COLUMBIA UNIVERSITY
MASTER OF SCIENCE IN SUSTAINABILITY MANAGEMENT
SPRING 2019 CAPSTONE

# A ROADMAP TO MAKING CRAIGVILLE NET ZERO BY 2050

*Authors: Bryan Rubio, Emily Caldwell, Abdulla Alishaq, Brian Balzar, Lennie Blake, Charlotte Gueye, Marc Johnson, Julia Magliozzo, Casey Plasker, Yaishna Santchurn and Elizabeth Suazo Di Paola-Otero*

Faculty Advisor: Thomas Abdallah

COLUMBIA UNIVERSITY

This report was prepared by graduate students from Columbia University's Masters of Science in Sustainability Management, co-sponsored by the Earth Institute and the School of Professional Studies.

The capstone workshop is a client-based consulting project that students undertake to address critical sustainability management issues. The workshop is designed to integrate the program's distinct curriculum areas, including integrative sustainability management, economics and quantitative analysis, environmental sciences, public policy, and general and financial management.

## Table Of Contents

**Acknowledgements**

The team members of the Spring 2019 Sustainability Management Capstone would like to thank the Christian Camp Meeting Association for the opportunity to support Craigville's Net Zero Goals. Throughout the development of this report, the Board Members and staff of the CCMA have been responsive, supportive, and enthusiastic. We would like to especially thank Jim Lane, Bill McKinney, Samuel Carpenter, Dick Delaney, and Matthew CastleMan for their incredible hospitality and generosity during our visit to Craigville. We would also like to thank Columbia University Professors Jonathan Dickinson and Stephanie Johnston for their guidance calculating Craigville's Greenhouse Gas Inventory and in researching alternative recycling solutions, respectively.

Lastly, we are extremely grateful for our faculty advisor Thomas Abdallah, whose support, insight, and enthusiasm throughout the semester were greatly appreciated and encouraging.

**Executive Summary**

Established as Camp Christian in 1871, Craigville is a small village in Cape Cod, Massachusetts. A long-term perspective is central to Craigville's motto: "Preserving the Past, Providing for the Future." In pursuit of this effort, the Christian Camp Meeting Association (CCMA) passed a motion in April 2018 to make Craigville a Net Zero Community by 2050. To achieve this goal, the CCMA intends to develop a series of sustainability plans to reduce its impacts across energy, water, and waste by using approaches that are economically viable, socially beneficial, and environmentally responsible. The CCMA tasked us with developing a roadmap to achieve their ambitious Net Zero goals. Main tasks included benchmarking against other communities' sustainability and climate action plans, analysis of energy, water, and waste data, and identifying recommendations across these three areas. Through our analysis, we discovered that this ambitious effort requires a significant commitment to energy decarbonization, renewable energy development, water conservation, waste management, and community engagement and education.

Regarding Net Zero energy, the CCMA plans to reduce the community's greenhouse gas emissions to zero by lowering energy consumption through efficiency and conservation measures and by producing and/or buying enough clean energy to meet all remaining needs. To achieve this goal, we developed a strategy and set of recommendations for the CCMA and Village residents to: 1) upgrade mechanical equipment to energy efficient equipment at end of life, 2) replace on-site natural gas fueled heating and hot water systems with electric heating systems, and 3) source all remaining electricity needs from renewable energy, whether deployed on-site or through the purchase of offsets, more commonly referred to as Renewable Energy Certificates (RECs).

More qualitative in nature, the Net Zero water goal is to continue to support the efforts of the Red Lily Pond Project, an independent nonprofit organization that is the steward of Craigville's Lake Elizabeth and Red Lily Pond, and work to preserve and protect the quality and availability of water needed to sustain the livability and beauty of the community despite sea level rise. We recommend that water be approached from two angles: 1) enhancing wetland preservation, via invasive species removal strategies, oyster farm water filtration, native plantings, and raising homes; and 2) water conservation efforts, which include installing water refilling stations, water efficient appliances, and individual metering systems.

The CCMA defines Net Zero waste as reducing waste to a minimum, reusing and/or composting as much as possible, recycling the rest, and sending zero waste to a landfill. As such, we have developed four initiatives across reduction, composting, recycling, and education and community engagement. Reduction recommendations include local vendor sourcing, selling reusable water bottles, eliminating single-use plastics, and removing trays from Craigville's dining areas. Composting efforts include the purchase of composting bins, while recycling initiatives include working with a private company to collect recyclables. Education and community engagement involves improving labeling on collection bins and the creation of marketing materials to distribute to the community.

We hope that the CCMA will use this report to inform conversations, identify opportunities for action, and implement these strategies. Considering a timespan of more than 30 years to achieve these goals and the rapid pace at which science and technology have been advancing, we recommend re-assessing Craigville's Net Zero opportunities at a minimum every three years. A list of all Net Zero recommendations ranked across the three impact categories can be found in Appendix 1. Achieving Net Zero by 2050 is an ambitious effort and will require the village of Craigville to profoundly live their motto of "Preserving the Past; Providing for the Future."

## Glossary of Terms

**CCMA:** Christian Camp Meeting Association

**EPA:** United States Environmental Protection Agency

**Diversion Rate:** The amount of waste diverted from landfill through recycling and composting.

**Net Zero Energy:** Reducing the community's greenhouse gas emissions to zero by reducing energy consumption through efficiency & conservation measures and by producing and/or buying enough clean energy to meet all remaining needs. Energy supply may include energy produced by fossil fuels, but only to the extent the Village's natural habitat can absorb the effects of said purchases (Christian Camp Meeting Association, 2018).

**Net Zero Waste:** Reducing waste to a minimum, reusing and/or composting where possible, recycling the rest, and sending zero waste to a landfill (Christian Camp Meeting Association, 2018).

**Net Zero Water:** Continue to support the efforts of the Red Lily Pond Project and working to preserve and protect the quality and availability of water needed to sustain the livability and beauty of the community (Christian Camp Meeting Association, 2018).

**Sustainability:** Managing the availability of natural resources by present generations in a way that does not compromise the ability of future generations to meet their needs.

**UCCR:** United Camps, Conferences, & Retreats

**Waste Stream:** Beginning at a domestic or industrial source, a waste stream is the flow of waste through to its recovery, recycling or final disposition.

**“The climate is a common good, belonging to all and meant for all”**

**- Pope Francis (2015)**

## Introduction

In 2018, the Earth experienced the 4th hottest year on record according to the National Oceanic and Atmospheric Administration. Induced by a warmer climate, the U.S. experienced 14 weather and climate disasters resulting in $91 billion in damage, countless injuries, and 247 deaths (National Oceanic and Atmospheric Administration, 2019). In parallel with these devastating events, Federal governments around the globe, most notably the U.S., have backed away from international climate commitments to address anthropogenic climate change. As a result, local governments have taken a leadership role in setting aggressive sustainability targets, preserving their natural resources, and protecting their communities. Craigville has chosen to take local action by committing to become a Net Zero community by 2050. This is an ambitious effort that requires a significant commitment to energy decarbonization, renewable energy development, water conservation, waste management, and community education.

