Updating Nantucket's GHG Inventory

By

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in partial fulfilment of the requirements for the
degree of Bachelor of Science

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Report Submitted To:

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Abstract

In 2011, Nantucket developed a climate action plan, yet it was never adopted. Now the town seeks to create a more robust plan. Our project was to establish a baseline greenhouse gas inventory to set climate action goals and measure progress. We used the Metropolitan Area Planning Council inventory tool to estimate the island's total annual greenhouse gas emissions, and found residential buildings and gasoline cars were the largest sources of emissions. Our survey revealed that the public favors electric vehicles and solar panels to reduce emissions from those sources. Based on our findings, we recommend climate action strategies the Nantucket Energy Office can pursue in the future and how the MAPC can improve the inventory tool.

Acknowledgements

We want to send our sincerest thanks to all the following individuals and organizations for their help in making this project possible.

- We first want to thank our sponsor, Lauren Sinatra, from the Nantucket Energy Office. She was instrumental in guiding us to the resources we needed to create both the inventory and the survey.
- We also want to thank Professor Dominic Golding for his guidance in constructing our reports and his extensive knowledge of the IQP project process.
- Graeme Durovich, Nantucket's Recycling and Solid Waste Coordinator, was a huge help with providing data on and explaining Nantucket's complicated waste streams.
- Paula Leary of the NRTA sent us all the data we needed about Nantucket's public transportation system and helped us form questions for the survey.
- Megan Aki, Clean Energy Analyst II of the MAPC and co-author of the MAPC GHG inventory guidelines, helped tremendously in completing our knowledge of the inventory tool.
- The Town of Arlington, Town of Natick, and City of Melrose were gracious enough to answer our questions about conducting a GHG inventory, or refer us to someone who could.
- All of the people of Nantucket who took the time to take our survey gave us some much needed insight into how the public perceives certain climate action policies.

Executive Summary

Many towns are concerned about the impact of their greenhouse gas (GHG) emissions on the global climate. For this reason many communities are creating climate action plans (CAPs) to mitigate their contributions to climate change. The first step in creating a CAP is often to develop a baseline GHG emissions inventory. These GHG inventories organize gasses by their source and sector to help show where improvements can be made. Over 10,000 cities around the world are joining together to fight climate change through action plans (Global Covenant of Mayors for Climate and Energy, 2020).

Nantucket's Select Board voted to join the Cities for Climate Protection Campaign - a program led by the International Council for Local Environmental Initiatives (ICLEI) - in 2008. As part of the campaign, the town developed a baseline inventory of greenhouse gas emissions and outlined some emissions reduction strategies in the form of their own climate action plan. The plan faced criticism because it did not address the local conditions and specific challenges for Nantucket and was never officially adopted. The Nantucket Energy Office (NEO), founded in 2011, aims to create a new climate action plan more tailored to the local community. As the first step in formulating this plan, Nantucket must perform a revised and up-to-date GHG inventory to serve as a baseline to measure progress on emissions reduction in the future.

The goal of this project was to assist the NEO in developing a baseline inventory of Nantucket's GHG emissions from residential, business, and municipal sectors. To achieve this goal, we identified five objectives:

1. Review MAPC guidelines and usage in other communities;
2. Determine how MAPC Protocol should be modified;
3. Source pertinent data to create the baseline inventory;
4. Gauge public opinion about GHG emissions and emission reduction strategies; and
5. Analyze and interpret key findings revealed by the inventory and explore the most effective way to present them to the local officials and the public.

We developed the inventory following the MAPC guidelines and emissions inventory tools. We modified some elements of the protocols to ensure the inventory accounts for the

special circumstances in Nantucket. Once we identified and obtained the data needed to complete the inventory, we cleaned it and used our modified version of the MAPC tools to create the baseline inventory. We summarized the key findings from the inventory and explored the most effective ways to present the findings to local officials and the public.

Data Analysis and Findings

Inventory Findings

Using the modified MAPC inventory tool, we were able to develop an effective baseline inventory and compile several conclusions regarding Nantucket's greenhouse gas (GHG) emissions. Currently, the inventory tool calculates emissions from the following sectors: stationary energy, transportation, and waste using data from state databases as well as local sources from the town. As shown in Table ES1, the resulting calculations determined that Nantucket's total GHG emissions equated to 141,484 metric tons of carbon dioxide equivalence (MT CO_2e). The stationary energy sector was the largest contributor with 67.6% (95,700 MT CO_2e) of emissions, followed by transportation making up 27.9% (39,527 MT CO_2e) and finally waste with 4.4% (6,257 MT CO_2e) as displayed in Figure ES1.

Table ES1: Community-wide Emissions Summary by Sector & Subsector

Sector	Subsector	Total Emissions (MT CO2e)	Percentage of Total Emissions
Stationary Energy	Residential Buildings	67,804	47.9%
	C&I Buildings & Manufacturing Industries*	23,065	16.3%
	Municipal Buildings	4,831	3.4%
	Construction	0	0.0%
Transportation	Passenger Vehicles	33,244	23.5%
	Commercial Vehicles	4,321	3.1%
	Municipal Vehicles	1,260	0.9%
	On-road Buses and Trolleys	702	0.5%
	Railways	0	0.0%
Waste	Solid Waste Disposal	0	0.0%
	Biological Treatment of Waste	4,386	3.1%
	Incineration and Open Burning	0	0.0%
	Wastewater Treatment and Discharge	1,871	1.3%
	All Sectors & Subsectors	**141,484**	

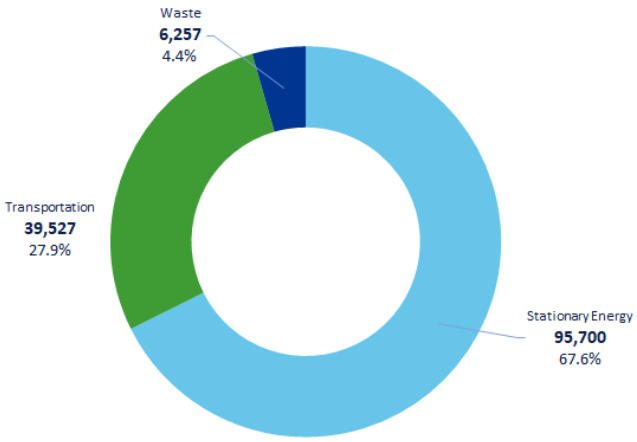

Figure ES1: Community-wide Emissions by Sector in MT CO_2e

For stationary energy, it was evident that buildings were responsible for the majority of CO_2e produced with the private sector being the dominant driver and municipal buildings having less of a significant impact as illustrated in Figure ES2. Upon further analysis, this was mainly attributed to high electricity and propane usage with electricity being 46% and propane comprising 36% of building emissions. This was mostly expected since propane is a popular heating fuel used on Nantucket. Overall, this sector poses a challenge for most communities in Massachusetts as it typically emerges as the largest source of emissions. This highlights a key opportunity area for communities like Nantucket who are looking to find ways to decrease their total emissions. Ultimately, the majority of improvements would need to be targeted towards residential and commercial buildings as they are the largest contributors.

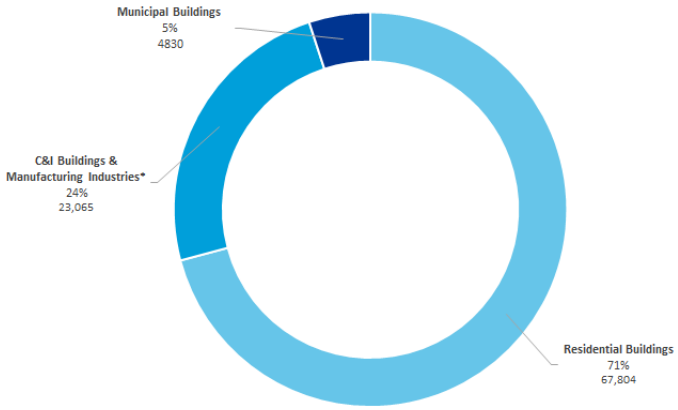

Figure ES2: Percentage of Stationary Energy Emissions by Subsector*

*Off-road included in the C&I Buildings & Manufacturing Industries subsector

The second largest contributor of emissions on the island was found to be transportation. The MAPC inventory tool splits this sector into emissions that result from different types of vehicles (passenger, commercial, municipal, etc.) and several types of fuels like gasoline and diesel. Based upon the results, passenger vehicles are by far the most prevalent emitters of transportation emissions making up 84% of the sector's CO_2e as shown in Figure ES3. This is likely a factor of passenger vehicles being the most common vehicle type registered with the town. This also correlates with gasoline being a substantial source of GHGs in the sector which accounted for 95% of all emissions. The inventories of Natick and Arlington also had similar findings within their transportation sectors.

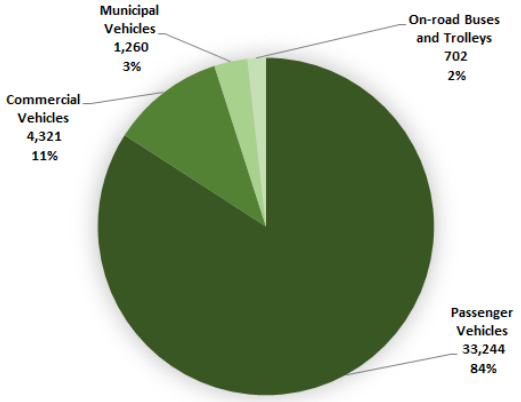

Figure ES3: Transportation Emissions (MT CO_2e) by Sector

The smallest proportion of the communities GHG emissions were attributed to the waste sector which includes emissions generated by the treatment of wastewater and the breakdown of solid waste. As shown in Figure ES4, the subcategory breakdown reveals that wastewater treatment accounts for 1,871 MT CO_2e or about 30% of waste emissions, while solid waste disposal by composting accounts for the other 4,386 MT CO_2e or around 70%. Compared to the inventories made by Natick and Arlington using the same protocols, Nantucket's waste makes up a higher percentage. However, neither Arlington nor Natick reported any emissions from composting waste, so their subcategory data is not comparable. The differences in percentages and subcategories are most likely due to the differences in how these towns and Nantucket manage solid waste, especially since Nantucket's waste management is unique amongst Massachusetts towns.

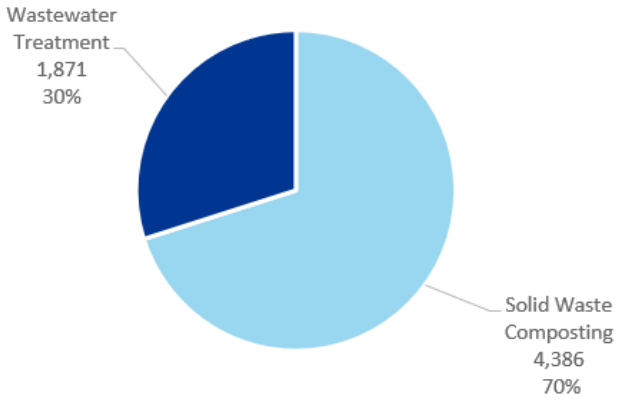

Figure ES4: Emissions (MT CO_2e) by Waste Subcategory

Survey Findings

In coordination with the Nantucket Energy Office (NEO), we conducted a climate action planning survey for the residents of Nantucket to gauge their opinion on various emission mitigation strategies. The goal was to highlight initiatives supported by the public for the NEO to possibly pursue in the future. The questions included in the survey assessed what types of actions Nantucket should prioritize to help mitigate emissions, and allowed people to express their own personal thoughts on the current climate situation and how to address it.

The survey results indicate that most emission reduction strategies were supported by the majority of respondents. The measures that had more divided responses referred to a 'pay as you throw' system and transitioning to electric vehicles. In contrast, the initiatives that were highly supported included installing home solar, developing more island based renewables, electrifying public transport, and expanding bike and pedestrian infrastructure. In addition, Nantucketers expressed their support for adopting a Climate Emergency Declaration, as they are becoming increasingly concerned about the futures of their children and the island.

Recommendations

Based on the findings, the team came up with recommendations for the stationary energy, transportation, and waste sectors.

For the stationary energy sector we recommended that the town should prioritize convincing people to switch to renewable energy sources like solar panels and increase

incentives for greener home heating/cooling systems like air source heat pumps. This is because 86% of stationary energy emissions come from private buildings which use large amounts of heating oil, propane, and other fossil fuels. Installation of home solar panels are also a popular option for going green based on the survey results.

In the transportation sector the team suggested the town further incentivize switching to electric cars and improve biking and pedestrian infrastructure. The town should consider this because 84% of transportation emissions come from passenger vehicles and reducing fuel emissions would have the most significant reduction in GHGs for this sector. Both of these options are also the ones most liked by Nantuckters according to the survey.

For the waste sector the town should offer home composting kits at little to no cost to the residents of Nantucket. It is the most popular option based on survey results and will reduce hauler trips and waste overall.

Authorship

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2.2	Callan	All
2.3	Brennan/Jared	All
3	All	All
3.1	Brennan	All
3.2	Jared	All
3.3	Tyler	All
3.4	Brennan	All
3.5	Callan	All
4	All	All
4.1	Tyler	All
4.2	Brennan	All
4.3	Jared	All
4.4	Callan	All
5.1	Tyler/Callan	All
5.2	Brennan/Callan	All
5.3	Jared/Callan	All
Appendix A	All	All
Appendix B	Tyler	All
Appendix C	Tyler	All

Table of Contents:

List of Figures:

List of Tables:

Chapter 1: Introduction

Many towns are concerned about the impact of their greenhouse gas (GHG) emissions on the global climate. For this reason many communities are creating climate action plans (CAPs) to mitigate their contributions to climate change. The first step in creating a CAP is often to develop a baseline GHG emissions inventory. These GHG inventories organize gasses by their source and sector to help show where improvements can be made. Over 10,000 cities around the world are joining together to fight climate change through action plans (Global Covenant of Mayors for Climate and Energy, 2020).

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Chapter 2: Background

Greenhouse gas inventories are becoming common practice in many communities that are increasingly concerned about fossil fuel consumption and climate change. Developing an inventory of GHG emissions is often the first step communities take in developing well-informed policies and strategies to reduce emissions. To make an inventory applicable to Nantucket, our team reviewed prior emission inventories conducted on the island and the history of energy policy on Nantucket. The team then looked into the development of the various existing inventory protocols and compared the differences in the approach that each takes. We analyzed the application of these protocols in different communities for lessons we could learn and key takeaways.

2.1 Overview of Energy Policy on Nantucket

As a result of its location and the fact that Nantucket is an island, a large portion of its energy is supplied via imports from the mainland. Whether its liquid fuels or electricity, the additional cost required to transport the energy from the supplier to the consumer means that residents and businesses of Nantucket often pay a premium for these commodities. Since the island is without connecting pipelines, liquid fuels must be delivered to the island by truck via ferries which raises costs substantially. For example, propane and gasoline typically cost $1/gallon more on Nantucket compared to the mainland. This additional cost heavily impacts residents and businesses, due to the island's large consumption of propane, diesel, gasoline, and aviation fuel. The island's electricity supply is transmitted by two submerged cables, however, this was not always the case.

From the late 1800s to 1996, coal-fired steam engines generated electricity on the island. Diesel generators powered by oil - a cheaper and more efficient alternative for electrical generation - later replaced these. Unfortunately, these newer facilities would prove incapable of satisfying the rapid growing demand for electricity on the island. This resulted in frequent outages that were most prominent during the summer months. To meet the demand, Nantucket transitioned from generating electricity independently and installed its first 36MW transmission cable in 1996. The installation of a second 38MW submersible cable rapidly followed, as a

course of action to both satisfy demand and provide greater reliability. However, the installation of these cables meant that Nantucket became entirely dependent on the Massachusetts Transmission System. This has come at quite the cost for the island with both cables having a total cost of $71 million ("Brief History", n.d.). To pay for the installation and maintenance, a cable surcharge is added to Nantucket resident's electricity bills which are on average $0.18/kWh, higher than the national average of $0.13/kWh (U.S. Energy Information Administration, 2020) and four cents higher than the average in Massachusetts. As summer peak loads have increased, many on Nantucket are worried that a third cable may be needed to ensure a reliable supply of electricity. Nantucket attracts large numbers of vacationers causing its population to swell from 17,000 in the off-season to more than 50,000 in the summer months (NDP, 2018). In addition to these concerns, residents of Nantucket have become increasingly aware of and concerned about the effects of climate change and sea-level rise. Islanders realize that emissions produced from burning fossil fuels for electricity production, transport, and home heating are major sources of greenhouse gases and are not sustainable. Nantucketers have shown a commitment to pursuing climate and energy policies that fit the needs of the island, although the plans, policies, and programs have been pursued with varying levels of enthusiasm. We review these prior efforts in the following sections.

2.1.1 The Previous Greenhouse Gas Emissions Inventory and Climate Action Plan

In March 2008, the Select Board voted to join the Cities for Climate Protection Campaign which was led by the International Council of Local Environmental Initiatives (ICLEI). Under this program, the town developed a baseline inventory of greenhouse gas emissions and a Climate Action Plan outlining emission reduction strategies. Data sourced from 2007 were entered in the ICLEI modeling software which translated various types of emissions to their CO_2 equivalent, totaling 353,142 metric tons of CO_2e. The inventory accounted for emissions from municipal buildings, transportation, residential electricity and heating, commercial electricity, industrial electricity, ferries and waste (Sustainable Nantucket, 2009). The Nantucket Climate Action Plan set the goal of reducing emissions to 20% below the baseline by 2020 (Sustainable Nantucket, 2010). Unfortunately, the baseline inventory and plan faced criticism from several officials and residents primarily regarding the lack of transparency in the ICLEI protocols. For

example, the analysis used the national average of the electricity production profile at the time instead of the Massachusetts profile. Nationally, approximately 50% of electricity was generated by burning coal, whereas Massachusetts generated most of its electricity from natural gas and only 6% from coal (State of Massachusetts, 2015). Also, the recommendations depicted in the Climate Action Plan (CAP) were far too generic to fit the specific needs of Nantucket and lacked guidance for implementation. As a result, the Select Board declined to vote on the CAP and instead recommended that Sustainable Nantucket adapt the plan into a more practical and comprehensive Nantucket Energy Plan (NEP). The measures included in the NEP were more focused on potential energy cost savings and promoting investments in long term energy solutions that localize Nantucket's energy supply. These recommendations were generated and evaluated using another ICLEI tool, however, the NEP, faced similar criticisms as the CAP. Most of the elements in each plan were generated by a top-down approach with strategies that theoretically aid in emissions reduction but fail to consider the specific conditions in Nantucket that limit implementation.

