Durham, New Hampshire

UNH Sustainability Institute

2019 Community-Wide Greenhouse Gas Inventory

Completed in 2021

Prepared by:
Emily Mello
UNH Sustainability Fellow (2020/2021)

Acknowledgements

I would like to thank the following people who provided me with invaluable insight, mentorship, data, and technical support throughout this project:

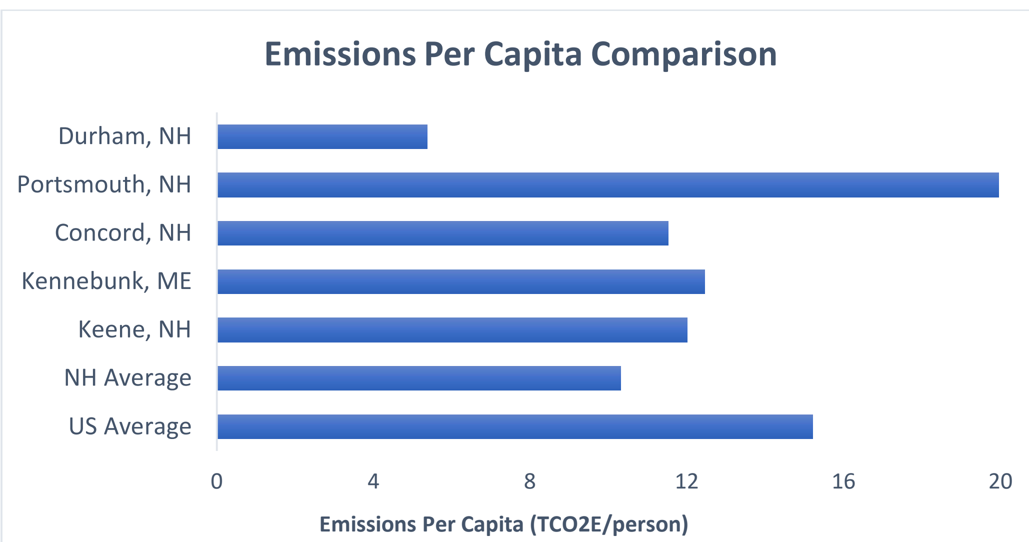
Todd Selig, Town of Durham
Jennifer Andrews, UNH Sustainability Institute
Cathy Fletcher, UNH Sustainability Institute Fellow
Nat Balch, Town of Durham
Mary Downes, Town of Durham
Jim Lawson, Town of Durham
Karina Graeter, Southern Maine Planning and Development Commission
Kyle Pimental, Strafford Regional Planning Commission
Kendall Gray, UNHSI and ORCSD-D
Rachel Dewey, Strafford Regional Planning Commission
Richard Reine, Durham Public Works
Jim Rice, Durham Town Assessor
Michael Behrendt, Durham Town Planner

Table of Contents

Executive Summary

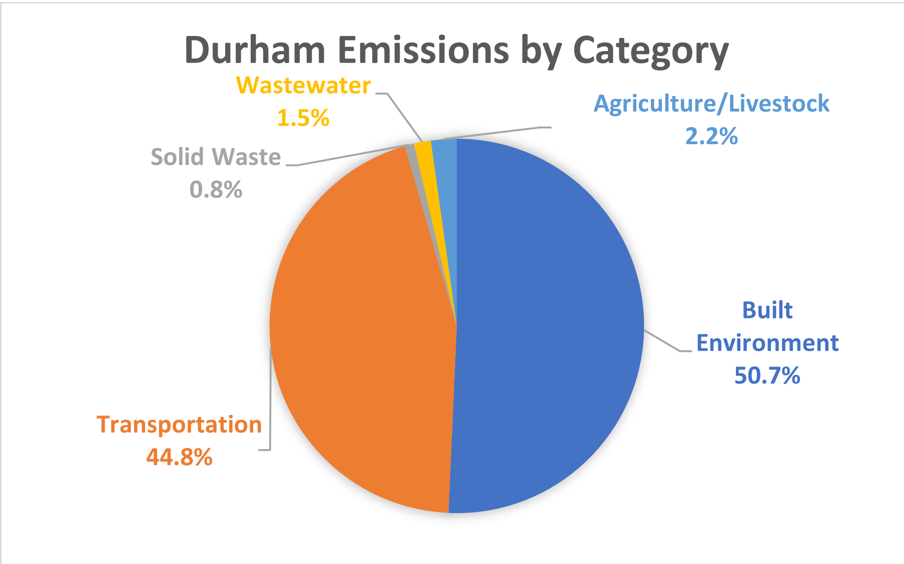
The Town of Durham, New Hampshire is committed to being a leader in sustainability by doing their part to reduce their greenhouse gas pollution and become as resilient as possible to the growing impacts of climate change. Over the past several years, the Town has made numerous efforts to increase sustainability and reduce emissions, aided and supported by Sustainability Fellows through the University of New Hampshire (UNH) Sustainability Institute. Durham has recently joined the Global Covenant of Mayors for Climate and Energy (GCoM), a global alliance of thousands of cities and towns who are committed to reducing emissions and increasing access to clean energy in just ways [9]. As part of their participation in GCoM, the Town undertook an analysis of their community-wide carbon footprint. Participation in GCoM also offers Durham valuable resources and a framework for continuing their work towards a more sustainable future.

One striking finding from the Community Greenhouse Gas (GHG) Inventory was how low Durham's community footprint is compared to other communities, as shown in the following figure. The total GHG emissions for Durham in 2019, were 87,566 Metric Tons of Carbon Dioxide Equivalent (tCO_2e), resulting in emissions per capita of 5.4 tCO_2e. This is strikingly lower than both the state [4] and national [7] averages of 10.3 and 15.2, respectively. Durham's low per capita footprint is likely due in large part to the presence of UNH, which is itself a dense and low carbon community; and to the efforts and engagement around energy and environmental issues on the part of the Town and local residents.

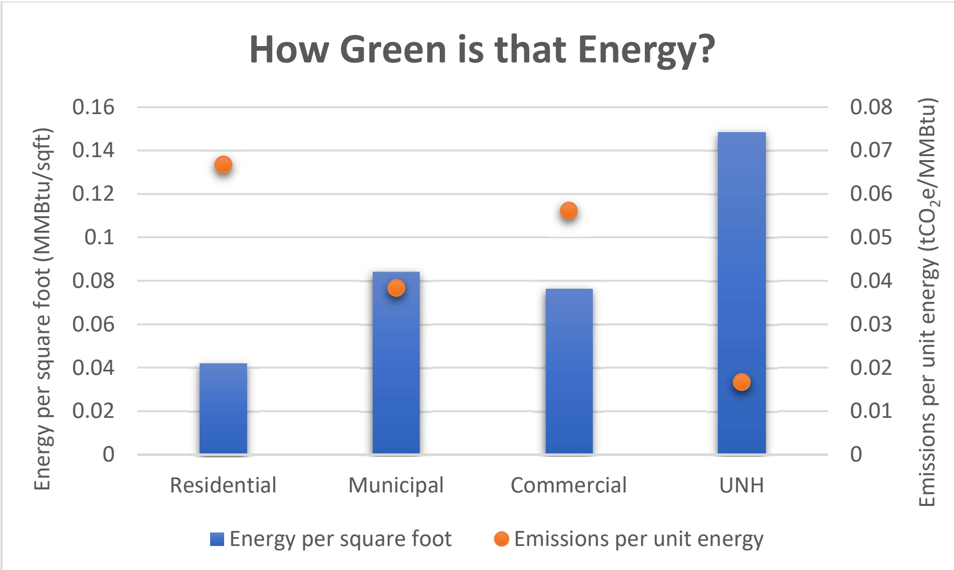


Also striking is the amount of carbon sequestration that currently happens annually from Durham's forested land area (which makes up about 59.7% of the total land in Durham as of 2016) and trees outside forests. Approximately 28,161 tCO_2e/year were sequestered in Durham from 2006 to 2016. That is equal to 32.2% of the total emissions in this 2019 community-wide inventory, or 31.2% if including land use emissions (2,691 tCO_2e) [14]. This points to the pivotal role of land use policies and practices as one tool that Durham can continue to employ in its climate and sustainability efforts.

The two largest emission categories were the Built Environment and Transportation, as shown in the following figure. These categories are the highest for most communities and have the most potential for reductions.



The Built Environment accounts for over half of Durham's community-wide emissions – 50.7%. Within the Built Environment, 75.2% of total emissions were due to stationary fuel, while 24.8% of emissions were due to electricity. However, energy usage does not directly correlate with the production of GHG emissions. This can be seen in the following figure, which shows how much energy per square foot was used and how many emissions were produced per unit of energy. UNH used and produced the most energy per square foot, but that energy was produced in the "greenest" way out of all the sectors. This is because UNH generates much of its own energy through its Co-generation plant that is powered mainly by landfill gas (a renewable source). This analysis demonstrates where there is the most potential for energy efficiency improvements: the Residential and Commercial sectors. Future efforts to reduce these emissions will entail finding ways to support the Residential sector in switching to greener electricity and electrifying the Commercial sector wherever feasible. These efforts could include encouraging the use of residential solar power and a community aggregation program that would switch all residential electricity to renewable sources.



As with most community-scale greenhouse gas inventories, the emissions from the Transportation category are largely estimated and include travel that is a result of "pass-through" traffic. This means that a portion of the transportation emissions are unlikely to be addressed by policies in Durham. Nevertheless, transportation-related emissions are substantial, and the Town will be well-served to continue its dedicated efforts related to Transportation Demand Management with UNH, which have been fruitful. This will not only involve continued initiatives focused on encouraging walking, biking, the use of public transportation, and remote work, but it is also likely to include efforts to expand Electric Vehicle (EV) infrastructure. Durham should also monitor the growing number of high-quality aggregated travel datasets becoming publicly available to state and regional planning agencies and take advantage of opportunities to re-evaluate transportation emissions totals if such data becomes available.

