Updated 2019 Greenhouse Gas Emissions Inventory, Emission Forecasts and Mitigation Scenarios

CONCORD, NEW HAMPSHIRE

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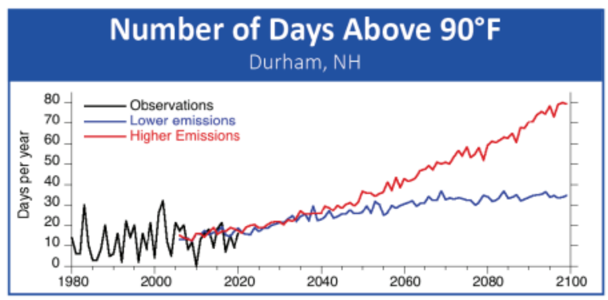
Introduction

Understanding Climate Change

Climate change is one of greatest global challenges of this century. According to the Intergovernmental Panel on Climate Change (IPCC), Earth's atmosphere, oceans, and land are changing due to human influence[1]. With the burning of fossil fuels and industrialization since the 1800s, humans have increased the amount of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other greenhouse gases (GHG) in the atmosphere, leading to cascading effects on our environment[1]. These effects include but are not limited to increased global surface temperature, increased global precipitation in some regions and decreased precipitation in other regions, intense and prolonged drought periods and floods, melting of glaciers and arctic ice, and warming oceans and increased sea level[1]. Climate change is already impacting every sphere of human life and disproportionately harms vulnerable populations such as indigenous peoples, island nations, and communities marginalized by their gender, ethnicity, and income status[2].

Figure 1: Average number of days above 90°F at Durham, NH in observations (black), modeled future outcomes for lower (blue) and higher emissions (red) from the 2022 New Hampshire Climate Assessment Executive Summary[4].



Climate change has a direct impact on the residents of New Hampshire and Concord. The 2021 New Hampshire Climate Assessment reports that the state has already become warmer and wetter with increased surface temperatures, decreased snowpack, increased warm-season drought, and increased extreme precipitation events[3]. Residents will see more hot days (above 90°F) (Figure 1), milder winders, more intense rain events, and short-term warm season droughts in the future[3]. This will negatively impact New Hampshire's water supply, agriculture, forested lands, and winter recreation industry[3]. All these environmental changes will affect New Hampshire residents' livelihoods and well-being over the next century. Since climate change is the result of human activity, we must change our infrastructure and behavior to mitigate the most harmful effects of climate change.

Objective of Report

The objective of this report is to update Concord, New Hampshire's 2019 Greenhouse Gas (GHG) Inventory and model several emissions scenarios using the ICLEI ClearPath Tool to inform infrastructure investments and policy decisions. All GHG including CO_2, CH_4, and N_2O are reported in metric tons (MT) of CO_2 equivalence (CO_2e) for clarity and continuity. In addition, this report documents preliminary estimations of carbon sequestration benefits by Concord's forests using the ICLEI Land Emissions and Removals Navigator (LEARN) Tool. These tools are used to evaluate how Concord might be able to reach its community-wide emissions reduction goals.

Emissions Reduction Goals

Concord has committed to reducing its GHG emissions by local, state, national, and international standards. In 2018, the City Council of Concord unanimously adopted three renewable energy goals:

1) 100% of electricity consumed would come from renewably sourced electricity by 2030;

2) 100% of thermal energy (heating and cooling) consumption from renewably sourced energy by 2050;

3) 100% of transportation would be clean transportation by 2050[4].

In addition, the City of Concord also adheres to the New Hampshire Climate Action Plan to **reduce GHG emissions by 80% by 2050**, which was last updated in 2009[5].

On the national scale, Concord Mayor Jim Bouley joined the U.S. Climate Mayors group in 2017, committing to the Climate Mayor's Agreement and pledging that Concord would uphold the Paris Climate Agreement[6,7]. Concord also joined the Race to Zero Campaign created by the United Nations Framework Convention on Climate Change (UNFCCC) in 2021 which stipulates that each joining municipality much decrease their **net GHG emissions by 50% by 2030** and **100% of their net GHG emissions by 2050**[8,9]. This campaign accepts the use of carbon sinks and credits to reach net zero emissions[9].

Each of these standards are intended to prevent the most severe and damaging impacts of climate change by exceeding no more than 1.5 - 2°C in global warming by 2100[1]. In New Hampshire, warming could increase by 8°F if no action is taken to reduce emissions[3]. Meeting these goals is critical to effective climate change mitigation.

Materials & Methods

Scope of Project

The geographic scope of this project is within the City of Concord, New Hampshire boundary. The municipality area encompasses 63.96 sq. miles and was home to 43,976 people as of 2020[10]. As the capitol of New Hampshire, the City serves an important role in setting a standard for sustainable development in the state and New England region. This project focuses on the GHG emissions produced from the built environment including local government operations and community-wide emissions, complemented by natural carbon stock emissions and removals from the city's vegetation and soils.

GHG Accounting Tools

This project used two main tools to calculate and compile Concord's GHG emissions from the built environment and removals from Concord's trees and forests: the ICLEI ClearPath Tool and the ICLEI LEARN Tool. ICLEI ClearPath was also used to forecast business-as-usual scenarios and model various mitigation scenarios.

ICLEI, formerly known as the International Council for Local Environmental Initiatives, is a non-governmental organization that developed a series of web-based calculators and models for municipalities to compile greenhouse gas inventories and future scenarios. In addition to maintaining the web tools, they also provide technical consulting and quality assurance[11]. The ICLEI tools are used by cities in at least 125 countries to promote sustainable municipal development[12].

ICLEI ClearPath Tool

The ICLEI ClearPath Tool allows users to create GHG inventories, forecast various business-as-usual (BAU) scenarios (i.e. scenarios in which a municipality takes no action to reduce their emissions), and model various mitigation strategies which are designed to reduce emissions. A user can model emissions on a Community scale which includes residential, commerical, industrial and municipal emissions, or a

Government Scale, which only includes local government operations such as street lights and waste water mangement.

The Community and Government Scale Tracks include the following sectors:

Community Scale Track

- Residential Energy
- Commerical Energy
- Industrial Energy
- Transportation & Mobile Sources
- Agriculture, Forestry, and Other Land Use (AFOLU)
- Solid Waste

Government Scale Tracks

- Buildings & Facilities
- Street Lights & Traffic Signals
- Vehicle Fleet
- Transit Fleet
- Employee Commute
- Solid Waste Facilities

Each emissions source and its respective input values was entered into the model as an inventory record. Each sector has inventory records. In some cases, the input values of inventory records represent aggregated fuel use or electricity use, while in other cases input values are stratified to specify the impact of different emissions sources. Once the appropriate data was entered, calculators computed the associated CO_2e emissions of each source. Each inventory record was compiled to create a Community scale or Government scale GHG inventory.

After all inventory records were compiled, the inventory was complete, and the forecasting began. Forecasting models what each sector's GHG emissions might be in the future under different policy and/or economic conditions. Forecasting requires a baseline (an established and complete GHG inventory) and projected growth rates to estimate future emissions. The next step was Planning, in which where mitigation strategies were applied to the Forecasts to see how Concord can reduce its GHG emissions. Several types of scenarios were modeled during the Planning stage. Some scenarios were guided by exisiting local initiatives (such as the Energy Committee's priorities or Capital Improvement Projects). Other scenarios are broader and seek to reduce Concord's emissions in each sector. Every mitigation strategy aims to reduce a city's emissions to help meet its climate goals.

ICLEI LEARN Tool

The ICLEI LEARN Tool is web-based map tool intended to quantify CO_2e emissions and removals from forests, urban trees, and land use change. The tool uses a 30-meter National Land Cover Database (NLCD) map from the US Geological Survey to categorize Concord's area into land use types and then assess changes in land use between 2001 and 2019[13]. The LEARN Tool also assesses trees outside of forests using 30m NLCD tree canopy coverage between 2011 and 2016. Using emissions and removal factors based on a tree sample from Boston, the tool calculates the net GHG balance of emissions and removals within Concord's municipality. The results were compared with Concord's 2019 GHG Inventory to determine how much of the City's emissions are offset by land-based carbon removals.

Quality Assurance

ICLEI's program associates provided quality assurance for the 2019 GHG Inventory, emissions forecasts, and mitigation scenarios by checking that inventory records were as accurate as possible and categorized properly.

Caveats

Not all sources of emissions are accounted within the ICLEI ClearPath model or the ICLEI LEARN Tool. These tools are designed to estimate emissions from sources with the *most* impact on Concord's overall emissions. Thus, sources which contribute few emissions, have highly uncertain emission estimates, or are rarely compiled into municipal GHG inventories may not be included in this report.