2.1.2 Ongoing Mission of the Town

With the creation of the Nantucket Energy Office in 2011, the town's approach to energy policy shifted to formulate a stronger understanding of the local community and its particular challenges and opportunities. Working in conjunction with the Select Board and the town administration, the Energy Office has endeavored to create energy-friendly policies, programs, and projects to assist the town in saving energy. The Energy Office negotiated with National Grid to overcome logistical issues and bring the MassSave program to the island. As a result, home energy assessments are now readily available to residents, and more than 2,778 assessments have been conducted since 2012 ("Mass Save", 2012). The office also assisted in establishing the local SOLAR Rebate Program to promote the adoption of solar photovoltaic (PV) systems on residential properties. The program provides homeowners up to $4,000 in rebates to help cover the cost of solar energy systems which typically cost between $25,000 to $35,000 (Clemente, 2017). Most recently, in March 2020, Nantucket was designated a "Green Community" as a result of the groundwork by the Energy Office. Accordingly, the town was awarded an initial grant of $139,340 and is now eligible to apply for other Green Community grants in the future. These grants can then be used to further support the implementation of

future clean-energy solutions for municipal operations to reduce energy use by 20% over 5 years (Green Communities, n.d.). With the local knowledge and expertise that the office has obtained, the goal is to build upon the accomplishments to outline a comprehensive plan for the whole island and not just for municipal operations. This plan would help coordinate future energy policy on Nantucket to assist the town as they look to reduce GHG emissions. Doing so requires the development of a baseline inventory of current emissions to gauge the future progress of climate policy (Lauren Sinatra, personal communication, September 15, 2020).

2.2 Climate Change on Nantucket

Nantucketers are becoming increasingly concerned about the impacts of climate change on Nantucket. In large part, this is because Nantucket is extremely vulnerable to rising sea levels and storms that are predicted to increase in frequency and intensity with global warming. If the world does not reduce its greenhouse gas emissions, the world's average temperature will rise 4 degrees Celsius by 2100 (Figure 1). This could cause the ocean to rise as much as 10 feet which will submerge a significant portion of Nantucket. However, if the world takes dramatic action and greenhouse gas emissions fall significantly then the temperature rise could be brought to a halt as shown Figure 1 (Karberg, 2018). To limit future adverse impacts from storms and sea level rise, Nantucket and the rest of the world must reduce greenhouse gas emissions, which will help slow global warming (Climate Tipping Points.com, 2020).

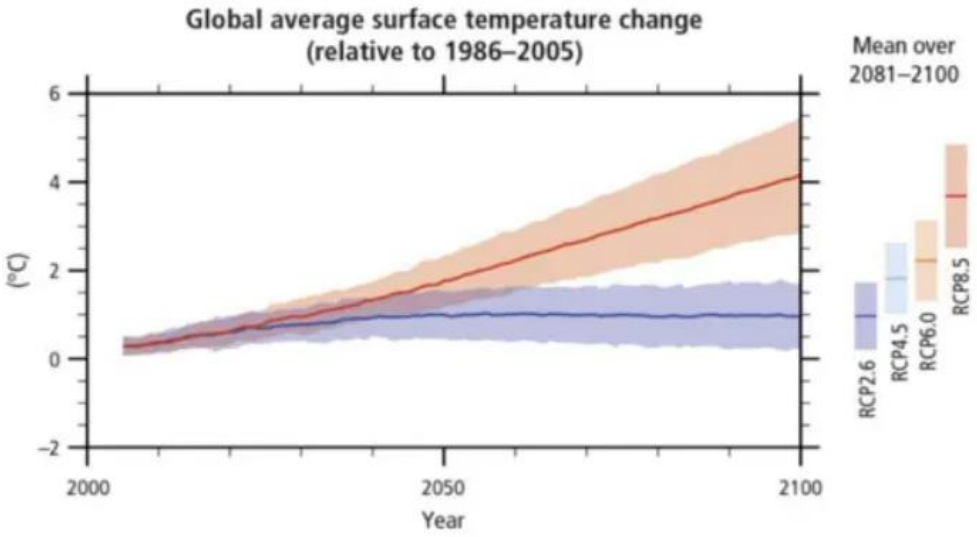

Figure 1: Predicting Future Temperature Changes 2000-2100 (Pachauri, 2014).

2.2.1 Types of Greenhouse Gases

The greenhouse effect is an essential Earth process that keeps the planet hospitable for life forms, but humans are emitting large amounts of greenhouse gases into the atmosphere causing an intensified greenhouse effect. This is causing Earth's climate to change, and if humans do not take action to slow the intensification of the greenhouse effect there will be serious consequences. Reducing greenhouse gas emissions is extremely important to slow down the greenhouse effect (Schwartz, 646-656).

There are four main types of greenhouse gases that contribute to the intensified greenhouse effect. Table 1 shows each greenhouse gas, its primary sources, and its potency in respect to carbon dioxide and Figure 2 shows the percentage of emissions by volume and potency for each greenhouse gas in 2018 for the US. For example, one metric ton equivalent (MTe) of nitrous oxide has the potency of 298 MTe of carbon dioxide. One major type of greenhouse gas is called carbon dioxide (CO_2). This type of greenhouse gas comes from the burning of many organic materials such as fossil fuels, waste, and other types of biological materials. It can also be produced by various industrial chemical reactions. This greenhouse gas can be naturally taken out of the atmosphere by plants through the carbon cycle. This is the most prominent greenhouse gas since it constitutes 80% of all greenhouse gas emissions by volume according to Figure 2

(EPA, 2020a). Methane (CH_4) comes from the production and transport of various fossil fuel-based products such as coal, natural gas, and oil. Other major sources of methane include certain agricultural activities, livestock, and decaying solid waste. Methane accounts for 10% of all greenhouse gas emissions according to Figure 2 (EPA, 2020a). Nitrous Oxide (N_2O) is also a byproduct of burning fossil fuels and waste. However, unlike carbon dioxide it can also come from certain agricultural activities and wastewater treatment. This greenhouse gas contributes 7% of the total volume of all greenhouse gases released into Earth's atmosphere according to Figure 2 (EPA, 2020a). The last major type is fluorinated gases which are produced by various industrial processes. Though they only make up 3% of all greenhouse gases in the atmosphere some of these gases - especially chlorofluorocarbons (CCI_2F_2) - are extremely potent and contribute to the greenhouse effect more per metric ton than other greenhouse gases and can remain in the atmosphere for more than a century (Schwartz, 2018, p.651; EPA, 2020a).

Table 1: Greenhouse Gases (EPA, 2020a; EPA, 2020c)

Greenhouse Gas Type	Primary Sources of Emissions	CO_2 Equivalent in Metric Tons (MTe)
Carbon Dioxide (CO_2)	Fossil Fuels, Solid Waste	1 MTe of CO_2 = 1 MTe of CO_2
Methane (CH_4)	Fossil Fuels, Agriculture	1 MTe of CH_4 = 25 MTe of CO_2
Nitrous Oxide (N_2O)	Agriculture, Industrial	1 MTe of N_2O = 298 MTe of CO_2
Fluorinated Gases	Industry, Chemical Reactions	1 MTe of fluorinated gases = 14997 MTe of CO_2

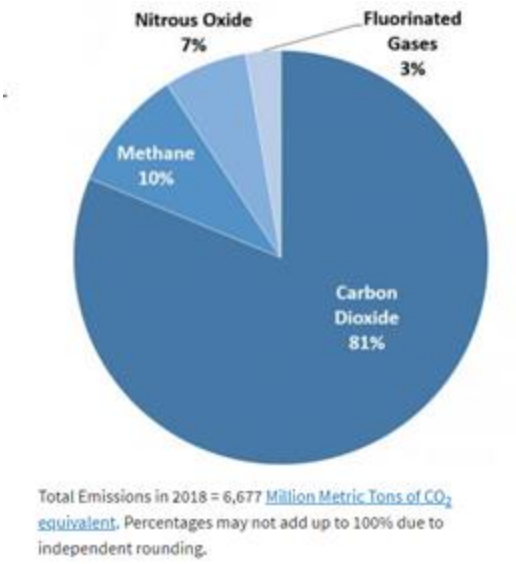

Figure 2: Greenhouse Gas Emissions in 2018 (EPA, 2020a)

2.2.2 GHG Emissions by Sector

Different sectors of the economy contribute differently to GHG emissions. Figure 3 shows the amount of greenhouse gas emissions from each economic sector in the US in 2018. The transportation sector is responsible for 28.2% of all emissions in the US (Figure 3). The main two greenhouse gases emitted by this sector are carbon dioxide and methane, since many forms of transportation require the burning of fossil fuels such as diesel fuels and oils (EPA, 2020b). Electricity generation contributes 27% of the US's greenhouse gas emissions, since 63% of electricity is generated by the burning of fossil fuels such as coal and natural gas, which produce a lot of CO_2 and small amounts of methane (EPA, 2020b). Figure 3 shows that industrial processes account for 22% of greenhouse gas emissions. The types of these emissions vary, with some processes producing carbon dioxide, methane, or fluoride gases (EPA, 2020b). Together agriculture, forestry, and residential sources make up for the remaining 23% of greenhouse gas emissions. Agriculture produces mainly methane and nitrous oxide, residential

emissions are mostly carbon dioxide and methane, and logging in the forestry industry removes carbon sinks, meaning more carbon dioxide remains in the atmosphere (EPA, 2020b).

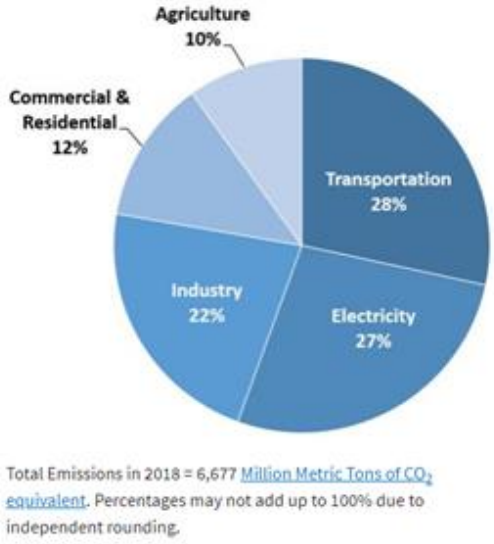

Figure 3: Greenhouse Gas Use by Economic Sector in 2018 (EPA, 2020b).

2.3 GHG Inventory History

GHG inventories have been conducted at local, national, regional, and global scales. Many communities conduct inventories as a first step in developing energy and climate change policies to serve as baselines by which to judge progress. The protocols for conducting inventories have been evolving for the past twenty-five years. The Intergovernmental Panel on Climate Change (IPCC) established some of the first standardized protocols for GHG inventories in 1996. The IPCC Guidelines for National GHG Inventories was a major step in the international fight against climate change. Although the guidelines were developed for the conduct of inventories at the national level, local communities adapted them for application at the local level. One of the many guides to evolve from the IPCC Guidelines is the Global Protocol for Community Scale GHG Emissions (GPC), developed by the World Resources Institute (WRI), C40, and ICLEI (Arioli, D'Agosto, Amaral, & Cybis, 2019).

2.3.1 The GPC

The GPC was created to help cities understand their greenhouse gas emissions sources. It splits the emission sources into three scopes: Scope 1 being direct emissions, Scope 2 being indirect emission via purchased electricity, and Scope 3 being any other indirect emissions (see Figure 4 for details). The GPC also establishes two different "levels" of inventories: Basic and Basic+ (WRI, C40 Cities, & ICLEI, 2014). Basic involves calculating most Scope 1 and Scope 2 emissions as well as a subset of Scope 3 emissions. Basic+ involves calculating all of the Scope 1 and 2 emissions as well as more of the Scope 3 emissions. The Basic+ level has the clear advantage of providing more accurate and comprehensive results, but inevitably involves more research and analysis. The Basic and Basic+ levels resemble another classification method known as the Urban Carbon Footprint (UCF). In a review of different GHG inventory methods, the researchers split the articles up by their UCF categorization. UCF Direct only involves taking Scope 1 and Scope 2 emissions data, while UCF Life Cycle Based (LCB) involves Scope 3 as well. They found that those inventories that fell under UCF LCB were more detailed and involved greater exploration of potential errors (Arioli et al., 2019). Similarly, Basic+ inventories are more detailed and less prone to errors than the Basic level inventories. Of course, retrieving such detail is not free. The GPC states that the sources covered in Basic+ "reflect more challenging data collection and calculation" than the sources in the Basic level (WRI et al., 2014).

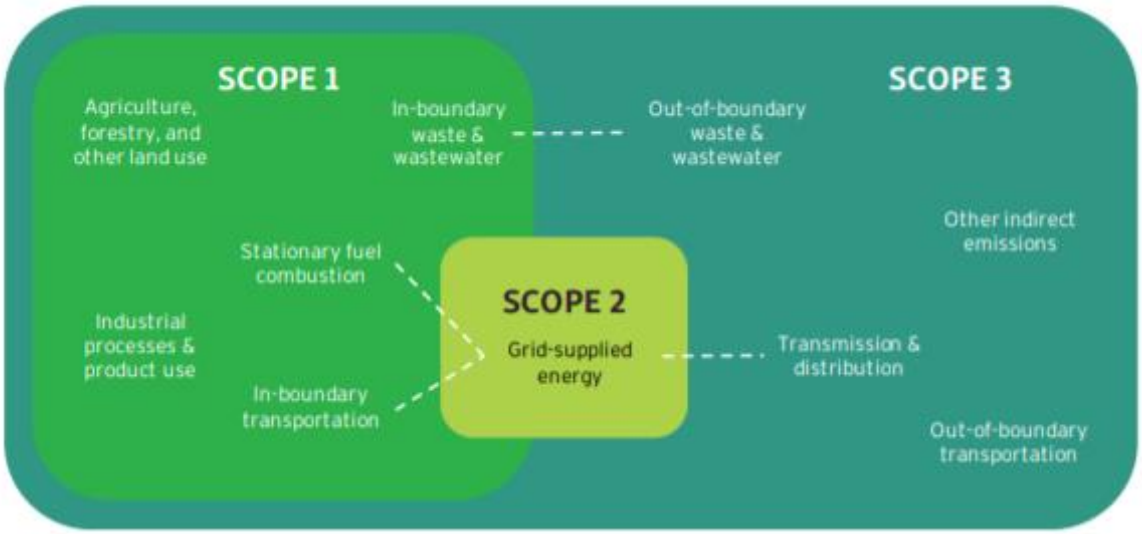

Figure 4: Emission Scopes Chart (Aki et al., 2020)

Another important note about the GPC is that it does not specify whether to use a top-down or bottom-up approach when gathering on-road emissions data. In a top-down approach, emissions are calculated by looking at fuel sold (Figure 5). In a bottom-up approach, emissions are calculated by vehicle activity (Arioli et al., 2019). A study of top-down versus bottom-up approaches in general concluded that a top-down approach is much more efficient, while a bottom-up approach can potentially be more accurate (Nicholls, Barnes, Acrea, Chen, Buluç, & Parker, 2015). The GPC also includes a breakdown of the advantages and disadvantages in the case of road transportation (Figure 5) where 'fuel sales' is the top-down approach and VKT is the 'bottom-up' approach. To sum it up: top-down is more in line with national standards and is less expensive, but the data it provides is incomplete and not as helpful for emission mitigation plans; whereas bottom-up is very helpful in creating a mitigation plan, but collection is substantially more expensive (WRI et al., 2014). It is this flexibility, with both the Basic and Basic+ levels as well as the top-down or bottom-up approach, that allows communities of almost any size to use the GPC.

Methodology	Advantages	Disadvantages
Fuel sales	• More consistent with national inventory practices • Well suited to aggregation with other city's transportation inventories if all fuel sold in boundary is classified as scope 1. • Less costly • Less time-consuming to conduct • Do not require high level of technical capacity	• Does not capture all on-road travel, as vehicles may be fueled at locations outside the city boundary but driven within the city • Does not disaggregate the reasons for travel emissions, e.g., origin, destination, vehicle efficiency changes, modal shift, etc. • Does not comprehensively demonstrate mitigation potential • Does not allow for allocating emissions by scope (unless additional steps are taken)
VKT and model-based (induced activity, territorial, resident activity)	• Can produce detailed and more actionable data for transportation planning • Integrates better with existing city transport models and planning processes	• More expensive, time consuming, and less comparable between cities due to variation in models used

Figure 5: Comparing Top-Down and Bottom-Up Methodologies for On-Road Transportation (WRI et al., 2014)

2.3.2 The MAPC Guidelines

In 2009, Sustainable Nantucket conducted a GHG inventory for the town following guidelines set by ICLEI at the time (Sustainable Nantucket, 2009). After developing an action plan based on the inventory, however, the town chose not to adopt it. One of the main complaints was that the ICLEI standards were too general, including some calculations based on national averages, and thus it did not work well for Nantucket (Personal Communication, Lauren Sinatra, 2020). Since then, the Metropolitan Area Planning Council (MAPC) has developed the "Greenhouse Gas Inventories for Massachusetts Cities and Towns" protocols which use data and assumptions that are more appropriate for towns like Nantucket.

The GPC heavily influenced the MAPC guidelines, and thus the two share many similarities. In fact, the MAPC recommends having a copy of the GPC "on hand" in case the reader wants to reference a specific data gathering method (Aki et al., 2020). For instance, they both use the same general principles for data collection (relevance, completeness, consistency, transparency, and accuracy) and consider emission activity by the same three sectors (stationary energy, transportation, and waste). The main difference between the MAPC guidelines and the GPC is that MAPC has predetermined what methodologies to use. The MAPC guidelines address only the Basic level emissions from the GPC; they leave out some Scope 1 and 2 emissions and most Scope 3 emissions. The guide explains that most of the subsectors omitted simply did not have enough data statewide to allow valid GHG emissions estimates (Aki et al., 2020). The guidelines also specify that on-road transportation emissions must be calculated using a bottom-up approach, no matter a community's size. The Massachusetts Vehicle Census is presumed to have all the data needed for this assessment (Aki et al., 2020). Although the MAPC guidelines are not as thorough or flexible as the GPC, they draw on more readily available local data that facilitates data collection and analysis.