The Solid Waste and Wastewater categories were relatively low for Durham, which is a direct result of some of the actions the Town has already taken. Solid waste for Durham is sent to a landfill that captures the methane and uses it for energy production, and thanks to some recent upgrades, the Durham Wastewater Treatment Plant is extremely efficient, removing about 90% of the nitrogen [11]. Agriculture and Livestock emissions were included in this inventory even though they are an optional category for the reporting framework. These emissions come from activities on the campus of UNH, and don't represent a large portion of the total community emissions.

Overall, the 2019 Durham Community-Wide Greenhouse Gas Inventory shows that the Town is clearly a leader in sustainability. There are still plenty of opportunities for reductions in emissions, however. This inventory will be used by the Durham Energy Committee to set ambitious emissions reduction goals and as a baseline to measure progress towards those goals.

Introduction

Scientists have warned for decades of the likely impacts of human-induced climate change resulting from the combustion of fossil fuel and other industrial activities including sea level rise, frequent and extreme weather events, droughts, crop failures, and severe flooding. In 2018, the International Panel on Climate Change (IPCC) released a Special Report [8] that contained an urgent call to action to keep global temperatures from rising more than 1.5°C. They outlined the consequences of a 1.5°C increase but emphasized that the consequences would be significantly worse if temperatures continued to warm further. To limit the effects of climate change, we need to rapidly lower GHG emissions, reaching net-zero emissions globally by 2050. The Biden Administration has also recently announced a GHG Emission Reduction target for the US, of a decrease of 50-52% from 2005 levels by 2030 [13].

Durham is a small town in Seacoast New Hampshire, home to about 5,900 permanent residents and to the University of New Hampshire (UNH) [1]. In 2019, its population was approximately 16,293 [16]. Durham is committed to sustainability and has already taken several steps to help to promote sustainability and reduce negative impacts on the environment.

In January 2021, Durham joined the Global Covenant of Mayors for Climate and Energy (GCoM) [9], which is a global alliance of over 10,000 cities and towns who are committed to climate leadership and emissions reductions. Durham's participation in GCoM is very exciting because it provides resources and a framework for members to make meaningful climate action. Within the first three years, members are required to submit the following:

- Community-Wide Greenhouse Gas Inventory
- Emission Reduction Targets (based on inventory findings)
- Climate Risk and Vulnerability Assessment
- Risk Reduction Goals (based on assessment findings)
- Climate Action Plan (covering mitigation and adaptation)

In fall of 2020, Durham began the next step in their journey to address climate change, undertaking a Community-Wide Greenhouse Gas Inventory; it will serve as a baseline and guide for future climate action that aligns with national goals and the need for global GHG reductions. The Durham Energy Committee will be working alongside UNHSI Fellows and the Strafford Regional Planning Commission to complete the rest of these tasks outlined in the GCoM initiatives and update them as needed.

Methods

This community-wide inventory follows the ICLEI US Community Protocol for Accounting and Reporting of Greenhouse Gases (US Community Protocol, USCP) [9], which offers a standardized set of methods, as well as a reporting framework recognized by GCoM. It is widely used by communities across New England and the US. Any future inventories that Durham performs should also follow this protocol so comparisons between years can be made, and the community's progress can be accurately tracked. Emissions factors (EF) used in this inventory are from the 2020 EF version of the Sustainability Management and Analysis Platform (SIMAP), which is a UNH-based carbon and nitrogen accounting tool.

The US Community Protocol requires reporting of five basic greenhouse gas emissions generating activities. In this inventory, these required activities are grouped into four categories, Built Environment, Transportation, Wastewater, and Solid Waste, with the addition of an optional category, Agriculture & Livestock. Explanations for what is covered within each category is provided in Table 1, and detailed explanations of the calculations for each category are presented in the appendices.

Table 1. Descriptions of Emission Categories

Category	Description
Built Environment	Covers the use of stationary fuel and electricity within five sectors (residential, municipal, commercial, UNH, and ORCSD-D)
Transportation	Covers on-road passenger and freight motor vehicles
Wastewater	Covers the treatment of the community's wastewater
Solid Waste	Covers solid waste produced within the Town boundaries
Agriculture and Livestock	Covers fertilizer use and livestock on the UNH campus

The three greenhouse gases that are emitted globally in the highest quantities are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These are the gases that are included in this inventory. The totals of each individual GHG are weighted using Global Warming Potentials (GWPs), so that the emissions can be presented as one value: Metric Tons Carbon Dioxide Equivalent (tCO_2e). GWPs are a measure of the potency of the greenhouse gas properties of each gas relative to carbon dioxide and are published by the IPCC. This inventory uses the values for a 100-year timescale from the latest version (AR5), which can be seen in Table 2.

Table 2. Greenhouse Gases and their Global Warming Potential

Greenhouse Gas	GWP (tCO_2e)
CO_2	1
CH_4	28
N_2O	265

Results

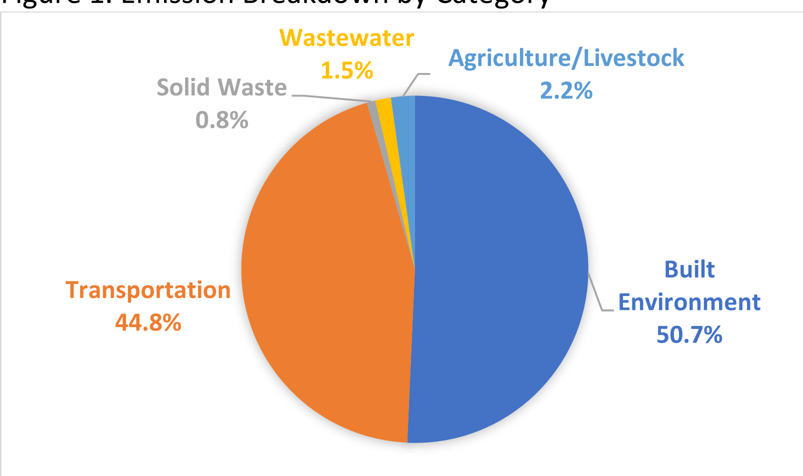
Results Summary

Durham's total emissions in 2019 were 87,566 tCO_2e. Table 3 and Figure 1 show the breakdown of emissions from each category. Like most communities, the two largest emitting categories were the Built Environment and Transportation, which together account for 95.5% of the total emissions. While the other categories are generally a small percentage of a community's total emissions, in Durham they are significantly smaller due to some of the strategies the Town has already implemented.

Table 3. Durham's 2019 Emissions by Category

Category	Emissions (tCO_2e)	% of Total Emissions
Built Environment	44,403	50.7%
Transportation	39,258	44.8%
Agriculture/Livestock	1,935	2.2%
Wastewater	1,290	1.5%
Solid Waste	680	0.8%
Total	**87,566**	-

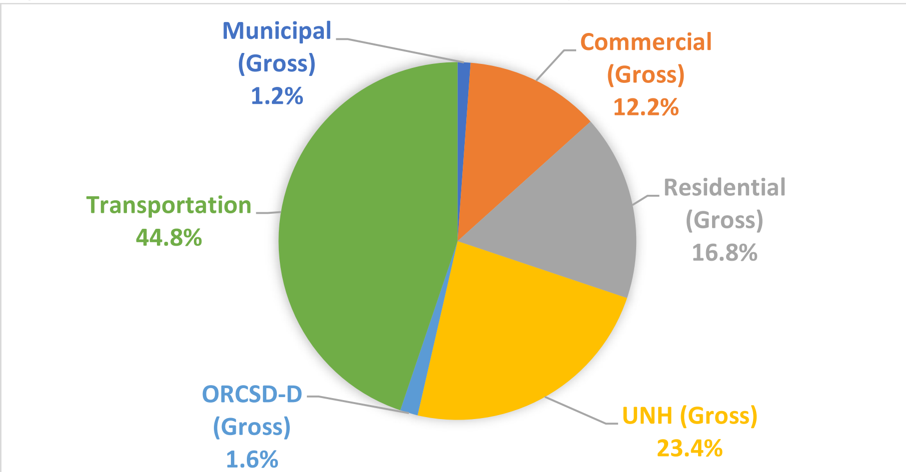
Figure 1. Emission Breakdown by Category



The emissions can also be broken down by different sectors within the Town of Durham. These sectors are Residential, Municipal, Commercial, the Durham buildings of Oyster River Cooperative School District (ORCSD-D) and UNH. Excluding Transportation emissions, because there is currently no accurate way to distinguish transportation between sectors, 57.6% of the "Total – Transportation" emissions come from the Durham Community outside of UNH (Residential, Commercial, Municipal, and ORCSD-D) and 42.4% comes from UNH.