Annual Growth Rates

Growth Rates are essential components of forecasting future emissions. They indicate what Concord can expect in terms of future electricity and resource use, which in turn determines associated emissions. According to the City of Concord, population and job creation are expected to grow over time, which means that more electricity and natural gas will be used Community-wide (Table 1). Population and job creation growth rates were devised in collaboration with the author of this report and Sam Durfee, Senior Planner.

Table 1: Annual Growth Rates used in ICLEI ClearPath Emission Forecasting

Type	Annual Growth Rate
Population	1.00%
Job Creation	0.75%
Default Transportation Carbon Intensity (CAFE standards)	-1.80%
Carbon Intensity Electricity ISO-NE 2040	-4.10%

Carbon Intensity describes the amount of CO_2 emissions released per unit of energy consumed or produced. Thus, it can be interpreted that transportation emissions will decrease by 1.8% per unit of energy consumed each year and that emissions from electricity generation can be predicted to decrease by 4.10% annually per unit of energy produced. Transportation emissions are projected to decrease as specified by the Corporate Average Fuel Economy (CAFE) standards. CAFE standards are national fleet-wide fuel economy averages of cars and light trucks[14]. The U.S. Department of Transportation's National Highway Traffic and Safety Administration increases the minimum fuel economy for vehicles every 5 years, which requires vehicles to burn fuel more efficiently and decrease their individual carbon intensity[14]. These nationwide standards allow Concord's transportation carbon intensity to decrease over time.

Carbon Intensity Electricity ISO-NE 2040 will be discussed in the next section.

Carbon Intensity and Electricity Generation Mixes

Carbon Intensity with regards to electricity describes the amount of CO_2 emissions released per unit of electricity produced. Electricity is made from various combinations of energy sources, which are called electricity generation mixes. Energy sources emit different amounts of GHG's depending on how the electricity is produced[15]. Burning fossil fuels like coal or natural gas will emit higher rates of CO_2e per unit of energy produced, while electricity created by renewable sources like solar and wind will produce lower rates of CO_2 per unit of energy[15]. Therefore, different generation mixes will result in higher or lower emissions, depending on the ratio of fossil fuel-based to renewable energy sources.

The ISO-New England (ISO-NE) reports on current and projected electricity generation mixes for the New England region (Table 2)[16]. This independent, not-for-profit corporation is the “marketplace” where energy suppliers can sell their electricity to prospective buyers, giving them a unique regional view of the electricity grid. The ISO-NE anticipates a 37% increase in renewably sourced electricity between 2020 and 2040, which will ultimately reduce New England’s electricity emissions (Table 3).

Table 2: Electricity Generation Mixes in 2020 and 2040 from the ISO-NE Pathways Study[17]. Fossil fuel-based energy sources are red and renewable energy sources are green.

Modified A2:F15 ISO-NE Pathways Study - Table V-1. Change in Resource Mix from 2020 to 2040, Status Quo Policy Approach (MW)					
Energy Source Type	**2020 generated electricity (Baseline) (MW)**	**% of 2020 total electricity generation**	**2040 electricity generation capacity (MW)**	**% of 2040 total electricity generation**	**Change in Capacity (MW)**
Biomass	972	2.5%	361	0.4%	-612
BTM Solar PV	2363	6.0%	7500	8.8%	5137
CC combined cycle	16158	40.8%	13474	15.8%	-2684
Coal	917	2.3%	0	0.0%	-917
Battery Storage	8	0.0%	12953	15.2%	12945
Fuel Cell	30	0.1%	94	0.1%	64
Hydroelectric	2234	5.6%	3311	3.9%	1077
GT/IC gas	3893	9.8%	6765	7.9%	2872
Nuclear	3349	8.5%	3349	3.9%	0
Offshore Wind	29	0.1%	16014	18.8%	15985
Pumped Storage	1826	4.6%	1826	2.1%	0
Solar PV	1807	4.6%	11928	14.0%	10121
Steam Turbine	4591	11.6%	3188	3.7%	-1403
Onshore Wind	1424	3.6%	4401	5.2%	2977
Total	39601	100.0%	85164	100.0%	

Table 3: Percentage of Electricity Sourced from Fossil Fuels or Non-Fossil Fuels in 2020 and 2040.

	Fossil Fuel Total	Non-Fossil Fuel Total
2020	64.5%	35.5%
2040	27.5%	72.5%

The Carbon Intensity Electricity ISO-NE 2040 annual growth rate refers to how much CO_2e emissions will decrease annually with the introduction of more renewably sourced electricity into the grid (Table 1). Therefore, the carbon intensity of the electricity grid is expected to decrease by 4.1% annually because more renewable sources will be introduced into the grid (Table 1, Table 2).

It is important to recognize that this shift in electricity generation mixes is not initiated or controlled by the City of Concord. There is a degree of uncertainty whether this will happen or not as the ISO-NE only makes predictions and does not control which energy sources are used to generate electricity. Thus, Concord may consider purchasing renewably sourced electricity through Community Power if the City wishes to control how they reduce their electricity emissions.

Updates to 2019 GHG Inventory

Several adjustments and additions were made to the 2019 GHG Inventory per recommendations of the ICLEI program associates. These updates input more accurate data into the ICLEI ClearPath model so that the emission estimations more accurately reflects Concord's activities in 2019. The ICLEI ClearPath model has two tracks as mentioned previously: Government scale and Community Scale. The Government Scale is a subset of the Community-wide emissions. Therefore, some inventory records will appear in both tracks to show how government operated facilities, such as Solid Waste and Wastewater Treatment facilities, impact the larger community scale.

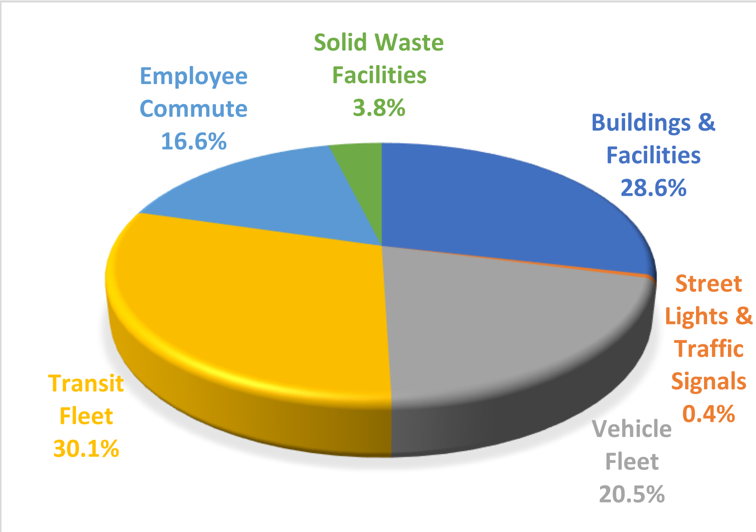
Local Government Operations 2019 GHG Inventory

The Local Government Operations (LGO) inventory represents all the activities and services operated by the City of Concord on behalf of their residents. The total Local Government Operation emissions were 7,573 MT CO_2e in 2019 (Table 4). The Process & Fugitive Emissions sector is available within ICLEI ClearPath, but emissions from this sector were not compiled into this inventory because it was not a priority Scope 3 sector for the City of Concord at the time of this report.

Table 4: Local Government Operations 2019 Emissions by Sector (MT CO2e)

Local Government Operations Sector	CO_2e (MT)
Buildings & Facilities	2,169
Street Lights & Traffic Signals	33
Vehicle Fleet	1,549
Transit Fleet	2,279
Employee Commute	1,256
Electric Power Production	0
Solid Waste Facilities	287
Total LGO Emissions	**7,573**

Figure 2: Local Government Operations 2019 GHG emissions by Sector (percentage)



As seen in Figure 2, among sectors analyzed, the Transit Fleet, Buildings & Facilities, and Vehicle Fleet contribute more than ¾ of Concord's municipal emissions. Transit and municipal vehicle fleets are powered entirely by gasoline and diesel fuels, both of which produce CO_2, CH_4, and N_2O because of burning these fossil fuels. Buildings & Facilities produce emissions by burning natural gas to heat and cool these facilities and by powering these buildings with majority fossil fuel-based electricity. Solid Waste Facilities mostly produce CH_4 due to anaerobic conditions in landfills. Street Lights & Traffic Signals produce emissions from their electricity use, which is dependent on fossil fuels. The Street Light emissions were based on their 2019 usage prior to replacement with LED bulbs in late 2021-2.

Updates to Local Government Operations 2019 GHG Inventory

In the **Buildings & Facilities** sector, some missing stationary fuel emission sources were added to the inventory to better represent the full scope of emissions from this sector.

The **Street Lights & Traffic Signals** sector did not need to be updated.

The **Vehicle Fleet** sector did not need to be updated.

In the **Transit Fleet** sector, some of the vehicle miles travelled (VMT) values were minorly adjusted – some values increased slightly while others decreased slightly. For the most part, the inventory records remain the same.

