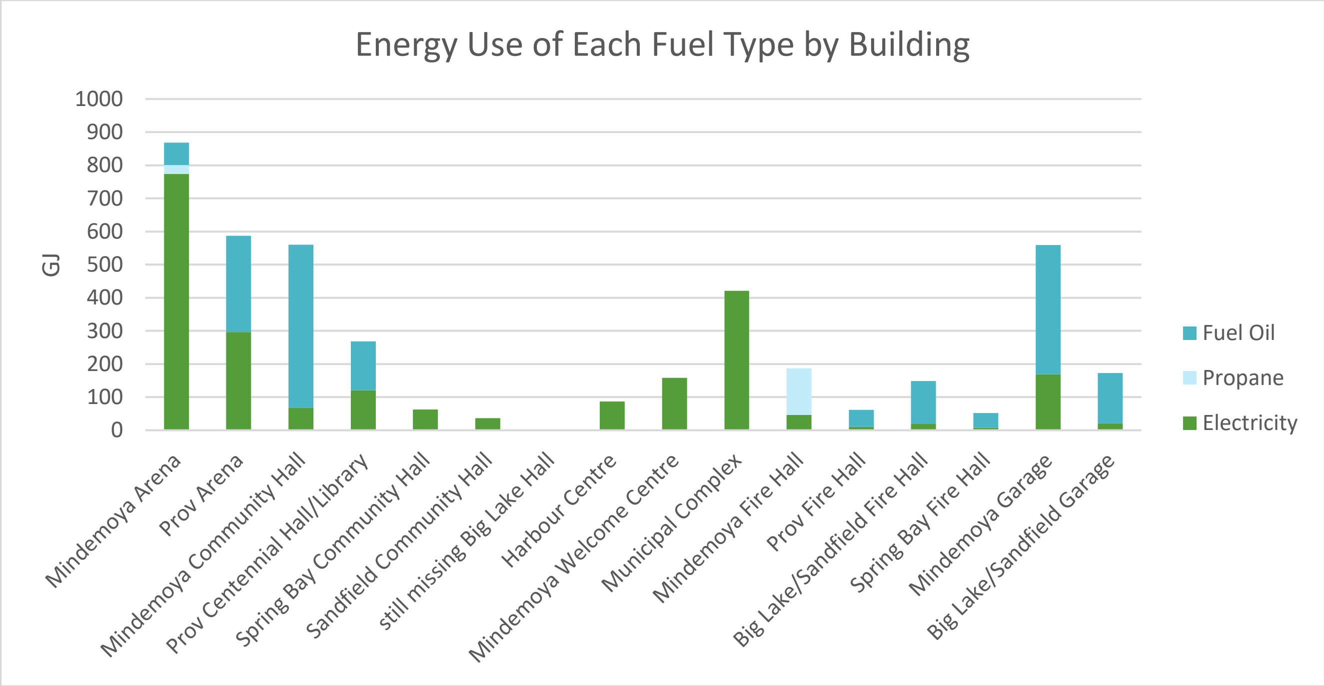


Municipal Buildings

For Centrals' inventory we decided to include all buildings with significant energy usage over which Central administration has both ownership and some degree of operational influence. This amounted to eighteen buildings: five community halls (Big Lake, Mindemoya, Providence Bay—which includes the change-house, Sandfield, and Spring Bay) four fire halls (Big Lake, Mindemoya, Providence Bay, and Spring Bay), two arenas (Mindemoya and Providence Bay), two garages (Big Lake/Sandfield and Mindemoya), two tourist hubs (the Welcome Centre and the Harbour Centre), and one municipal complex.