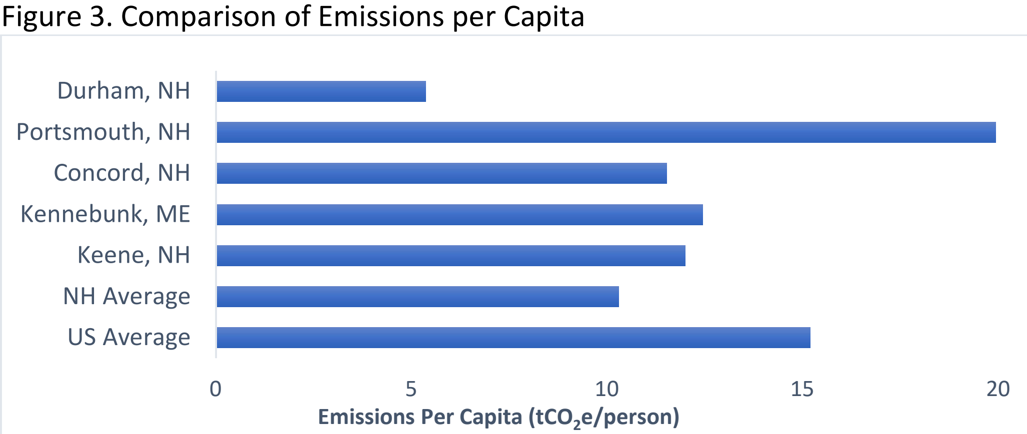
Figure 2 provides a further breakdown of each sector's contributions to total emissions. The "Municipal (Gross)" includes the municipal emissions from the Built Environment, the emissions associated with the Durham sewer lines from the WWTP and the Durham Solid Waste emissions. Because not all emissions from the sewer lines and Solid Waste are solely from Municipal operations, and are likely contributed to by the other sectors as well, this percentage is likely larger than Municipal-only emissions. However, even with this in mind, 1.2% is significantly lower than the average US municipality. The "Commercial (Gross)" only includes the Commercial built environment emissions, and the "Residential (Gross)" category includes the residential emissions from the built environment and the septic tank emissions. For the "UNH (Gross)" category, this includes the UNH built environment emissions, the UNH sewer lines from the WWTP, the UNH solid waste emissions, and the emissions from the agriculture & livestock sector. "ORCSD-D (Gross)" includes the ORCSD-D emissions from the built environment and the ORCSD-D solid waste emissions. In this figure, the "Transportation" category is simply the transportation emissions.

Figure 2. Contributions to Total Emissions by Sector



As shown on Figure 3, the Town's emissions per capita (5.4 tCO_2e/person, or about 11,905 pounds of CO_2e/person) are relatively low compared to both the state and national averages as well as nearby towns and cities that have recently completed a community-wide GHG inventory. This is likely low for a few reasons. First, Durham has already taken several steps to reduce their environmental impacts. Second, because Durham is also home to UNH, which is not in session year-round, both the emissions generated and the number of people living in the Town vary significantly throughout the year. The emissions per capita calculation assumes that the emissions are generated evenly throughout the year by a steady population, which simply is not the case for Durham. Third, UNH is a leader in sustainability for higher education institutions and their emissions are significantly lower than the average community.

Figure 3. Comparison of Emissions per Capita



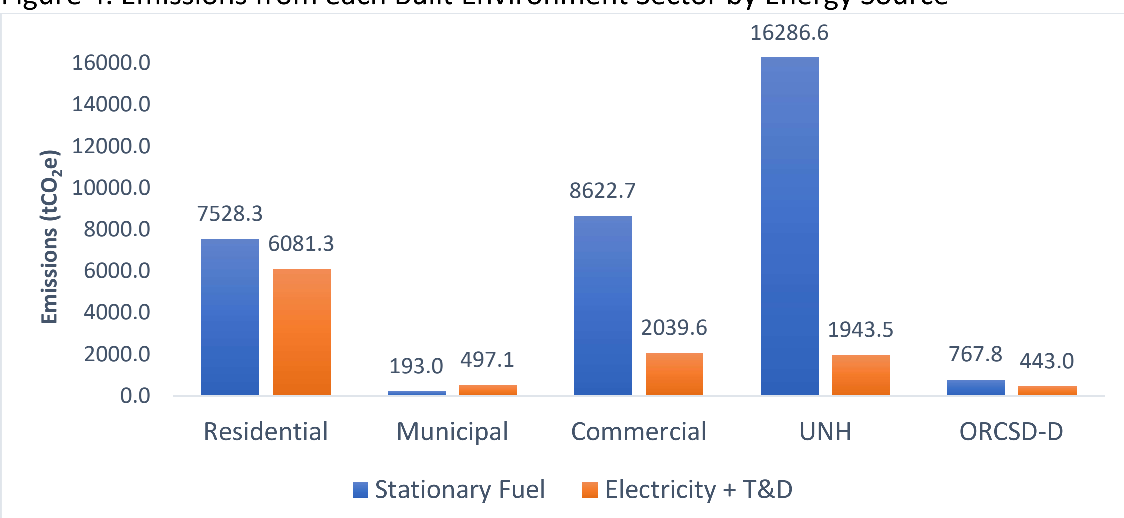
Built Environment (BE)

The Built Environment category was Durham's largest source of emissions, emitting 44,403 tCO_2e in 2019, which is 50.7% of community-wide emissions. It consists of five sectors: Residential, Commercial, Municipal, UNH, and the Durham buildings of Oyster River Cooperative School District (ORCSD-D). Emissions from this category are from the use of stationary fuel and electricity. Stationary fuels are generally used for heating and cooking and include fuel oil, natural gas, propane, and wood. Fugitive emissions from fossil fuel due to the mining, processing, storage, and transportation of coal as well as natural gas activity were considered to be not occurring and insignificant, respectively. The natural gas distribution lines within Durham's Town boundary are all less than 25 years old and are closely monitored for leakage. Electricity is supplied to Durham businesses and residents by Eversource, and a substantial amount is generated on-site by UNH for use on its campus. Emissions included are from both purchased electricity and the emissions from transmission and distribution losses (T&D) for purchased electricity. Emissions from the Built Environment category were calculated using the methods recommended in the USCP and can be seen in detail in Appendix A. Table 4 and Figure 4 show each sector's energy usage and emissions, respectively. Note that for ORCSD-D, only total emissions were known because they were calculated by the school district.

Table 4. Total Energy Use from each Built Environment Sector (units in MMBtu)

Sector	Energy Source	Energy Use (MMBtu)	Sector Total (MMBtu)
Residential	Stationary Fuel	117,213	**203,928**
	Electricity	86,715	
Municipal	Stationary Fuel	3,407	**10,496**
	Electricity	7,089	
Commercial	Stationary Fuel	160,730	**189,814**
	Electricity	29,083	
UNH	Stationary Fuel	953,636	**981,349**
	Electricity	27,713	

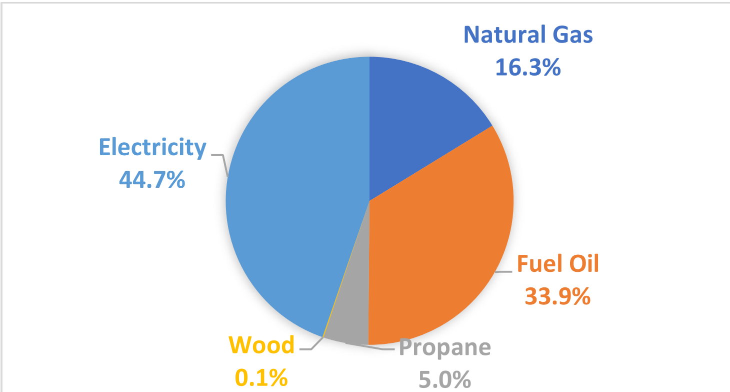
Figure 4. Emissions from each Built Environment Sector by Energy Source



Residential Sector

Residential Built Environment sector accounted for 30.7% of the Built Environment footprint and 15.5% of the total community-wide emissions. Of this sector's emissions, 55.3% is from stationary fuel and 44.7% is from electricity. Figure 5 shows a further breakdown of the emission sources within the Residential sector.

Figure 5. Residential Built Environment Emissions by Source

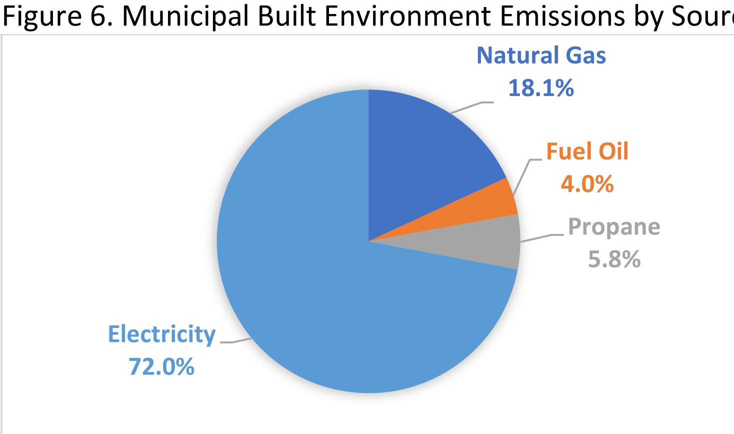


In this sector, there are a total of 2,240 households (consisting of houses and condos) with 11,159 people [15] and a total living space of 4,849,531 ft^2 [12]. The average Residential emissions per household are about 6.1 tCO_2e, or approximately 1.2 tCO_2e/person.

Municipal Sector

The Municipal Built Environment sector accounted for 1.6% of the Built Environment footprint and 0.8% of the total community-wide emissions. Of this sector's emissions, 28.0% is from stationary fuel and 72.0% is from electricity. Figure 6 shows a further breakdown of the emission sources within the Municipal Built Environment sector.

Figure 6. Municipal Built Environment Emissions by Source



There was a total of 124,543 ft^2 of Municipal space, which results in emissions of 0.006 tCO_2e per ft^2 for this sector. Breaking down emissions by location (including both municipal buildings and non-building entities like “streetlights” that produced built environment emissions) gives 34.5 tCO_2e per location.