The **Employee Commute** sector was reworked. Previously individual inventory records were aggregated into a single inventory record based on fuel type. Several assumptions were made to provide an inventory record. It is assumed here that all employee vehicles were gasoline powered in 2019 because the original survey did not ask this question. It is also assumed that all single occupancy vehicles were passenger cars or SUVs unless the respondent specified that their vehicle was a truck, van, or police cruiser. These latter types of vehicles were counted as light trucks. Lastly, the total annual VMT value (3.4 million VMT) is weighted based on the ratio of employees who responded to the survey to prevent overestimation of employee commute emissions.

The **Solid Waste Facilities** inventory records were reduced to only include the emissions from waste gathered from municipal buildings. A full record of waste generation emissions is in the Community-wide Track.

Previous **Water & Wastewater Treatment Facilities** inventory records were incorrect, providing data that overestimated GHG emissions from this sector, so all previous inventories have been excluded from the inventory. This sector will not be accounted for in either the Government or Community scale tracks in this report due to lack of data. More accurate data needs to be provided before this sector can be accounted for in this report.

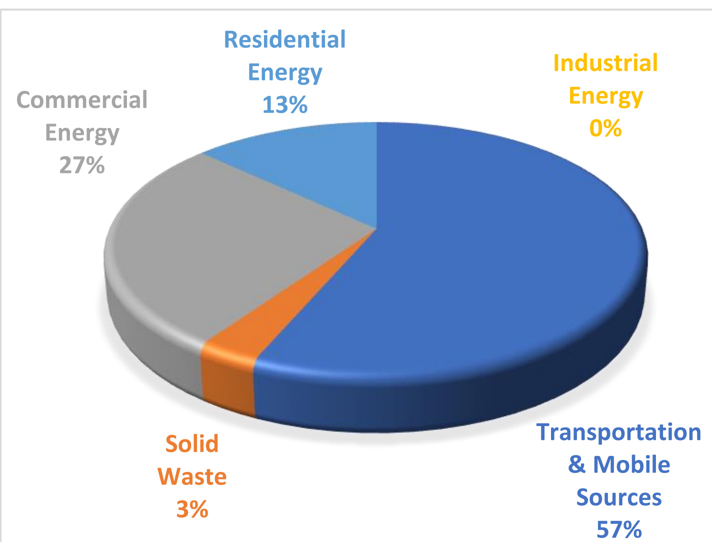
Community 2019 GHG Inventory

The Community-wide GHG Inventory represents emissions from all activities and operations conducted by the community. Some activities are directly under the influence of the City of Concord, such as Solid Waste Facility emissions. Other community activities are enacted by individuals or businesses, such as most of the Transportation & Mobile Sources emission and the Energy related emissions. Regardless of whether activities are under local government operations or individual jurisdiction, the City of Concord government can impact all sectors because they supply energy and natural gas to the community. The updated inventory shows that Community-wide emissions in 2019 were 481,567 metric tonnes (MT) CO_2e (Table 5).

Table 5: Community Emissions by Sector (MT CO2e)

Community Sector	**CO2e (MT)**
Transportation & Mobile Sources	271,994
Solid Waste	15,722
Commercial Energy	130,549
Industrial Energy	148
Residential Energy	63,154
Total Community Emissions	**481,567**

Figure 3: Community Emissions by Sector (percentage)



As seen in Figure 3, Transportation & Mobile Sources contribute 57% of Concord's total community-wide emissions. About 40% of total emissions come from Commerical and Residential energy use to power and heat buildings. Transportation & Mobile Source emissions include CO_2, CH_4, and N_2O released through burning gasoline and diesel. Commerical and Residential Energy emissions come from burning natural gas to heat and cool buildings and majority fossil fuel-based electricity generation. As mentioned previously, Solid Waste

Facilities produce CH_4 through the anaerobic conditions in landfills. Industrial Energy emits less than 1% of Concord's emissions since there are only a few industrial facilities in the municipality. Similar to Residential and Commerical Energy, emissions associated with industrial process are mostly from burning natural gas to heat and cool buildings and powering buildings and machinery with majority fossil-fuel based electricity.

Updates to Community 2019 GHG Inventory

In the **Residential Energy** sector, aggregated natural gas fuel use (MMBtu) was increased and electricity useage (kWh) was increased slightly to better reflect Concord's residential energy use.

In the **Commerical Energy** sector, aggregated commerical natural gas fuel use (MMBtu) was updated to show an increase in use. Meanwhile, electricity usage (kWh) decreased slightly compared to previous records. Since Unitil, Concord's electricity provider, did not separate commerical and industrial electricity useage, this inventory record was left aggregated in the Commerical Energy sector.

The **Industrial Energy** sector is a newly added sector. Industrial Natural gas use (MMBtu) was previously included in the commerical sector. Since Liberty, the natural gas provider, distinguished between commerical and industrial natural gas fuel use, a new inventory record was created for industrial natural gas use in the Industrial Energy sector.

The **Transportation & Mobile Sources** sector was completely reworked with new data from Google EIE. Google EIE uses live tracking to measure on-road gasoline and diesel VMTs. This is the preferred data source for this inventory record because you can calculate the percentage of passenger vehicles, light trucks, and heavy trucks for each fuel type.

The **Solid Waste** sector was also completely reworked. Waste generation is now disaggregated into three inventory records: Commerical/Industrial, Residential, and Municipal. Doing this reveals how Commercial and Industrial waste generation created the most emissions per sector (9,860 MT $CO2_e$), with Residential following (5,426 MT $CO2_e$). Municipal waste generation contributed distinctly few emissions (287 MT $CO2_e$). Lastly, leaf and yard waste compost produced the least emissions (113 MT $CO2_e$) compared all other solid waste emission sources.

Two **Water & Wastewater Treatment Facilities** inventory records in a previous iteration of the 2019 GHG Inventory detailed emissions from the Hall Street and Penacook wastewater treatment plants. Unfortunately, these records were not accurate, leading to an overestimation of emissions in this sector. The initial data request did not provide enough information to properly modify the inventory record and the re-request for data did not arrive before the publication of this report. Incorporating Water & Wastewater Treatment Facilities data is vital because without it, it is unknown to what extent this sector contributes to Concord's community-wide emissions. Looking forward, it may be difficult to mitigate emissions from standard wastewater treatment processes since these processes rely on microbial activity to break down organic matter and produce clean water. If the City of Concord wishes to mitigate the emissions from the wastewater treatment process, they will likely have to consider carbon offsets because it is unlikely that Concord will be able to institute new technologies that prevent emissions from wastewater treatment. The extent of mitigating wastewater treatment emissions is unknown until Concord can gather the appropriate data and complete the 2019 GHG Inventory.

The **Agriculture, Forest, and Other Land Use (AFOLU)** is a newly added sector to the Community-wide GHG Inventory. This sector documents the GHG emissions and removals by forests, trees outside of forests as a result of growth land use changes (Non-forest to Forest, Forest to Settlement, Forest to Grassland, and Forest to other non-forest lands). This information was calculated through the ICLEI Learn Tool (see above in Materials & Methods). This sector can be used to compare how development projects, planting more trees, or improving forest health by reducing forest disturbances can impact carbon stocks and emissions (see Concord's Land-based Carbon Storage). Consistent with GHG accounting approaches recommended by ICLEI, this sector is labeled as "Information Only" and removals are not automatically included in the forecast or mitigation models. The logic behind this action is that the tool is meant to help municipalities reduce their GHG emissions as much as possible and the creators of the model did not wish to disincentivize fully achieving zero GHG emissions. Furthermore, carbon sequestration can only be counted as an offset of emissions if it is additional to previous carbon sequestration rates, so as not to double count emission reductions. Therefore, carbon removals are calculated but not included in the Forecasting.

Emission Forecasts and GHG Reduction Scenarios

This section details possible future emission scenarios for Concord, depending on the City's municipal policy and infrastructure choices. The first step was to estimate Concord's future emissions in a business-as-usual (BAU) scenario using the 2019 GHG Inventory as a baseline. A BAU scenario extrapolates what the emissions of Concord might be if there was no government intervention to mitigate climate change.

There are two BAU scenarios: BAU 35.5% renewable energy and BAU 72.5% renewable energy. The first BAU scenario (BAU 35.5% renewable) models what emissions will look like if 35.5% of electricity is produced from renewable sources (wind, solar, etc.). This composition of electricity generation mix was used in 2020 and this scenario models if this generation mix was used all the way into 2050. The second BAU scenario (BAU 72.5%) models emissions from each sector if 72.5% of electricity was generated from renewable sources. These scenarios are informed by the ISO-NE's observations and predictions about New England's electricity generation mix (Table 3)[17].

In both BAU scenarios, emissions are modeled assuming that Concord's population increases by 1% annually, Concord's job count increases by 0.75% annually, and if vehicle carbon intensity decreases by 1.8% annually as explained earlier in the Growth Rates section.