The electricity, propane, and fuel oil use in these buildings resulted in a total of 147.33 tCO_2e being released in 2018. The total amount of energy used was 4231 GJ, which cost $151 927.43 excluding leased out properties. The following charts break this down by building and by energy type:





Water and Sewage Treatment

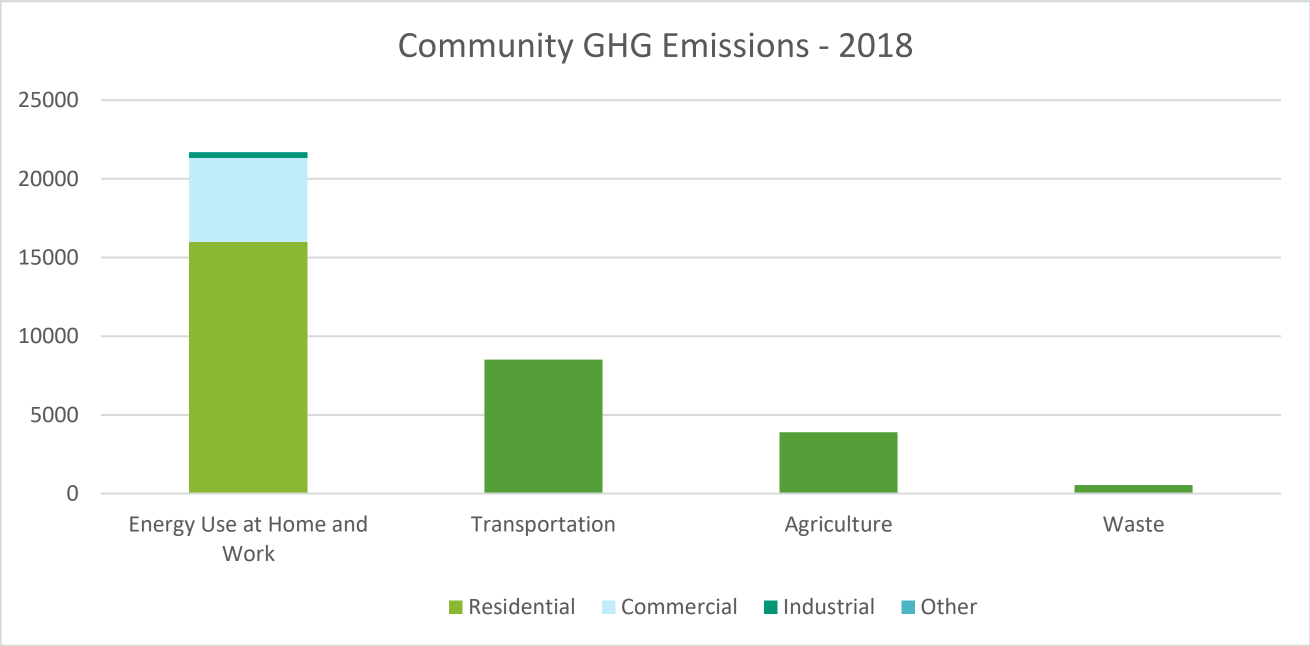
The 157 920 kWh of electricity used in the sewage treatment plant cost the municipality $26 094.54 and resulted in **2.73 tCO_2e** of emissions. The 82 843 kWh of electricity used in the water treatment plant cost the municipality $31 041.87 and resulted in **1.43 tCO_2e**. **Operations of these two facilities resulted in a total of 4.16 tCO_2e combined.**

Streetlights

The electricity use of all streetlights was found to total 146 298 kWh in 2018, costing the municipality $39 343.35. **This resulted in 2.54 tCO_2e**.

Community Emissions

Typically much more substantial than corporate emissions, community emissions can be subdivided into categories of building energy use (or "energy use at home and work"), transportation, land/agriculture, and waste. The only components included here which involve emissions happening outside our geographic boundaries are emissions from production of electricity elsewhere and emissions from decomposition of waste that has been produced here but landfilled elsewhere. The electricity production emissions are included so that electricity use-related emissions can be compared with the direct emissions from other home heating sources i.e. the burning of fuel oil, propane, and wood, which occurs on-site (though for these sources, production-related emissions are not included by the PCP Tool). The emissions from waste that is trucked to a landfill outside our municipality is included so that it can be considered alongside emissions from waste directly landfilled within our boundaries. In total our community emissions were **34 663.48 tCO_2e** for 2018.



Energy Use at Home and Work

In the PCP Tool, this category is termed "Stationary Energy," meaning energy that is used in buildings of every kind, as well as off-road farm equipment—energy that is being used in one place. In many Ontario homes, people source their energy from electricity and/or natural gas, but with no natural gas available on the Island, our sources also include propane and fuel oil, as well as firewood—this category includes both energy for heating as well as for powering lights, appliances, etc.