Located on the southern coastline of Cape Cod, Massachusetts, the small Village of Craigville is vulnerable to threats from anthropogenic climate change. By the most extreme models, the world may experience as much as an 11 foot increase in sea level rise—which will engulf homes in flood zone areas (National Oceanic and Atmospheric Administration, 2017a). Originally established as Camp Christian in 1871, Craigville was renamed in 1881 in honor of a prominent spiritual leader Dr. J. Austin Craig. With a population of slightly more than 10,000 people and residential seasonality typical of a beach town, Craigville's local economy is highly dependent on visitors to the Craigville Retreat Center and private beach. Helping Craigville achieve its Net Zero goals does not only serve as an important case study for other communities to follow, but it also represents an opportunity for Craigville to increase its visitors, become more resilient, and preserve its unique history for generations to enjoy. This long-term perspective is central to Craigville's motto: "Preserving the Past, Providing for the Future."

## Client Profile

Our client, the Christian Camp Meeting Association (CCMA) was established as the governing body of Craigville in 1872. Consisting of an 18 member volunteer Board of Directors, the CCMA's mission is to ensure the continued beauty and sustainability of Craigville for future generations. The CCMA owns 11 buildings, which include the Craigville Retreat Center, the Beach House, the Historic Tabernacle, and all of the parks and roads within Craigville. Though owned exclusively by the CCMA, other entities are involved in the management and operation of many of the CCMA's buildings. As Figure 1 illustrates, the Craigville Retreat Center, a series of buildings that hosts nearly 12,000 guests per year, is managed by United Camps, Conferences, and Retreats (UCCR) and the private beach is operated by the Craigville Beach Association. The private beach and Retreat Center serve as the main economic drivers for the village. Other important stakeholders include The Red Lily Pond Project Association, an independent 501c-3 nonprofit organization that is the steward for the unique ecosystem within Craigville's Lake Elizabeth and Red Lily Pond, and the Craigville Cottage Owners Association, which represents the interests of Craigville's 97 residential homeowners.

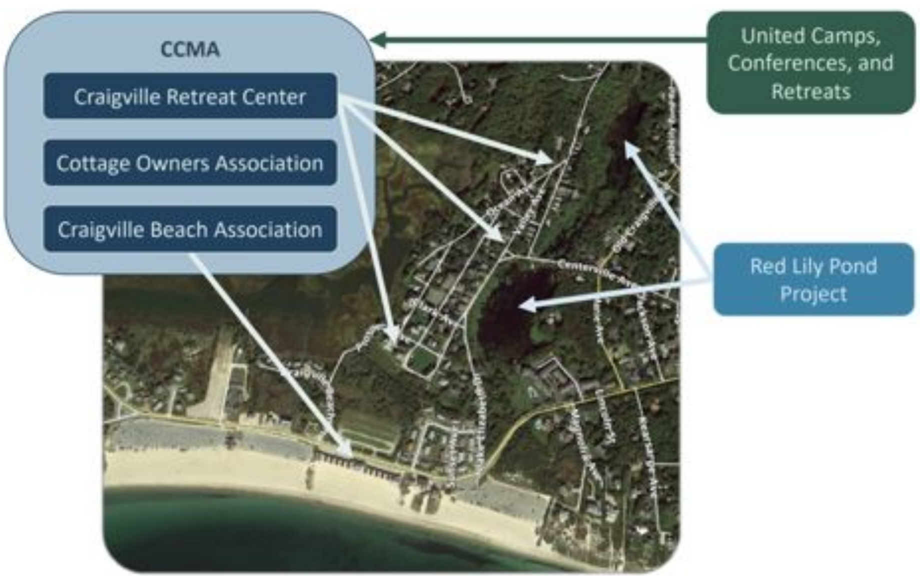



**Figure 1:** Map of Craigville.

In recognition of its mission and the increased risks from anthropogenic climate change, as well as increased operating costs and declining revenue, the CCMA passed a motion on April 14, 2018, to use its best efforts to make Craigville a Net Zero Community by 2050 (Christian Camp Meeting Association, 2018). The complete Board resolution can be viewed in Appendix 9. To achieve this goal, the CCMA intends to develop a series of plans to reduce its impacts across energy, water, and waste by using approaches that are economically viable, socially beneficial, and environmentally responsible.

#### Project Scope

The CCMA tasked us with developing a roadmap to achieve their ambitious Net Zero goals. Main tasks included benchmarking against other communities' sustainability and climate action plans, analysis of energy, water, and waste data, and identifying recommendations across these three areas. In the area of residential energy usage, the team was tasked with identifying and comparing trends or patterns according to different types of housing stock, based on method of heating type, age of residential units, and size of units, as well as providing data on effects of future trends, including increased use of electricity for electric vehicles, air and potentially ground-source heat pumps, and the potential for increased solar photovoltaic installations. Regarding water, the team was asked to recommend strategies to take advantage of the work previously performed by the Red Lily Pond Project to ensure the lasting availability of quality drinking water, management of the quality and quantity of wastewater and stormwater, and continued long term sustainability of Craigville's surrounding aquatic habitats. The CCMA also requested that we identify practices to avoid potential risks related to sea level rise. Lastly, regarding solid waste, the team was tasked with making recommendations for increasing recycling and composting efforts to ultimately achieve a 100% diversion of waste from landfills. It is important to note that providing the CCMA with a methodology to measure their progress towards these goals was not considered within the scope of this project.

#### Net Zero Definitions

The term 'Net Zero' can be defined in many ways. As such, the recommendations in this report are based on the CCMA's definitions of Net Zero as outlined in their April 2018 Board resolution. These definitions have been outlined below.

Net Zero energy means lowering the community's greenhouse gas emissions to zero by reducing energy consumption through efficiency and conservation measures and by producing and/or buying enough clean energy to meet all remaining needs. Energy supply may include energy produced by fossil fuels, but only to the extent the Village's natural habitat can absorb the effects of said purchases.

Net Zero water means continuing to support the efforts of the Red Lily Pond Project and working to preserve and protect the quality and availability of water needed to sustain the livability and beauty of the community.

Net Zero waste means reducing waste to a minimum, reusing and/or composting what we can, recycling the rest, and sending zero waste to a landfill.

**Methodology**

As the CCMA develops its Sustainability Plan, we sought to identify a list of recommendations by employing a common methodology across all three Net Zero goals. As shown in Figure 2, our methodology consisted of data collection, benchmarking, and analysis to identify Net Zero recommendations and develop an implementation plan.