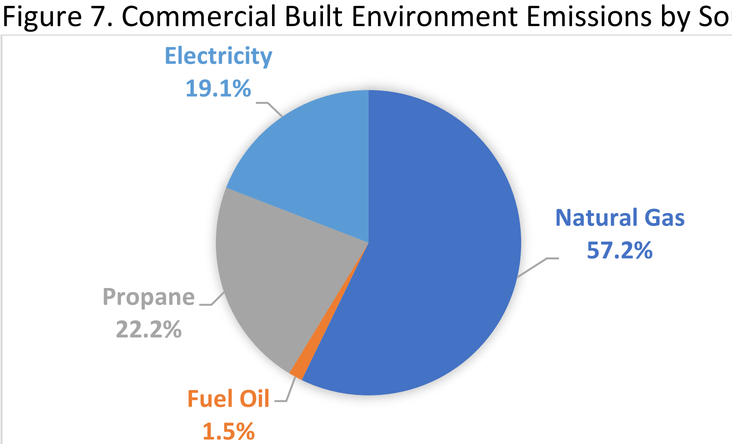
The Municipal BE emissions do not account for the 1,192 MWh of Renewable Wind Energy that the Town purchased in 2019 for the Wastewater Treatment Plant. If those Renewable Energy Credits (RECs) are taken into account, the Municipal BE emissions are reduced by 42% to 403 tCO_2e. Details about how the RECs were accounted for can be found in Appendix A, and more information about the Municipal footprint can be found in the 2019 Durham Municipal GHG Inventory Report [11].

In 2019, Durham was also participating in two power purchase agreements (PPAs). PPA 1, with ReVision Energy, covered the solar arrays on the library, police station, and Churchill Rink, for a total of 120 kW. Thanks to recommendations from the Summer 2020 Sustainability Fellow [11], the Town purchased PPA 1 in 2021. Now, any future inventories will also include the RECs from these solar arrays, worth 43tCO_2e of emissions savings [11]. PPA 2, with IGS Solar, is a 640 kW solar array at the gravel pit on Town-owned property in Lee. This PPA is available for purchase in 2022, and if purchased, the Town could then claim the emissions savings from that solar array as well.

Commercial Sector

The Commercial Built Environment sector accounted for 24.0% of the Built Environment footprint and 12.2% of the total community-wide emissions. Of this sector’s emissions, 80.9% is from stationary fuel and 19.1% is from electricity. Figure 7 shows a further breakdown of the emission sources within the Commercial Built Environment sector. The Commercial sector consisted of 2,767,197 ft^2 over 74 buildings [12], with average emissions of 0.004 tCO_2e/ft^2 and 144.1 tCO_2e/building.

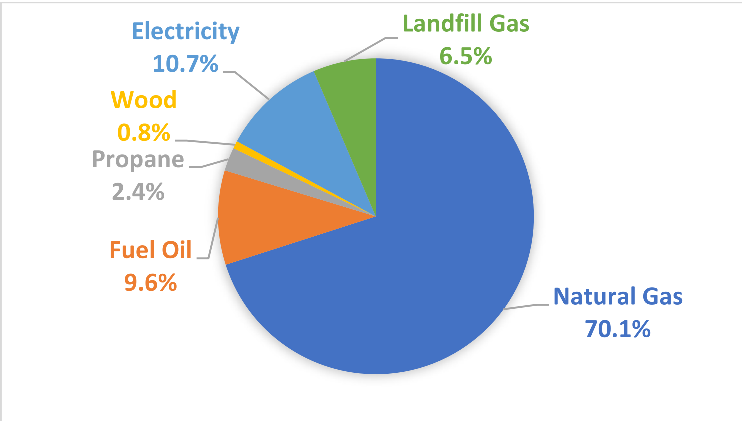
Figure 7. Commercial Built Environment Emissions by Source



UNH Sector

The UNH Built Environment sector accounted for 41.1% of the Built Environment footprint and 20.8% of the total community-wide emissions. Of this sector's emissions, 89.3% is from stationary fuel and 10.7% is from electricity. Figure 8 shows a further breakdown of the emission sources within the UNH Built Environment sector.

Figure 8. UNH Built Environment Emissions by Source



The average emissions per unit area for UNH is 0.0028 tCO_2e/ft^2. The UNH sector is unique because it produces much of its own heating, cooling, and electricity through its Co-generation plant on campus. Much of the fuel used in the UNH Co-generation plant is from landfill gas which has been piped to UNH from the Turnkey Landfill in Rochester, NH. This landfill gas, consisting mostly of captured methane, accounts for 68% of the total energy used by UNH, but only 6.5% of the emissions generated. This is discussed further in the Built Environment Summary.

In 2019, UNH purchased 68,871 MWh of RECs, which covers 902% of their purchased electricity. This means that when their RECs are accounted for, UNH's only Built Environment emissions are from their use of stationary fuels.

ORCSD-D Sector

The ORCSD-D sector consists of the following buildings: Oyster River High School, Oyster River Middle School, the School Administration Building, and the Service Building. The ORCSD-D Built Environment sector accounted for 2.7% of the Built Environment footprint and 1.4% of total community-wide emissions. Of this sector's emissions, 63.4% is from stationary fuel and 36.6% is from electricity. The emissions for the ORCSD-D sector were calculated in SIMAP by the school district, and their detailed inventory results were published in a report in December 2020 [3]. Because of this, we were unable to breakdown emissions by energy source. The ORCSD-D sector also had 20.4 MWh of RECs from a solar array. Accounting for this would reduce their BE emissions by 3% to 1,180 tCO_2e. Table 5 on the next page shows a further breakdown of the ORCSD-D's Built Environment emission sources by building.

Table 5. ORCSD-D Built Environment Emissions by Building

Location	Stationary Fuel (tCO_2e)	Electricity (tCO_2e)	T&D (tCO_2e)	Total Emissions (tCO_2e)	% of Total ORCSD-D BE Emissions
Middle School	240.6	114.5	5.9	361.0	**29.8%**
High School	508.0	291.2	15.0	814.1	**67.2%**
School Administration Building	-	10.3	0.5	10.8	**0.9%**
Service Building	19.2	5.1	0.5	24.9	**2.1%**
Total	**767.8**	**421.1**	**21.9**	**1210.8**	-

Built Environment Summary

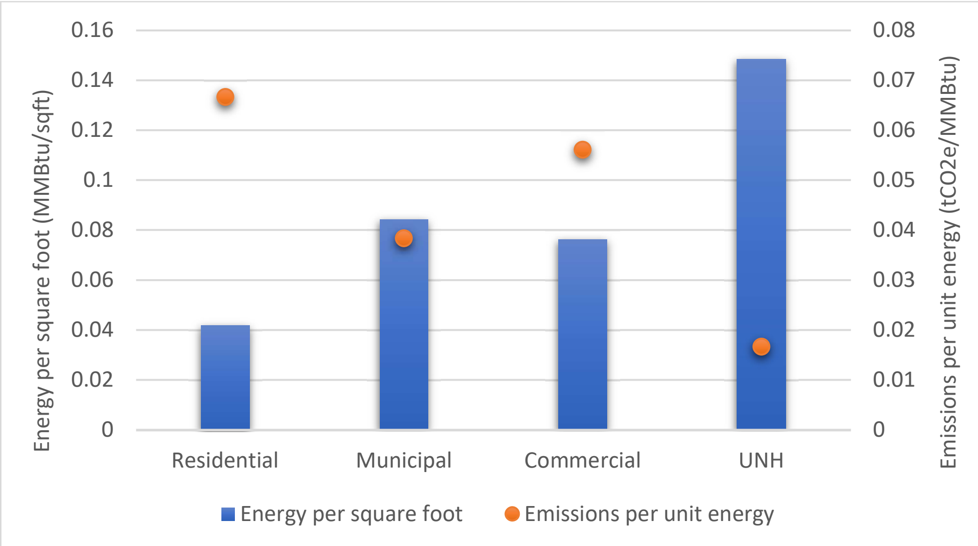
75.2% of Built Environment Emissions were due to stationary fuel energy sources, while 24.8% were due to electricity sources. However, contributions to these emissions were not equal. Example Table 6 shows differences between each Built Environment Sector. This shows the areas where Durham can focus emission reduction efforts. For example, the residential sector accounted for 55.3% of electricity emissions. Therefore, increasing energy efficiency and reducing electricity demand in that sector would drive down those emissions.

Example Table 6. Built Environment Sector Contributions by Energy Source

Sector	% of Total Stationary Fuel Emissions	% of Total Electricity Emissions
Residential	22.5%	55.3%
Municipal	0.6%	4.5%
Commercial	25.8%	18.5%
UNH	48.8%	17.7%
ORCSD-D	2.3%	4.0%

When analyzing these emissions, it is important to look at the different sources of energy being used, as some sources are much greener than others. For example, UNH accounted for 70.8% of the BE energy use, but only accounted for 42.2% of the BE emissions (both percentages excluding ORCSD-D). This is because of UNH's Co-generation plant that is powered by landfill gas, consisting mostly of captured methane, which is a greener alternative to traditional fossil fuels like natural gas or fuel oil. Figure 9 on the next page shows how "green" each sector's energy use was in 2019, including the use of RECs. The blue bars show how much energy was used per square foot in each sector, and the orange dots show how much CO_2e was emitted per unit of energy. The lower the orange dot, the greener the energy. As can be seen from the graph, the blue bar for UNH is the highest, but their orange dot is the lowest. They used the most energy per square foot but generated the smallest amount of emissions from that energy.

Figure 9. Energy per unit area Compared to Emissions per unit Energy



Durham has already taken steps to help reduce emissions from the Built Environment category by implementing a stretch code on building insulation. This requires new buildings to be insulated to the levels required in the next colder climate zone. Having more insulation reduces the amount of fuel needed to heat buildings and can help keep them cooler in the summer (therefore reducing the need for air conditioning as well). Because of the type of data available, however, the method used to calculate the Built Environment emissions (specifically, the use of fuel oil, propane, and wood), does not capture the potential emissions reductions that would result from this stretch code. Therefore, the Built Environment emissions presented here are likely an overestimation of the Town's emissions from this category.

Transportation

The Transportation category is Durham's second largest source of emissions, emitting 39,258 tCO_2e in 2019, which is 44.8% of community-wide emissions. These emissions result from on-road passenger and freight motor vehicles driven through and within Durham. Method TR.1.B from the USCP was used to calculate the transportation emissions, and detailed explanations of the method can be found in Appendix B. Emissions from rail were determined to be insignificant (less than 1 tCO_2e annually) based on the frequency of rail as well as track distance within Durham's boundary.