Through calculations based on provincial average home energy requirements, local building age[1], estimates on how many people use which types of fuel, and District-level Hydro data, we found that in Central Manitoulin approximately **280.75 tCO_2e are being annually emitted from electricity, 3577.02 tCO_2e from propane, 3077.04 tCO_2e from fuel oil, and 9069.36 tCO_2e from wood, for a total of 16 004.17 tCO_2e from residential energy use, attempting to include seasonal residents**.

Using the District-wide ratio of electricity use in residential vs. commercial vs. industrial vs. other sectors as a starting point, we came up with estimates resulting in **final values of 5315.01 tCO_2e for commercial, 381.73 tCO2e for industrial, and 0.56 tCO_2e for "other",** including estimated fuel oil and propane use in commercial and industrial sectors.

We do not have sufficient data at this time to calculate emissions from off-road farm vehicles and equipment, which would normally be included in this category. However, the National Farmers' Union[2] lists fuel combustion as being among the top three sources of emissions from farms, so this should still be considered in our action plan.

Transportation

The ideal way to calculate transportation emissions is to estimate the number of kilometres travelled within the municipal boundaries by all vehicles in a given year (this is called the Vehicle Kilometres Travelled (VKT)), then to multiply this number by the amount of CO_2e that the average vehicle of average fuel type emits per kilometre. To estimate VKT, we multiplied traffic counts done for provincial highway segments[3] by the length of those segments that fall within our municipal boundaries, then added to this an estimate for commuter travel on municipal roads based on commute durations as found in the Census[4]. This resulted in a total of 23 262 740 km travelled within municipal boundaries in one year. **When entered into the PCP Tool, this yields emissions of 8521.05 tCO_2e.** This number does not however account for recreational travel on municipal roads, so is very likely to be an underestimate.

We do not have sufficient data at this time to calculate emissions from off-road transportation such as snowmobiles, ATVs, and landscaping/construction equipment, though in our area this could make up a sizeable amount of emissions—typical snowmobiles are known as being extremely heavy polluters.

Agriculture

Agricultural emissions are one of the more complicated categories to calculate, and directions for doing so are not yet included in the PCP Protocol. However, since agriculture is a large part of life in Central, we have managed to include it by following the PCP Tool's suggestion of referencing Chapter

10 of the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC). This chapter divides agricultural greenhouse gas emissions into three categories: those from livestock, those from land use and land use change, and those from "aggregate sources and non-CO_2 emissions sources on land", in other words substances that are added to the soil, as well as other actions such as harvesting of wood.

Livestock

For emissions from livestock, we focused only on cattle, getting approximate numbers for our municipality by dividing the total number of cattle in the District[5] by our percentage of land area. These numbers for each cattle type were then multiplied by corresponding emissions factors found in Canada's National Inventory Report (NIR). It should be noted that these emissions factors are based on average practices for each cattle type across Ontario, and due to practices likely being more sustainable on Manitoulin, the resulting numbers of **3710.03 tCO_2e** from enteric fermentation (burps) and **185.35 tCO_2e** from methane emissions from manure management may be overestimates. We were not able to get an estimate for nitrous oxide (N_2O) emissions from manure management, however, so in this sense our **total of 3895.38 tCO_2e** could be an underestimate.

Land Use and Land Use Change

Carbon release from soils in Central's croplands is assumed to be zero, based on the likelihood that this soil would have lost most carbon it could lose in its early years of being tilled. No more is likely being lost on a yearly basis; however, carbon could be restored to the soil through a change in practices. The effects of grasslands, wetlands, settlements, and other land use types have not been included here.

For aggregate sources and non-CO_2 emissions sources on land

It was assumed that there is no field burning or rice production within the municipality. Only two farms in the District reported lime use in the 2016 Census, and the acreage is not reported, so we have excluded this from our inventory. We were not able to estimate the amount of nitrous oxide (N_2O) being emitted as a result of fertilizer application either. Seeing as very little land within the District has fertilizer applied to it, it is tempting to say that omitting this category is just as well. However, every bit counts when it comes to greenhouse gases, and N_2O in particular has an extremely high Global Warming Potential—265 times that of CO_2[2]. So, reducing fertilizer use should still be considered as a valuable action.