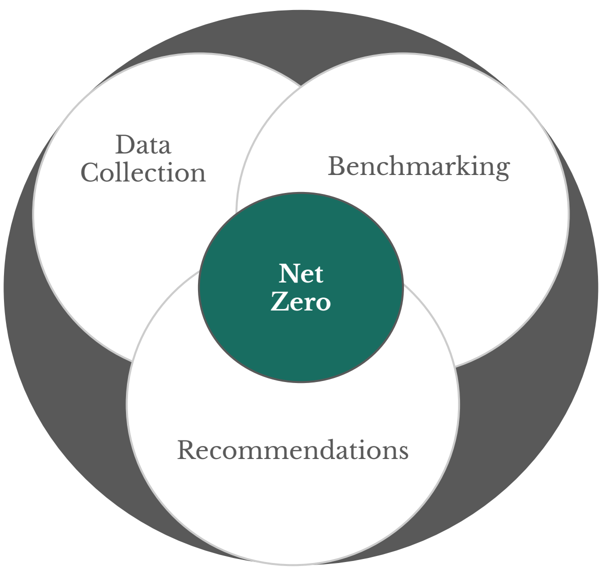
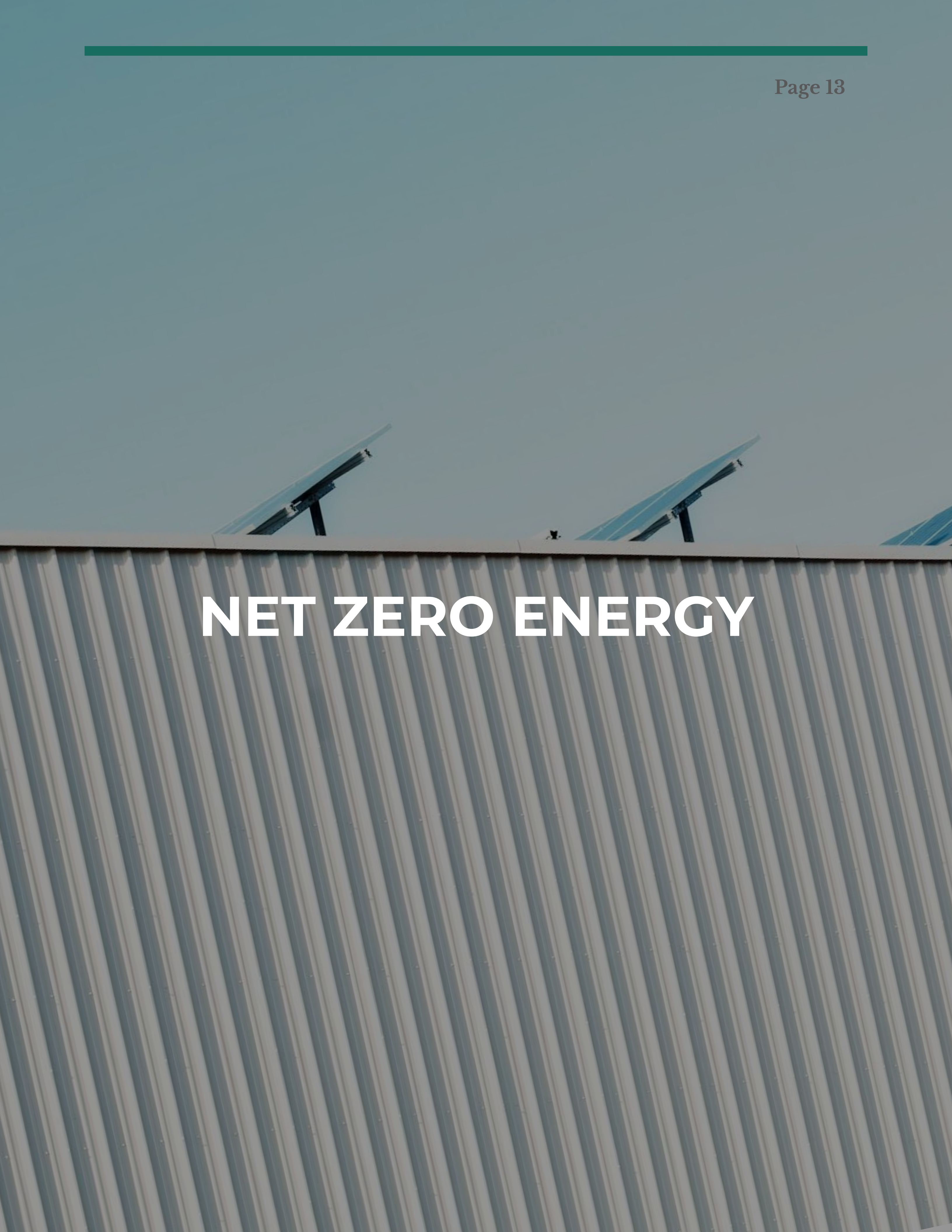



**Figure 2:** Methodology approach.

Our data collection efforts began with assessing the current state of energy, water, and waste in Craigville through an analysis of bills, interviews with CCMA Board members, and a site visit to Craigville in February 2019. The output of this process was a baseline of Craigville's impacts across the three Net Zero goals. This process also helped to inform our understanding of Craigville's current sustainability efforts. Next, we benchmarked Craigville's baseline data against applicable metrics and similar communities to identify opportunities for improvement.

Once the opportunities were identified, we developed recommendations within each Net Zero goal, considering sustainability impact, financial cost, and feasibility. Finally, based on these factors, we prioritized our recommendations into different implementation timeframes. The resulting implementation plan outlines our recommendations to achieve the specific Net Zero goal, while also including a time component. Lastly, we ranked our recommendations across all three Net Zero goals to provide the CCMA with additional insight for budgetary planning.



# NET ZERO ENERGY

### Net Zero Energy

As previously stated, the CCMA defines Net Zero Energy as lowering the Village's greenhouse gas emissions to zero by reducing energy consumption through efficiency and conservation measures and by producing and/or buying enough clean energy to meet all remaining needs. By their definition, energy supply may include energy produced by fossil fuels, but only to the extent the Village's natural habitat can absorb the effects of said purchases.

To deliver on this definition of Net Zero Energy we developed a strategy and set of recommendations for the CCMA and Village residents to: 1) upgrade mechanical equipment to energy efficient equipment at end of life, 2) replace on-site natural gas fueled heating and hot water systems with electric heating systems, and 3) source all remaining electricity needs from renewable energy, whether deployed on-site or through the purchase of offsets, more commonly referred to as Renewable Energy Certificates (RECs).

Developing this comprehensive strategy and set of recommendations was no easy task, and it's worth noting that the value of the recommendations detailed herein will only be recognized to the extent that the CCMA and Village residents abide by, and preserve, the recommendations in a continuous and iterative fashion.

### Initial Analysis

To begin our analysis, we took a number of preliminary steps to identify the energy consumption patterns of CCMA and Village residents based on building profiles. While often considered tedious, these preparatory steps were vital as they allowed us to establish baseline figures from which we were able to later determine the impacts of the various recommendations, and ultimately led to the creation of our recommendations.

With assistance from the CCMA, we began by accumulating and analyzing data from the CCMA's electricity and natural gas utility bills for the months between January 2018 and January 2019. For the electricity, the bills included separate accounts for each building as well as street lights. The site is served by two natural gas accounts. One account is located at 39 Prospect Ave, which is near the Manor and Lodge. The other account is located at the Beach Association building and is located at 915 Craigville Beach Road. For the baseline period (2018), CCMA consumed 177,719 kWh of electricity and 9,781 therms of natural gas. The following two charts provide summaries of CCMA's electricity and natural gas consumption.