The average daily vehicle miles traveled (VMT) in Durham is estimated to be 240,185 VMT[1], and the average annual vehicle miles traveled is 87,667,582 VMT [6]. To put those numbers into perspective—the Moon is 238,900 miles away and the Sun is 93,400,000 miles away! These VMT are not just a result of Durham residents, but also from commuters coming from outside of the Town, and vehicles simply passing through. In fact, it is assumed that a large portion of the miles traveled in Durham are from pass-through traffic, which is preferably not included in a community-wide footprint because it is not a direct consequence of the Town's land use or activities, and the Town has little influence over it. However, data for transportation within Durham that excludes the pass-through traffic is not yet available. This is the method that is most commonly used by communities to calculate Transportation emissions, but it is likely an overestimation.

The National Vehicle Mix [10] was used to determine types of vehicles. As shown in Figure 10, on-road vehicles are separated into three categories: Light Duty, Heavy Duty, and Motorcycles. Most passenger vehicles are categorized as "Light Duty" vehicles, including sedans, coups, SUVs, small vans, and pickup trucks. "Heavy Duty" vehicles include any road vehicle larger than the Light Duty vehicles, like large vans, buses, commercial trucks, and semi-trucks. The "Motorcycle" category includes both motorcycles and mopeds.

Figure 10. National Vehicle Mix

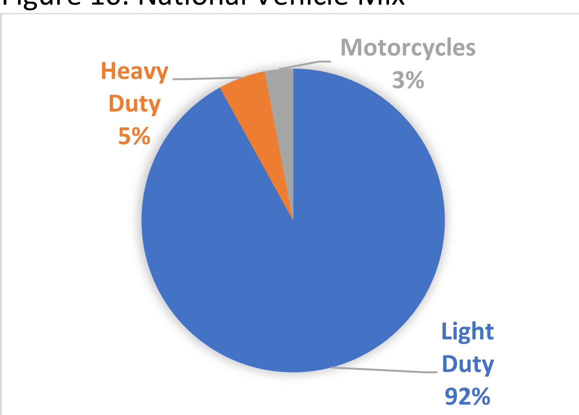
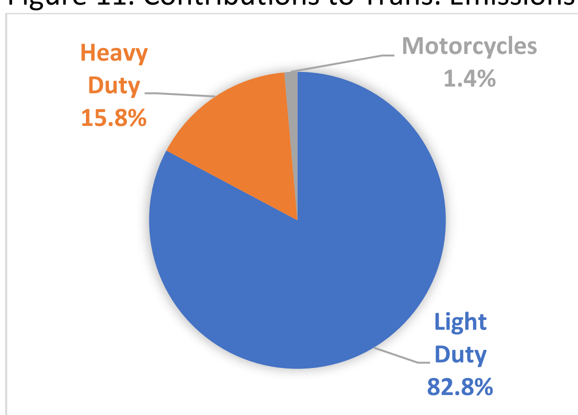


Figure 11. Contributions to Trans. Emissions



[1] Disclaimer: Traffic volume estimates and regional factors are intended for use in target setting for National Performance Management Measures, specifically those described in 23CFR Part 490 only. Estimated values included in HPMS or values derived from those estimates may not be applicable to other analyses and may not correlate with measured traffic volumes.

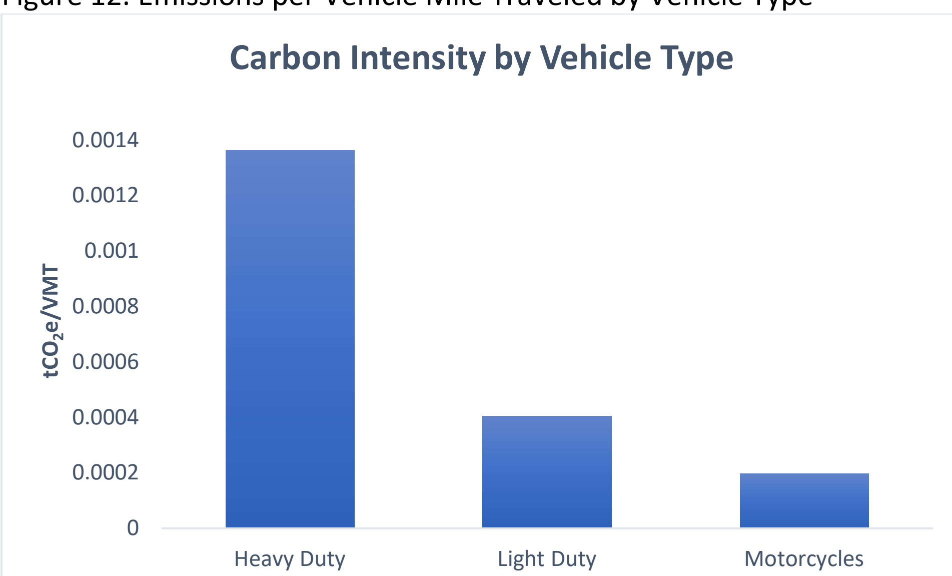
Emissions from electric vehicles are not counted in the Transportation category because they are already accounted for in the electricity portion of the Built Environment emissions. However, the Town should keep track of the number of electric and hybrid vehicles registered each year to see progress towards vehicle electrification and fossil fuel reduction. This will also help to monitor the demand for electric charging stations. In 2019, there were 53 electric cars and 185 hybrid cars registered in Durham.

There was a total of 39,258 tCO_2e from the Transportation category in 2019, with 32,492 tCO_2e (82.8%) coming from Light-Duty vehicles, 6,218 tCO_2e (15.8%) coming from Heavy-Duty Vehicles, and 548 tCO_2e (1.4%) coming from Motorcycles, as shown in Figure 11. Comparing these emissions to the community-wide inventory, Light-Duty vehicles, Heavy-Duty vehicles, and Motorcycles accounted for 37.1%, 7.1%, and 0.6%, respectively.

It is important to note that these emissions do not take into account the compressed natural gas-powered fleet that UNH operates, which would lower emissions, and also does not account for the moped use on campus, which would likely increase emissions. The transportation emissions for the municipal fleet, from the 2019 Municipal GHG Inventory Report [11], were estimated to be 493 tCO_2e, or about 1.5% of the total transportation emissions.

While the Light-Duty vehicles are responsible for most of the Town's transportation emissions, it is not because they are the most carbon-intense type of vehicle, but because they represent the vast majority of the vehicles driven in Durham. Figure 12 shows the emissions per VMT for each vehicle type. It is clear that the most carbon-intense vehicle type is the Heavy-Duty vehicle, with more than three times the emissions of the Light-Duty vehicles per mile, and almost seven times more than the Motorcycles.

Figure 12. Emissions per Vehicle Mile Traveled by Vehicle Type



Solid Waste

The Solid Waste is Durham's smallest source of emissions, emitting 680 tCO_2e in 2019, which is 0.8% of community-wide emissions. Solid Waste emissions are a result of solid waste generated within the community. For the Durham community (consisting of residents, commercial, and municipal), UNH, and ORCSD-D, the solid waste is sent to the Turnkey Landfill in Rochester, NH. The Solid Waste emissions for Durham as a whole in 2019 were split almost evenly between Durham, UNH, and ORCSD-D, as shown in Table 7.

Table 7. Solid Waste Emissions by Sector

Sector	Emissions (tCO_2e)	% of Solid Waste Emissions
Durham	247	36.3%
ORCSD-D	185	27.2%
UNH	249	36.5%
Total	680	-

When solid waste is sent to a landfill, as it decays, it produces methane, which is normally released into the atmosphere. However, the Turnkey Landfill captures this methane. The landfill gas is then used to power the landfill facility and is also piped to UNH through the EcoLine™ where it is used in the UNH Co-generation plant. When the methane is burned for energy, it gets converted to carbon dioxide, so it still produces emissions, but less so than methane. Therefore, the Solid Waste emissions are relatively low; if the waste were sent to a landfill that did not capture and use the methane for energy, the emissions would be 807% higher (5,492 tCO_2e). The methods for how the Solid Waste footprint was calculated can be found in Appendix C.

Wastewater

The Wastewater category is Durham's second smallest source of emissions, emitting 1,290 tCO_2e in 2019, which is 1.5% of community-wide emissions. This category includes the fugitive emissions from the treatment of wastewater produced in the Town. There are two sources of emissions in this category: the Wastewater Treatment Plant (WWTP) and septic tanks. The energy used to power the WWTP is included in the Built Environment category. As shown in Table 8, 85.6% of wastewater emissions were due to septic tanks and 14.4% were due to the WWTP, which serves both UNH and the larger Durham community.