Once Concord's BAU emissions are projected, various mitigation strategies are applied to reduce LGO and Community emissions. The goal of these scenarios is to find ways to reduce community-wide emission to meet the climate goals while also addressing some of Concord's municipal infrastructure and energy initiatives. For both the LGO and Community reduction scenarios, BAU 35.5% renewable energy was used as foundation for GHG reduction modeling. This is because GHG accounting best practices recommend modeling emissions conservatively to encourage reduction of the most emissions possible.

Local Government Operations GHG Forecasts

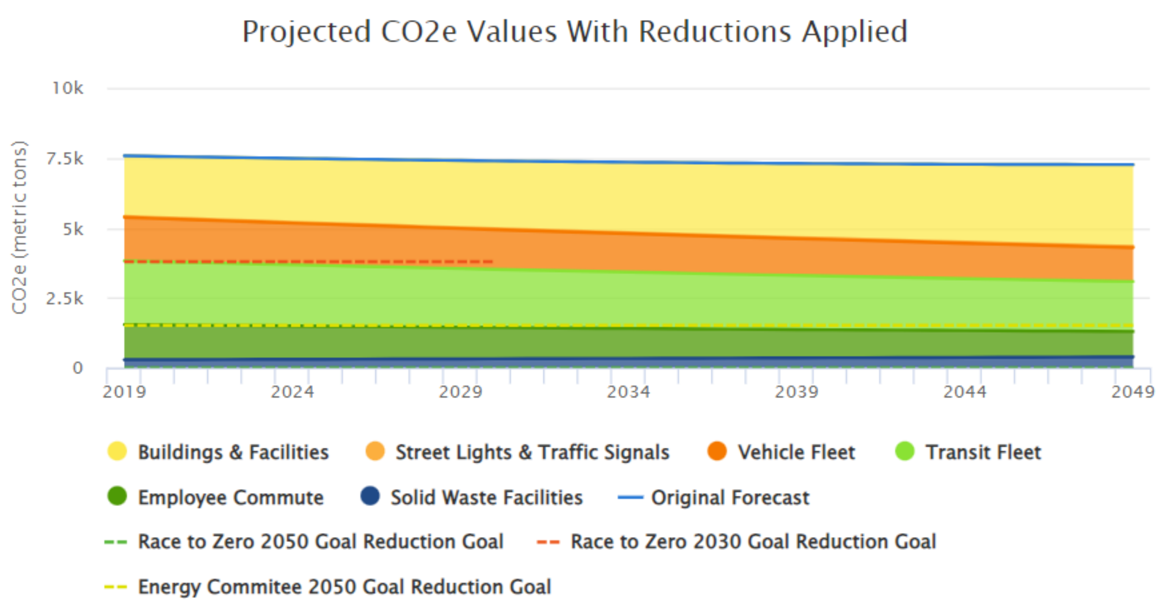
The LGO GHG Forecast projects what Concord's municipal emissions might be in the future up to 2050. The first BAU forecast scenario is BAU 35.5% renewable energy. If LGO activities continue without climate action, LGO emissions will be released at relatively the same rate throughout the mid-century

(Figure 4). The slight decrease in Total LGO Emissions over time is due to better fuel economy as mandated by the CAFE standards (refer to Annual Growth Rates section). As seen in Figure 4, Concord would not meet their climate action goals under the BAU 35.5% scenario.

Table 6: LGO Business-As-Usual Forecast with 35.5% renewable energy (MT CO2e)

Year	Buildings & Facilities	Street Lights & Traffic Signals	Vehicle Fleet	Transit Fleet	Employee Commute	Solid Waste Facilities	**Total LGO Emissions**
2019	2,169	34	1,550	2,279	1,256	287	**7,575**
2030	2,420	38	1,416	2,083	1,117	320	**7,394**
2050	2,923	46	1,211	1,782	912	387	**7,261**

Figure 4: LGO Business-As-Usual Forecast with 35.5% renewable energy (MT CO2e)

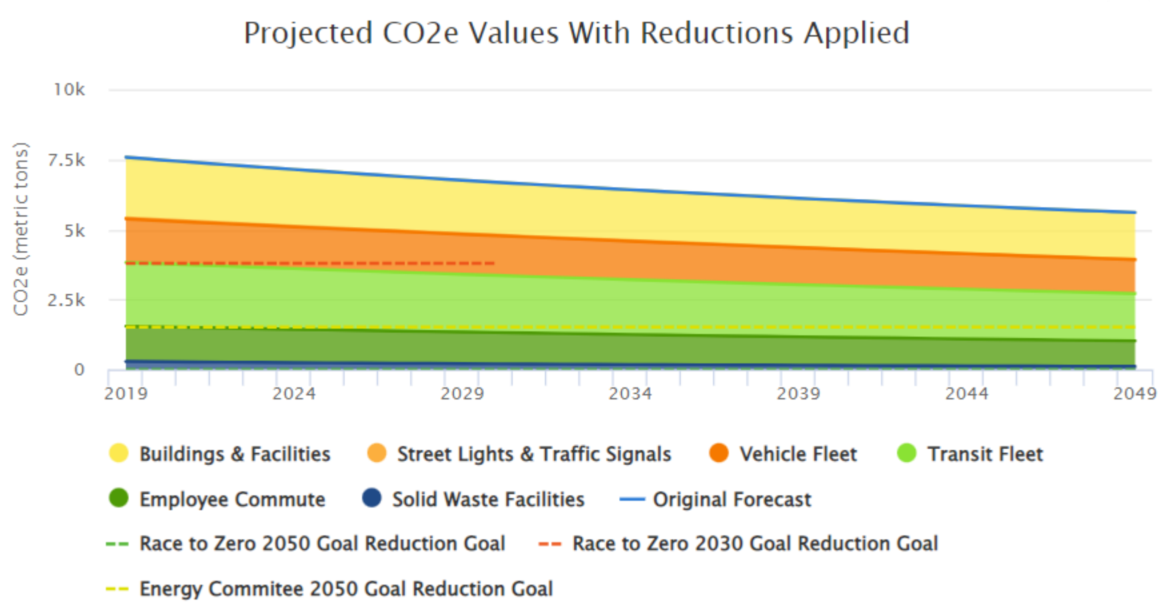


The second BAU forecast scenario is BAU 72.5% renewable energy. If LGO activities continue in this context without implementing climate action policy , LGO emissions will decrease by about 2,000 MT CO_2e to mid-century (Table 4, Figure 5). The significant decrease in Total LGO Emissions over time is due to better fuel economy as mandated by the CAFE standards, and a higher ratio of renewable energy sources in the electricity generation mix. Even with external climate action, Concord would not meet their climate action goals (Figure 5).

Table 7: LGO Business-As-Usual Forecast with 72.5% renewable energy (MT CO2e)

Year	Buildings & Facilities	Street Lights & Traffic Signals	Vehicle Fleet	Transit Fleet	Employee Commute	Solid Waste Facilities	**Total LGO Emissions**
2019	2169	34	1550	2279	1256	287	**7575**
2030	1885	24	1416	2042	1117	202	**6686**
2050	1672	13	1211	1688	912	110	**5606**

Figure 5: LGO Business-As-Usual Forecast with 72.5% renewable energy (MT CO2e)



Since Concord would not be able to reduce their GHG emissions enough to meet their climate targets by 2030 and 2050, the City would need to implement policies and infrastructure changes.

Local Government GHG Reduction Scenarios

The author only simulated three reduction scenarios for LGO activities: installing heat pumps into Municipal Buildings & Facilities, fuel source switching among Concord's municipal vehicle and transit fleets, and the combination of the two. This is because the author focused more on the Community-wide Forecasting and Reduction Scenarios, as they represent all of Concord's GHG emissions. The following reduction scenarios are built upon the LGO BAU 35.5% renewable energy forecast. In addition, all of these reduction scenarios incorporate emissions reductions from Concord's LED Streetlight Retrofit project which was completed in 2021. Please consider that these are only some of the many possible scenarios and thus are not meant to be prescriptive, but rather demonstrative of the possibilities.