**Table 1:** CCMA 12 Month Electricity Consumption by Account.

| CCMA Energy Analysis | | | | |
|---|---|---|---|---|
| 12 Month Electricity Usage | | | | |
| Building Name | Address | Annual Usage (kWh) | Max kW | Annual Cost |
| Craigville Inn | 208 Lake-Elizabeth Dr. | 50,362 | 28 | $9,205.77 |
| Groves | 125 Ocean Ave. | 3,648 | 0 | $915.64 |
| Union | 222 Lake-Elizabeth Dr. | 1,626 | 0 | $452.65 |
| Yale | 198 Lake-Elizabeth Dr. | 1,807 | 0 | $489.32 |
| Boston | 194 Lake-Elizabeth Dr. | 5,036 | 0 | $1,218.74 |
| Manor | 45 Prospect Ave - The Manor | 6,834 | 0 | $1,534.24 |
| Andover | 202 Lake-Elizabeth Dr. | 1,616 | 0 | $446.74 |
| Marsh | 45 Prospect Ave - Marsh | 4,206 | 0 | $1,045.28 |
| Lodge | 39 Prospect Ave - Lodge | 70,040 | 14 | $2,413.52 |
| Tabernacle | 135 Ocean Ave - Tabernacle | 4,385 | 0 | $977.50 |
| Beach Association | 915 Craigville - Beach Rd. (Beach Association) | 23,335 | 0 | $3,560.31 |
| Post Office | 149 Ocean Ave. (Post Office) | 578 | 0 | $92.17 |
| Parking Lights | 229 Lake-Elizabeth Dr. - Parking Lights | 898 | 0 | $276.49 |
| Lights | 130 Lake-Elizabeth Dr. Lights | 87 | 0 | $89.21 |
| Lights | 133 Lake-Elizabeth Dr. Lights | 62 | 0 | $83.90 |
| Lights | 137 Lake-Elizabeth Dr. Lights | 5 | 0 | $60.95 |
| Lights | 9 Valley Ave - Lights | 73 | 0 | $86.55 |
| Lights | 39 Prospect Ave. (Service Address: Ocean Ave. Light | 3,121 | 0 | $1,600.81 |
| | Total: | 177,719 | 42 | $24,549.79 |

**Table 2:** CCMA 12 Month Natural Consumption by Account

| CCMA Energy Analysis | | | |
|---|---|---|---|
| 12-month Natural Gas Data | | | |
| Address | Account Number | Therms | Cost |
| 39 Prospect Ave | 54689-10031 | 9,080 | $18,767.07 |
| 915 Craigville Beach Road | 54626-11561 | 701 | $716.58 |
| | Total | 9,781 | $19,483.65 |

After establishing a consumption baseline, we then used the U.S. Energy Information Administration's Commercial Buildings Energy Consumption Survey (CBECS) data to benchmark the CCMA's buildings against other buildings of similar dimensions to gain a more holistic view of their energy patterns, above and beyond the insights garnered from the utility bills (US Energy Information Administration, 2016). The CCMA's buildings total approximately 38,000 square feet. When treated as a whole, CCMA's energy use index (EUI), which is a metric that expresses a building's energy use as a function of its size or other characteristics, is 41.5 kBtus/sf. CBECS organizes buildings into several categories and determines average energy consumption. The table below shows how the CCMA site compares with the national average for buildings categorized as "Lodging."

**Table 3:** A comparison of energy consumption in CCMA vs CBECS lodging.

| Energy Comparison of CCMA Vs. CBECS Lodging | | | |
|---|---|---|---|
| Category | Unit | National Average | CCMA |
| [1] Electricity | kWh/sf | 15.3 | 4.7 |
| [2] Heating | cf/sf | 43.8 | 24.7 |
| [3] EUI | kbtus/sf | 96.9 | 41.5 |

As displayed above, the CCMA utilizes significantly less energy than similar buildings across the country. This is due mostly to the seasonal nature of Craigville where a majority of the consumption is in the summer months, with little use in the off-season. Additionally, with such low energy consumption, we came to the conclusion that standard energy efficiency measures are not viable because there are not enough savings to justify the implementation costs.

From here, we compiled information from the utility bills, CBECS data, and additional data points that we obtained during our site visit in February about mechanical equipment and Village residential homes size to develop a model of the CCMA's and Village residents' consumption patterns through eQuest, which is a building energy simulation tool developed by the U.S. Department of Energy (DOE-2, 2009). The purpose of utilizing eQuest for this task was to construct a digital replica of the CCMA buildings and Village residential homes to make comparisons against multiple energy improvements. For example, this software allowed us to calculate the electricity impact of converting one building from a natural gas furnace to an electric furnace.

For the CCMA buildings, we modeled each building individually, with the exception of the smaller lodges: Yale, Harvard, Boston, Union, Andover, and Groves. For these smaller lodges, we modeled one lodge and multiplied that value by six to obtain a total value for the CCMA.

For the Village residents' homes, rather than building 97 separate building models, we took a sample and grouped the buildings into three size categories: small houses that were 1,250 square feet, medium houses at 2,000 square feet, and large houses at 3,000 square feet. We also further segmented the houses into two subgroups: year-round and seasonal. Based on these parameters, we modeled a generic house in eQuest for each subgroup, effectively creating six models.

Thanks to our group members' previous working experience with eQuest, we were aware that a common pitfall is to inaccurately size the model constraints, however, we safeguarded against this and were able to validate the accuracy of our eQuest model by comparing the energy consumption output of our model to the total energy consumption from the CCMA's utility bills. The two total consumption figures were within a 5% range.

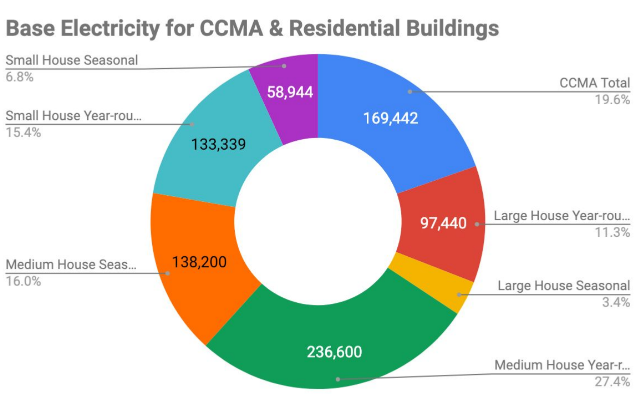
Once the models were created, we utilized the CCMA's utility bills and our eQuest model to determine the impact of implementing various facility improvement measures by changing efficiency ratings and type of HVAC equipment in eQuest. It's important to note here, that while it did not result in any substantial changes, during our modeling there were a few parameters that we did not have real-life data to reference, and in these situations we utilized the default values in eQuest.

The chart on the following page provides a comprehensive overview of the proposed electricity consumption from our building model, which includes the results of implementing various facility improvement measures to eliminate the use of natural gas for heating purposes.

**Table 4:** CCMA eQuest Building Model Electricity Consumption with Facility Improvement Measures

| CCMA Electricity Consumption (eQuest) | | | | | |
|---|---|---|---|---|---|
| Building | Qty | Base Elec (kwh) | Gas (therms) | Proposed Elec | Proposed Gas |
| Inn | 1 | 51,380 | 3,995 | 126,000 | 0 |
| Manor | 1 | 9,297 | 634 | 30,500 | 0 |
| Lodge | 1 | 62,170 | 1,339 | 88,610 | 0 |
| Yale | 6 | 3,465 | 524 | 14,380 | 0 |
| Beach House | 1 | 21,420 | 669 | 35,740 | 0 |
| Tabernacle | 1 | 4,385 | 0 | 4,385 | 0 |
| CCMA Total | | 169,442 | 9,781 | 371,515 | 0 |
| Large House Year-round | 6 | 16,240 | 984 | 35,590 | 0 |
| Large House Seasonal | 3 | 9,710 | 94 | 11,470 | 0 |
| Medium House Year-round | 20 | 11,830 | 795 | 27,700 | 0 |
| Medium House Seasonal | 20 | 6,910 | 64 | 8,170 | 0 |
| Small House Year-round | 24 | 5,556 | 626 | 18,520 | 0 |
| Small House Seasonal | 24 | 2,456 | 37 | 3,287 | 0 |
| Private Residence Total | | 693,653 | 39,242 | 1,488,718 | 0 |
| Total | | 863,095 | 49,023 | 1,860,233 | 0 |

As can be seen in the above table, and in following two charts, if the CCMA implements all facility improvement measures to eliminate the use of natural gas for heating purposes, the electricity consumption increases substantially, by a factor of approximately 2.15.