Table 8. Wastewater Emissions by Sector

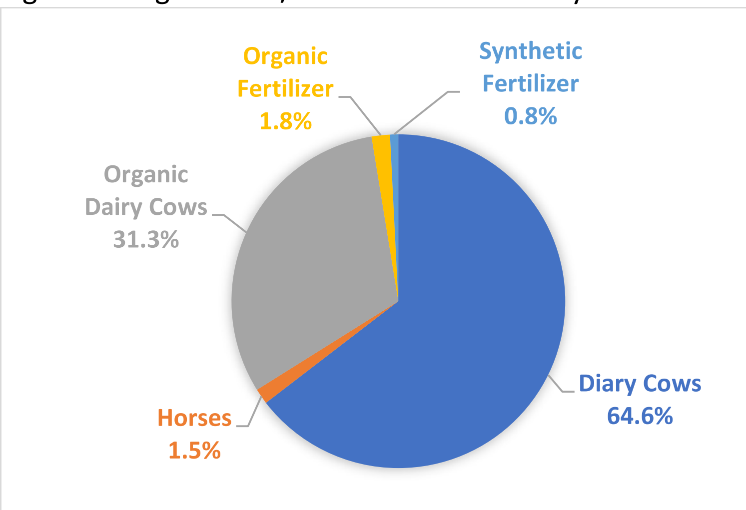
Sector	Emissions (tCO_2e)	% of Wastewater Emissions
Septic Tanks	1,104	85.6%
WWTP (Durham sewer lines)	102	7.9%
WWTP (UNH campus sewer lines)	84	6.5%
Total	1,290	-

The Durham WWTP has a very good nitrogen removal performance, as explained in detail in the Municipal GHG Inventory Report [11]. Therefore, the emissions from the WWTP are already relatively low. Because of the efficiency of the WWTP and the large portion of Durham residents who use septic tanks, most of the emissions from this category come from the fugitive methane released in the use of septic tanks. The methods for the calculation of the Wastewater footprint can be found in Appendix D.

<u>Agriculture/Livestock</u>

The Agriculture/Livestock category emitted 1,935 tCO_2e in 2019, which is 2.2% of community-wide emissions. These emissions are from the use of fertilizer and livestock at UNH. Accurate data for emission sources outside of campus were not readily available, and it was assumed that the number of livestock and the use of fertilizer in the rest of the Town were small compared to UNH. Therefore, emissions for this category outside of campus were not included. Figure 13 shows the share of each source of emissions for the Agriculture and Livestock category.

Figure 13. Agriculture/Livestock Emissions by Source



Sequestration Potential

The Potential Sequestration category includes emissions reductions from activities and land-use within the Town, including composting, land use sequestration, and purchasing of RECs. While the US Community Protocol does not allow these reductions to be directly subtracted from the total emissions, they are important values to be aware of as they can be used to compare with the total emissions and to track the Town's progress.

Composting would allow for emissions reductions within the Solid Waste category. At the time of this inventory, composting data were only available for the UNH and Municipal sectors, and not for the Residential, Commercial, and ORCSD-D sectors. In the UNH dining halls, 148 tons of food waste was generated, composted, and reused as fertilizer, equating to a sequestration potential of 43.6 tCO_2e. The Durham Transfer Station received approximately 20 tons of organic materials from municipal operations. However, since the use of the compost is unknown, its sequestration potential could not be calculated. As for the remaining sectors, a follow-up study is in progress thanks to efforts by the Durham Integrated Waste Management Advisory Committee and the Oyster River Cooperative School District Sustainability Committee.

Land Use is a unique category within the US Community Protocol because it can be both a source of emissions and can sequester emissions. These emissions and removals occur due to change in land-use over a specific period. For example, if an old, paved parking lot in the Town is converted to an area with trees, it would increase carbon removals because of the trees' ability to sequester carbon. However, if a field is turned into a paved parking lot, the carbon stored within the trees would be released into the atmosphere, increasing Durham's emissions. The Summer 2021 fellow investigated Durham's land use changes from 2006-2016 and found that Durham emitted approximately 2,691 tCO_2e/year and sequestered approximately 28,161 tCO_2e/year – approximately 31.2% of Durham's emissions (including land use emissions). More information about the land use sector can be found in that report. [14]

UNH, the Town of Durham, and ORCSD-D also purchase RECs. If the combination of RECs and UNH's compost were applied to Durham's emissions (excluding land use), Durham's total emissions would be reduced by approximately 2.53%. This percentage is higher than the Agriculture/Livestock (2.2%), Wastewater (1.5%), and Solid Waste (0.8%) contributions to Durham's 2019 emissions, meaning it is not a trivial amount.

Discussion and Recommendations

Comparison to the 2007 Inventory

In 2007, with the help of a UNH student, Durham conducted a greenhouse gas inventory [2]. This inventory included less categories and used very different assumptions and methods than the 2019 inventory. For example, the 2007 inventory's transportation emissions were calculated by using the number of cars registered in Durham, the national mpg average for efficiency, and the national average number of miles driven in a year to calculate the amount of gasoline used. In comparison, the 2019 inventory calculated transportation emissions by using the average yearly vehicle miles traveled in Durham as well as the national vehicle mix to calculate the number of gallons of diesel and gasoline.

Because differences between the 2007 and 2019 inventories are so great, any comparisons between the two should be done with caution. Nevertheless, when comparing only the categories that overlap between the 2007 and 2019 inventories, total emissions decreased by 21%. Because each inventory used different assumptions, it is impossible to know the true change in emissions without recalculating the 2007 inventory with 2019 methods. However, it is likely that total emissions decreased, particularly because emissions from the electric grid alone decreased by 37% based on the amount of emissions per KWh.

Recommendations

Due to the lack of available, localized data, yearly tracking of GHG emissions would not be an efficient or even accurate way to see the changes that Durham is making. However, there are several things that Durham could keep track of other than GHG emissions that would still show the Town's progress towards becoming more sustainable because they can be directly measured by the Town on a yearly basis. Examples include the total amount of solid waste sent to the landfill each year versus the amount recycled or composted, the number of electric and hybrid vehicles registered in Durham, and the amount of electricity used from Town-owned charging stations. Those data points are information that the Town already has access to, and additional data points could be collected using surveys or other types of public input. This may include the number of residences and commercial buildings that have solar panels (and what size), how many residences or businesses compost (and roughly how much), and how many residences or businesses have newly installed high efficiency electric heat pumps.

Because 95.5% of the total emissions come from the Built Environment and Transportation categories, these are the categories where much of the emission reduction efforts should be focused. However, emissions reductions from other categories should still be pursued because even small emissions reductions are still reductions.

The Residential sector produced most of their emissions from the use of stationary fuel (55.3%) with 33.9% coming from fuel oil. This is a common heating source in New England, but it is very carbon intensive. Efforts should be made to help residents switch to other heating sources such as high efficiency electric heat pumps. To further reduce emissions from the Residential sector, efforts should be made to help residences switch to greener power sources, such as solar arrows, and to increasing energy efficiency. By switching to greener electricity while also reducing the amount of electricity used, the residential sector could drastically lower their emissions.

Another reduction strategy is Community Power Aggregation. This is when a municipality purchases electricity from the whole-sale market for the entire community, and therefore can choose to purchase electricity from different energy sources. If Durham decided to take this route and purchase electricity for residences from only renewable sources, it could reduce the Residential Built Environment emissions by 44.7%, Built Environment emissions by 13.7%, and the community-wide emissions by 6.9%. Since the electricity is purchased in bulk, it is also generally less expensive than when each resident purchases their electricity separately, meaning it could also result in cost savings. There are several ways of going about a Community Power Plan so the Town should decide what would work best for Durham. One option is to become a member of the Community Power Coalition of New Hampshire, a non-profit Joint Powers Agency that helps municipalities create and run Community Power programs.

Within the Commercial sector, much of the emissions were generated from the use of natural gas (57.2%). Many of the businesses in the downtown area are restaurants, so it is assumed that much of this natural gas use is from cooking, but it would be beneficial to figure out the actual usage by way of surveys. A strategy to reduce emissions from the Commercial sector would be to switch from fuel oil and gas to electricity wherever possible. Automation and energy efficiency should also be encouraged as this could reduce emissions even further.

UNH already has a relatively low carbon intensity from the Built Environment category because they produce much of their own electricity and heating using their Co-Generation plant, powered mainly by landfill gas. To help UNH further reduce their Built Environment emissions, the Town should help to support them in energy efficiency efforts.

Within the Transportation category, it is difficult to make meaningful recommendations until more accurate data becomes available. However, the Town has already taken several steps to encourage walking, biking, and electrification, and should continue with those efforts. For the Solid Waste sector, there should be efforts to reduce the amount of waste that gets sent to the landfill, especially because the Turnkey Landfill methane-capture project will be reaching the end of its life around 2030. By diverting organic waste from the landfill and instead composting it, emissions from the Solid Waste sector can be reduced.

The most important thing that Durham can do to reduce their overall emissions is to engage the public. Significant emissions reductions will not be possible if the public is not actively involved in these reduction efforts. A few suggestions that can be used to involve the public would be to use the Friday Updates to share information, conduct surveys, and to regularly update the Town's website. The 2021 Summer Fellow will be exploring in more detail ways that Durham can use community outreach to both inform and involve the public.

References

[1] Michael Behrendt. email communications. Durham Town Planner.
[2] Scott Cloutier. *Durham, New Hampshire, Greenhouse Gas Inventory, 2007*. Durham Energy Committee, 2008.
[3] Kendall Gray. *Greenhouse Gas Inventory Report (FY14-20)*. Oyster River Cooperative School District, 2020.
[4] *Introduction and Key Concepts: State Energy-Related Carbon Dioxide Emissions Tables*. Tech. rep. Table 5: Per capita energy-related carbon dioxide emissions by state (1990-2018). Environmental Protection Agency. URL: https://www.eia.gov/environment/emissions/state/.
[5] Justin Klingler. *Climate Resilience Assessment and Planning: Durham NH*. UNH Sustainability Institute, Town of Durham, 2019.
[6] Rachel Dewey Kyle Pimental. email communications. Strafford Regional Planning Commission.
[7] Kelly Levin and Katie Lebling. *CO2 Emissions Climb to an All-Time High (Again) in 2019: 6 Takeaways from the Latest Climate Data*. World Resources Institute, 2019. URL: https : / / www . wri . org/insights/co2- emissions- climb- all- time- high- again- 2019- 6- takeaways- latestclimate-data.
[8] Valerie Masson-Delmotte et al. *IPCC, 2018: Summary for Policymakers*. Tech. rep. World Meteorological Organization Technical Document, 2018, p. 32.
[9] Global Covenant of Mayors for Climate and Energy. URL: https://www.globalcovenantofmayors. org/.
[10] *National Vehicle Mix*. US Department of Transportation. URL https://www.fhwa.dot.gov/policyinformation/statistics/2018/vm1.cfm.
[11] Mary Potts. *Addressing Durham's Climate Impact: Municipal Greenhouse Gas Inventory and Estimation of Carbon Benefits in Conservation Land*. UNH Sustainability Institute, Town of Durham, 2020.
[12] Jim Rice. email communications. Durham Assessor's Office.
[13] *Statements and Releases*. April 21, 2021. The Whitehouse Briefing Room, 2021. URL: https://www. whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-presidentbiden- sets- 2030- greenhouse- gas- pollution- reduction- target- aimed- at-creatinggood-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/.
[14] Cathy Fletcher. *Exploring Land Use as an Aspect of Community Climate Action: Land Use Greenhouse Gas Inventory*. UNH Sustainability Institute, Town of Durham, 2021.
[15] U.S. Census Bureau. (2019). *2015-2019 American Community Survey 5-year Demographic and Housing Estimates* [SAS Data file]. Retrieved from https://data.census.gov/cedsci/table?tid=ACSDP5Y2019.DP05&g=0400000US33_1600000US33 19620

Appendices

Appendix A – Built Environment

A. Built Environment Methods

The GHG emissions from the Built Environment were calculated using the methods outlined in Appendix C of the US Community Protocol. There are several fuel types used in the Stationary Fuels emissions category, and emissions for each fuel type were calculated separately for each sector.