Harvested wood products is also included in this section of the GPC, but as we have included the burning of harvested firewood under "Energy Use at Home and Work"/Stationary Energy, we have not included it in this section. Harvesting wood to be otherwise used for construction or furniture-making etc., can actually act as a carbon sink, since the carbon may be stored in that format for a long time. However, we do not have data for this activity at this time.

Waste

Waste is slightly different from all the other categories because the emissions from waste deposited in a landfill are released over the course of many years, through the process of that waste's decomposition. Therefore there are two main ways to calculate emissions for a given year: you can either calculate the amount of emissions that the waste deposited within that year will produce over the course of its decomposition, assigning all future emissions to the current year, or you can attempt to calculate the amount of emissions actually being released in the current year by all waste that has already accumulated in the landfill. The former is much simpler and more frequently used, but runs the risk of yielding a false sense of security—if, say, a municipality were to achieve going zero waste, this approach would then say that they have zero emissions, when in fact there could still be emissions coming from waste of the previous years. If something can be done to better manage that old waste, or to off-set its emissions through some other means, it may be worth calculating with the second method.

For now, we will use the first method, on the assumption that most of our actions will involve reducing the amount of waste being produced. A total of 5445.05 cubic yards of waste was sent to landfill in 2018; 1543 cubic yards were sent to the Dodge landfill in Espanola while 3912.05 cubic yards were deposited in our own landfill. This combined amount is equal to 433.01 metric tonnes, which was entered into the PCP Tool along with an estimated waste breakdown of 20% food, 15% garden/plant debris, and 20% paper/cardboard (sourced from Green Economy North, a program of ReThink Green) to calculate how much methane would be produced by this amount of waste over the course of its decomposition.

The waste landfilled in 2018 will result in 545.58 tCO_2e over the course of its decomposition; we will use this as a proxy for the approximate amount released from the existing pile at the dump each year.

Local Carbon Sequestration

In addition to quantifying the greenhouse gas emissions occurring within our municipal boundaries, the Land Use section of the GPC also addresses carbon sequestration—the capacity of our trees, for instance, to remove some carbon from the atmosphere. We used an estimate of 50% of land in Central Manitoulin being forested, combined with an estimate of carbon storage per hectare of forest taken from a study[6] on the northern Bruce Peninsula (which has a similar tree species composition to here), to calculate an estimate of **approximately 90 768.2 tCO_2 being absorbed by the forests of Central Manitoulin each year, although in reality, the amount that a forest absorbs changes as it**

ages. Typically, younger forests absorb carbon more quickly, since more rapid growth is occurring, while older forests have more carbon stored up on the whole. Therefore, it's possible that an absorption rate of 90 768.2 tCO_2 per year may be an overestimate when looking forward. The impact of changing climate conditions on the forest's ability to hold onto CO_2 should be considered as well.

Conclusion

It's important to note that some activities occurring here—or engaged in by community members when they are elsewhere—result in further emissions being produced in other parts of the world. Actions such as travelling outside of the municipality, buying goods and food that were produced outside the municipality, and even investing money indirectly in industries outside the municipality, all have a climate impact we can control. Similarly, some of the emissions occurring within the municipality are connected to consumption habits of folks who don't live here. By improving the sustainability of all local activities, we can make it possible for those who source our products or visit our locations to reduce their footprints, and make it possible for local residents to reduce the portion of their footprints tied to local emissions.

Even though it turns out that within our geographic boundaries, more carbon is likely being absorbed by trees than is being emitted by human activities, that does not exempt Central from taking climate action. Climate change is a global issue, and globally we are nowhere near being carbon neutral, let alone carbon negative like Central. While Central residents are fortunate to be living in the midst of one of the world's carbon sinks, that does not make their own contribution to the global levels of greenhouse gases any less important—Canadians have some of the highest carbon footprints in the world. Given the global context, this inventory shows that Central has the capacity to aid the fight against climate change by both enhancing our substantial carbon sinks and by reducing our substantial carbon footprints.