Heat Pumps in Municipal Buildings & Facilities

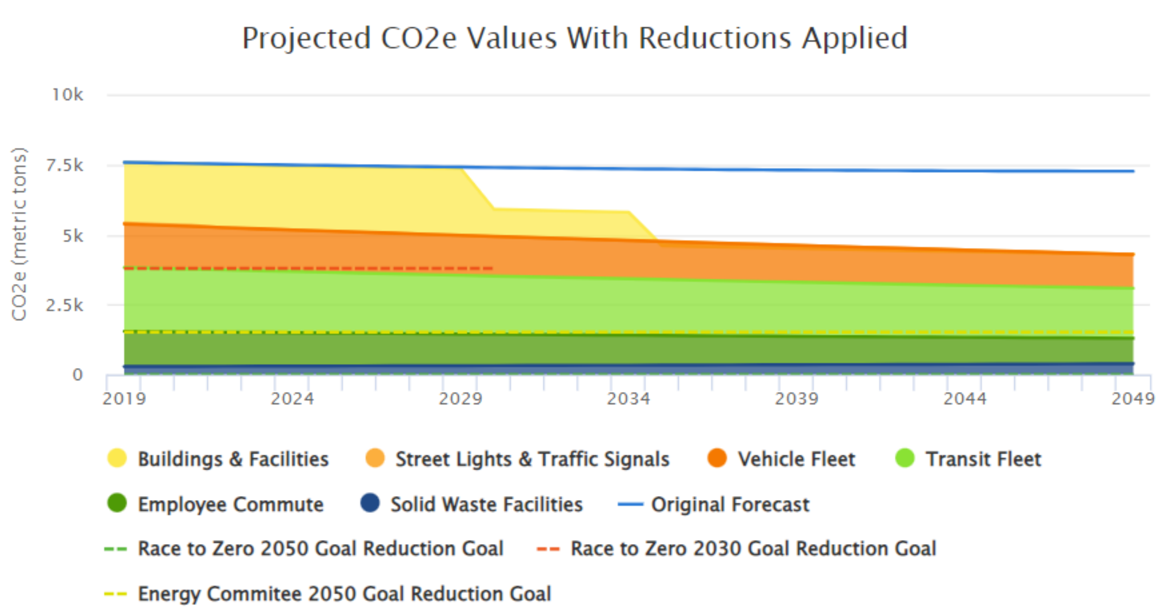
This scenario simulates what would happen if Concord switched to 100% renewably sourced electricity by 2030 and installed heat pumps in 100% of all municipal buildings & facilities by 2035. Municipal building and facility emissions would decrease by 100% over the course of 28 years (Table 8). To accomplish this, Concord would need to retrofit all current municipal buildings with heat pumps and mandate that all future municipal buildings be installed with heat pumps. By doing this, none of these buildings would be powered or heated with fossil fuels.

The deadline for installing heat pumps into all municipal buildings does not have to be 2035; this date was just chosen for the purposes of this scenario.

Table 8: Heat Pumps in Municipal Buildings & Facilities Reduction Scenario (MT CO2e)

Buildings & Facilities Emissions (MT CO2e)	
2019	2,169
2030	972
2049	0

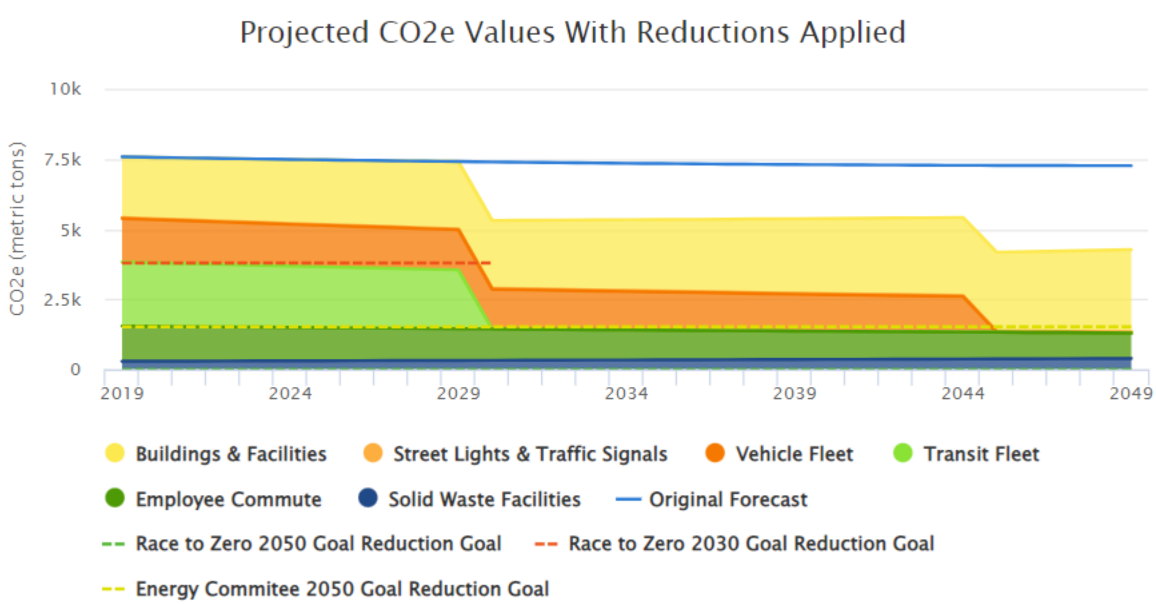
Figure 6: Heat Pumps in Municipal Buildings & Facilities Reduction Scenario (MT CO2e)



Fuel Switching Municipal Vehicle and Transit Fleets

This scenario simulates what would happen if Concord switched 100% of all transit fleets to electric buses and vans by 2030 and switched 100% of all vehicles in the municipal fleet to electric vehicles by 2045. Vehicles emissions in both sectors would decrease by 100% over the course of 28 years (Figure 7). This includes the 200+ cars, buses, vans, pick-up trucks, police vehicles, heavy-duty vehicles, construction equipment, utility vehicles and recreation equipment in the Concord fleets. There are currently some electric alternatives on available, but as of this report, construction equipment, utility vehicles, and recreation equipment do not have electric equivalents. It will be necessary to consider what is feasible for Concord to achieve by 2050. Hopefully by 2050, there will be electric alternatives for all gas- and diesel-powered vehicles.

Figure 7: Fuel Switching Municipal Vehicle and Transit Fleets Reduction Scenario (MT CO2e)



LGO Combined Reduction Scenarios

Concord would be able to reduce their municipal emissions by 50% by 2030 and roughly 80% by 2050 if they do the following:

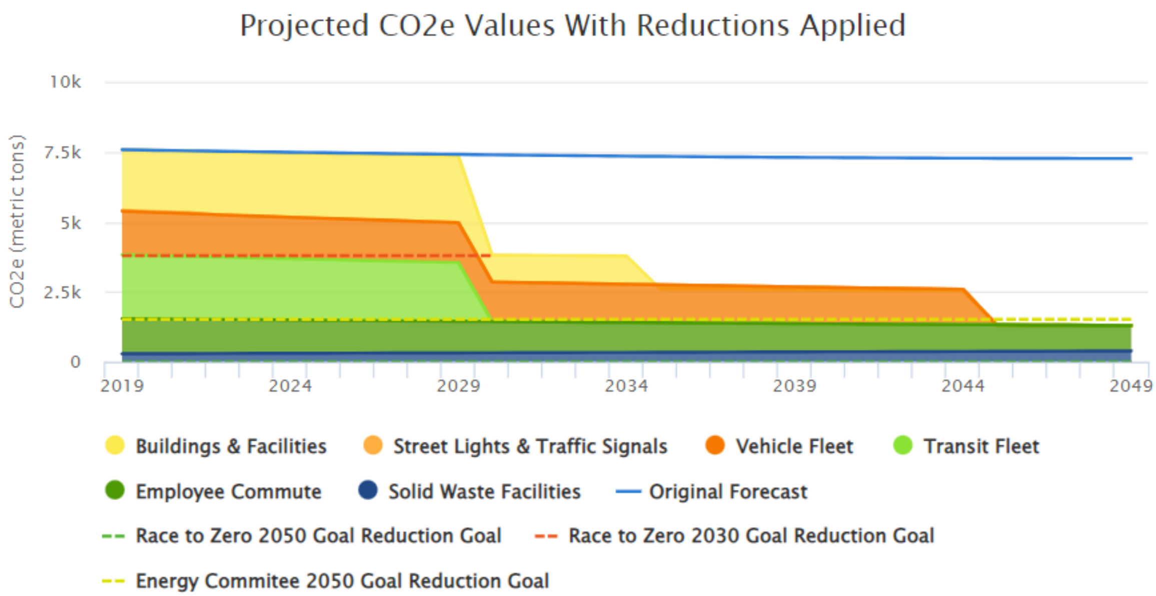
1) Power their municipal buildings & facilities with 100% renewably sourced electricity by 2030.

2) Install heat pumps in to 100% of the municipal buildings and facilities by 2035. Heat pumps would need to be powered by 100% renewable electricity.

3) Replace 100% of gas and diesel-powered vehicles in the municipal and transit fleets with electric vehicles. Electric vehicles would need to be powered by 100% renewable electricity.

Enacting these municipal policies would help Concord get closer to achieving their climate goals. As mentioned before, this may prove difficult if there are not viable electric alternatives to some of the gas- and diesel-powered vehicles. However, it will eventually be necessary to reduce Concord's emissions to zero without the aid of carbon offsets.