2.3.3 Previous Massachusetts GHG Inventories

Many other towns in Massachusetts have also performed GHG inventories. Table 2 summarizes some of the differences between the reports reviewed, and Figure 6 shows the

results for each emissions category. Note that the categories are slightly different due to different methodologies used, but the patterns are similar.

Table 2: Comparing GHG Inventories from Four Other Towns

City	Year	Protocol used	Scope
Boston	2017	Based on ICLEI	Includes emissions directly produced by the city's operations and emissions from private energy and fuel use and leakage. This includes on-road and off-road vehicle emissions.
New Bedford	2017	Based on ICLEI	Includes emissions directly produced by the city's operations and emissions from private energy and fuel use (and leakage), and from the decomposition of solid waste. The transportation emissions category includes ground vehicles, airplanes, and city-owned watercraft.
Cambridge	2012 (published in 2017)	MAPC	Includes emissions from the government and private citizens and corporations by measuring the burning of fuel and gas, electricity use, and the solid waste and wastewater produced. The transportation sector does not include emissions from aircraft or watercraft.
Natick	2013 (published in 2017)	MAPC	Includes emissions from the government and private citizens and corporations by measuring the burning of fuel and gas, electricity use, and the solid waste and wastewater produced. The transportation sector does not include emissions from aircraft or watercraft.

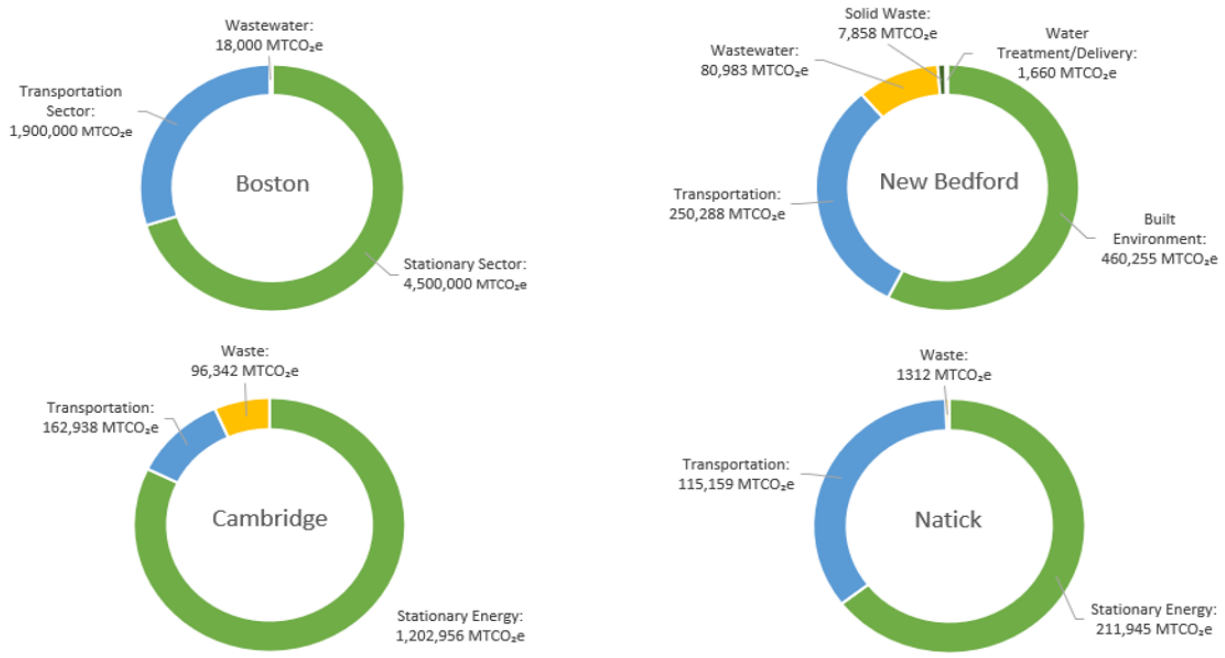

Figure 6: Results of Other GHG Inventories by Sector

Boston's 2017 GHG inventory was separated into three categories: the stationary sector, transportation, and wastewater treatment. The stationary sector refers to energy used by commercial, industrial, residential, hospital, university, and research buildings, as well as construction and manufacturing, and fugitive emissions from oil and natural gas systems. Half of the emissions from this sector are estimated to be from the electricity consumed, 40% are produced by burning or leaking natural gas, and the rest come from fuel oil and steam. Overall, the stationary sector was responsible for about 70% of Boston's total 2017 emissions. The transportation sector was calculated using on and off-road Vehicle Miles Traveled (VMT) within the city limits, as well as the miles traveled outside the city by government owned vehicles. The final category, waste, only totals to around 1% of the city's emissions. This category only accounts for emissions from wastewater treatment, since almost all of Boston's solid waste is burned in waste-to-energy plants, and thus counted towards the stationary sector (Boston's Carbon Emissions, 2017). Boston's GHG inventory was based on the ICLEI Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions (*Cape Cod Inventory Framework,* 2019).

In 2017, New Bedford commissioned Kim Lundgren Associates (KLA) to perform a GHG inventory based on both the ICLEI Protocol and the GPC. The emissions categories are similar to Boston: built environment, transportation, waste, water treatment and delivery, and wastewater treatment. The built environment category is effectively the same as Boston's stationary sector, using electricity, natural gas, and fuel oil consumption as well as statistics on natural gas leakage to estimate the emissions. The New Bedford transportation sector emissions calculations omit off-roading but do factor in air travel and city-owned watercraft. VMT and the EPA's emission factors are used to calculate on-road vehicles emissions, which are only counted when within the city's limits. Emissions for airplanes and city-owned marine vessels were calculated based on the amount of fuel supplied to them at New Bedford ports. While normally airplane emissions are divided between the departure and destination cities KLA used fuel consumption because they assumed that the planes would require an equal amount of fuel once they reached their destination. In the waste category, the methane emissions are estimated for all the solid waste generated in 2017, although it will be many years before the trash breaks down fully. This will allow the town's improvements in solid waste GHG emissions to be more easily measured without the need to wait for the waste to completely decompose. The tool used to

estimate the solid waste emissions was developed by the California Air Resources Board. The water treatment category estimates the emissions from the electricity and natural gas used by well water extraction, pumping stations, and water treatment facilities. Similarly, the wastewater treatment category includes all the power and natural gas used by wastewater treatment facilities, as well as the emissions from the treatment and incineration of organic materials removed from the water (*2017 GHG Inventory Methodology Report*, 2017). Compared to Boston, New Bedford's GHG inventory included a few additional sources of emissions and had a more comprehensive report that was not split between methodology and results.

The City of Cambridge developed a GHG inventory for 2012, consulting the MAPC. The three categories that the inventory was divided into were stationary energy, transportation, and waste, but each was further subdivided. The stationary sector includes emissions due to electricity use by sources ranging from buildings to streetlights to water-pumps. This category accounts for greenhouse gasses produced by buildings' natural gas and fuel oil, and also includes the emissions from off-road vehicles used in construction, as they are included under the construction subsector. The transportation sector included all of the emissions from on-road vehicles registered in the city including public transit. The inventory even accounted for the difference between weekend and weekday traffic. Additionally, public rail transit emissions within city limits were estimated by fuel use information provided by the Massachusetts Bay Transport Authority, but this GHG inventory lacks any information on air or marine vehicles. The solid waste section includes emissions from both waste that is deposited in landfills and incinerated. All trash produced within the city is counted even if it is dumped or burned outside of city limits. Wastewater treatment is, again, calculated for wastewater produced within Cambridge even though it is treated elsewhere (*Cambridge GHG Inventory Report*, 2017).

Natick, one of the first towns to use the MAPC inventory tool, made a very similar GHG inventory (Schwan, 2020). It gave estimates for the same emissions sources in the same three categories as the Cambridge inventory. The difference is the way it was presented to the public; instead of a 51-page report, Natick presents its emissions data in the form of a 12-slide presentation with easy to understand graphics and minimal text. The presentation contains links to relevant sites, including the city's webpage for their energy aggregation program. It ends with a link to a survey containing information about Natick's plans to have net-zero carbon emissions

by 2050 and asking the public how they would be willing to help achieve that goal (*Findings from Natick's 2017 GHG Inventory,* 2017). Compared with the City of Cambridge inventory using the same MAPC protocols, the Natick data is presented in a far more accessible format, although the presentation lacks a thorough description of the methodology used.

2.3.4 Why Use MAPC?

The MAPC guidelines and tool for greenhouse gas inventories provide a few advantages and disadvantages. They are easy to use and already define a set of methodologies for determining emissions. MAPC is also more tailored to Massachusetts than the more general GPC and ICLEI guidelines. MAPC does not account for some sources of GHG emissions, such as propane, that Nantucket would like to include. For the Nantucket 2020 greenhouse gas inventory we could simply augment the MAPC-style inventory to add estimates for emissions from this source. Despite this shortcoming, the MAPC's specific relevance to Massachusetts and the ease of using the GHG inventory protocol have made it an enticing option for Nantucket to use for its own emissions inventory.

Chapter 3: Methods

The goal of this project was to develop a baseline inventory of Nantucket's greenhouse gas (GHG) emissions from residential, business, and municipal sectors. To achieve this goal, we identified five objectives:

1. Review MAPC guidelines and usage in other communities;
2. Determine how MAPC Protocol should be modified;
3. Source pertinent data to create the baseline inventory;
4. Gauge public opinion about GHG emissions and emission reduction strategies; and
5. Analyze and interpret key findings revealed by the inventory and explore the most effective way to present them to the local officials and the public.

We developed the inventory following the MAPC guidelines discussed in the background section above, and used the MAPC emissions inventory tool. We modified some elements of the protocols to ensure the inventory accounted for the differences between Nantucket and other towns in Massachusetts. Once we identified and obtained the data needed to complete the inventory, we cleaned it and used our modified version of the MAPC tool to create the baseline inventory. We analyzed and summarized the key findings from the inventory for a presentation to local officials and the public. Figure 7 highlights the relationship between the project tasks and objectives that we discuss in more detail below.

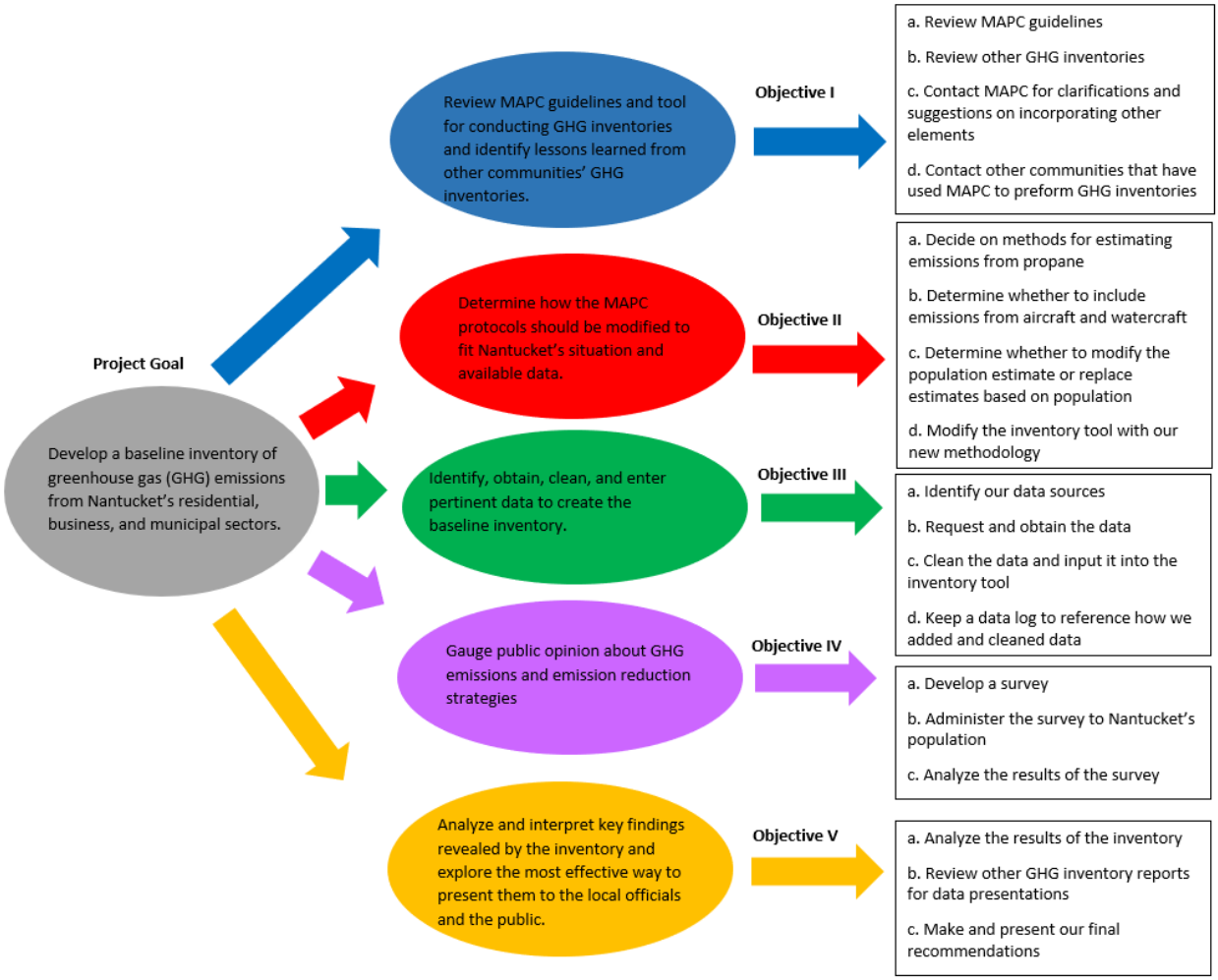

Figure 7: Graphic Summary of the Relationship Between Project Goal, Objectives, and Tasks

3.1 Review MAPC and Usage in Other Communities

Our first objective was to review the MAPC guidelines for creating GHG inventories and see what we could learn from the application of the protocols in other Massachusetts communities. In the beginning, we conducted an initial review of the MAPC guidelines and completed the preliminary checklist with our sponsor. Subsequently, we further reviewed the document, specifically the "Data Collection Summary Worksheet" and "Calculate Emissions Using the Tool" sections, so that we could have a better idea of what lay ahead. After coming up with a few questions about the tool we consulted Clean Energy Analyst Megan Aki, one of the authors of the MAPC GHG inventory guidelines, on Friday, November 6th to understand more about how the tool functioned. She was especially helpful with regard to modifications that might be appropriate to meet Nantucket's particular situation, including how to include propane rather than natural gas. We also consulted her about the best ways to accommodate Nantucket's significant variation in population between winter and summer.

We also completed the second part of the objective, to learn what we could from the development of GHG inventories in other communities. We acquired and reviewed the GHG inventories for New Bedford, Cambridge, Boston, Natick, and Arlington. We reviewed the inventories to identify lessons learned in the application of the protocols, such as examples of data, as well as innovative ways to present the data most effectively to the public, businesses, and local officials. For those communities that specifically used the MAPC guidelines to create their inventories (Natick, Arlington, and Melrose), we chose to contact them about their process and any tips they had. While Natick and Melrose simply redirected us to Megan Aki at the MAPC, Arlington was willing to answer some of our questions.

3.2 Modify MAPC Protocols

The MAPC guidelines were created with the Boston Metropolitan Area in mind, and thus we needed to modify them to ensure the Nantucket GHG inventory accurately accounts for all the island's emissions. Unfortunately, due to time and data constraints, we were unable to make some of our proposed modifications. For example, although the MAPC does not provide guidelines for marine vessels, we wanted our inventory to account for greenhouse gas emissions

from the ferries that transport people to and from the island. We would have estimated these emissions based on the amount and type of fuel provided to the ferries, which is how New Bedford's inventory accounted for public marine vessels (*2017 GHG Inventory Methodology Report*, 2017). To ignore emissions that Nantucket is not responsible for, we planned to calculate the proportion of the distance traveled by the ferries only to and from Nantucket and multiply it by the total emissions. We were unable to acquire the data on ferry fuel use, and thus this change will need to be saved for a future inventory. In a similar way, the amount of fuel delivered to planes departing Nantucket Memorial Airport would have been used to estimate aircraft emissions. There were, however, changes we were able to make. We estimated emissions from propane burnt on the island via a modified version of the existing gasoline emission calculation logic, since the MAPC guidelines address natural gas (methane) only. Since wastewater estimates made in the MAPC inventory protocol use census estimates of population, and the amount of people on the island fluctuates greatly due to tourism, we used an effective population estimate from the Nantucket Data Platform (NDP, 2018). In sum, the MAPC guidelines and inventory tool guided most of our data gathering and analysis, but we also made a few adjustments to better estimate Nantucket's actual emissions from the data we had available.

3.3 Source Pertinent Data

Using the MAPC guidelines and in consultation with our sponsor, we identified the types and sources of data necessary to complete the inventory. We attempted to gather the most recent calendar year data available, most of which was from 2018 or 2019. The MAPC guidelines referenced many pertinent data sources, which included state and national databases. We supplemented this with local data sources, such as estimates of total solid waste and recyclables as well as waste characterization information from the Nantucket Department of Public Works. We contacted various private companies, such as Harbor Fuels and Yates Island Gas, and attempted to gather estimates of heating oil and propane gas consumption. This data was not retrieved within the time available, however, so we utilized the tool's method of estimating heating oil consumption using various state databases. Since the tool does not capture propane emissions, we amended the tool to accept consumption data for residential, commercial/institutional, and municipal accounts. Residential propane data was obtained from

the Nantucket Emissions Inventory for 2009 while municipal was sourced from the Town's MassEnergyInsight Software. Once we had a clear and complete understanding of the types of data needed and the appropriate formats, we acquired the data from the pertinent sources. The team reviewed what information was necessary for the inventory tool and clearly outlined it in our request to those individuals. This mainly involved formatting data that was provided in fiscal year to calendar year to function with the tool's inputs.