Appendix A: Corporate Emissions - Data Collection and Calculations

Municipal Fleet:

The number of litres of gasoline and/or diesel used by each department's vehicles was collected from the financial ledger sheets for each department for the year of 2018. These ledger sheets themselves are compiled from slips submitted upon each fill-up of each vehicle. In cases where the number of litres was not included, an estimate of litres was deduced from the dollars paid for fuel, using an average amount of litres per dollar based on the complete entries from the Roads department's ledger for diesel and the Maintenance department's for gas. The total litres of gasoline and diesel from each department were then added together for one grand total for each fuel type, which was then multiplied by the emissions factors contained within the PCP Tool to find out the carbon dioxide equivalent of greenhouse gases emitted by burning these amounts of fuel.

For the one large truck coming from Espanola each week to collect commercial waste and deliver it to the Dodge landfill in Espanola: As of November 19th 2019, for the preceding thirteen weeks, this truck had required an average of 190 litres of diesel fuel per round-trip (according to GFL Environmental). The amount of fuel required can vary slightly depending on the weight of the garbage that is in the truck. However, the average amount of garbage picked up each week by the truck during those thirteen weeks was very close to the average amount of garbage picked up weekly over the course of the year, so this average fuel amount for that thirteen-week period can be reasonably used as an approximate annual average as well. We will assume that the amount of waste picked up in 2018 was approximately similar to that in 2019. (The amount of garbage trucked each week was obtained directly from in-house pick-up receipts). Therefore, 190 litres for each of every fifty-two weeks in a year results in a total of 9880 litres of diesel fuel used annually for commercial garbage haulage.

For the three smaller trucks coming all the way from Blind River each week to collect both curbside garbage and recycling, taking the garbage to our own landfill: Each of these trucks require an average of 180 litres of diesel fuel per round-trip—less than what's required by the garbage truck doing commercial pick-up despite the longer distance, likely because these trucks are smaller and/or because they don't carry a full load their whole trip. Multiply that by three trucks and fifty-two weeks and the result is that 28 080 L of diesel are burned each year for curb-side garbage pick-up.

For 1/6 of the two larger front-end trucks, one for cardboard and one for plastic, taking the recycling all the way to Blind River: An estimate for how much diesel fuel would be burned by each truck each trip was obtained by referencing the numbers given for the large garbage pick-up truck mentioned above. Given that the large garbage pick-up truck for commercial waste requires 190 L of diesel for each round-trip from Espanola, and Espanola is 109km from Central Manitoulin (according to Google Maps), that means that truck is burning approximately 0.87 litres of diesel per kilometre. The recycling plant, however, is in Blind River, which is 200 km from Manitoulin Island (using the centralized location point on Google Maps, used since this service is shared with other communities), so for a round-trip it can be assumed that the large recycling trucks each burn 348 L of diesel. Multiplied by two trucks and 52 weeks and divided by six to get our share, that means that for Central's recycling pick-up from the dump, approximately 6032 L of diesel are burned in a year.

Municipal Buildings:

We did not include the Cenotaph structures as the municipality does not control energy usage at that site, nor did we include the cold storage building or the Mindemoya change-house as they have very low energy use, already minimized by installing motion-sensor lights. We did not include the Old School either, as it is not in use.

For Sandfield Hall and Big Lake Hall, which are leased out, we contacted the groups leasing them to access energy bills; unfortunately those for Big Lake Hall were not provided at the time of this report. For the remaining sixteen buildings, we obtained fuel oil delivery data directly from Manitoulin Fuels for 2018. Electricity and propane usage for those sixteen buildings were obtained from our in-house 2018 Energy Consumption Reporting Form. Total expenditures for each energy source—electricity, propane, and fuel oil—were obtained from this form as well. Operating hours and floor area were obtained from the Broader Public Sector reporting chart (2017) for all buildings not leased out, and updated where necessary (due to renovations and corrections for seasonal use) with help from the Maintenance Supervisor; new values are now in an in-house excel.

Water and Sewage Treatment:

The amounts of electricity used by the water treatment plant and the sewage treatment plant were obtained from the 2018 Energy Consumption Reporting Form and were inputted into the PCP Tool.