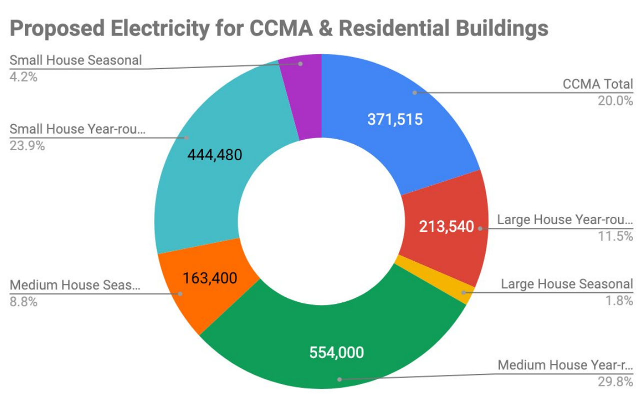




**Figure 3:** CCMA Electricity Consumption before and after Facility Improvement Measures from eQuest Building Model

Additionally, the chart below provides a comprehensive overview of all proposed facility improvement measures built into the eQuest model.

**Table 5: CCMA eQuest Building Model Facility Improvement Measures**

| Craigville Facility Improvement Measures | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Building | Description | For Rec | Cost | Electric Baseline | Natural Gas Baseline | Baseline Annual Utility Cost | Measure Electric | Measure Natural Gas | Measure Utility Cost | Electric Impact | Natural Gas Impact | Cost Impact |
| Craigville Inn | Electric Furnace | Craigville Inn - Electric Furnace | $15,000 | 51,380 | 3,995 | 11,165 | 122,850 | 1,623 | 19,322 | 71,470 | -2,372 | 8,157 |
| Craigville Inn | Air-source Heat Pump | Craigville Inn - Air-source Heat Pump | $30,000 | 51,380 | 3,995 | 11,165 | 91,330 | 1,623 | 14,752 | 39,950 | -2,372 | 3,587 |
| Craigville Inn | Electric HW | Craigville Inn - Electric HW | $5,000 | 51,380 | 3,995 | 11,165 | 86,090 | 2,373 | 14,690 | 34,710 | -1,622 | 3,525 |
| Craigville Inn | Solar HW | Craigville Inn - Solar HW | $22,000 | 51,380 | 3,995 | 11,165 | 68,900 | 2,373 | 12,197 | 17,520 | -1,622 | 1,032 |
| Craigville Inn | Upgrade Kitchen Equipment | Craigville Inn - Upgrade Kitchen Equipment | $25,000 | 51,380 | 3,995 | 11,165 | 49,310 | 3,995 | 10,865 | -2,070 | 0 | -300 |
| Manor | Electric Furnace | Manor - Electric Furnace | $7,500 | 9,297 | 634 | 1,938 | 14,060 | 134 | 2,163 | 4,763 | -500 | 225 |
| Manor | Air-source Heat Pump | Manor - Air-source Heat Pump | $6,000 | 9,297 | 634 | 1,938 | 18,120 | 134 | 2,752 | 8,823 | -500 | 815 |
| Manor | Electric HW | Manor - Electric HW | $1,500 | 9,297 | 634 | 1,938 | 12,180 | 499 | 2,231 | 2,883 | -135 | 293 |
| Manor | Solar HW | Manor - Solar HW | $5,000 | 9,297 | 634 | 1,938 | 10,786 | 499 | 2,028 | 1,489 | -135 | 91 |
| Lodge | Electric Furnace | Lodge - Electric Furnace | $12,500 | 62,170 | 1,399 | 10,316 | 79,110 | 444 | 11,884 | 16,940 | -955 | 1,568 |
| Lodge | Air-source Heat Pump | Lodge - Air-source Heat Pump | $12,000 | 62,170 | 1,399 | 10,316 | 83,470 | 443 | 12,515 | 21,300 | -956 | 2,199 |
| Lodge | Electric HW | Lodge - Electric HW | $2,000 | 62,170 | 1,399 | 10,316 | 71,670 | 955 | 11,280 | 9,500 | -444 | 964 |
| Lodge | Solar HW | Lodge - Solar HW | $7,000 | 62,170 | 1,399 | 10,316 | 66,295 | 955 | 10,501 | 4,125 | -444 | 185 |
| Yale (6) | Electric Furnace | Yale (6) - Electric Furnace | $4,500 | 4,157 | 492 | 1,060 | 14,380 | 0 | 2,085 | 10,223 | -492 | 1,025 |
| Yale (6) | Air-source Heat Pump | Yale (6) - Air-source Heat Pump | $4,500 | 4,157 | 492 | 1,060 | 13,020 | 0 | 1,888 | 8,863 | -492 | 828 |
| Yale (6) | Solar HW | Yale (6) - Solar HW | $7,500 | 4,157 | 492 | 1,060 | 8,215 | 492 | 1,648 | 4,058 | 0 | 588 |
| Beach House | Electric HW | Beach House - Electric HW | $2,000 | 47,050 | 1,014 | 7,765 | 68,740 | 0 | 9,967 | 21,690 | -1,014 | 2,202 |
| Beach House | Solar HW | Beach House - Solar HW | $8,000 | 47,050 | 1,014 | 7,765 | 57,210 | 0 | 8,295 | 10,160 | -1,014 | 530 |
| Beach House | Upgrade Kitchen Equipment | Beach House - Upgrade Kitchen Equipment | $10,000 | 47,050 | 1,014 | 7,765 | 43,520 | 1,014 | 7,253 | -3,530 | 0 | -512 |