We reviewed and adjusted as necessary the data from various sources prior to entering it into the inventory tool. We did so by maintaining a spreadsheet that noted the data that we needed, the form the tool required it in, and where to request the data from. This was mainly to organize the data collection process and eliminate the potential for missing or inaccurate data entries. If we found inaccuracies in the data sources, we followed up with the appropriate officials for clarification and amended data as necessary. Occasionally we had to make assumptions to best interpolate potential missing data which was indicated in a data log that was upkept alongside the inventory tool. Other modifications to the data included the conversion of units from the source so that it was compatible with the format of the tool. When doing so, transparency was a priority with all conversions indicated in the data log as a reference for future inventories on Nantucket. Once the data was reviewed and cleaned, it was entered into the inventory tool. The calculations were verified by reviewing the "All Emission - Summary" and "Report Charts" tab as shown in Appendix B, to ensure the spreadsheets updated and all the data was accounted for correctly. Every addition and modification made to the inventory was followed with an entry in the data log with the team member's name, the date, an indication of whether it was a modification or addition, and where in the inventory it was done. This helped to organize the data inputting process and provide transparency to those who review and look to replicate the baseline inventory in the future.

3.4 Gauge Public Opinion

In order to help Nantucket with future climate and energy policy and to help us create the baseline GHG inventory, the Energy Office wanted us to uncover what emission reduction strategies the public believes to be most important. Thus, we conducted an online survey.

3.4.1 Developing the Survey Instrument

We utilized a combination of questions from surveys developed for Natick, San Diego, and Nantucket (City of San Diego, 2020; ReMain Nantucket, 2020; Town of Natick, 2020), along with additional questions from our sponsor, to craft the final survey instrument. This was an iterative process that involved both our sponsor and our advisor helping us to ensure that the finished product could collect all of the data we needed as well as be easily understood by the participants. The final version of this survey is presented in Appendix C.

The survey begins with a short preamble describing Nantucket's unique situation and the goal of the survey, followed by a short description of climate action planning. The first two questions regard living situation (own a home, rent a home, etc.) and employment status (own a business, retiree, etc.). The second set of questions is adapted from the San Diego survey and asks a series of questions about what the participant would or would not consider doing to help reduce emissions. In this section we also ask if the current virus outbreak has affected their answers in any way, as well as what climate action benefits they are looking forward to apart from simply reducing emissions. The next set of questions is adapted from the Natick survey and asks the participants to rate several potential initiatives the town could take to reduce emissions from low to high priority. Then our sponsor helped concoct the next few questions, one asking about their opinion on climate action versus the island's historical integrity, and another asking about if they would support a climate emergency declaration. The survey closes with a few open-response questions about why the participant was interested, other strategies they think should be considered, and what their concerns are about climate action planning. The very end of the survey contains a list of resources for more information, as well as a link to another survey that they can take if they would like to provide their email. The email survey also has a couple questions about how the participant would like to be involved and how they normally hear about town policy.

3.4.2 Administering the Survey

Our final survey instrument was set up in Google Forms and distributed using our sponsor's mailing list, a mailing list of town staff, and the ACK Smart Energy Instagram account. The initial release date of our sponsor's mailing list was on Saturday, November 21st,

followed by another message to the town staff on Monday the 23rd. We later heard on the first of December that ACK Smart Energy had shared our survey on their Instagram account as well. Normally, we would have closed the survey after a week or two of receiving responses, however our sponsor requested that we leave it open for future use. The email that accompanied the survey link explained who was conducting the survey and that it would be completely anonymous.

3.4.3 Data Entry and Analysis

Since we used Google Forms, we did not need to worry about data entry, since it was all compiled for us in a spreadsheet. While the closed-response questions were ready to be analyzed as soon as we got them, the open-response questions needed to be coded manually. Once we analyzed the data and extracted the information we wanted, we presented our key findings with descriptive statistics and graphs. This ultimately helped us and the Energy Office discover what climate and energy policies the public thought should be prioritized.

3.5 Analyze and Interpret Key Findings

The last objective was to research and interpret the key findings of the GHG inventory and find the best way to present them to the local public and officials. After that was accomplished, we studied the data in order to help create the best possible visualization of the results. The population that this data was presented to was Nantucket's general public and its Select Board. The more straightforward representation of the data made it easier for the audience to understand the facts. After the team found a clear understanding of the results, we used the key findings to help determine how Nantucket can develop its future climate plan.

After the data was collected the team coordinated with the energy office and other Nantucket town officials and learned some methods on how to scrutinize the data and distribute it. A few examples of how we considered sharing the data included a 'GHG Emissions by Sectors' pie chart (see Figure 8), bar graphs comparing emissions from residents to businesses and municipal sources (see Figure 9), and pie charts representing the emissions based on sources like gasoline and electricity (see Figure 10) (*Findings from Natick's 2017 GHG Inventory,* 2017). Figures 8-10 represent different GHG datasets from the Natick GHG Inventory. We chose

to show our data in the same format as Figure 8 in our presentation. Another thing the team did was look at techniques other towns have used to present GHG data in order to get a groundwork for how to confer both straightforward and complicated data. These specific figures were chosen because they contain some of the data formats that the team used when looking at Nantucket's emissions. Strategies that were used to help present the data included organizing the data into different categories based on each sector with the same types of data.

We used data presentation formats similar to those used by Natick, which we believed to be clear and compelling. We identified emissions in the stationary energy, transportation, and waste sectors, further subdivided into smaller groups (Aki, 2020). The data was presented by first covering its meaning in basic terms, then describing how it was calculated when explaining the visuals, and then discussing the team's suggestions for actions to mitigate emissions. In order to help record and manage data, we analyzed different data graphs in separate files with data analysis tools such as Microsoft Excel.

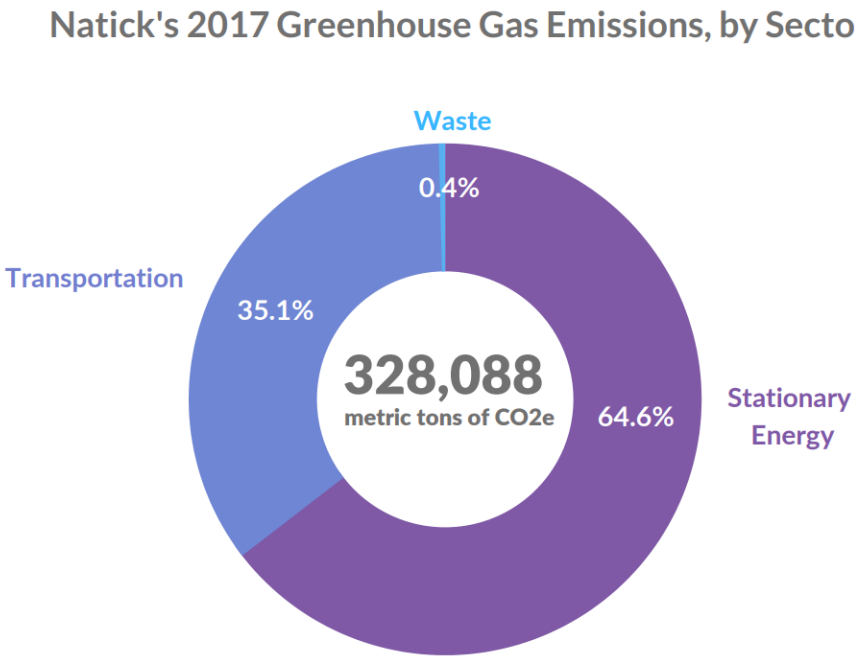

Figure 8: Natick GHG Emissions by Sector (*Findings from Natick's 2017 GHG Inventory,* 2017)

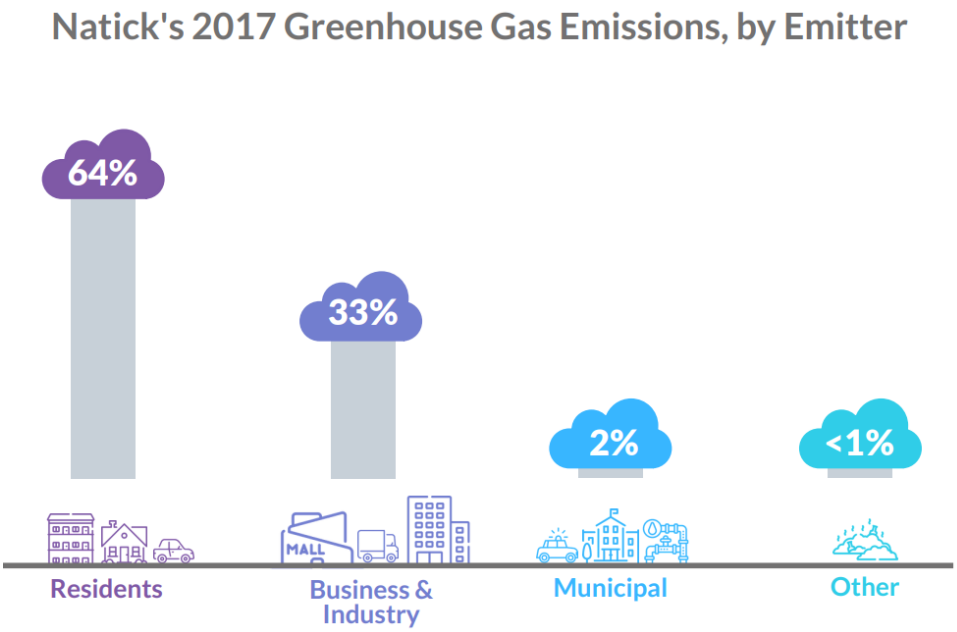

Figure 9: Natick GHG by Which Group is Responsible for Them. (*Findings from Natick's 2017 GHG Inventory*, 2017).

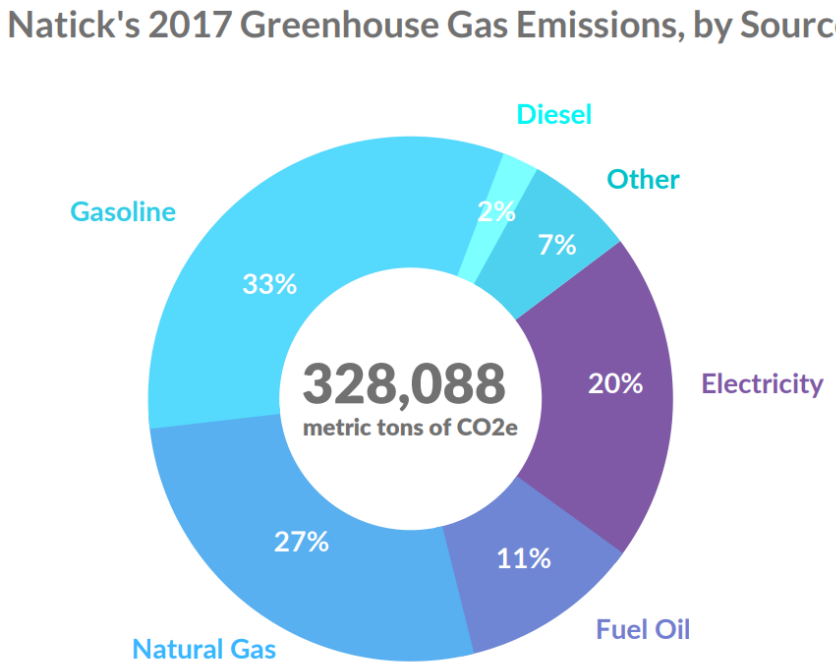

Figure 10: Municipal Operations Emissions (*Findings from Natick's 2017 GHG Inventory,* 2017).

Chapter 4: Findings

In creating a GHG inventory for Nantucket, we have found and analyzed data that the town can use to strategize future climate action planning on the island. Additionally, we conducted a survey of the public and discovered which climate action approaches were most widely supported by the citizens of Nantucket. The findings section comes in two parts - first we discuss what the inventory reveals about Nantucket's emissions, and second we examine the results of the survey.

We discovered that the stationary energy sector is the largest contributor to greenhouse gas emissions on the island, followed by the transportation sector and the waste sector (Figure 11). Nantucket's stationary energy accounts for 67.6% of the island's total emissions or 95,700 metric tons of CO_2 equivalent (MT CO_2e). In comparison the Nantucket Emissions Inventory of 2009 estimated the stationary sector was responsible for 124,272 MT CO_2e in 2007 (Sustainable Nantucket, 2009). The difference in emission estimates may be due to refinements in methods over the years. It is important to note that the previous inventory calculated emissions from electricity using the US energy production profile at the time which was predominantly from coal. The current inventory uses the state's electricity production profile which is mostly from 'cleaner' fuels like natural gas.

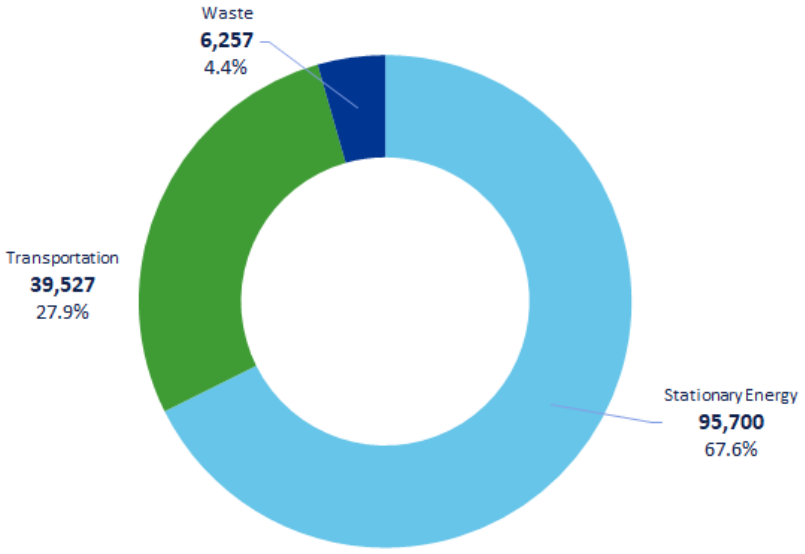

Figure 11: Community-Wide Emissions by Sector in MT CO_2e

Our estimate of emissions from the transportation sector, is much smaller in both proportion and amount when compared to Sustainable Nantucket's 2009 GHG inventory. In their inventory, they estimated transportation emissions on Nantucket to be 217,890 MT CO_2e or 61.7% of the town's total emissions (Sustainable Nantucket, 2009) while we estimate 39,527 MT CO_2e or 27.9% of emissions.

Our inventory calculated 6,257 MT CO_2e in waste emissions, which made up 4.4% of the total. The previous inventory estimated 12,867 MT CO_2e or 3.1% of their emissions at the time. The proportions of the emissions that this sector made up were relatively similar between inventories, though the 2009 inventory's raw number was far larger.

4.1 Stationary Energy

The stationary energy sector accounts for GHG emissions from various levels of scope that result from stationary sources. The MAPC uses a three scope level framework to distinguish how GHGs are attributed to a community's inventory.

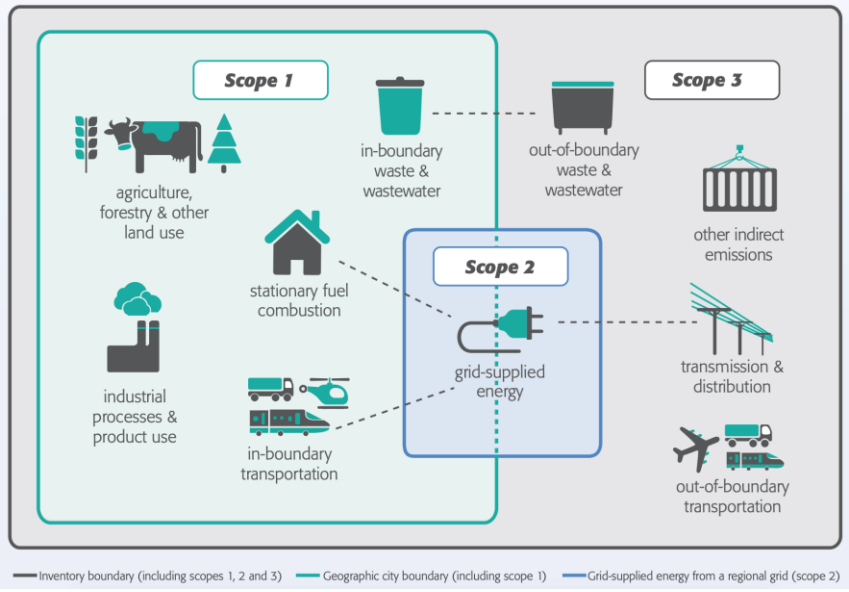

Figure 12: Global Protocol for Community Scale GHG Inventories Levels of Scope (WRI et al., 2014)

As displayed in Figure 12, Scope 1 consists of emissions that occur within the physical boundaries of the community which would include the combustion of fuels like heating oil and propane. Scope 2 regards emissions that result from grid-supplied energy which tends to be the largest contributor to the stationary energy sector, and finally Scope 3 which includes those that occur outside of the community's boundaries. For stationary energy, this refers to fugitive emissions that result from transmission line loss as the electricity is distributed from the power generation facilities to the consumer.

Table 3: Community-wide Emissions Summary by Sector, Subsector, Sources & Scope

Sector	Subsector	Source	Scope	Carbon Dioxide Equivalent Emissions (MT CO2e)
Stationary Energy	Residential Buildings	Electricity	2	25,787
		Electricity T&D Losses	3	1,249
		Propane	1	30,528
		Fuel Oil	1	10,240
		Natural Gas	1	0
		Nat. Gas. Dist. Losses	1	0
		Subtotal		67,804
	Commercial & Institutional Buildings & Manufacturing Industries	Electricity	2	12,987
		Electricity T&D Losses	3	634
		Propane	1	306
		Fuel Oil	1	5,488
		Natural Gas	1	0
		Nat. Gas. Dist. Losses	1	0
		Off-Road (Various Fuels)	1	8,480
		Subtotal		27,896
	Construction	Off-Road (Various Fuels)	1	0
		Subtotal		0

Outlined in Table 3 above, is an overview of the stationary energy emissions in MT CO_2e for each subsector, their relevant sources, and levels of scope. Residential buildings were responsible for 67,804 MT CO_2e, commercial & institutional buildings & manufacturing industries (including municipal) was 27,896 MT CO_2e and no emissions for construction. The stationary energy sector is a large contributor to emissions in comparison to other sectors. This is common amongst most communities in Massachusetts due to the large amount of energy that is used to heat homes during the winter months. We see this with other communities who have also used the MAPC protocols like Natick and Arlington whose stationary sectors were 64.6% and 61.9% respectively of their total emissions (Town of Natick & MAPC, 2020; Town of Arlington & MAPC, 2020). This highlights a key area of opportunity for most communities trying to decrease their total emissions. Most of the improvements would need to be targeted towards residential and commercial buildings as they are the largest contributors to emissions. As shown

in Table 3, off-road equipment from construction and landscaping also contribute significantly to emission in the commercial and institutional building sector. Following is in depth analysis of the sector's emissions that are attributed to buildings and limitations within each.