In the Residential sector, emissions from the combustion of natural gas, propane, fuel oil (#2), and wood were calculated. The activity data for natural gas was provided to us by the natural gas utility company in Durham, Unitil. Residential activity data for all other fuels were estimated using data from the American Community Survey (ACS) and the US Energy Information Administration (EIA). Method BE 1.1 is shown below. This was the only method used to calculate the natural gas emissions since the activity data was already known. For the other fuels, Method BE 1.2 was used to estimate the usage data, and then the results were plugged into method BE 1.1 to calculate the emissions.

BE 1.1. Calculating Emissions from Stationary Fuel Combustion
Step 1: Determine annual use of each fuel combusted by each sector (residential, commercial, industrial) in your community.
Step 2: Determine the appropriate CO_2 emission factors for each fuel.
Step 3: Determine the appropriate CH_4 and N_2O emission factors for each fuel.
Step 4: Calculate each fuel's CO_2 emissions.
Step 5: Calculate each fuel's CH_4 and N_2O emissions.
Step 6: Convert CH_4 and N_2O emissions to CO_2 equivalent and determine total emissions.

BE 1.2. Estimating Fuel Use in the Residential Sector
Step 1: Obtain the total number of households in your state that use the fuel type for any purpose from the Energy Information Administration's (EIA) Residential Energy Consumption Survey dataset, Tables HC1.8 – HC1.11.
Step 2: Obtain the total state-level fuel use from the Energy Information Administration (EIA) State Energy Data System (SEDS) for each fuel type.
Step 3: Calculate per-household energy use by dividing total fuel use obtained in Step 2 divided by the total households using the fuel type, obtained in Step 1.
Step 4: Obtain the number of households that use the fuel in your community using American Community Survey data from Census.gov.
Step 5: Calculate total residential fuel use by multiplying per-household energy use, calculated in Step 3 by the total number of households that use the fuel, obtained in Step 4.

For the Commercial sector, the emissions from natural gas usage were calculated using BE 1.1 since that activity data was provided by Unitil. Information about commercial buildings in Durham was provided by the Durham Assessor's Office. This information included the square footage, year built, primary use, owner, lot number, and heating type (oil, gas, or electric).

Many of the commercial buildings in the downtown area of Durham have apartments above the commercial first floor, but the square footage given in the Assessor's data is the total square footage of the entire building. Since the emissions from the residential sections of these buildings are already included in the Residential Sector, I needed to make sure I was only using the commercial square footage in my emissions calculations for the Commercial Sector. To do this, I used the Street View on Google Maps to figure out how many floors each combined residential/commercial building had. I then made two assumptions—first, that there was only one floor of commercial space, with the rest being residential, and second, that each floor had the same area. Then I simply took the total square footage, and divided by the number of floors, to determine the area of just the commercial space. BE 1.3, shown below, was used to estimate the fuel oil use in the Commercial sector.

BE 1.3. Estimating Fuel Oil Use in the Commercial Sector
Step 1: Obtain data on commercial buildings in your community.
Step 2: Calculate the total number of buildings that use the fuel in your community by applying the appropriate factor from Table B.6 for your region.
Step 3: Classify your community's buildings according to building age, size, or primary usage depending on the information that is available in you building records.
Step 4: Estimate the total square footage of building space in each class, by using either known building information or by applying a best available average building size.
Step 5: Calculate total fuel usage by applying the appropriate building energy intensity factor from Table B.7 which matches your building classifications.

The information needed for Steps 2, 3, and 4 was obtained from the Durham Assessor's office. For Step 5, the building energy intensity factor was taken from the 2012 US Commercial Building Energy Consumption Survey (most recent data available), using the building age and the census region. Once the commercial fuel oil usage was calculated, the results were plugged into BE 1.1 to calculate the emissions.

As mentioned above, the heat type for the commercial buildings was listed as oil, electric, or gas, but did not specify what type of gas was used. The natural gas usage was known from the utility, but propane use needed to be estimated. To do this, I compared the location of each "gas" building, with a map of the natural gas pipeline from Unitil to determine if the building had access to natural gas. I assumed that if the building had access to the pipeline that it used natural gas, and that if it did not have access to the pipeline, that it used propane. I then calculated the total square footage of commercial space that used natural gas and the total that used propane. I found that 72% of the commercial area listed as "gas" used natural gas, and 28% used propane. I then assumed that 72% of the total energy used by gas was from natural gas, and 28% was from propane use. Because I knew the total energy used from natural gas (from the utility data), I was then able to calculate the total amount of energy used from gas, and then the energy used from propane. Once I had estimated the amount of propane used, I then calculated the emissions from it using BE 1.1.

The activity data for UNH and the Municipal Sector were known directly and were already recorded in SIMAP. Because I had access to both the UNH and Town of Durham accounts on SIMAP, I was able to simply use the results calculated in SIMAP for each fuel type and sector. The stationary fuel emissions from the Durham buildings of the Oyster River Cooperative School District (ORCSD-D), were provided by Kendall Gray who wrote their GHG Inventory Report for 2019. SIMAP was used to calculate these emissions, but the activity data was not given to us.

BE 2.1 was used to calculate emissions from electricity use. Electricity usage data for the Residential and Commercial Sectors were provided by Eversource, the only electric utility in Durham. Again, for UNH and the Municipal sector, electricity use and emissions were already in SIMAP. Emissions factors for the NEWE eGRID region were used to calculate the electricity emissions.

BE 2.1 Emissions from Electricity Use
Step 1: Obtain your community's annual electricity use.
Step 2: Select or obtain the appropriate emission factor(s) for the electric utility serving the community.
Step 3: Calculate the community's annual CO_2e emissions associated with electricity use.

Some electricity is lost as it travels from where it is produced to where it is used. This means that if we only account for electricity emissions from the amount of electricity used, then we would be under-counting emissions because more electricity is generated than is used (due to the losses along the way). BE 4 was used to calculate the emissions from the transmission and distribution (T&D) losses associated with electricity use.

BE 4. Emissions from Electric Power Transmission and Distribution Losses
Step 1: Obtain your community's annual electricity use, as tabulated in BE.2.
Step 2: Determine the appropriate CO_2e electricity emission factor. Use the same factor (for either eGRID subregion or utility) that you used in calculating emissions from community electricity use in BE.2.
Step 3: Obtain your community's regional electricity T&D loss factor. These are tabulated on an annual or biennial basis in the U.S. EPA's eGRID database.
Step 4: Calculate your T&D CO_2 emissions from Equation BE.4.1.1.

Equation BE.4.1.1 Calculating Electricity GHG Emissions Using a CO_2e Emission Factor

Annual CO_2e emissions (metric tons/year) =

$$\frac{\textit{Community electricity use} \times \textit{grid loss factor} \times CO_2\,e\ \textit{emission factor}}{2204.6}$$

Where:

- Electricity is the community's annual electricity use in MWh from Step 1,
- the CO_2e emission factor is the combined carbon dioxide *equivalents* emission factor from Step 2 in lbs/MWh,
- the grid loss factor is from Step 3, and
- 2204.6 is the conversion factor to convert from pounds to metric tons.

Appendix B – Transportation

B. Transportation Methods

The emissions from transportation within Durham were estimated in two ways. The first, with the results presented in the main report, used method TR.1.B from Appendix D of the US Community Protocol. I'll call this method the "National Mix Method". The second method used TR.1.B in combination with more localized data, and will be referenced as the "Local Mix Method".

TR.1.B Alternative Method for Estimating In-Boundary Passenger Vehicle Emissions
Step 1: Estimate vehicle miles traveled within jurisdiction.
Step 2: Calculate CO_2 emissions using equation TR.1.B.2
Step 3: Calculate CH_4 and N_2O emissions for each vehicle type in the same way.

***Equation TR.1.B.2* CO_2 Emissions from Passenger Vehicles:**

Estimate of CO_2 emissions:

$$CO_2 = \sum_{b,f} \left(\frac{VMT \times \%b}{MPG_b} \times Emission\ Factor_f \right)$$

for each vehicle type, *b* (see *Table TR.1.3*), average MPG for *b* (see *Table TR.1.5*), and emissions factor for fuel type, *f* (see *Table TR.1.6*)

	Description	*Value*
VMT	*Annual vehicle miles*	*User Input*
%b	*% of vehicle miles by vehicle type b*	*From local data (Table TR.1.1 conditions L2, L3, or L4), or Table TR.1.3 (condition L5).*
MPG_b	*Average MPG of vehicle type b*	*From local data (Table TR.1.1 conditions L2, L3, or L4), or Table TR.1.5 (condition L5).*
Emissions $Factor_f$		*From TableTR.1.6*

Source: Adapted from The Local Government Operations Protocol, based on various EPA Inventory Appendices and Guidance Documents.