| Craigville Facility Improvement Measures | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Building | Description | For Rec | Cost | Electric Baseline | Natural Gas Baseline | Baseline Annual Utility Cost | Measure Electric | Measure Natural Gas | Measure Utility Cost | Electric Impact | Natural Gas Impact | Cost Impact |
| Large House Year-round | Electric Furnace | Large House Year-round - Electric Furnace | $13,500 | 16,240 | 984 | 3,269 | 30,000 | 262 | 4,594 | 13,760 | -722 | 1,324 |
| Large House Year-round | Electric HW | Large House Year-round - Electric HW | $2,700 | 16,240 | 984 | 3,269 | 21,840 | 722 | 3,838 | 5,600 | -262 | 569 |
| Large House Year-round | Solar HW | Large House Year-round - Solar HW | $6,300 | 16,240 | 984 | 3,269 | 18,720 | 722 | 3,386 | 2,480 | -262 | 116 |
| Large House Seasonal | Electric Furnace | Large House Seasonal - Electric Furnace | $7,500 | 9,710 | 94 | 1,495 | 9,500 | 92 | 1,463 | -210 | -2 | -32 |
| Large House Seasonal | Electric HW | Large House Seasonal - Electric HW | $1,500 | 9,710 | 94 | 1,495 | 11,680 | 2 | 1,695 | 1,970 | -92 | 200 |
| Large House Seasonal | Solar HW | Large House Seasonal - Solar HW | $3,500 | 9,710 | 94 | 1,495 | 10,310 | 2 | 1,497 | 600 | -92 | 2 |
| Medium House Year-round | Electric Furnace | Medium House Year-round - Electric Furnace | $8,625 | 11,830 | 795 | 2,454 | 24,020 | 172 | 3,643 | 12,190 | -623 | 1,189 |
| Medium House Year-round | Electric HW | Medium House Year-round - Electric HW | $1,725 | 11,830 | 795 | 2,454 | 15,510 | 622.7 | 2,828 | 3,680 | -172 | 374 |
| Medium House Year-round | Solar HW | Medium House Year-round - Solar HW | $4,025 | 11,830 | 795 | 2,454 | 13,660 | 622.7 | 2,560 | 1,830 | -172 | 106 |
| Medium House Seasonal | Electric Furnace | Medium House Seasonal - Electric Furnace | $5,625 | 6,910 | 64 | 1,061 | 6,860 | 61 | 1,051 | -50 | -3 | -10 |
| Medium House Seasonal | Electric HW | Medium House Seasonal - Electric HW | $1,125 | 6,910 | 64 | 1,061 | 8,220 | 2 | 1,194 | 1,310 | -62 | 133 |
| Medium House Seasonal | Solar HW | Medium House Seasonal - Solar HW | $2,625 | 6,910 | 64 | 1,061 | 7,720 | 2 | 1,121 | 810 | -62 | 60 |
| Small House Year-round | Electric Furnace | Small House Year-round - Electric Furnace | $4,875 | 5,556 | 626 | 1,387 | 16,790 | 80 | 2,509 | 11,234 | -546 | 1,122 |
| Small House Year-round | Electric HW | Small House Year-round - Electric HW | $975 | 5,556 | 626 | 1,387 | 7,286 | 544 | 1,562 | 1,730 | -82 | 175 |
| Small House Year-round | Solar HW | Small House Year-round - Solar HW | $2,275 | 5,556 | 626 | 1,387 | 6,550 | 544 | 1,456 | 994 | -82 | 68 |
| Small House Seasonal | Electric Furnace | Small House Seasonal - Electric Furnace | $1,800 | 2,456 | 37 | 391 | 2,666 | 8 | 394 | 210 | -29 | 3 |
| Small House Seasonal | Electric HW | Small House Seasonal - Electric HW | $360 | 2,456 | 37 | 391 | 3,075 | 29 | 473 | 619 | -8 | 82 |
| Small House Seasonal | Solar HW | Small House Seasonal - Solar HW | $840 | 2,456 | 37 | 391 | 2,756 | 29 | 427 | 300 | -8 | 36 |

While we will delve into the finer aspects below, it's worth noting here that if these proposed measures are implemented, the CCMA can achieve its goal of cutting greenhouse gas emissions to zero by reducing energy consumption through efficiency and conservation measures and by producing and/or buying enough clean energy to meet all remaining needs because all of Craigville's energy use will be electric, which is easier to offset when eliminating net emissions. The following charts provide a high-level overview of the expected change in the CCMA's energy mix if they implement all proposed measures to eliminate the use of natural gas for heating purposes.

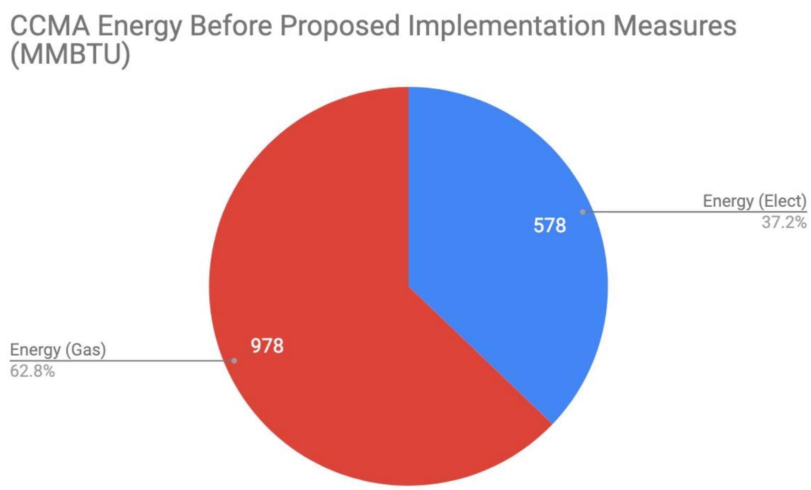



**Figure 4: CCMA Energy Before Proposed Implementation Measures (MMBTU)**

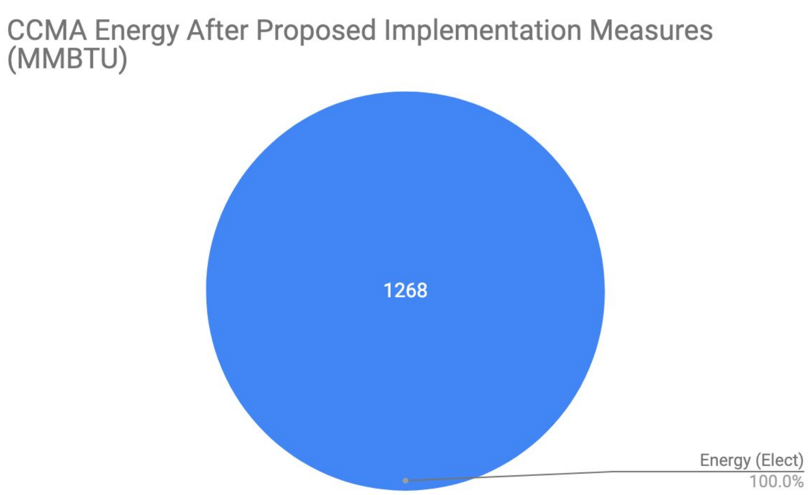



**Figure 5: CCMA Energy After Proposed Implementation Measures (MMBTU)**

For additional information on the eQuest Building Model and Facility Improvement Measures, please refer to Appendices 2 and 4, respectively.

In addition to the utility bills, our team also utilized property data and maps (found in Appendix 3), vehicle information, and previous solar proposals obtained from the CCMA to identify and analyze the energy consumption profile of the CCMA and establish our baseline metrics.

**Greenhouse Gas Inventory**

A secondary task related to establishing baseline figures from which we were able to later determine the impacts of the various recommendations was to conduct a Greenhouse Gas (GHG) Inventory for the CCMA's energy-related economic activities.

Based on our initial analysis, GHG Emissions from electricity, gas, and vehicle fuel consumption for Craigville owned buildings totaled 102 t/$CO_2$e for 2018. Of which, 44.0 t/$CO_2$e originated from the consumption of electricity, 52.0 t/$CO_2$e originated from the consumption of natural gas for heating purposes, and 5.69 t/$CO_2$e originated from our estimates of annual vehicle use. These amounts are based on activity data of 177,179 kWh of electricity consumption, 9,781 Therms of Natural Gas consumption, and an estimated 8,500 miles of gas powered vehicle use. The following chart provides a high-level summary of our findings:

**Table 6:** CCMA GHG Inventory Summary

| CCMA GHG INVENTORY SUMMARY | |
|---|---|
| **Results** | **Metric tons $CO_2e$** |
| $CO_2e$ total | **101.64** |
| $CO_2e$ from electricity | **44.00** |
| $CO_2e$ from natural gas | **51.95** |
| $CO_2e$ from vehicles | **5.6937** |
| Total buildings $CO_2e$ per square feet | **0.0011** |
| $CO_2e$ per square feet Craigville Inn | **0.0045** |
| $CO_2e$ per square feet Lodge | **0.0067** |
| $CO_2e$ per square feet Beach Association | **0.0090** |
| Metric tons $CO_2e$ per Volunteer Staff | **1.26** |
| Metric tons $CO_2e$ per FTE | **8.80** |
| $CO_2e$ per Annual Visitor | **0.0044** |

We developed our GHG Inventory model by combining elements from the Greenhouse Gas Protocol: *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* and the International Council for Local Environmental Initiatives' (ICLEI) *U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions* (Fong et al., 2014; ICLEI, 2013).