Buildings are responsible for a large amount of the emissions in the stationary sector, most of which are produced from the private sector as shown in Figure 13 below. This consists of residential buildings as well as commercial/institutional buildings and manufacturing industries. Since industry and manufacturing are not prevalent on the island, the majority of these emissions can be attributed to residential (71%) and commercial buildings (24%), with a relatively minor contribution (5%) from municipal buildings. Evidently, reducing residential and commercial emissions are essential to overall emission reductions in the long term, although this does not diminish the significant role that the Town can play in leading by example when implementing GHG reduction strategies. These strategies would mainly have to target electricity, propane, and fuel oil usage as they are responsible for the bulk of building emissions. Figure 14 shows that for residential and commercial buildings combined, electricity consumption is responsible for 46% of GHG emissions, propane 36%, and fuel oil 18%. We conducted further analysis of how emissions were quantified for each energy source in buildings and findings for each.

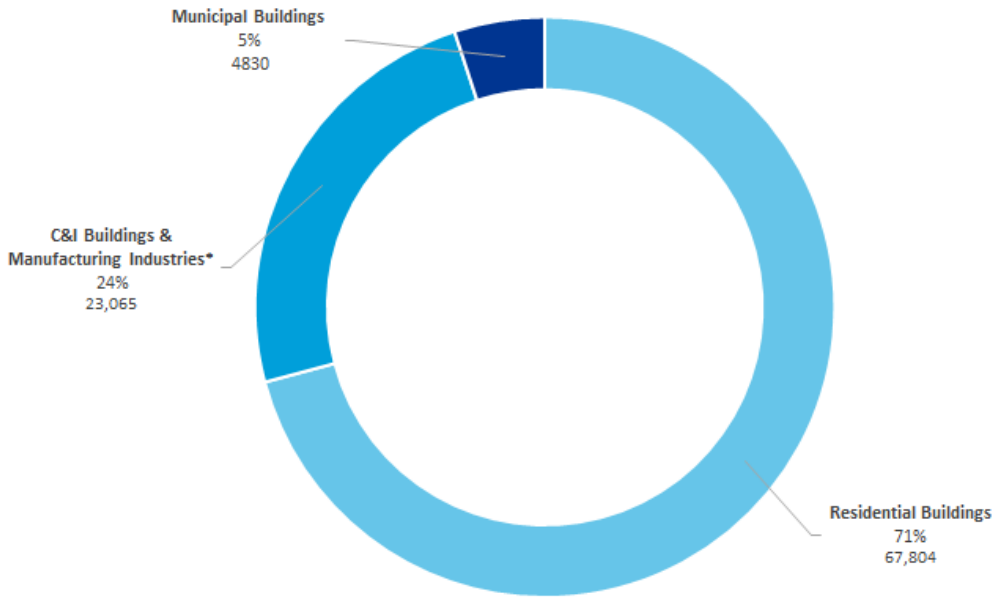

Figure 13: Percentage of Stationary Energy Emissions by Subsector*

*Off-road included in the C&I Buildings & Manufacturing Industries subsector

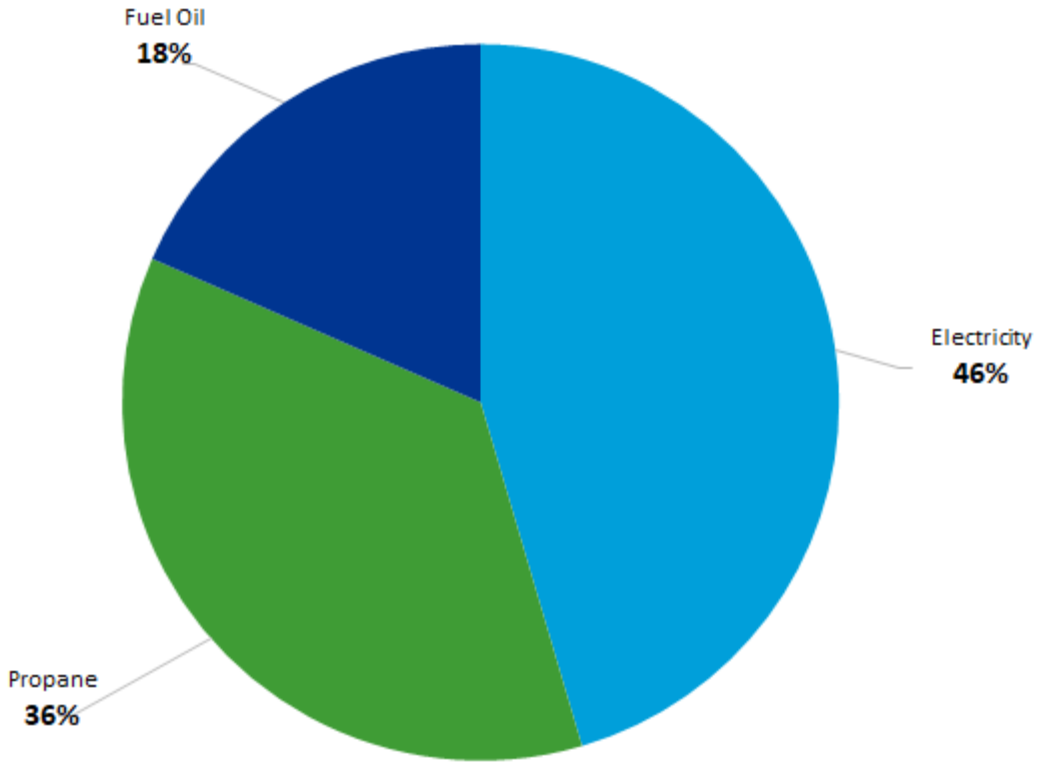

Figure 14: Percentage of Building Energy Emissions by Source Energy

4.1.1 Electricity Emissions

We calculated emissions from electricity consumption for Nantucket based upon usage data from a MassSave data source. The data encompasses residential and commercial/institutional (including municipal) accounts that are supplied by National Grid's default plan. The yearly electricity consumption is given in units of megawatt-hour (MWh) which is multiplied by the state's 2016 CO_2 conversion factor for National Grid to calculate the CO_2 equivalency. In addition, we accounted for the plans provided by the community-choice aggregation program where its emissions were weighted separately depending on the composition of renewable sources. Electricity was found to be the largest source of building emissions as shown in Figure 14 which slightly differs from communities like Natick whose emissions from electricity were lower in proportion. This is expected in part because Nantucket does not have access to natural gas and instead relies on electricity for their general home energy use and for some high energy use utilities like home heating systems.

4.1.2 Propane Emissions

The most common energy source that residents on Nantucket choose to heat their homes with is propane. A study conducted by HeatSmart found that around 40% of homes are heated by propane in comparison to 32% for fuel oil and 23% for electric (Meister Consultants Group [MCG] & Camp, E., 2018).

To capture the resulting emissions from propane in the inventory, we amended the tool to accept propane data and make the appropriate calculations. In its modified form, the tool accepts propane data in gallons per year for residential accounts as well as commercial/institutional which includes municipal accounts. Residential and commercial propane consumption data was requested from the propane distributors on Nantucket. Unfortunately, this data was not obtained within the time available and therefore we defaulted to using the propane emission values from the previous GHG inventory conducted by the town in 2009.

For municipal accounts, propane consumption was obtained via the MassEnergyInsight software which tracks the energy usage of all the town's operations. The total annual propane use was multiplied by the EPA's fuel emission factor to determine the CO_2e that was produced. Based upon our results in Figure 14, propane was the second largest contributor of CO_2e consisting of 36% of building emissions or 30,834 MT CO_2e which is consistent with its popularity as a heating and cooking fuel on Nantucket. However, it is important to consider that the data from the 2009 inventory is dated which affects the results of this inventory. It would be expected that as the permanent population on Nantucket has grown over the years that propane usage would also increase. It is also unclear what methods were used to calculate the emissions and how the data was obtained in the previous GHG inventory which only quantified residential propane emissions. This would ideally be replaced with more current data from local sources but provides value as an appropriate placeholder to give the town an idea of its role in emissions.

4.1.3 Heating Oil Emissions

The smallest source for building emissions was from fuel oil which was responsible for 18% of emissions as displayed in Figure 14. Heating fuel oil consumption is indirectly calculated by the tool since consumption data is not widely available for most towns.

For consumption from residential properties, the tool uses a database operated by the MAPC which sources data from the American Community Survey to quantify housing unit types for municipalities throughout Massachusetts. Given the US average fuel oil consumption supplied by the U.S. Energy Information Administration (EIA) which is marked up using an adjustment ratio to make the values more representative of the state's higher fuel oil usage. This step is conducted since the EIA does not track average fuel oil emissions by housing type for each state. The state's average fuel oil consumption is then multiplied by the number of households on the island that use fuel oil to determine the total annual consumption which is converted to its CO_2 equivalent.

For commercial and institutional heating oil usage, the tool uses employment data from the Massachusetts Executive Office of Labor and Workforce Development (EOLWD) to quantify the number of employees by their buildings primary activity. Which is then multiplied by the fuel oil consumption per employee by the building's primary activity established by the EIA to calculate total fuel oil consumption. Since not all commercial buildings use fuel oil, the tool uses the results from a EIA survey in 2012 which concluded that 40.07% of commercial buildings in New England use fuel oil as their primary heating source(EIA, 2012). This is then converted to MT CO_2e by using the fuel emission factor for distillate fuel oil No.2. This method used for fuel oil is easily replicable for most communities since the data that is required by the tool is readily available. It is not clear whether this method is entirely accurate for an island community like Nantucket, especially since it makes a few assumptions regarding the percentage of commercial buildings using fuel oil. This may work within reason for most New England communities but could be less accurate for Nantucket which is unique in comparison. The current edition of the tool does not enable the direct input of heating oil data but is something that the MAPC is looking to integrate in future versions. As a result, this becomes a limitation to

our heating oil estimate and would ideally need to be acquired directly from local sources on Nantucket to improve its accuracy.

4.1.4 Off-Road Emissions

The off-road section of stationary energy encompasses emissions that result from mobile activities like landscaping, construction, and manufacturing. Despite these sources of emissions being mobile, they tend to be localized to job sites which allows them to be considered within the stationary energy sector. The tool estimates CO_2 emissions from off-road services at the national and county level by using the Motor Vehicle Emission Simulator (MOVES) by the EPA. Since Nantucket is unique in that it is both a county and a town, 100% of the estimated emissions calculated by the software were allocated. The tool then attributes the emissions to the larger commercial & institutional buildings & manufacturing industries subsector. As shown in Table 3 above, emissions from off-road sources produce 8,480 MT CO_2e which is about 30% of the commercial subsector and 8% of the stationary energy sector emissions. Unfortunately, the current inventory does not include emissions that result from construction due to time constraints but would recommend including for future renditions of the baseline.

4.2 Transportation

The transportation sector is the second largest source of GHG emissions on Nantucket (Figure 12) and is responsible for 39,527 MT CO_2e or 27.9% of the emissions in the inventory. This makes it a great deal smaller than the stationary sector, while also a great deal larger than the waste sector. The share of emissions attributed to transportation is comparable to those calculated for Natick (35.1%) and Arlington (35.5%) using the MAPC tool and guidelines (Town of Natick & MAPC, 2020; Town of Arlington & MAPC, 2020).

The MAPC inventory tool splits the transportation emissions by sector (such as passenger vehicle and commercial vehicle) and fuel type (such as gasoline and diesel). We will begin by analyzing the emissions by sector.

4.2.1 Emissions by Sector

Passenger vehicles are by far the most prevalent source of emissions in the transportation sector (Figure 15). The MAPC inventory tool splits transportation into five subsectors: passenger vehicles, commercial vehicles, municipal vehicles, on-road buses and trolleys, and railways. As Nantucket does not have any railways the emissions for that subsector were zero, and it was removed from Figure 15. Looking at the remaining subsectors, passenger vehicles take up an entire 84% of the total emissions. This is likely because passenger vehicles make up about 90% of the vehicles registered on Nantucket. Natick and Arlington also had similar numbers when it came to passenger vehicle emissions, with them taking up 88% and 94% of their transportation sector respectively (Town of Natick & MAPC, 2020; Town of Arlington & MAPC, 2020).

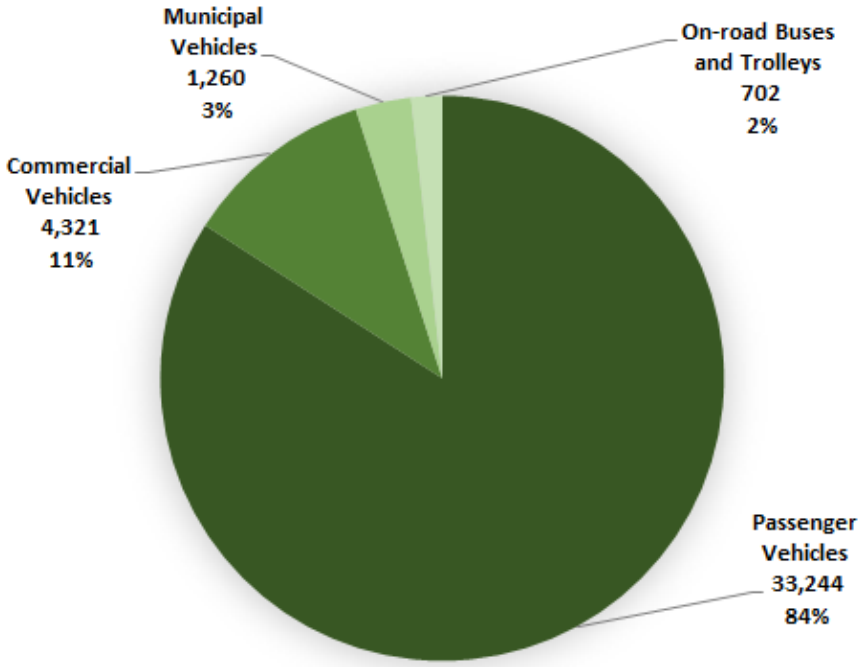

Figure 15: Transportation Emissions (MT CO_2e) by Sector

While the subsector for passenger vehicles is the largest, it is important to note that we did not include two other potential subsectors that could have made an impact on the final results: ferries and airplanes. The MAPC inventory tool does not come equipped to handle such inputs by default. Since we had already made some modifications to the tool by including propane and were running short on time, we opted to leave it for a future iteration of the

inventory. While it is unlikely that either ferries or airplanes would have surpassed passenger vehicles as the largest subsector, they certainly would have had an impact on transportation emissions as a whole and could have been areas where we recommend improvements.

4.2.2 Emissions by Fuel Type

Gasoline is without a doubt the largest fuel type contributor (Figure 16). The MAPC inventory tool breaks up transportation fuel into four types: compressed natural gas (CNG), diesel, electricity, and gasoline; with one additional section for transmission and distribution (T & D) losses. Since no vehicles on Nantucket use CNG, and the electricity usage from electric vehicles is small enough that no emissions from electricity T & D losses were recorded, those sections were removed from Figure 16. Of the fuel types that remain, gasoline is clearly the main contributor, accounting for 95% of all emissions. As with passenger vehicles, this is likely because about 92% of Nantucket's vehicles run on gasoline. This can once again be supported by observing Natick and Arlington's inventories which reported that 94% and 97% of transportation emissions came from gasoline respectively (Town of Natick & MAPC, 2020; Town of Arlington & MAPC, 2020).

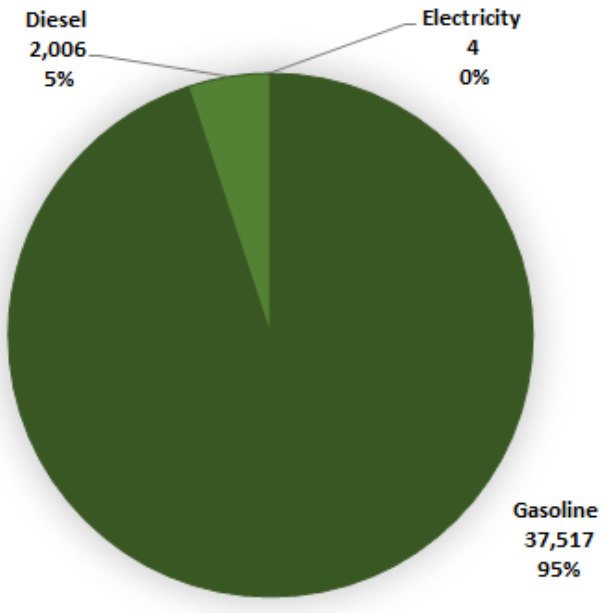

Figure 16: Transportation Emissions (MT CO_2e) by Fuel Type

We did not identify any major limitations with the MAPC tool regarding the assessment of fuel type, however there was one instance of confusion. The inventory tool not only looks for fuel consumption for municipal vehicles, but also the number of vehicles of each fuel type (gasoline or diesel). We had access to the list of municipal vehicles and were able to research the fuel type for most of them, however the Ford F-Series of trucks can come with a gasoline or a diesel engine. We attempted to reach out to some of the departments that had these vehicles, but without getting any responses we opted to make the following assumptions. All F-150s and F-250s were classified as gasoline, all F-450s and F-550s were classified as diesel, and the F-350s were split in half (8 considered gasoline, 7 considered diesel). Regardless of these modifications, it seems the number of vehicles has little impact, if any, on the final emissions calculations.