The Vehicle Miles Traveled (VMT) for Durham were provided by the Strafford Regional Planning Commission (SRPC) in partnership with the New Hampshire Department of Transportation. The VMT were generated for 2016. For the National Mix method, the total VMT were used, along with the national vehicle mix, and a regional fuel mix (provided by Karina Graetor at the Southern Maine Planning and Development Commission). This method is thought to be an overestimation of emissions from Heavy Duty vehicles because those types of vehicles are not very common in Durham except potentially on State Route 4. This is why we also calculated the emissions using a second method.

For the Local Mix method, the VMT were separated by road type into two categories: State Roads (Route 4, red road in Figure B.1.) and Local Roads (all other roads in Durham). For these two categories, 44% of all VMT were on Rt. 4, and 56% were on Local Roads. It is predicted that a large portion of the VMT on Rt. 4 are from pass-through traffic and would include a larger percentage of Heavy-Duty vehicles than the Local Roads. Therefore, the national vehicle mix was used to calculate emissions on Route 4 and the “local vehicle mix” was used to calculate the emissions on all other roads. The local vehicle mix consists of the vehicles registered in Durham in 2019. The same regional fuel mix was used for both methods

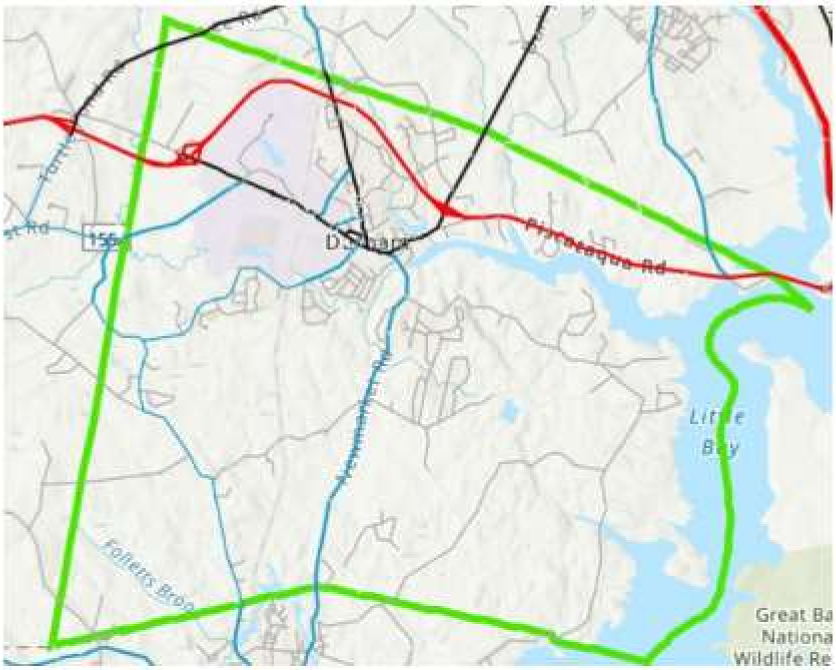


Figure B.1: Durham Road Types

The emissions results from the Local Mix method were 7% lower than the National Mix method, with total emissions of 36,511 tCO_2e. This would bring the total community emissions down by 3% to 77,901 tCO_2e. It is likely that the Local Mix method is a more accurate estimate of Durham’s transportation emissions, but until more localized data is available it is hard to say for sure.

Appendix C – Solid Waste

C. Solid Waste Methods

The Municipal Solid Waste emissions for Durham were initially reported in the Municipal GHG inventory in 2020. For this report, the initial data was used in SIMAP to recalculate the emissions using the most up to date emissions factors. The solid waste emissions for UNH were also calculated in SIMAP, and the emissions results for ORCSD-D were sourced directly from their report.

Appendix D – Wastewater

D. Wastewater Methods

Wastewater emissions come from two main sources in Durham—the Wastewater Treatment Plant (WWTP) and septic tanks. The emissions from the WWTP were calculated using SIMAP since the activity data for the plant was already recorded in the tool for the Municipal Inventory. The activity data for the WWTP also includes the wastewater from UNH.

The emissions from the use of septic tanks were calculated using method WW.11(alt) from the US Community Protocol. This alternative method was chosen because we had the necessary data to calculate it, whereas for the preferred method, we did not. For WW.11(alt) the only information needed is the population served by septic tanks. We did not have this exact value, but the protocol also presents a way to estimate this. For communities under 50,000 people, it says to estimate that 90% of the community is served by septic tanks. Therefore, the population of Durham residents, plus the number of students living off campus, were used to calculate the emissions resulting from septic tanks. Below is a picture of the equation used.

***Equation WW.11(alt)* Alternate Methane Emissions from Septic Systems**

Annual CH_4 emissions = (P x BOD_5 load x Bo x MCFs x 365.25 x 10^{-3}) x GWP

Where:

Description		Value
Annual CH_4 emissions	= Total annual CH_4 emitted by septic system ($mtCO_2e$)	Result
P	= Population served by septic system	For some Metropolitan Areas see Table WW.11(alt) For all other areas multiply population of community by rural or urban default from Table WW.11(alt).2
BOD_5 load	= Amount of BOD_5 treated per day (kg BOD5/person/day)	0.090
Bo	= Maximum CH_4 producing capacity for domestic wastewater (kg CH4/kg BOD_5)	0.6
MCF_s[29]	= CH_4 correction factor for septic systems	0.22
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{CH_4}	= Global Warming Potential; conversion from mt of CH_4 into mt of CO_2 equivalents	GWP[30]

Source: *As listed in LGO protocol Equation 10.5 from EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006, Chapter 8, 8-8 (2008).*

Appendix E – Agriculture and Livestock

E. Agriculture & Livestock Methods

The Agriculture & Livestock emissions category is not a mandatory reporting category but was included because of the significant number of livestock and amount of fertilizer used on the campus of UNH. Specific data for livestock and fertilizer in the rest of Durham was not available, but it was assumed to be significantly less than that of UNH and was therefore excluded from this calculation. Because we decided to only use the activity data from UNH, the emissions presented for this category were calculated in the UNH SIMAP account.

Appendix F – Additional Sequestration

F. Additional Sequestration Methods

The sequestration from the UNH compost was calculated in SIMAP and the results were taken directly from that. The land use emissions and sequestration in Durham were taken from the 2021 Exploring Land Use as an Aspect of Community Climate Action: Land Use Greenhouse Gas Inventory report. [14]
To calculate the emissions reductions from the use of RECs, the amount of electricity purchased through RECS (kWh) from each sector was subtracted from the total electricity purchased by each sector. That result was then multiplied by the "residual" emissions factor for electricity, taken from SIMAP, giving the new total emissions from electricity for each sector. These two results were then added together for the total emissions from electricity including the use of RECs. To calculate the emissions reduction, the electricity emissions that included RECs were subtracted from the total electricity emissions.

Appendix G – Usage and Activity Data

G. Usage and Activity Data Methods

Table G.1: Energy Use from the Built Environment Category for each Sector and fuel source (with purchased electricity).

Energy Use (MMBtu)							
Source	**Fuel Oil**	**Propane**	**Natural Gas**	**Wood**	**Electricity**	**Landfill Gas**	**Total**
Residential	62,579	11,524	41,687	1,423	86,715	-	**203,928**
Municipal	378	677	2,352	0	7,089	-	**10,496**
Commercial	2,155	43,640	114,936	0	27,713	-	**189,814**
UNH(non Co-generation)	8,565	7,370	107,781	13,296	27,713	-	**164,726**
UNH (Co-generation)	15,260	0	132,778	0	0	668,585	**816,623**

Energy Use data was not available for ORCSD-D, only total emissions were available.

Table G.2: Vehicle Miles Traveled (VMT) and Fuel Usage for each vehicle type.

National Mix (All Roads)			
Source	**Total VMT**	**Gallons Gas**	**Gallons Diesel**
Light Duty	80,332,448	3,692,520	44,990
Heavy Duty	4,558,315	178,266	459,250
Motorcycles	2,776,819	63,162	0
Total	**87,667,582**	**3,933,948**	**504,240**

These values are from the "National Mix Method"

Table G.3: Vehicle Miles Traveled (VMT) and Fuel Usage for each vehicle type.

National Mix Route 4, Local Mix Local Roads			
Source	**Total VMT**	**Gallons Gas**	**Gallons Diesel**
Light Duty	80,754,914	3,692,520	44,990
Heavy Duty	2,809,568	99,694	243,646
Motorcycles	3,726,114	77,847	0
Total	**87,290,595**	**3,870,061**	**288,636**

These values are from the "Local Mix Method"

Table G.4: Amount of Solid Waste received at the Durham Transfer Station in 2019

Durham Solid Waste	
Source	**Short Tons**
Landfilled Waste	1,573
Recycled	825
Compost	20
Total	**2,418**

Table G.5: Usage Data for the Wastewater category

Wastewater Usage Data	
Population Served by Septic Tanks	**Gallons Treated at WWTP**
9,090	350,000,000

Table G.6: Activity Data for the Agriculture & Livestock Category

Agriculture & Livestock Activity Data		
Source	**Quantity**	**Unit**
Animal Husbandry: Dairy Cows	196	Head
Animal Husbandry: Horses	49	Head
Animal Husbandry: Other (Organic Dairy Cows)	95	Head
Fertilizer: Organic	17,921	Pound N
Fertilizer: Synthetic	6,941	Pound N