By combining elements from both of these industry standard protocols, we were able to construct a comprehensive overview of the CCMA's emissions that originated from the consumption of energy resources.

While a detailed overview of all metrics used is beyond the scope of this report, when constructing our GHG Inventory model we used industry standard conversions, equivalencies, coefficient units, and emissions factors. We used these metrics to standardize the activity data we accumulated from our clients' utility bills into SI Units (International System of Units) (Fong et al., 2014; ICLEI, 2013; "International System of Units," 2019). The following chart provides an overview of the conversions, equivalencies, and emissions factors used:

| Unit Conversion Table | | | | | Abbreviation |
|---|---|---|---|---|---|
| 1 | gallons | = | 3.785 | liters | l |
| 1 | therms | = | 0.1055 | gigajoules | GJ |
| 1 | kWh | = | 0.0036 | gigajoules | GJ |
| 1 | mlbs | = | 453.59237 | kilograms | kg |
| 1 | lb | = | 0.0004536 | metric tons | t |
| 1 | MMBtu | = | 1.055 | gigajoules | GJ |
| 1 | t | = | 1 | metric tons | t |
| **Unit Conversion Table (Equivalencies)** | | | | | **Abbreviation** |
| 1 | MWh | = | 1000 | kilowatt hours | kwh |
| 1 | mlbs | = | 1000 | pounds | lbs |
| 1 | lbs | = | 0.45359237 | kilograms | kg |
| 1 | kg | = | 1000 | grams | g |
| 1 | mt | = | 1000 | kilograms | kg |
| 1 | MMBtu | = | 1000000 | Btu | Btu |
| 1 | t | = | 23.46 | cf | cubic feet |
| 1 | scf | = | 0.0001 | t | ton |
| **Emission Factors** | | | | **Global warming potentials** | |
| | lbs CO2/MWh | lbsCH4/MWh | lbs$N_2O$/MWh | $CO_2$ | 1 |
| Electricity | 545.79 | 0.0163 | 0.00724 | $CH_4$ | 25 |
| | kg$CO_2$/MMBtu | gCH4/MMBtu | g$N_2O$/MMBtu | $N_2O$ | 298 |
| Steam | 66.33 | 1.25 | 0.125 | **Steam Heat Rate** | Btu/lb |
| Natural gas | 53.06 | 1 | 0.1 | | 1194 |
| | kg$CO_2$/gallon | g$CH_4$/mile | g$N_2O$/mile | Truck mpg | 10 |
| Diesel - trucks | 10.21 | 0.0051 | 0.0048 | Car mpg | 24 |
| Gasoline - cars | 8.78 | 0.0173 | 0.0036 | | |

**Figure 6:** CCMA GHG Inventory Conversions, Equivalencies, Emission Factors, and Global Warming Potentials

Once all activity data for electricity consumption, natural gas consumption, and vehicle fuel use was converted into SI Units, we converted the emissions data into equivalencies of metric tons for the three most prominent Greenhouse Gas types; Carbon Dioxide ($CO_2$), Methane ($CH_4$), and Nitrous Oxide ($N_2O$).

Next, we converted these emission types into their $CO_2$ equivalences ($CO_2e$) by multiplying the Global Warming Potential (GWP) values referenced in the IPCC Fourth Assessment Report (Intergovernmental Panel on Climate Change, 2007). As can be seen in Figure 6 above, the GWP's used were as follows; $CO_2$: 1, $CH_4$: 25, $N_2O$: 298. By converting all emissions data from the various sources into $CO_2e$, we were able to calculate the total emissions from each area of energy consumption.

As stated earlier, the GHG Emissions originating from electricity consumption, natural gas consumption, and estimated vehicle fuel use for CCMA owned buildings and vehicles totaled to 102 t/$CO_2e$ for 2018. Of this total, 44.0 t/$CO_2e$ originated from the consumption of electricity, 52.0 t/$CO_2e$ originated from the consumption of natural gas for heating purposes, and 5.69 t/$CO_2e$ originated from annual vehicle use. The following charts provide a comprehensive overview of the CCMA's GHG Inventory from electricity consumption, natural gas consumption, and estimated vehicle fuel use.

Table 7: CCMA GHG Inventory - Electricity

| CCMA Electricity Analysis & GHG Inventory | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 12 Month Electricity Usage | | | | Standardization | | | Metric tons | | | |
| Building Name | Address | Annual Usage (kWh) | Annual Cost | Units | SI units | SI activity | CO2 | CH4 | N2O | CO2e |
| Craigville Inn | 208 Lake-Elizabeth Dr. (Craigville Inn) | 50,362 | $9,205.77 | kWh | GJ | **181.30** | 12.47 | 0.000001 | 0.000001 | 12.47 |
| Groves | 125 Ocean Ave. | 3,648 | $915.64 | kWh | GJ | **13.13** | 0.90 | 0.000000 | 0.000000 | 0.90 |
| Union | 222 Lake-Elizabeth Dr. | 1,626 | $452.65 | kWh | GJ | **5.85** | 0.40 | 0.000000 | 0.000000 | 0.40 |
| Yale | 198 Lake-Elizabeth Dr. | 1,807 | $489.32 | kWh | GJ | **6.51** | 0.45 | 0.000000 | 0.000000 | 0.45 |
| Boston | 194 Lake-Elizabeth Dr. | 5,036 | $1,218.74 | kWh | GJ | **18.13** | 1.25 | 0.000000 | 0.000000 | 1.25 |
| Manor | 45 Prospect Ave - The Manor | 6,834 | $1,534.24 | kWh | GJ | **24.60** | 1.69 | 0.000000 | 0.000000 | 1.69 |
| Andover | 202 Lake-Elizabeth Dr. | 1,616 | $446.74 | kWh | GJ | **5.82** | 0.40 | 0.000000 | 0.000000 | 0.40 |
| Marsh | 45 Prospect Ave - Marsh | 4,206 | $1,045.28 | kWh | GJ | **15.14** | 1.04 | 0.000000 | 0.000000 | 1.04 |
| Lodge | 39 Prospect Ave - Lodge | 70,040 | $2,413.52 | kWh | GJ | **252.14** | 17.34 | 0.000002 | 0.000001 | 17.34 |
| Tabernacle | 135 Ocean Ave - Tabernacle | 4,385 | $977.50 | kWh | GJ | **15.79** | 1.09 | 0.000000 | 0.000000 | 1.09 |
| Lights | 130 Lake-Elizabeth Dr. Lights | 87 | $89.21 | kWh | GJ | **0.31** | 0.02 | 0.000000 | 0.000000 | 0.02 |
| Lights | 133 Lake-Elizabeth Dr. Lights | 62 | $83.90 | kWh | GJ | **0.22** | 0.02 | 0.000000 | 0.000000 | 0.02 |
| Lights | 137 Lake-Elizabeth Dr. Lights | 5 | $60.95 | kWh | GJ | **0.02** | 0.00 | 0.000000 | 0.000000 | 0.00 |
| Parking Lights | 229 Lake-Elizabeth Dr. - Parking Lights | 898 | $276.49 | kWh | GJ | **3.23** | 0.22 | 0.000000 | 0.000000 | 0.22 |
| Lights | 9 Valley Ave - Lights | 73 | $86.55 | kWh | GJ | **0.26** | 0.02 | 0.000000 | 0.000000 | 0.02 |
| Beach Association | 915 Craigville - Beach Rd. (Beach Association) | 23,335 | $3,560.31 | kWh | GJ | **84.01** | 5.78 | 0.000001 | 0.000000 | 5.78 |
| Post Office | 149 Ocean Ave. (Post Office) | 578 | $92.17 | kWh | GJ | **2.08** | 0.14 | 0.000000 | 0.000000 | 0.14 |
| Lights | 39 Prospect Av. (Service Address: Ocean Ave. Light) | 3,121 | $1,600.81 | kWh | GJ | **11.24** | 0.77 | 0.000000 | 0.000000 | 0.77 |
| Director's House | 186 Lake Elizabeth Dr | | | kWh | GJ | - | - | - | - | - |
| Total: | | 177,719 | $24,549.79 | | | | 44.00 | 0.000005 | 0.000002 | 44.00 |