4.2.3 Comparison to Sustainable Nantucket's Inventory

Compared to Sustainable Nantucket's 2009 GHG inventory, the transportation sector is much smaller both in the amount of emissions as well as the proportion when compared to the rest of the inventory. The 2009 inventory estimated transportation emissions on Nantucket to be 217,890 MT CO_2e or 61.7% of the town's total emissions (Sustainable Nantucket, 2009) compared with our estimate of 39,527 MT CO_2e or 27.9% of emissions. Although we have already established that the 2009 GHG inventory was based on some limited assumptions and thus the associated plan was rejected by the town, there may be another explanation for the large discrepancy. In addition to not including ferries and aircraft in our calculations (which Sustainable Nantucket did include), we also excluded any vehicles that were not registered to the town itself. In order to avoid double-counting emissions, where emissions from one community are also counted by another, the MAPC recommends counting only vehicles that are registered to the town that is conducting the inventory (Aki et al., 2020). We are unsure whether or not Sustainable Nantucket included the vehicles brought over on the ferries by vacationers, but if they did, that could be another reason for the large difference in emissions numbers.

4.2.4 Remaining Limitations

We have already covered many of the limitations we faced while gathering data for the transportation sector, but there is still one important limitation to consider - most of the data is from 2014. At the time of conducting our inventory, the most recent information available from

DataCommon (containing data from the Massachusetts Vehicle Census) came from 2014. This was acknowledged by the MAPC in their instructions for retrieving said data, so there is likely no widely-available source that has more recent or more accurate information (MAPC, 2020). Still, having data that is six years old that accounts for all passenger and commercial vehicles will no doubt have an impact on the veracity of our results.

4.3 Waste

The third sector under the MAPC protocol is waste, which consists of GHG emissions generated by wastewater treatment and the decomposition of solid waste. These are responsible for 6,257 MT CO_2e, meaning they comprise around 4.4% of Nantucket's total GHG emissions, by far the smallest of the three sectors. The subcategory breakdown, as shown in Figure 17, reveals that wastewater treatment accounts for 1,871 MT CO_2e or about 30% of waste emissions, while solid waste disposal by composting accounts for the other 4,386 MT CO_2e or around 70%. MAPC also has subcategories for landfill decomposition and incineration, which are not relevant to the Nantucket inventory. Compared to the inventories made by Natick and Arlington using the same protocols, waste comprises a higher percentage of Nantucket's emissions. Arlington's Inventory estimated waste emissions to be 7,472 MT CO_2e, making up 2.6% of their total emissions (Town of Arlington & MAPC, 2020). Natick's 1,312 MT CO_2e waste emissions made up only 0.4% of their total emissions (Town of Natick & MAPC, 2020). Neither Arlington nor Natick reported any emissions from composting waste, so their subcategory data is not comparable. The differences in percentages and subcategories are due to the differences in how these towns and Nantucket manage and report solid waste.

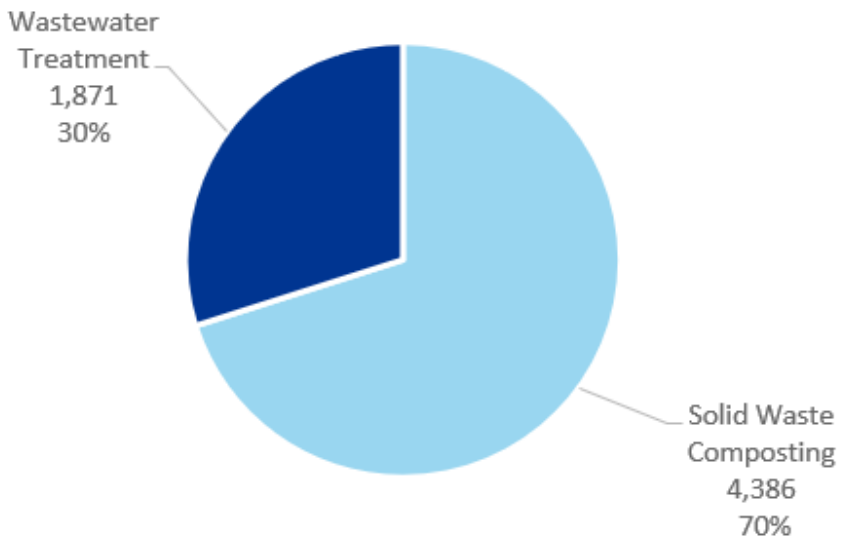

Figure 17: Emissions (MT CO_2e) by Waste Subcategory

4.3.1 Solid Waste

Nantucket's waste management is unique within Massachusetts. Waste brought to Nantucket's recycling center is sent through a composter for three days, only after which non-compostable items such as plastic are removed and landfilled. After this the remainder of waste begins a seven-month journey through a composting facility where it is processed into soil. On the island, only corrugated cardboard is recycled, and all other paper is composted. Lawn and garden waste is also brought to the recycling center, where it is composted in windrows rather than by the biodigester. Nantucket does not produce or process industrial waste, though it does generate construction and demolition waste, which is shipped off-island. This resulted in some difficulty in processing the data for the inventory.

4.3.2 Solid Waste Difficulties

Our initial emissions calculations for waste brought it to around the equivalent of 28,682 MT CO_2, which made up a far larger portion of the inventory compared to any that we had reviewed, especially considering the smaller population of Nantucket. After a follow up meeting with Recycling and Solid Waste Coordinator, Graeme Durovich and Megan Aki at the MAPC, we corrected the error, and removed waste from streams not accounted for by the MAPC tool. This reduced the number for total solid waste tonnage from 54,542 US tons to 25,244 tons, reducing our emissions estimate to 6,257 MT CO_2e. To calculate the tonnage and percentage in

each waste category, we developed a spreadsheet that converts waste tonnage and characterization data from Nantucket's categories to those in the inventory tool.

4.3.3 Wastewater and Wastewater Difficulties

Nantucket processes all of its wastewater at two on-island facilities, with the sludge removed from the water being processed by the composting facility. For this estimate the MAPC inventory tool's calculations are based on the population, which for Nantucket is listed as 11,327 in 2018 by the census link provided. We chose to replace this with the effective population estimate of 17,200 produced by the Nantucket Data Platform as the seasonal fluctuation due to tourism would have an effect on the amount of wastewater being produced and processed on Nantucket (NDP, 2018).

4.4 Public Opinions About Climate Action

The last task our team conducted was a Climate Action survey on the citizens of Nantucket. The purpose of the survey was to assess what actions people are currently taking, what types of actions Nantucket should prioritize to help mitigate emissions, and to allow people to express their own personal thoughts on the current climate situation and how to address it.

The survey consisted of a series of open and closed questions in six sections.

- Section 1 contained two questions that asked people about their living situation and their employment on Nantucket.
- Section 2 included five questions about what actions people are currently taking to help with climate change.
- Section 3 comprised 15 questions from five different climate action sectors about what actions Nantucket should take to mitigate climate change.
- Section 4 comprised just one question about whether Nantucket should focus more on climate action or maintaining its historical presence.
- Section 5 also comprised just one question about whether Nantucket should adopt a climate emergency declaration in the next annual town meeting or not.

- Section 6 asked three open-ended questions about their final thoughts on the Climate Action Plan.

We received a total of 118 responses at the time the survey was analyzed on December 1st. Eighty-six percent of respondents live on Nantucket, 10% live on Nantucket seasonally, and 4% gave other responses (Figure 18). Sixty-eight percent own a home, 26% rent their homes, and 6% gave other responses (Figure 19). In terms of employment, 32% own a business or are self-employed, 31% work for the town, 17% are retired, and 20% work in other areas of employment (Figure 20). Given the nature of the distribution of the survey and the time of year, the sample of respondents may not be representative of the entire population, and likely under-represents some segments of the population, such as seasonal residents. Nevertheless, we believe the responses are indicative of public opinion.

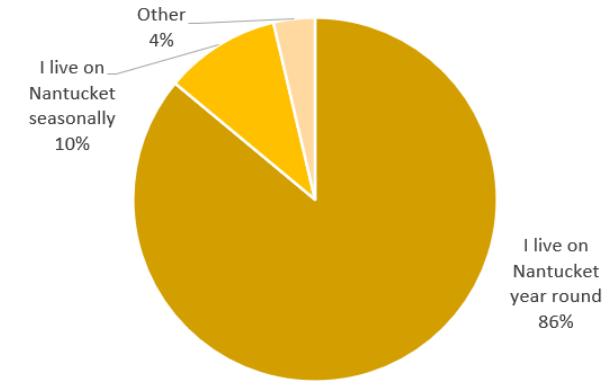

Figure 18: Respondents Living Situations on Nantucket (n=118)

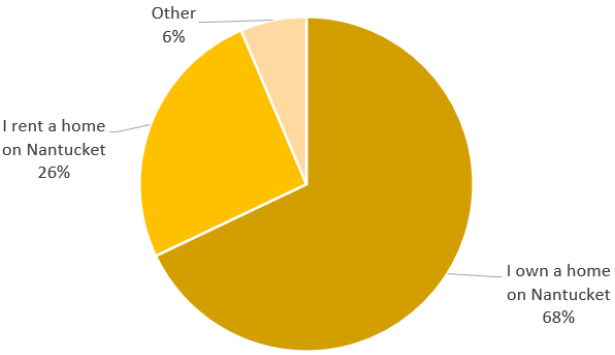

Figure 19: Respondents Home Ownership on Nantucket (n=118)

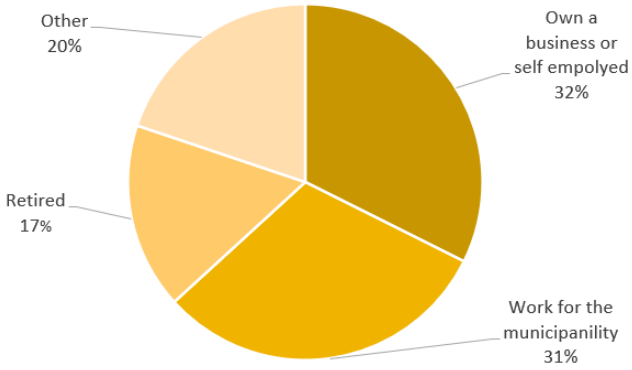

Figure 20: Respondents Employment on Nantucket (n=116)

We found that 52% of people who responded to the survey would consider installing solar panels or purchasing a greener power supply (Figure 21). This is crucial because solar panels can greatly reduce CO_2 emissions by replacing various fossil fuels used in the current generation of electricity.

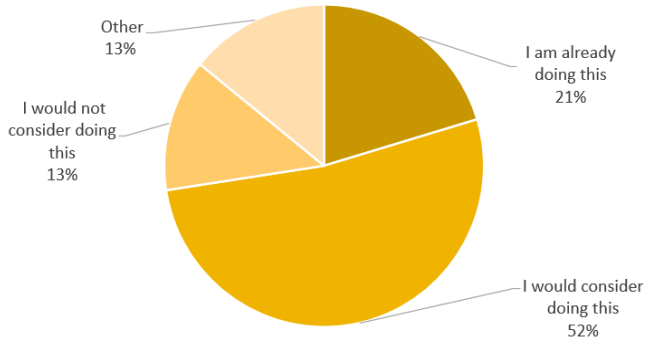

Figure 21: Respondents Who Would Consider Installing Solar Panels on their Homes (n=118)

The second key discovery was that 50% of respondents would consider switching to an electric vehicle (Figure 22), although actual behavior might differ from intentions based on a host of factors, such as vehicle price, available subsidies, and so forth. Many people switching to electric vehicles would greatly decrease the amount of fuel needed for passenger vehicles and reduce CO_2 emissions depending on the fuel mixed used in the generation of electricity.

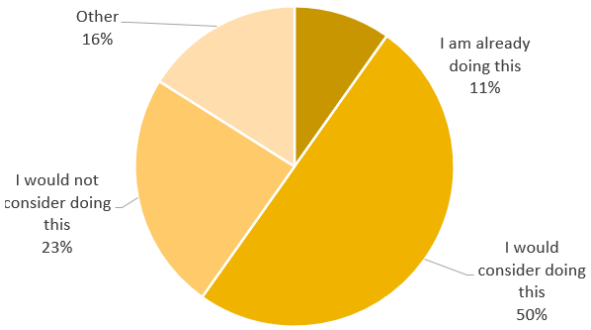

Figure 22: Respondents Who Would Consider Switching to Electric Vehicles (n=117)

Section three had several critical results. In the energy sector, 91% of respondents said that it was at least a moderate priority to develop more island based renewable energy and sources in order to prevent a third undersea cable from being built (Figure 23). Preventing a third undersea cable will avert an additional financial burden on both the town and its residents who are still paying for the installation of the existing cables.

Another key finding about the energy sector is that 89% of respondents believe it is at least a moderate priority to increase incentives to go greener by installing solar panels and energy storage systems (Figure 23). For example, Nantucket currently offers $4000 per year in tax rebates for people who install solar panels. Similar incentives will encourage more people to install solar panels and use other energy storage methods.

In the transportation sector there were two major results. Over 80% of respondents think it is a moderate or high priority to expand bike and pedestrian infrastructure and to begin transitioning to electronic based public transportation (Figure 23). Such improvements would likely cut down the need for fossil fuels and will also reduce expenses since improving non-vehicle infrastructures will encourage residents to switch to greener methods of transportation.

In the waste sector 73% of respondents said it is at least a moderate priority to provide at-home composting kits at little to no cost to them. By contrast only 44% people said implementing a ‘pay-as-you-throw’ trash and recycling program was a moderate priority (Figures 23). Promoting home composting kits would ultimately reduce hauling trips and reduce waste in the landfill.

Figure 23: Respondents Opinions About Town Policies Priorities

Section four had one crucial discovery. In the survey 23% of respondents think that climate action planning is more important than conserving Nantucket's historical culture, 63% believe climate action planning and persevering Nantucket must be balanced, and 10% think that keeping Nantucket's historical culture is more important than climate action planning (Figure 24). This indicates that Nantucket should be cautious in how it implements its new climate policies so that it does not significantly affect Nantucket's historical assets.

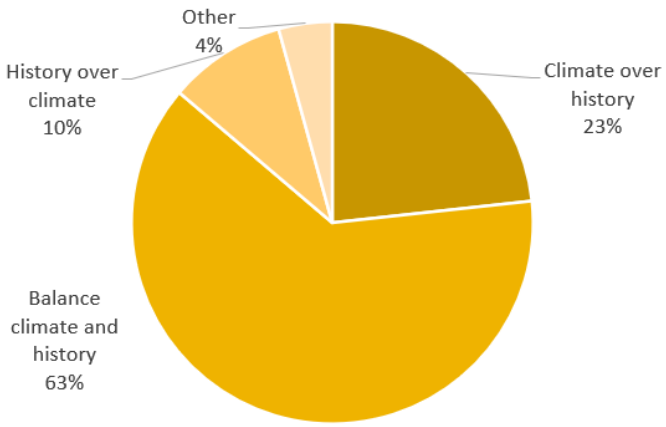

Figure 24: Respondents Opinion on Balancing Climate Action With Historical Nantucket (n=116)

Section five had one critical finding. According to the survey 69% of respondents said they would favor adopting a climate emergency declaration in the next annual town meeting

(Figure 25). A climate emergency declaration would commit the town to tackling climate change and would help promote future climate actions in the community.

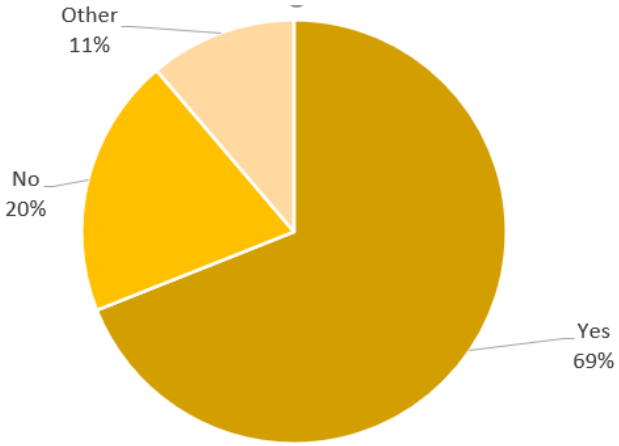

Figure 25: Respondents Who Think That Nantucket Should Adopt a Climate Emergency Declaration (n=114)

In section six of the survey respondents indicated why they are interested in Nantucket's climate action plan. Most of the reasons why people were interested was because they were worried about the future of the island, especially rising sea levels and the future of the island for their children. Another prominent interest was saving money on energy bills. Respondents also expressed some concerns about promoting a climate action plan. For example, some of them said that it would be too expensive, Nantucket should be more focused on flooding or hazard mitigation, and that climate action planning is not happening fast enough.

Chapter 5: Conclusions & Recommendations

The assessment reveals that stationary sources emit 95,700 MT CO_2e or 67.6% of the island's total GHG emissions, the transport sector emits 27.9% (39,527 MT CO_2e) and waste contributes 4.4% (6,257 MT CO_2e). We conclude that the revised inventory developed using the MAPC guidelines and tools provides a superior assessment of the GHG emissions on Nantucket than the inventory conducted in 2009, primarily because the assumptions and data are better tailored to the particularities of Nantucket. Nevertheless, we recommend that the MAPC and the Nantucket Energy Office continue to refine the tools and gather additional data to enhance the accuracy and completeness of the GHG inventory in the future.

In addition to these general conclusions and recommendations, we have developed separate take-aways and suggestions for each sector of the inventory (stationery energy, transportation, and waste).

5.1 Stationary Energy Sector

We conclude that the modified MAPC inventory tool and guidelines provides an effective framework to capture emissions from the stationary energy sector on Nantucket. Using the tool, we found that the sector is responsible for 67.6% of the island's total emissions, equivalent to 95,700 MT CO_2e. The majority of this was from buildings in the private sector, accounting for 86.1% (82,389 MT CO_2e) of emissions, followed by landscaping and manufacturing at 8.9% (8,480 MT CO_2e) and municipal buildings at 5.0% (4,831 MT CO_2e). Emissions from buildings were predominantly from high electricity and propane use with fuel oil having less impact. From these conclusions, we propose several recommendations for the town and the Nantucket Energy Office (NEO) regarding the stationary energy sector. We also suggest several modifications the Nantucket Energy Office should pursue in the future to enhance the inventory tool's ability to calculate emissions from stationary sources.