Figure 8: Combined LGO Reduction Scenario (MT CO2e)



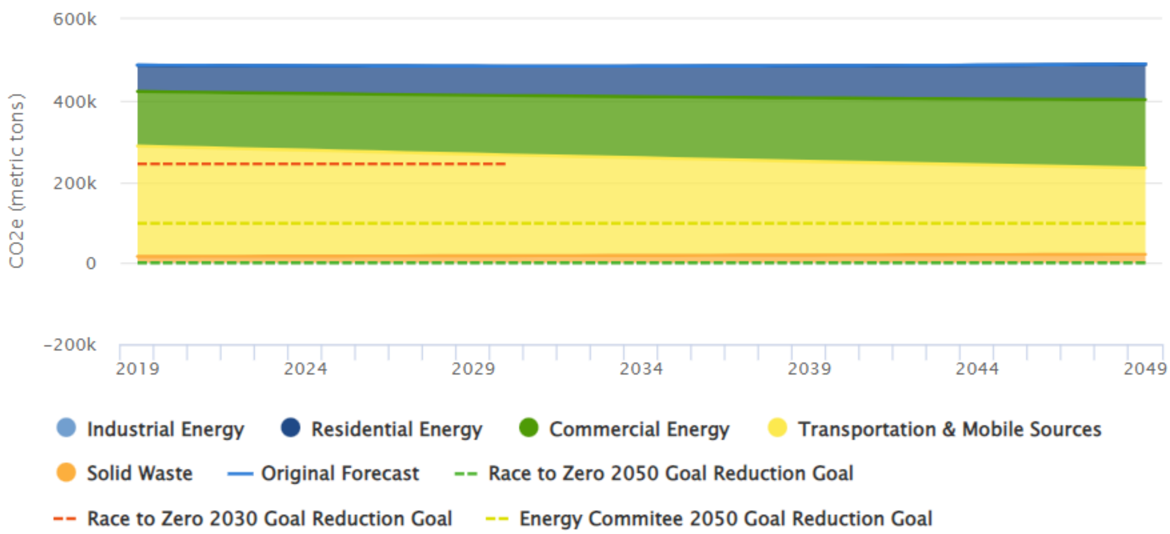
Community GHG Forecasts

Similar to the LGO Forecasts, there are two Community-wide GHG BAU Forecasts based on different electricity generation mixes: BAU 35.5% renewable energy and BAU 72.5% renewable energy. In the first scenario, BAU 35.5% renewable energy, Concord's GHG emissions will be consistent tomid-century (Table 9). Increases in energy and natural gas associated emissions due to population and job growth are countered by the reduction of emissions due to better fuel economy. As seen in Figure 9, if the City of Concord does not implement any mitigation strategies, they will not be able to meet their community's GHG climate action goals.

Table 9: Community Business-As-Usual Forecast with 35.5% renewable energy (MT CO2e)

Year	Industrial Energy	Residential Energy	Commercial Energy	Transportation & Mobile Services	Solid Waste	**Total Community Emissions**
2019	148	63155	130549	271838	15723	**481,413**
2030	161	70460	141732	248355	17541	**478,249**
2050	185	85123	163352	212470	21192	**482,322**

Figure 9: Community Business-As-Usual Forecast with 35.5% renewable energy (MT CO2e)

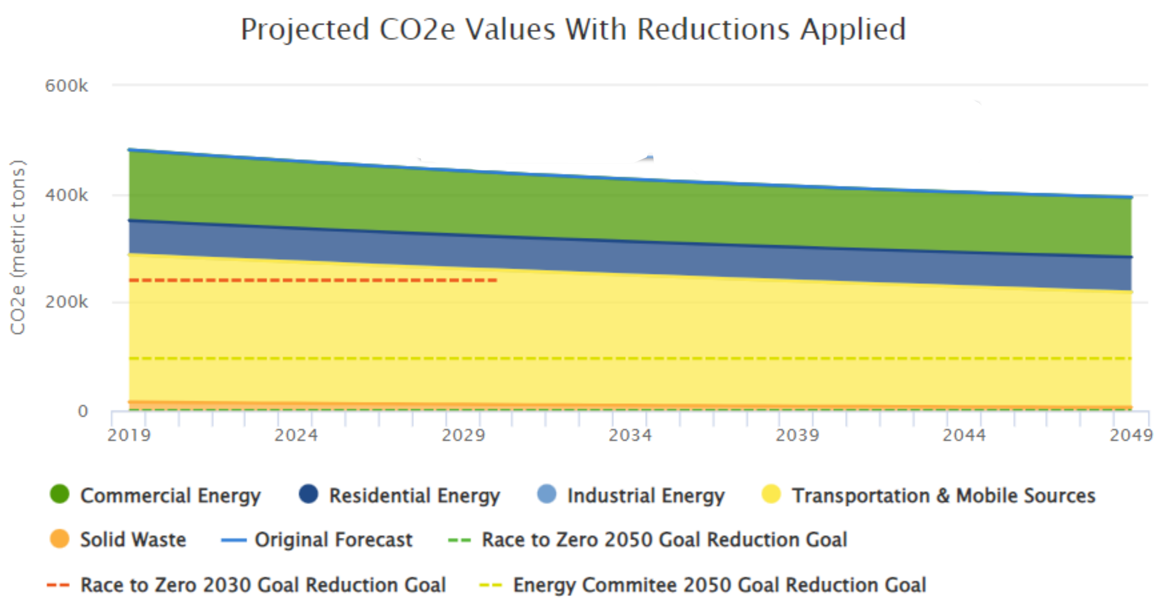


Looking at the BAU 72.5% renewable energy, Community-wide emissions will decrease by about 88,000 MT CO2e throughout the mid-century (Table 10, Figure 10). The significant decrease in Total Community Emissions over time is due to better fuel economy as mandated by the CAFE standards and a higher ratio of renewable energy sources in the electricity generation mix. Despite the predicted regional shift in electricity generation towards renewable energy, Concord would not meet their climate action goals (Figure 10). Therefore, Concord will need to implement mitigation strategies to bring their emissions down even more. Additionally, as mentioned previously, this forecast uses the ISO-NE's prediction of electricity generation mixes, which means that there is some chance this shift toward renewables might not happen. Policy decisionmakers will need to keep this in mind as they work to reduce their emissions.

Table 10: Community Business-As-Usual Forecast with 72.5% renewable energy (MT CO2e)

Year	Commercial Energy	Residential Energy	Industrial Energy	Transportation & Mobile Sources	Solid Waste	**Total Community Emissions**
2019	130549	63154	148	271994	15723	**481568**
2030	118064	61654	161	248497	11068	**439444**
2050	110487	64507	185	212591	6036	**393806**

Figure 10: Community Business-As-Usual Forecast with 72.5% renewable energy (MT CO2e)



Community GHG Reduction Scenarios

Reduction Scenarios typically follow two types of formats: a top-down or a bottom-up approach. A top-down approach looks at Concord's whole GHG inventory and demonstrates how Concord can reduce emissions to meet their climate goals. This approach considers the significant changes to Concord's total energy use in each sector that Concord must make to their infrastructure and policies to mitigate climate change to the degree described by the IPCC. The High Level Target Planning Scenarios are top-down approach scenarios. A bottom-up approach applies more detailed mitigation strategies to reduce emissions in individual sectors. All reduction goals are compared to a GHG baseline set by the 2019 GHG inventory.

High Level Target Planning Scenarios

These scenarios apply Community-wide mitigation strategies to the five main emission sectors: Residential Energy, Commerical Energy, Industrial Energy, Transportation & Mobile Sources, and Solid Waste. Two High Level Target Planning Scenarios were modeled to demonstrate infrastructure and policy changes that would need to be implemented to decrease emissions by 50% by 2030, 80% by 2050, or 100% by 2050.

80% by 2050 – To reduce Concord's community-wide emissions by 80% by 2050, Concord would need to do the following:

1) Power their residential and commerical spaces with 100% renewably sourced electricity.

2) Switch 75% of residential and commerical natural gas end uses (heating, cooling, cooking) to electric.

3) Replace 100% of gas vehicles on the road with electric vehicles.