Streetlights:

The electricity use of all streetlights was added up from our Hydro bills.

Appendix B: Community Emissions - Data Collection and Calculations

Energy Use at Home and Work:

Propane and fuel oil usage numbers are not readily available from suppliers, and Hydro One is not able to provide data delineated by municipal boundaries. Instead, we have made use of a tool developed by ReThink Green (a non-profit based in Sudbury) that allows communities to carefully estimate residential usage of electricity, propane, fuel oil, and wood using provincial per home energy requirements, filtered through the age of buildings in this area, and multiplied of course by our number of dwellings (a video explaining this tool should be available at http://www.smartgreencommunities.ca/resources/), with data having been sourced from Natural Resources Canada and the National Inventory Report. Using this tool also requires a breakdown of how many houses use which heating source, for which we are temporarily using an estimate of 25% each between electricity, propane, fuel oil, and wood.

Residential:
To find out the age and number of dwellings built in this area, we referenced the 2016 Census[1], as recommended by ReThink Green. Running this and the aforementioned information through the ReThink Green excel tool resulted in finding out that Central residents use a total of 809 216 L of fuel oil, 6 439 383 kWh electricity, 1 464 074 L of propane, and 3 090 809 kg of wood to heat their houses. They also use approximately 5 321 398 kWh electricity for non-heating needs such as running appliances, etc. The ReThink Green tool assumes a breakdown of 95% of non-heating energy use being supplied by electricity and 5% by natural gas, but since we have no natural gas, we have assumed that this 5% is instead supplied by propane. This would then amount to 5376 GJ of propane, or approximately 210 524 L of propane, since the ReThink Green tool lists 39.16 L of propane as being required to generate one GJ worth of energy. The PCP Tool asks for residential energy use all inputted in one category for each energy source however, so we inputted 809 216 L fuel oil, 11 760 781 kWh electricity, and 1 674 598 L propane. The PCP Tool does not have an emissions factor for wood, so we used the ReThink Green tool's calculation for emissions from this source instead.

The PCP Tool says that this resulted in 203.44 tCO_2e from electricity, 2592.04 tCO_2e from propane, and 2229.74 tCO_2e from fuel oil. ReThink Green's calculation for wood was 6572 tCO_2e —this could then be added directly to the PCP Tool through option 2 "set total emissions". Our total preliminary number for residential energy use emissions was therefore 11 597.22 tCO_2e.

However, these emissions only reflect the energy use of year-round residents, as the housing data came from Census Canada, which only reports on year-round dwellings. Actual electricity usage data from Hydro One for all postal codes in Manitoulin District, when divided by the percentage of the District's year-round population that resides within Central, yielded a higher number than ReThink Green's—this may be due to the fact that this actual-use data would include energy use by seasonal residents. In order to attempt to incorporate seasonal residents into our estimates, we have multiplied all of the residential energy emissions calculated above by the ratio by which the Hydro One data departs from the electricity use number estimated in the tool from ReThink Green. With Hydro One reporting District-wide residential electricity use as being 103 185 830 kWh in 2018, and Central's population being 15.72% of the entire District's (according to the Census), this results in a Hydro-based estimate of 16 220 812.48 kWh residential electricity use. This is approximately 1.38 times the ReThink Green estimate of 11 760 781 kWh electricity, so we will multiply all emissions results by 1.38. What this estimate doesn't account for is a potential difference in the energy use mix between summer and winter—if some energy is being used for cooling dwellings during the summer as opposed to heating, then it is likely that summer energy use is more electricity-based. Therefore the actual emissions could be slightly lower than what is estimated.