Based upon our findings for the stationary energy sector, we recommend that the town and the Nantucket Energy Office continue to inform the public of their energy consumption. Ultimately the best approach to lower emissions is to focus on reducing the community's collective energy use, particularly in the residential sector. This can be done through the continued promotion of the Mass Save program to help homeowners install energy-saving

products and high-efficiency insulation. In addition, the town could expand the current building stretch code to continue to improve the efficiency of new construction on Nantucket. Despite the initial additional construction costs associated with the stretch code, the homeowner or business would ultimately save money on energy costs in the future and help the town decrease their emissions. We also recommend that the Nantucket Energy Office continue to promote the adoption of solar panels on homes and businesses through increased incentives to property owners. This would help to offset some of the emissions that result from grid-supplied electricity. There is also evidence that the people of Nantucket would also support these recommendations because 21% of survey respondents already have solar panels while 52% would consider installing solar panels. Besides energy reduction, we recommend that the town incentivize the adoption of cleaner heating and cooling methods like air source heat pumps and solar hot water systems to supplement current systems wherever applicable. Solar hot water systems can provide up to 80% of a building's hot water needs but would substantially help residents save on increasingly more expensive traditional heating fuels (Meister Consultants Group & Camp, E., 2018). Ideally, the primary system would be electrified where possible for residents and businesses. This may seem counterintuitive with electricity being the predominant source of building emissions but Massachusetts's electricity grid continues to be supplied by more renewable sources over the years. Over time, the cleaner fuel mix for generating electricity will result in lower GHG emissions.

To improve the current inventory, we recommend that the Nantucket Energy Office continue to follow up on requests for more precise data on fuel oil usage from the suppliers on the island, such as Harbor Fuels and Sun Island Fuel. By using specific local data rather than assumptions based on average state data, the town will have a more accurate estimate for fuel oil consumption on the island and thus the related emissions.

In the same vein, we suggest that the Nantucket Energy Office follow up with the propane suppliers on the island to gather consumption data for residential and commercial/institutional accounts. Since propane is a popular option for home heating, we felt it was important to incorporate it in the GHG inventory. Absent actual data on current consumption, the inventory uses propane emissions calculated from Nantucket's GHG Inventory for 2009. Using current data on actual consumption from propane suppliers will provide a better baseline of Nantucket's current GHG emissions. If the Nantucket Energy Office continues to

find this to be a challenge for future inventories, it could modify the tool to adopt a similar approach to the way fuel oil is calculated.

Finally, we recommend that the NEO obtain data on the square footage of commercial development that is under construction assuming the Town's Planning Department tracks this information. Entering this data into the tool is optional, however it enables emissions from construction to be accounted for in the GHG inventory which currently is not captured. Since Nantucket has a large amount of construction that occurs on the island, we felt it would be an important addition to the baseline GHG inventory.

5.2 Transportation Sector

We found that the transportation sector is responsible for 27.9% (39,527 MT CO_2e) of Nantucket's emissions, making it the second largest contributor of the three sectors. Within this sector, we discovered that passenger vehicles accounted for 84% (33,244 MT CO_2e) of transportation emissions, and gasoline contributed 95% of all transport emissions by fuel type at 37,517 MT CO_2e. Since these subsectors were the largest by far we recommend, in the case of the transportation sector, that the Town of Nantucket try to adopt emissions reduction strategies focused on these areas first. As most passenger vehicles use gasoline, these reduction strategies tend to go hand in hand. Some of the strategies that we recommend pursuing include: broadening the scope of public transportation, encouraging or incentivizing bicycles and walking over driving, and encouraging or incentivizing switching to electric vehicles. Nantucket's general public would back these suggestions as indicated by 83% of respondents in the survey answering that it is of moderate or high priority to expand bike and public infrastructure. Additionally, 50% of survey respondents would consider switching to an electric car. While the effectiveness of these strategies ultimately comes down to the people of the community, the town still must do its part to steer them in the right direction.

In addition to our recommendations for the Town of Nantucket, we also have some suggestions for the MAPC and their inventory tool. One of the major hurdles we had to overcome was being able to include propane emissions into the tool. Unfortunately, we were unable to do the same for ferries and aircraft. We recommend that the MAPC include ferries and aircraft as optional inputs in a later iteration of the tool. We understand that not every town has ferries or an airport, but that does not mean that emissions from them should be omitted from

towns that do. If the MAPC collaborates with towns such as Nantucket and other regions like Cape Cod, while also consulting the GPC for guidance, they could achieve this goal. We also recommend that the MAPC update their vehicle data. The data they provide from the Massachusetts Vehicle Census is from 2014, which is much older than most of our data which came from 2018 or 2019. If the MAPC could conduct another vehicle census using the same methodology, it would greatly increase the accuracy of transportation emissions estimates.

5.3 Waste Sector

Waste produced only 4.4% (6,257 MT CO_2e) of Nantucket's total emissions, and it is by far the smallest of the three sectors in terms of GHG emissions. Between the two subsectors, composting solid waste generates 70% (4,386 MT CO_2e) of waste related emissions, and wastewater treatment generates 30% (1,871 MT CO_2e). Unlike the larger sectors of transportation and stationary energy, strategies for significant reduction of emissions within this category are difficult to imagine. However, this does not mean there is no room for improvement. Encouraging citizens to reduce waste would decrease emissions from the breakdown of waste, and affect the transportation sector since less waste must be hauled. The method that is most supported by the general public in the waste sector (with 73% of respondents saying it is a moderate or high priority) is to provide at-home composting kits at little to no cost to those who want them. Despite having potential benefits, a 'pay as you throw' system likely does not have enough public approval to be implemented (with 44% of respondents saying it is a moderate or high priority). Overall Nantucket already has a well designed system for handling waste. In 2025, the Town's contract with Waste Options is expiring, so the waste management may drastically change before another GHG inventory is performed.

The need to pare down the waste data to include only the streams in the MAPC's solid waste categorization system was unclear, and has confused other towns using the inventory tool in the past (Personal Communication, Megan Aki, 2020). Confusion of which waste is accounted for by the inventory, can result in overestimates, such as our initial waste emissions estimate of 28,682 MT CO_2e, over four times the correct amount. This could also lead to inconsistencies comparing emissions between towns that both used the MAPC protocol but included improper waste streams. We would recommend to them that they make it more clear exactly which types of waste must be accounted for in the inventory.

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Appendices:

Appendix A: Sponsor Description

From the late 1800s to the 1990s, diesel generators or steam-based engines located on the island - powered by burning coal or wood - produced the entirety of Nantucket's electricity. Due to high demand for electricity during the summer tourism season, and concerns about the cost, maintenance issues, and reliability of on-island generation, Nantucket was subsequently connected to the Cape Cod power grid by two underwater cables. In 1996 National Grid laid the first $30 million 36MW cable, and ten years later they added a $41 million 38MW cable to deal with growing energy demands. Residents of Nantucket must pay high prices for electricity, gas, and propane because of the extra expenses involved in bringing them to the island, and energy consumption and costs remain a major concern for town residents and officials (Brief History of Energy on Nantucket, 2020).

In 2011, the Town of Nantucket founded the Nantucket Energy Office to improve energy efficiency and conservation, and to implement renewable energy programs that are economically viable for the island. The Office was funded by a yearly grant from ReMain Nantucket until 2014 and run by two part-time consultants. In 2014, the Town secured a grant from the Massachusetts Department of Energy Resources that allowed the office to hire a full time Energy Coordinator (Brief History of Energy on Nantucket, 2020).

Energy Coordinator, Lauren Sinatra, is the sole employee in the Energy Office. As the Energy Coordinator, Sinatra serves the entire community of Nantucket. She must not only deal with the wants and needs of the public, but also works with the Selectboard and other town officials to find plans that are feasible and cost effective (Energy Office, 2020). Sinatra coordinates closely with National Grid on efforts such as the "No-Wires Alternative" to reduce Nantucket's peak energy load and the MassSave program to improve the energy efficiency of homes and businesses (Town of Nantucket Energy Office, 2020).

The Nantucket Energy Office is a small department which is a part of the larger Planning & Land Use Services (PLUS) department (Energy Office, 2020). According to the FY20 budget information, PLUS as a whole was allocated roughly 2.1 million dollars for fiscal year 2020

(FY20 Budget Information, 2020). PLUS is a large department, formed from combining the Code Enforcement and Planning and Zoning departments (see Figure 26).

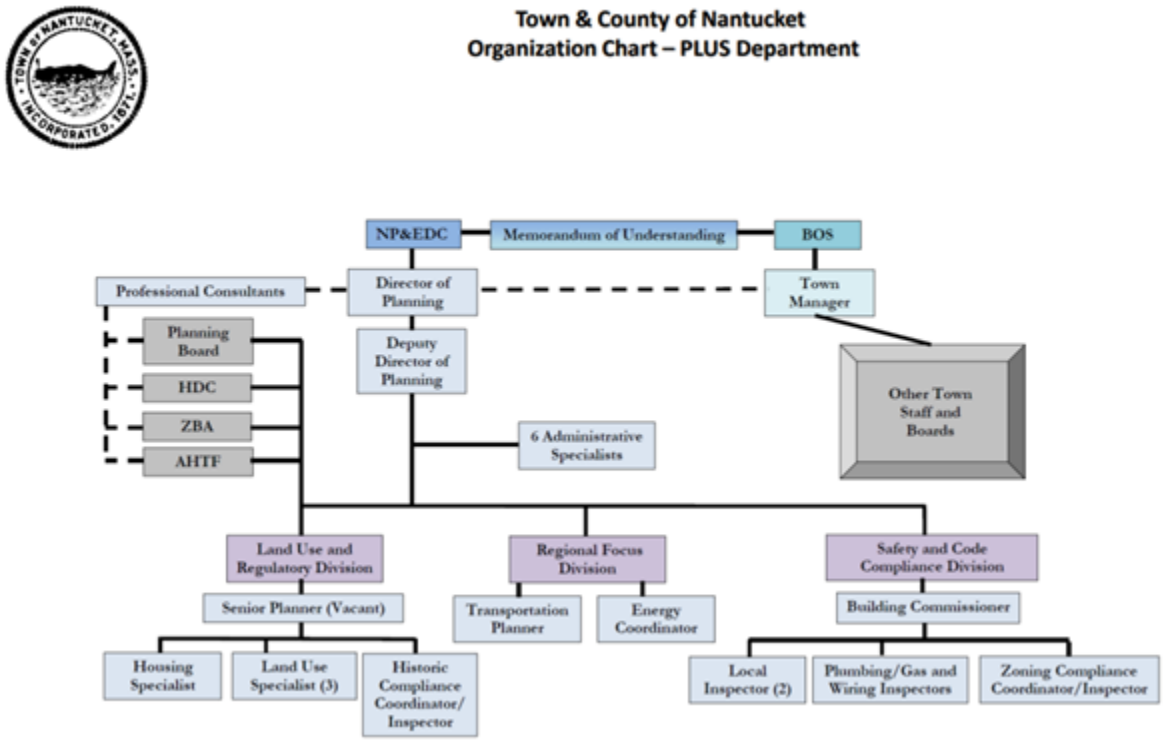


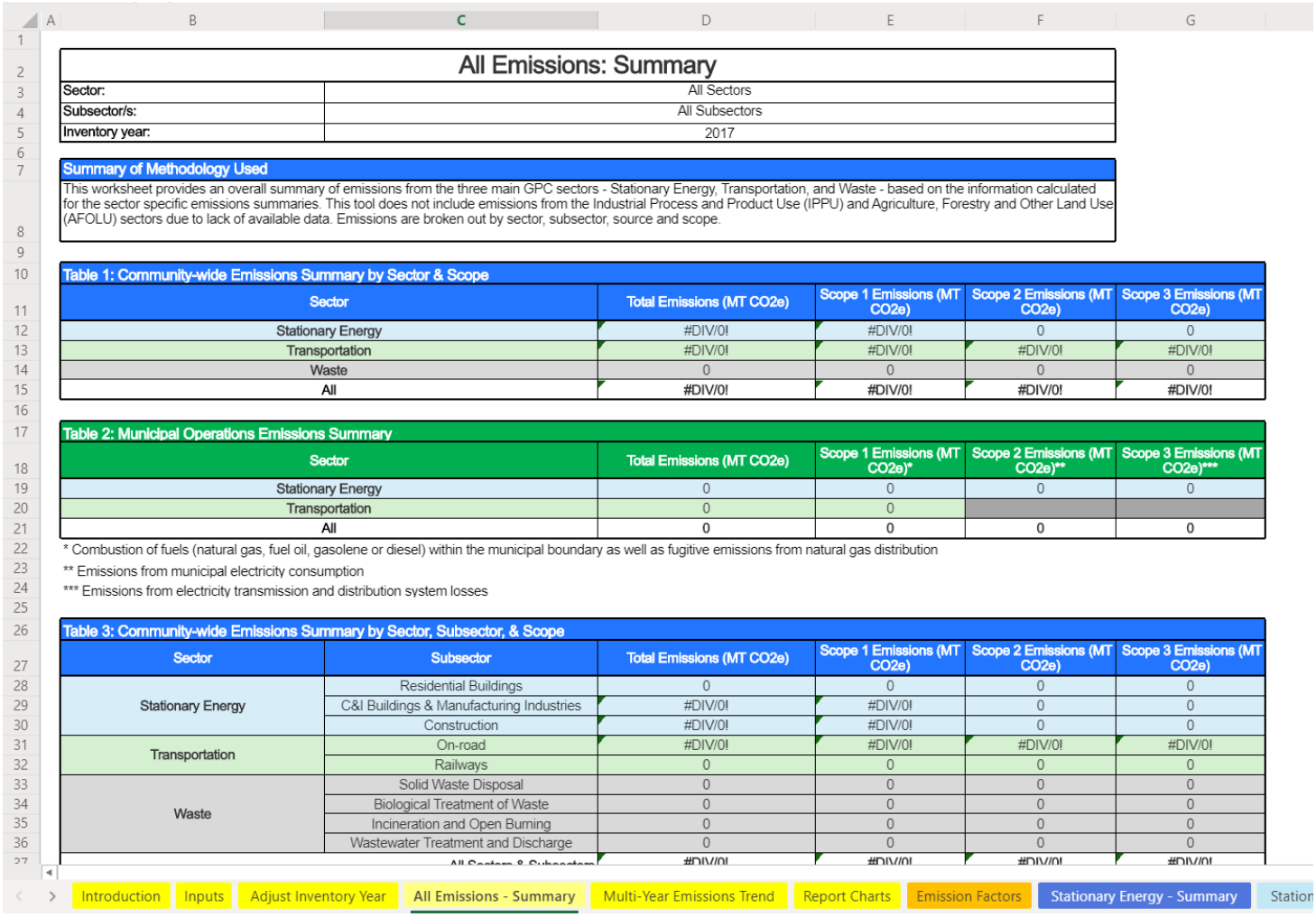
Figure 26: Organizational Chart of the PLUS Department (FY20 Budget Information, 2020)

The Energy Office helps the town with many important functions. Some of these functions include working with the town's Selectboard and the town administration to create energy-friendly policies, practices, and projects that will help the town save energy and prevent a third cable. The estimated cost of a third submersible cable is projected by National Grid to be $100-170 million ("Beat the Peak!", 2020). With energy consumption at its highest during the summer months, where it typically exceeds the capacity of one cable. If the trend continues as it has, National Grid estimates that by 2029 it would have to install a third cable to ensure adequate redundant capacity on the island. The office also generates reports based on data from the electric, oil, and propane companies that serve the island to determine energy use. The office conducts a variety of outreach programs to educate residents and businesses about energy issues, such as the stretch code. ways to reduce energy waste. The organization also aims to educate

students on the importance of energy conservation by providing research and educational opportunities to them (Town of Nantucket Energy Office 2020).

The organization has made some significant progress with their goals. A couple of them include dropping the towns energy cost and use by 10% since 2012 and more recently on February 4th, 2020 the island was declared a Massachusetts Green Community, receiving a grant of $139,340 from the Massachusetts Department of Energy Resources (Energy Office, 2020). This further supports their goals by the town pledging to cut municipal building energy use by 20% by 2025, by creating a solar panel overlay district, and creating a fuel-efficient vehicle policy (Town of Nantucket Energy Office, 2020). The office has also coordinated with Mass Save to provide no-cost home energy assessments. They provide customers a variety of free products such as LED light bulbs, low-flow showerheads, smart thermostats, and 100% off certain insulations (Virtual Assessments, n.d.). There are additional programs that focus on renewable sources of energy including the local SOLAR Rebate Program provided by Nantucket Power Choice and HeatSmart Nantucket. Both programs provide homeowners with an option to minimize their energy dependency on the grid. The SOLAR Rebate Program gives up to $4,000 in rebates for those who purchase solar PV systems and HeatSmart provides an alternative solution to heating and cooling homes (“Beat the Peak!, n.d”). Nantucket Power Choice program has also worked to bypass National Grid as the sole energy supplier utilizing its buying power to obtain contracts with alternate suppliers to lower energy costs (How aggregation works, 2020). There are also large scale projects that have been completed by Tesla in conjunction with National Grid to provide an energy storage solution. This would be utilized as a backup source for the island should one of the sea cables fail (Gellerman, 2019).

Appendix B: MAPC Spreadsheets



All Emissions: Summary

Sector:	All Sectors
Subsector/s:	All Subsectors
Inventory year:	2017

Summary of Methodology Used

This worksheet provides an overall summary of emissions from the three main GPC sectors - Stationary Energy, Transportation, and Waste - based on the information calculated for the sector specific emissions summaries. This tool does not include emissions from the Industrial Process and Product Use (IPPU) and Agriculture, Forestry and Other Land Use (AFOLU) sectors due to lack of available data. Emissions are broken out by sector, subsector, source and scope.