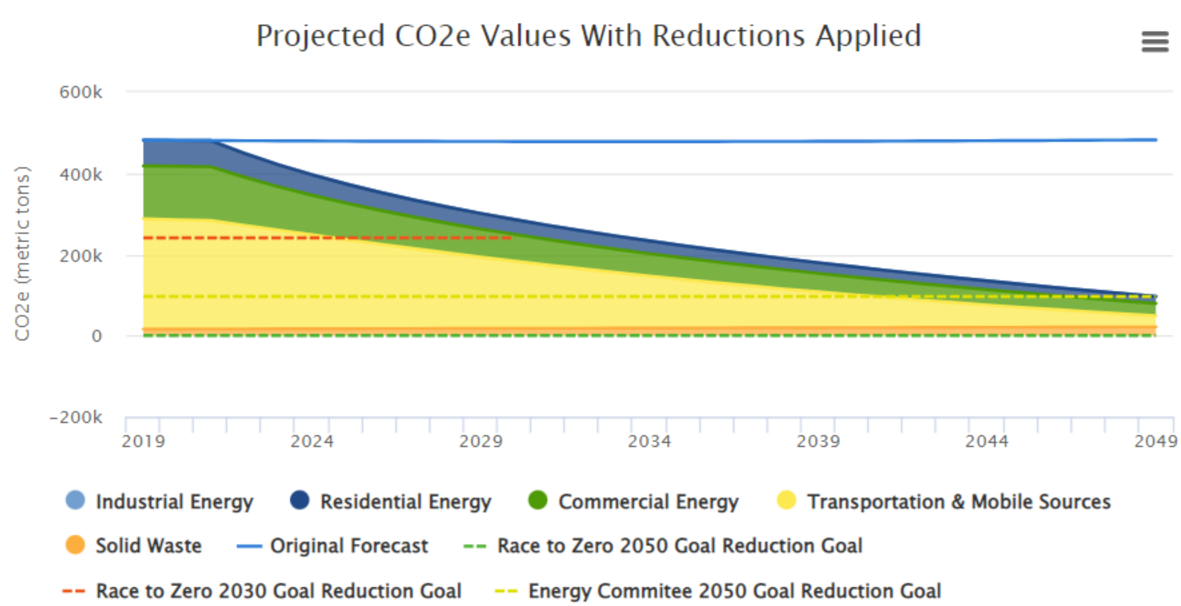
4) Replace 50% of diesel vehicles on the road with electric vehicles. All electric vehicles must be powered with 100% net zero carbon energy to receive all the mitigation benefits.

In this 80% by 2050 emissions reduction scenario, Concord would reduce their GHG emissions by 40% by 2030 (Table 11, Figure 11). This scenario assumes that gasoline vehicle carbon intensity will increase by 34% by 2050, meaning that vehicles on the road will use gasoline more efficiently than previously, either due to regulation or better vehicle design. Making these energy and infrastructure changes will require quick action and ample funds. Accessing state and federal funding will be essential to actualize this scenario.

Table 11: High Level Target Planning Scenario - 80% reduction by 2050 (MT CO2e)

Year	Industrial Energy (MT CO2e)	Residential Energy (MT CO2e)	Commercial Energy (MT CO2e)	Transportation & Mobile Sources (MT CO2e)	Solid Waste (MT CO2e)	**Total Emissions (MT CO2e)**
2019	148	63155	130549	271838	15723	**481413**
2030	161	36583	65868	165758	17541	**285911**
2050	185	17138	30343	27591	21192	**96449**

Figure 11: High Level Target Planning Scenario – 80% reduction by 2050 (MT CO2e)



100% by 2050 – This scenario models strategies to reduce Concord's emissions by 100% by 2050 (Table 12, Figure 12). This scenario also reduces 50% of emissions by 2030. To achieve this goal, Concord would need to:

1) Power their residential and commerical spaces with 100% renewably sourced electricity.

2) Switch 100% of residential and commerical natural gas end uses (heating, cooling, cooking) to electric.

3) Replace 100% of gas and diesel vehicles on the road with electric vehicles. All electric vehicles must be powered with 100% net zero carbon energy to receive all the mitigation benefits.

4) Reduce total waste generation by 50% by diverting waste to recycling and increasing composting services.

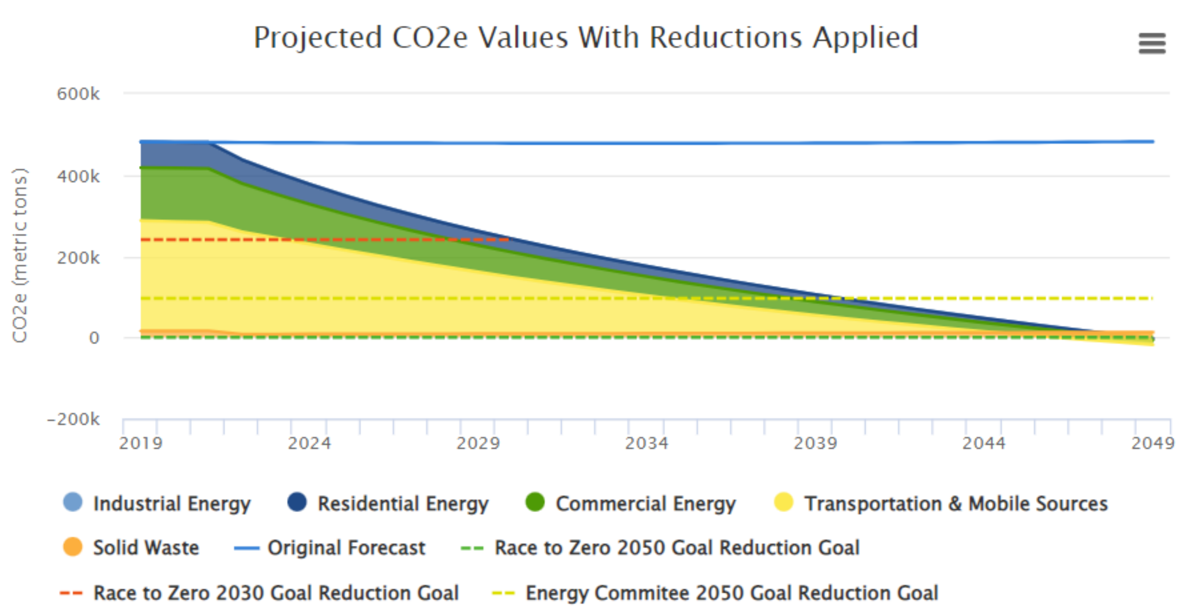
This scenario is not modelled perfectly as it overestimates reductions in the Transportation sector and calculates negative emissions, which is unlikely since vehicles are not carbon sinks. That being said, this scenario can demonstrate the significant measures needed to reduce emissions in every sector and reach Concord's climate goals.

Reaching 100% GHG reduction would require addressing Industrial emissions, diverting all waste generation (or offsetting the associated emissions) from landfills, and implementing more complex strategies to completely reduce Residential, Commerical, and Transportation emissions. Enacting these strategies is significantly challenging within a 28-year timeframe, but decarbonization infrastructure investments will be necessary to reduce emissions to reach the Race to Zero goal of 100% net emission reduction by 2050.

Table 12: High Level Target Planning Scenario - 100% reduction by 2050 (MT CO2e)

Year	Industrial Energy (MT CO2e)	Residential Energy (MT CO2e)	Commercial Energy (MT CO2e)	Transportation & Mobile Sources (MT CO2e)	Solid Waste (MT CO2e)	Total Emissions (MT CO2e)
2019	148	63155	130549	271838	15723	481413
2030	161	32384	61397	139339	9218	242499
2050	185	4076	10671	-30612	12868	-2812

Figure 12: High Level Target Planning Scenario - 100% reduction by 2050 (MT CO2e)



Concord's Land-based Carbon Storage

Concord's natural lands and vegetation, including its forests, grasslands, wetlands, and cultural areas offer an important service in terms of carbon storage and sequestration. Trees and plants remove CO_2 from the atmosphere through photosynthesis and store it in their biomass. Forests also represent a significant source of CO_2 and other GHG's to the atmosphere when there are forest disturbances (fires, disease, pests) or when forests are cut down and converted to a different land use (settlement, grassland, cropland, etc). Forests act as a sink for CO_2 when the rate of CO_2 removal is higher than the rate of emissions.

In terms of land-based carbon accounting, the carbon stored in tree and plant biomass would not count as a carbon offset, because they are already included in the baseline of Community-wide emissions. However, land-based carbon accounting can still be an option if there is additional biomass growth that sequesters carbon. For example, if the Concord City government planted 30 additional acres with trees, the carbon stored in this new forest could be considered additional and counted as a carbon offset.

This option should be considered since some community-wide emissions are difficult to reduce. For example, wastewater treatment plants produce emissions as a byproduct of the water purification process using standard technologies. Without the implementation of advanced wastewater treatment technologies – which may or may not be appropriate to handle an entire city's load – it will be difficult to reduce these emissions. Therefore, municipalities like Concord may consider how to offset these emissions. One option is to estimate how many tons of CO_2e per year are the forests removing from the atmosphere.

According to the ICLEI LEARN Tool, 59% of Concord is forested (43,003 acres). Concord's forests act as a very important sink, removing approximately 60,128 MT CO_2e every year through growth and photosynthesis (Table 13). As mentioned before, these forests cannot be considered as a carbon offset since they already exist. However, this analysis demonstrates the extent to which trees act as a reservoir of stored carbon. Additional trees would increase carbon storage and help offset some of Concord's community-wide emissions.