Commercial, Industrial, and Other:

In order to get estimates for commercial and industrial energy use, we turned again to electricity use data provided by Hydro One by postal code. Unfortunately we do not have any fuel oil, propane, or wood data for these commercial or industrial categories, but will assume that fuel oil and propane are used in the same proportion as they are in the residential sector. Hydro One was able to give us the electricity used by residential, commercial, industrial, and "other" categories for each postal code within Manitoulin District, for the year of 2018. The total electricity use was 103 185 830 kWh for residential, 59 533 652 kWh for commercial, 618 314 kWh for industrial, and 207 147 kWh for "other". Assuming that all communities across the District have the same residential electricity use per person, this would amount to about 16 220 812.48 kWh residential electricity being used in Central, as shown above. We will use the ratio between this and the commercial, industrial, and "other" categories for the District to estimate Central-specific numbers for those categories. For the District, commercial electricity use is 57.5% that of residential, industrial electricity use is 0.6% that of residential, and other is 0.2% that of residential. When applied to Central's residential use—assuming that commercial, industrial, and other uses are distributed across the District in proportion to population—this would result in 9 326 967.18 kWh of commercial electricity use, 97 324.87 kWh industrial electricity use, and 32 441.62 kWh "other" electricity use. We assume that these sectors have the same breakdown of electricity compared to other fuel sources as the residential sector does, with the exception of wood—this is corrected for after the following calculations. For the residential sector, the ratio from our entries to the ReThink Green tool was 1 kWh electricity: 0.14L propane: 0.07L fuel oil: 0.26kg wood. So commercial use would be 9 326 967.18 kWh electricity, 1 305 775 L of propane, 652 888 L of fuel oil, and 2 425 011 kg wood. For industrial, those numbers are: 97 324.87 kWh electricity use, 13 625 L propane, 6813 L fuel oil, and 25 304 kg wood. Since the "other" category comprises Hydro-specific energy uses we will only enter a value for electricity: 32 441.62 kWh. As done in the previous section, we used the PCP Tool to calculate resulting emissions for all fuel types except for wood. This resulted in 3986.26 tCO_2e from commercial, 286.30 tCO_2e from industrial, and 0.56 tCO_2e from "other". We do not have an easy way of inputting the wood values into the ReThink Green tool, as that was designed for residential emissions, and as we are not confident wood is readily used by commercial and industrial sectors to the same extent it is in the residential sector, we have multiplied the emissions from these sectors by 4/3 to approximate electricity, fuel oil, and propane taking the place of wood.

Transportation

As it was not feasible to do our own traffic counts for all road segments within the municipality, we instead used traffic counts that had been done in 2016 by the Ontario Ministry of Transportation[3] on provincial highways, and isolated the information pertaining to the segments of provincial highway within our boundaries. These traffic counts were then multiplied by road lengths of the associated highway segments, or rather the portion of them falling within our municipal boundaries, taken as rough measurements on our GIS files. These numbers were then added together and multiplied by 365 since the traffic counts represent the average two-way traffic passing through that stretch of road on one average day. In Central, this worked out to 21 288 625 km being travelled on provincial highways within our boundaries in a year.

Since no traffic counts were available for our municipally-managed roads, and roads classifications were not precise enough, we decided to base the estimate for VKT on municipal roads on commuting habits as documented by Statistics Canada. In the 2016 Census[4], the number of Central residents who commute to a regular work location is recorded, along with the time durations and transit modes of their commutes. 100 people are said to commute to work either as a passenger, by bike, or by "other" mode of transportation, while the remaining 650 commute to work by driving a vehicle. If we assume that the 100 people who are passengers, cyclists, or using "other" transportation are also among those whose commutes are less than fifteen minutes, then this leaves 190 people in the less-than-fifteen-minutes category who are driving themselves to work. There are also 460 people driving themselves to work whose commute takes more than fifteen minutes.

To determine how much of these peoples' commutes take place on municipal roads vs. provincial highways, we used our GIS maps to determine the residential point furthest away from a provincial highway (this was Government Road near the Tehkummah boundary). This is 12.10km away from the highway, so we used a median distance-from-highway of 6.05 km to approximate how much driving each commuter does on municipal roads before reaching the highway; given that our roads are fairly highspeed, and you can travel 20 km in fifteen minutes at 80 km/h, it is probably fair to say that all commuters travelling more than fifteen minutes are travelling to the highway. If we assume that those travelling less than fifteen minutes are travelling for an average of 7.5 minutes, which would allow them to cover 10 km if they are driving at 80 km/hr, this means that we could also assume these people are travelling to the highway, as they could easily cover the 6.05 km median distance-from-highway. Therefore we will assume that all 650 commuters who drive themselves to work are travelling 6.05 km on municipal roads (on their way to the highway) both to and from work each day. With 251 work days in 2016, this would add up to 1 974 115 km on municipal roads. It's possible that commuter travel is slightly overestimated since the 6.05 km is a median, not an average, but seeing as this estimate does not include traffic from residents of other areas travelling into Central for work, or for any recreational travel at all, it probably is an underestimate overall.