Table 1: Community-wide Emissions Summary by Sector & Scope

Sector	Total Emissions (MT CO2e)	Scope 1 Emissions (MT CO2e)	Scope 2 Emissions (MT CO2e)	Scope 3 Emissions (MT CO2e)
Stationary Energy	#DIV/0!	#DIV/0!	0	0
Transportation	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Waste	0	0	0	0
All	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Table 2: Municipal Operations Emissions Summary

Sector	Total Emissions (MT CO2e)	Scope 1 Emissions (MT CO2e)*	Scope 2 Emissions (MT CO2e)**	Scope 3 Emissions (MT CO2e)***
Stationary Energy	0	0	0	0
Transportation	0	0		
All	0	0	0	0

* Combustion of fuels (natural gas, fuel oil, gasolene or diesel) within the municipal boundary as well as fugitive emissions from natural gas distribution

** Emissions from municipal electricity consumption

*** Emissions from electricity transmission and distribution system losses

Table 3: Community-wide Emissions Summary by Sector, Subsector, & Scope

Sector	Subsector	Total Emissions (MT CO2e)	Scope 1 Emissions (MT CO2e)	Scope 2 Emissions (MT CO2e)	Scope 3 Emissions (MT CO2e)
Stationary Energy	Residential Buildings	0	0	0	0
	C&I Buildings & Manufacturing Industries	#DIV/0!	#DIV/0!	0	0
	Construction	#DIV/0!	#DIV/0!	0	0
Transportation	On-road	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Railways	0	0	0	0
Waste	Solid Waste Disposal	0	0	0	0
	Biological Treatment of Waste	0	0	0	0
	Incineration and Open Burning	0	0	0	0
	Wastewater Treatment and Discharge	0	0	0	0
	All Sectors & Subsectors	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Introduction | Inputs | Adjust Inventory Year | All Emissions - Summary | Multi-Year Emissions Trend | Report Charts | Emission Factors | Stationary Energy - Summary | Station

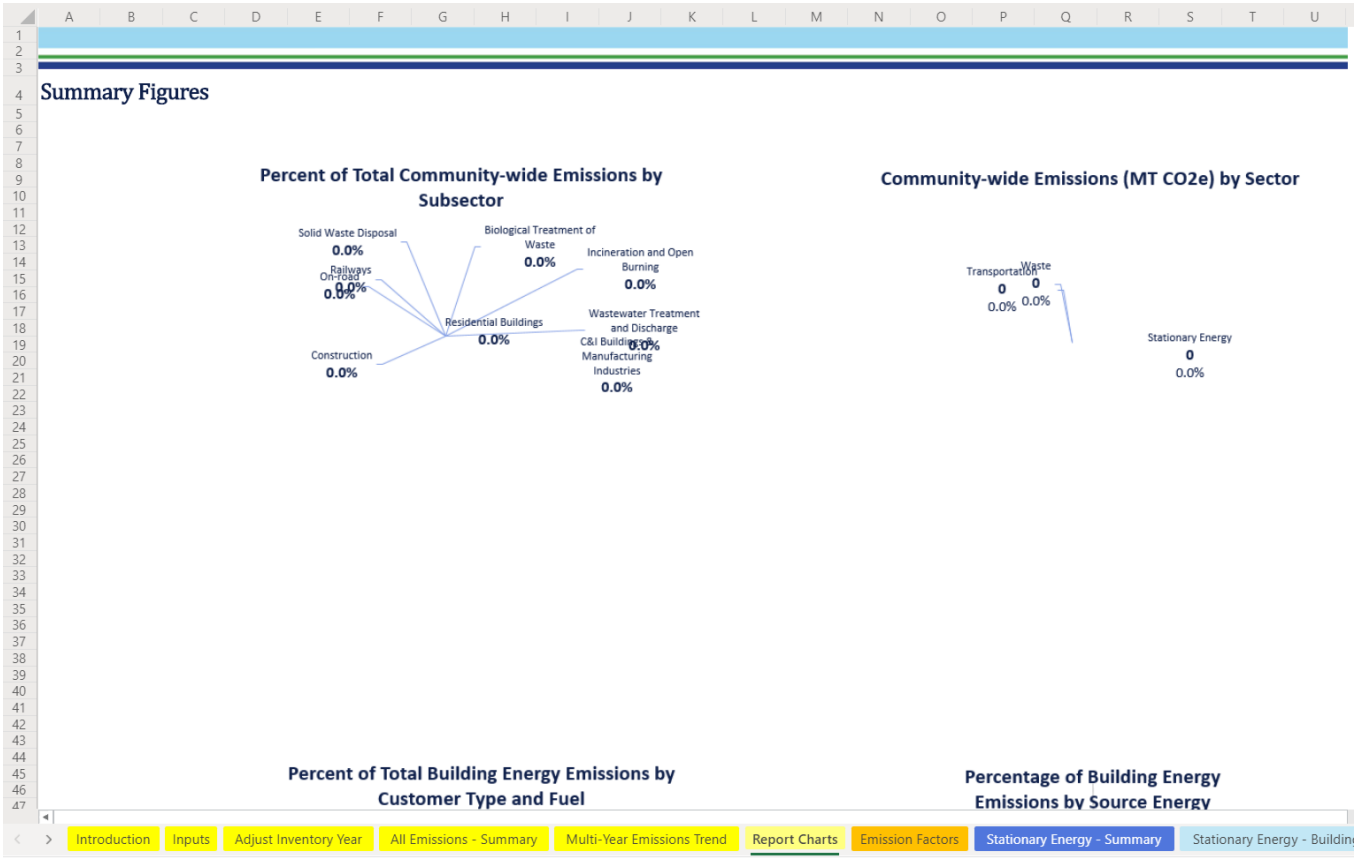
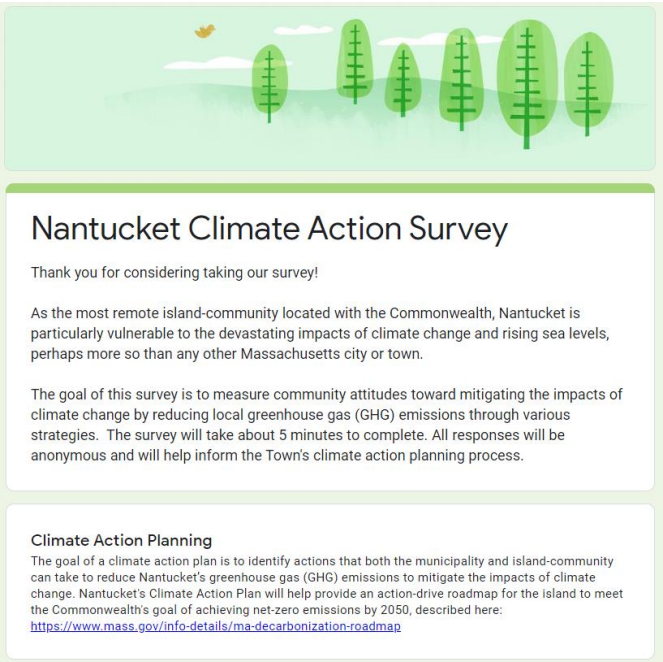


*Table provided from: Metropolitan Area Planning Council. (April 10, 2020). *MAPC Emissions Inventory Too*l. Retrieved from: https://www.mapc.org/planning101/community-ghg-assessment/

Appendix C: Survey



Nantucket Climate Action Survey

Thank you for considering taking our survey!

As the most remote island-community located with the Commonwealth, Nantucket is particularly vulnerable to the devastating impacts of climate change and rising sea levels, perhaps more so than any other Massachusetts city or town.

The goal of this survey is to measure community attitudes toward mitigating the impacts of climate change by reducing local greenhouse gas (GHG) emissions through various strategies. The survey will take about 5 minutes to complete. All responses will be anonymous and will help inform the Town's climate action planning process.

Climate Action Planning

The goal of a climate action plan is to identify actions that both the municipality and island-community can take to reduce Nantucket's greenhouse gas (GHG) emissions to mitigate the impacts of climate change. Nantucket's Climate Action Plan will help provide an action-drive roadmap for the island to meet the Commonwealth's goal of achieving net-zero emissions by 2050, described here: https://www.mass.gov/info-details/ma-decarbonization-roadmap

Let's start with introductions. Please check all that apply:

- [ ] I live on Nantucket year-round
- [ ] I live on Nantucket seasonally or part-time
- [ ] I own my Nantucket home
- [ ] I rent my Nantucket home
- [ ] I rent one or more properties on Nantucket to others
- [ ] Other: _____

And now for your employment:

- [ ] I work for the municipality or within the school system
- [ ] I am an elected or appointed official on Nantucket
- [ ] I own a business or am self-employed on Nantucket
- [ ] I am a retiree
- [ ] I am a student
- [ ] I am an employee, member or volunteer in an environmental or sustainability-related field
- [ ] Other: _____

What actions you currently take?

For the next set of questions, please select the option that best matches your actions.

I can reduce home energy use by getting a home energy assessment, upgrading to high-efficiency HVAC and appliances, or replacing bulbs with LEDs

- ◯ I am already doing this.
- ◯ I would consider doing this.
- ◯ I would not consider doing this.
- ◯ Other: _____

I can offset the emission of my personal energy use by installing solar panels on my home or by purchasing a greener power supply (i.e. Nantucket PowerChoice Green)

- ◯ I am already doing this.
- ◯ I would consider doing this.
- ◯ I would not consider doing this.
- ◯ Other: _____

I can reduce emissions by using public transit, walking, or riding a bicycle to work or school at least once per week instead of driving

- ◯ I am already doing this.
- ◯ I would consider doing this.
- ◯ I would not consider doing this.
- ◯ Other: _____

I can reduce emissions by switching to an electric vehicle

- ◯ I am already doing this.
- ◯ I would consider doing this.
- ◯ I would not consider doing this.
- ◯ Other: _____

I can reduce home landfill waste by recycling more, switching to reusable options for common disposables like plastic water bottles, or setting up an at-home compost bin to collect kitchen scraps

- ◯ I am already doing this.
- ◯ I would consider doing this.
- ◯ I would not consider doing this.
- ◯ Other: _____

Has the current health crisis from coronavirus (COVID-19) had an impact on how you answered these questions? Please elaborate, if possible.

Your answer

Climate action has benefits beyond reducing greenhouse gasses. Which of the following are most important to you? (Choose up to 3)

- ☐ Safe routes for walking and bicycling
- ☐ Improved natural spaces
- ☐ A more active lifestyle
- ☐ Savings on vehicle fuel
- ☐ Savings on energy bills
- ☐ Workforce development and quality jobs
- ☐ Improved air quality
- ☐ Improved community adaptation and resilience to climate change

What should Nantucket Prioritize?

Listed below are an assortment of short-term emission reduction strategies that the island could adopt. Please indicate what strategies you think Nantucket should prioritize in the coming years.

ENERGY: Increase the percentage of clean energy supplied to residents and businesses, even if the cost per kilowatt hour ($/kWh) is incrementally higher

- ◯ Low Priority
- ◯ Moderate Priority
- ◯ High Priority
- ◯ Other: _____

ENERGY: Develop more island-based renewable energy and energy storage to reduce peak load, increase local grid reliability, and defer the need for a costly 3rd undersea delivery cable

- ◯ Low Priority
- ◯ Moderate Priority
- ◯ High Priority
- ◯ Other: _____

ENERGY: Adopt a more aggressive "Net Zero Stretch Code" for all new residential and commercial construction. (A net-zero building is designed to be extremely energy efficient, with all remaining electrical and thermal energy needed for the building supplied by renewable sources).

- ◯ Low Priority
- ◯ Moderate Priority
- ◯ High Priority
- ◯ Other: _____

ENERGY: Require all new and renovated municipal buildings to incorporate net-zero design principals, such as solar panels and high-efficiency HVAC

- ◯ Low Priority
- ◯ Moderate Priority
- ◯ High Priority
- ◯ Other: _____

ENERGY: Increase the incentives for residents to install solar panels and energy storage systems (Town of Nantucket currently offers a local solar rebate up to $4,000 for year-round residents)

- ◯ Low Priority
- ◯ Moderate Priority
- ◯ High Priority
- ◯ Other: _____

ENERGY: Support the development of Massachusetts offshore wind farms

- ◯ Low Priority
- ◯ Moderate Priority
- ◯ High Priority
- ◯ Other: _____

ENERGY: Pilot new and emerging energy technologies (e.g. smart meters, energy storage, microgrids, anaerobic digestion/bio-gas generation)

- ◯ Low Priority
- ◯ Moderate Priority
- ◯ High Priority
- ◯ Other: _____

TRANSPORTATION: Provide residents with incentives to switch to electric vehicles, such as expanded access to public charging ports across the island or free off-peak charging

- ◯ Low Priority
- ◯ Moderate Priority
- ◯ High Priority
- ◯ Other: _____

TRANSPORTATION: Improve and expand bike and pedestrian infrastructure

- ◯ Low Priority
- ◯ Moderate Priority
- ◯ High Priority
- ◯ Other: _____

TRANSPORTATION: Implement a dependable Park and Ride system which would utilize satellite parking areas and transport people via NRTA shuttle busses

- ◯ Low Priority
- ◯ Moderate Priority
- ◯ High Priority
- ◯ Other: _____

TRANSPORTATION: Begin the transition to electric public transportation systems

- ◯ Low Priority
- ◯ Moderate Priority
- ◯ High Priority
- ◯ Other: _____

WASTE: Provide no-cost or discounted home composting kits for yard trimmings and food residuals*. (*Home composting would reduce plastic trash bag usage and trips to the Recycling Center, while providing great soil for gardens)

- ◯ Low Priority
- ◯ Moderate Priority
- ◯ High Priority
- ◯ Other: _____

WASTE: Implement a "Pay As You Throw" system that would charge disposal fees according to how much you throw away that cannot be recycled or composted at the landfill

- ◯ Low Priority
- ◯ Moderate Priority
- ◯ High Priority
- ◯ Other: _____

LAND USE: Expand tree planting efforts in open spaces on Nantucket

- ◯ Low Priority
- ◯ Moderate Priority
- ◯ High Priority
- ◯ Other: _____

ENVIRONMENTAL JUSTICE: Pursue climate initiatives that result in equitable outcomes for marginalized communities who are disproportionately affected by climate change issues and solutions

- ◯ Low Priority
- ◯ Moderate Priority
- ◯ High Priority
- ◯ Other: _____

Balancing Visual Impacts of Climate Action Strategies on Historic Nantucket

I agree with which of the following statements:

- ◯ Climate action measures, such as solar panels and elevated structures, must be pursued regardless of their visual impact upon the Nantucket - National Historic Landmark (NHL)
- ◯ We must balance the island's historical integrity with modern climate adaptation needs and sustainability/GHG reduction goals
- ◯ Climate action measures with discernible visual impacts would be inappropriate and should not be pursued
- ◯ Other: _____

Climate Emergency Declaration

Many municipalities in the Commonwealth, including on Cape Cod, have declared Climate Emergency Declarations and have adopted accelerated net-zero emissions goals.

An example of such a declaration would read:

The Town of Nantucket recognizes that the climate emergency, driven by human activity including energy consumption and land use practices and leading to global warming, rising seas, deadly storms, dangerous heat waves, acidifying oceans, and melting ice sheets, poses an imminent threat to the health, safety and economic security of the residents of the Town. The Town of Nantucket therefore adopts as its policy the objective of reducing net greenhouse gas emissions from human activity within and by the Town to zero at the earliest technically and economically feasible time, and directs that all officers and departments of the Town take such measures within the scope of their respective responsibilities and authority as may be necessary and prudent to facilitate such policy and objective.

Would you consider adopting a Climate Emergency Declaration at the next Annual Town Meeting?

- ◯ Yes
- ◯ No
- ◯ Other: _____

Your Final Thoughts

Describe in a few words why you are interested in Nantucket's Climate Action Planning?

Your answer

Are there other strategies or ideas you have to reduce greenhouse gas emissions on Nantucket?

Your answer

What are your concerns about Nantucket's Climate Action Planning (if any)?

Your answer

Thank You for Taking the Survey!

Please reference the list of resources below to learn more about ongoing climate action initiatives on the island! If you want to go back and change any of your answers now, please do so, otherwise don't forget to hit submit!

List of Climate Action References & Resources:

Questions? Contact: Lauren Sinatra, Energy Coordinator; LSinatra@nantucket-ma.gov

Local SOLAR Rebate Program: https://www.nantucket-ma.gov/solarrebate

Mass Save Program: http://www.ackenergy.org/mass-save.html

Net-Zero Stretch Code: https://energynews.us/2019/05/20/northeast/massachusetts-considers-net-zero-standard-for-new-buildings/

Coastal Community Resilience Planning: https://nantucket-ma.gov/1369/Coastal-Community-Resilience-Planning

Town of Nantucket Recycling website with information on where waste items should go and/or where to donate them: https://www.nantucket-ma.gov/1428/Waste-Items-A-to-Z

NRTA Park & Ride: http://www.nrtawave.com/routes/parkandride.php

Locations for refilling your water bottle on Nantucket: https://www.nantucket-ma.gov/1371/Water-Stations

Massachusetts Offshore Wind: https://www.mass.gov/service-details/offshore-wind

Thank you for taking the survey! We value your input.

If you would like to be involved in the climate action planning process further, please follow this link to provide your email to the Town's Energy Coordinator (it will NOT be connected to your survey responses or sold to any third party): https://forms.gle/3SZcy1Cpb3pLGq5u7

Nantucket Climate Action Email Survey

If you would like to continue to be involved with Nantucket's climate action planning, please leave your email below:

* Required

Email: *

Your answer

How would you like to be involved in Nantucket's climate action planning? (Check all that apply)

- [ ] Take online surveys
- [ ] Share feedback at community events
- [ ] Attend planning meetings
- [ ] Advocate for specific strategies
- [ ] Participate in focus groups
- [ ] Attend public forums
- [ ] Watch videos online
- [ ] Tell friends, family, and neighbors about this initiative
- [ ] I would not like to be involved
- [ ] Other: _____

How do you normally hear about town policy?

- [ ] Town Website (nantucket-ma.gov)
- [ ] Committee Meetings
- [ ] The Inquirer & Mirror
- [ ] Newsletters
- [ ] Radio
- [ ] By following the town's social media
- [ ] By following private social media accounts and groups
- [ ] Word of mouth
- [ ] Other: _____

Thank you!

Sincerely,
Lauren Sinatra and the WPI Team: Brennan, Callan, Jared, and Tyler