Table 13: Concord's Forest Net GHG Balance from ICLEI LEARN Tool

	Removals(t CO2e/yr)	Emissions(t CO2e/yr)
Undisturbed Forest	-64,070	
Forest Disturbances		5,555
Non-Forest to Forest	-1,642	
Forest to Settlement		5,696
Forest to Grassland		2,898
Forest to other non-forest lands		648
Trees outside of forests	-9,399	186
Harvested Wood Products	0	
TOTAL	-75,111	14,983
Net GHG balance	-60,128	

The ICLEI Learn Tool also provided a record of historical land use changes in Concord and act as the baseline for carbon storage regarding development. One important result is that once land of any type is converted to Settlement (developed with buildings), it usually stays developed and will not act as a carbon sink. This indicates that development projects can negatively impact Concord's land-based carbon storage if these projects are in forested or highly vegetated areas. Therefore, it is important for Concord to consider where they choose to build (preferably on already developed land) to maintain their current carbon storage and not emit more GHG emissions through land conversion.

Caveats and Suggestions for Future Improvements

The ICLEI LEARN Tool is just one method to estimate of carbon removals via forests and this method has its limitations. As with any estimation of GHG emissions and removals, 100% accuracy is virtually impossible. We use estimations to guide policy and uncertainty must be considered when using an emissions/removals estimation to make local government decisions. According to the ICLEI LEARN report, uncertainties may be as high as ±45% (with 95% confidence). This means we can be 95% confident that the actual value of Net GHG removals by Concord forests is between 33,070 MT CO_2e and 87,186 MT CO_2e. While the ICLEI LEARN Tool's results may be a good starting place for Concord to assess their forest's GHG removals, it may not be accurate enough for policymaking. To increase the accuracy of forest CO_2 removal estimations, different methods may be used, as discussed below.

This tool also only analyzes at carbon sequestration of forests and trees in urban areas with the NLCD data. The ICLEI LEARN Tool does not compute carbon sequestration occuring in cropland, wetlands, grasslands, and other green spaces. Thus, this estimation does not encapsulate all of Concord's land-based carbon storage. Concord will need to employ different methods to measure carbon sequestration in additional ecosystems.

Potential Methods for Future Land-Based Carbon Accounting

One method is to use a higher resolution map such as a 1m map as the source of data instead of the 30m map used by the ICLEI LEARN Tool. A 1m map has smaller pixelation of an image and allows you to provide a more detailed map of Concord's forests and urban trees, detecting individual trees as opposed to patches of trees (Claggett, 2022). A more detailed map can be used to calculate more accurate estimations of carbon storage in forests and trees.

There are already several different maps available to Concord either through their own archives, UNH GRANIT (New Hampshire's Statewide GIS Clearinghouse) or government agencies. Two maps that may be helpful are "2012 1-meter NAIP Orthophotography for New Hampshire (CIR)" from UNH GRANIT and "Coastal Change Analysis Program (C-CAP) Land Cover and Change" from the NOAA Office for Coastal Management, which is a 30-meter map from 2016[18,19]. Analyzing these maps to compute carbon storage in vegetation requires advanced remote sensing or geographic information system skills and thus was not completed for this report.

Carbon emissions and removal estimations can be customized to Concord through field surveys aimed at collecting tree data in Concord's local forests. With a sample, one can calculate the removals and emissions using IPCC guidelines[20]. While this method would provide the highly accurate and site-specific estimations of carbon sequestration, it may not be the most feasible method, as it requires time, resources, and expert knowledge to account for land-based carbon storage via sample data. One benefit of using the IPCC guidelines is that it provides equations to calculate carbon storage in wetlands, croplands, grasslands, and other green spaces.

In addition, there are other tools to estimate removals and emissions from agriculture specifically. The AFOLU Carbon Calculator by USAID may be useful for estimating carbon sequestration through forest management[21]. COMET-Farm created by the USDA may also be a good place to start for calculating agricultural emissions and removals[22]. For more complex agricultural estimations, the DayCent model can be used, although using this model requires training and familiarity with R coding software. It may also be helpful to connect with experts from the University of New Hampshire (UNH) or other academic institutions to understand which methodologies will be the best for a municipality and to find students and staff to complete a land-based GHG accounting project.

Discussion & Conclusion

Significant changes must be made to prevent global and local climate disaster. In Concord, this includes broad changes to shift the city's electricity energy sources, residential and commerical infrastructure, and vehicle fleets. These changes represent investments that should elicit returns in the form of reduced energy costs over time, energy independence, improved quality of life (e.g., air quality, noise reduction), municipal and private revenue-raising options (e.g., interstate tourism), job opportunities, and attractiveness as a place to live. It is necessary that Concord make decarbonization infrastructure changes soon so that the city can do its part in averting the harshest effects of climate change while reaching its emissions reduction goals.

Regarding the ICLEI emission scenarios, it is important to recognize that these are scenarios in a model, which are simplifications of possible futures. These scenarios are not prescriptive - there are dozens of ways that Concord can reduce its emissions to meet its goals. However, this report can act as a guide for policymakers as they decide what city projects and policies to invest in. Based on the results of these models, the most impactful actions Concord can take to reduce their LGO and Community emissions is to invest in renewable electricity, install electric heating and cooling systems like heat pumps in to every building, and replace all vehicles with electric alternatives.

Limitations of Report

This report is not all-encompassing and lacks information that may be useful to Concord City officials.

The ICLEI ClearPath emissions scenarios are helpful for projecting what emissions might be in the future. However, uncertainty of emissions estimates are not quantified within the model, meaning there is some risk that these emissions are inaccurate. The model did not calculate a 95% confidence interval or a range of possible emissions. Future analyses may consider including an uncertainty analysis to provide policymakers with more insight to their city's GHG inventories.

The ICLEI Learn Tool was the only method used to calculate land-based carbon storage and sequestration. This tool is limited because it only measures CO_2 removals and emissions from forests, trees outsides of forests, and forest-related land use change. This means that emissions and removals from agricultural land, wetlands, grasslands, and other green spaces are not calculated or compiled into this inventory. This means that a full complete estimation of AFOLU emissions sources and sinks needs to be calculated outside of the tool. Further discussion of how to do this is in the conclusion.

In addition, a cost-benefit analysis of the mitigation strategies was not addressed in this report. There was not enough time to estimate the cost of each mitigation strategy and provide recommendations to Concord City Hall with the added financial information. All recommendations are therefore based on which strategies will reduce the most GHG emissions to meet their climate goals. Further research must be completed to assess the cost of investing in 100% renewable energy, electric heating and cooling systems, and electric vehicles.

Key Findings

The key findings highlight Concord's Updated 2019 GHG Inventory results and projected emissions scenario results.

- Concord's total Local Government Operation (LGO) emissions were 7,573 MT CO_2e in 2019.
- Total Community-wide emissions in 2019 were 481,567 MT CO_2e.
- In the BAU 35.5% renewable energy scenario in which Concord City government does not implement climate mitigation policies, both LGO and Community emission levels will be consistent to midcentury.
- To reduce LGO emissions by 50% by 2030 and 80% by 2050, Concord would need to:
    - Invest in 100% renewably sourced electricity.
    - Install heat pumps in 100% of the municipal buildings and facilities
    - Replace 100% of gas and diesel-powered vehicles in the municipal and transit fleets with electric vehicles.
- To reduce Community-wide emissions by 80% by 2050, Concord would need to:
    - Power their residential and commerical spaces with 100% renewably sourced electricity.
    - Switch 75% of residential and commercial natural gas end uses (heating, cooling, cooking) to electric.
    - Replace 100% of gas vehicles on the road with electric vehicles.
    - Replace 50% of diesel vehicles on the road with electric vehicles.
- To reduce Community-wide emissions by 100% by 2050, Concord would need to
    - Power their residential and commerical spaces with 100% renewably sourced electricity.
    - Switch 100% of residential and commerical natural gas end uses to electric.
    - Replace 100% of gas and diesel vehicles on the road with electric vehicles.
    - Reduce total waste generation by 50% by diverting waste to recycling and increasing composting services.
- Concord's forests, which cover 59% of the municipality, act as a very important sink, removing approximately 60,128 MT CO_2e every year through photosynthesis. By enacting land and tree protection policies and ordinances, dissuading development in treed areas, mitigating tree loss from development, incentivizing the planting of trees on public and private land, and encouraging climate smart agriculture, the city can avoid land-based emissions and perhaps even mitigate GHG emissions from some difficult sources in the built environment, such as waste.

Final Thoughts

Concord, NH is one of many municipalities in the U.S, that will need to decarbonize their infrastructure to help avoid the most harmful effects of climate change. Further work must be done to invest in renewable energy sources, electrification of heating systems, and electric transportation and infrastructure. While significant, Concord is taking the steps to tackle this global challenge through commissioning this project and already implementing green initiatives in the community.

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