When this is combined with our previous number for provincial highways, we end up with a total of 23 262 740 km travelled within municipal boundaries in one year.

Agriculture

Livestock:
Livestock numbers for Manitoulin District were obtained from Statistics Canada for 2016[5]. The percentage of land in the District that falls within Central Manitoulin's boundaries was calculated from land areas as listed on Wikipedia: 431.11 sq km / 3107.13 sq km = approximately 0.1387, so Central comprises 13.87% of land within the District. The resulting estimates for cattle numbers within Central can be found in an internal spreadsheet.

For methane emissions from enteric fermentation, the estimated number of cattle in each category was multiplied by the corresponding emissions factors for 2016 provided on page 233 of Part 2 of the NIR, and divided by 1000 as per the equation in the GPC. To convert the amount of methane emitted to CO_2e, we multiplied by 25, as this is the Global Warming Potential for methane most recently used by the PCP program. The same process was repeated for methane emissions from manure management, using a separate set of corresponding emissions factors for each cattle type for this category, found on page 92 of Part 2 of the NIR.

The NIR is not able to provide country-specific emissions factors for nitrous oxide (N_2O) from manure management, let alone provincial ones, and to use international emissions factors seemed too inaccurate. We excluded this category from our inventory.

Land Use and Land Use Change:
The GPC refers readers to their national inventory reporting bodies, among other sources, as a source for numbers on this, and Part 2 of Canada's NIR refers us on pg 241 to Annex 3.5.4, which assumes that if cropland is remaining cropland, and has not seen any change in soil management practices, then its carbon stock change has probably already reached equilibrium.

Aggregates:

Our best bet at estimating the amount of nitrous oxide (N_2O) being emitted as a result of fertilizer application would be to estimate how much fertilizer is applied based on the number of square kilometres to which fertilizer, etc., is applied, according to data from OMAFRA. However, the number of square kilometres to which fertilizer is applied in Manitoulin District is so small that this calculation could be a privacy issue, and furthermore emissions factors and input data are not readily available for this category.

Waste

The amount of waste deposited in our municipal landfill in 2018 was recorded as 2990.98 cubic metres in our year-end report; this is equal to 3912.05 cubic yards. 1543 cubic yards of commercial waste was also trucked to the Dodge landfill in Espanola, as tallied from our haulage receipts. Combined, this amounts to 5445.05 cubic yards, or 433.01 metric tonnes.

Local Carbon Sequestration

For forest land, Annex 3.5.2 of Part 2 of the NIR describes how Canada's carbon stock change was calculated using a model developed by Kurz et al. 2009, called Version 3 of CBM-CFS3. This model could potentially be used to estimate the current and future carbon storage potential of the forests within the municipality. However, this requires information on the growth pattern of forest stands which we do not currently have available.

Instead, we have made an estimate based on a study done on the forests of the northern Bruce Peninsula, which used three different models for estimating the amount of carbon stored in the northern Bruce's trees (more precisely, in Eco-district 6E14). The average result for the amount of carbon stored in the region's forests was 11 492 047 tCO_2, which is equal to 231.6 tCO_2 per hectare of forest[6]. To find out how many hectares of forest there are within Central, we looked at Google Maps satellite, and decided on a rough, conservative estimate of 50% of land being forested. Since Central Manitoulin covers 431.11 square kilometres (according to Wikipedia), which equals 43 111 hectares, this would amount to 9 984 507.6 tCO_2 being stored in Central forests. In order to approximate how much carbon is added to that store every year, this number was then divided by the approximate average age of the forests. For the Bruce Peninsula, another source[7] states that most of the forest stands date from either the early 1900s or the 1920s, as regrowth following fires, logging, and farm abandonment. Assuming that the forests of Manitoulin Island have a similar recent history, we used an average age of 110 years.

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