Table 8: CCMA GHG Inventory - Natural Gas

| CCMA Nat Gas Analysis & GHG Inventory | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 12 Month Natural Gas Consumption | | | | | Standardization | | Metric tons | | | |
| Address | Account Number | Date | Therms | Cost | SI units | SI activity | CO2 | CH4 | N2O | CO2e |
| 39 Prospect Ave | 54689-10031 | 1/2/18 | 201 | $3,695.66 | GJ | 21.21 | 1.07 | 0.000020 | 0.000002 | 1.07 |
| 915 Craigville Bea Rd | 54626-11561 | 1/2/2018 | 14 | $27.98 | GJ | 1.48 | 0.07 | 0.000001 | 0.000000 | 0.07 |
| 39 Prospect Ave | 54689-10031 | 1/31/18 | 3228 | $4,029.68 | GJ | 340.55 | 17.13 | 0.000323 | 0.000032 | 17.15 |
| 915 Craigville Bea Rd | 54626-11561 | 1/31/2018 | 0 | $11.29 | GJ | - | - | - | - | - |
| 39 Prospect Ave | 54689-10031 | 3/1/18 | 2141 | $3,082.23 | GJ | 225.88 | 11.36 | 0.000214 | 0.000021 | 11.37 |
| 915 Craigville Bea Rd | 54626-11561 | 3/1/2018 | 0 | $11.29 | GJ | - | - | - | - | - |
| 39 Prospect Ave | 54689-10031 | 4/2/18 | 2144 | $3,384.81 | GJ | 226.19 | 11.38 | 0.000214 | 0.000021 | 11.39 |
| 915 Craigville Bea Rd | 54626-11561 | 4/2/2018 | 0 | $12.46 | GJ | - | - | - | - | - |
| 39 Prospect Ave | 54689-10031 | 5/1/18 | 0 | $1,770.06 | GJ | - | - | - | - | - |
| 915 Craigville Bea Rd | 54626-11561 | 5/1/2018 | 4 | $16.96 | GJ | 0.42 | 0.02 | 0.000000 | 0.000000 | 0.02 |
| 39 Prospect Ave | 54689-10031 | 6/1/18 | 305 | $262.55 | GJ | 32.18 | 1.62 | 0.000031 | 0.000003 | 1.62 |
| 915 Craigville Bea Rd | 54626-11561 | 6/1/2018 | 42 | $45.82 | GJ | 4.43 | 0.22 | 0.000004 | 0.000000 | 0.22 |
| 39 Prospect Ave | 54689-10031 | 7/2/18 | 309 | | GJ | 32.60 | 1.64 | 0.000031 | 0.000003 | 1.64 |
| 915 Craigville Bea Rd | 54626-11561 | 7/2/2018 | 155 | $138.37 | GJ | 16.35 | 0.82 | 0.000016 | 0.000002 | 0.82 |
| 915 Craigville Bea Rd | 54626-11561 | 8/1/2018 | 257 | $226.10 | GJ | 27.11 | 1.36 | 0.000026 | 0.000003 | 1.37 |
| 915 Craigville Bea Rd | 54626-11561 | 8/30/2018 | 212 | $187.15 | GJ | 22.37 | 1.12 | 0.000021 | 0.000002 | 1.13 |
| 915 Craigville Bea Rd | 54626-11561 | 10/1/2018 | 17 | $24.95 | GJ | 1.79 | 0.09 | 0.000002 | 0.000000 | 0.09 |
| 39 Prospect Ave | 54689-10031 | 10/30/18 | 752 | $631.08 | GJ | 79.34 | 3.99 | 0.000075 | 0.000008 | 3.99 |
| 39 Prospect Ave | 54689-10031 | 11/30/18 | | $1,911.00 | GJ | - | - | - | - | - |
| 915 Craigville Bea Rd | 54626-11561 | 11/30/2018 | 0 | $14.21 | GJ | - | - | - | - | - |
| Total: | | | 9,781 | $19,483.65 | | 1,031.90 | 51.90 | 0.000978 | 0.000098 | 51.95 |

**Table 9:** CCMA GHG Inventory - Vehicle Fuel Use

| CCMA Vehicle Analysis & GHG Inventory | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 12 Months of Estimated Vehicle Use | | | | Standardization | | Metric tons | | | |
| Name | Emissions source | Activity | Units | SI units | SI activity | CO2 | CH4 | N2O | CO2e |
| Toyota Tundra | Gas | 5,000 | miles | 1 | **1,892.50** | 4.39 | 0.0002076 | 0.0000432 | 4.4080636 |
| Hyundai Santa Fe | Gas | 3,500 | miles | 1 | **551.98** | 1.280416667 | 0.00006055 | 0.0000126 | 1.285685217 |
| | | | | Total: | 2,444.48 | 5.670416667 | 0.00026815 | 0.0000558 | 5.693748817 |

We've conducted this exercise in the hopes that it will act as a baseline measurement for the CCMA to better understand and manage their carbon footprint, and to serve as a point-of-reference when considering mitigation actions. By establishing this baseline of GHG emissions, the CCMA should be able to assess the future impact of product upgrades, building retrofits, vehicle purchases, and additional energy-related activities.

## Recommendations

In parallel with accumulating and analyzing various data points regarding the CCMA's energy consumption patterns, and in recognition that no panacea for decarbonization exists, our team also researched a multitude of viable recommendations for the CCMA to mitigate the continued discharge of greenhouse gas emissions. Generally speaking, our strategy was to identify viable energy efficient measures, convert fossil fuel usage to electricity, and power the remaining electricity through on-site renewable energy generation. Any remaining GHG emissions should be offset through the purchase of RECs.

### Energy Efficiency Measures

The first step in any Net Zero Energy strategy should be to identify methods to reduce overall energy consumption through energy efficiency measures. However, due to already low electricity and natural gas consumption, many energy efficiency options simply do not generate a positive Return on Investment (ROI). Based on our initial analysis, the CCMA spends $43k per year in energy costs. As such, there is little opportunity for savings to justify standard energy efficiency upgrades such as additional insulation, window replacement, or upgrades of mechanical equipment. If implemented, these solutions would have paybacks in excess of 20 years. The CCMA's financial resources would be better invested elsewhere.

One strategy where the CCMA could reduce energy consumption is through the purchase of energy efficient equipment when their current equipment reaches the end of it's useful life. Over the course of the next 30 years, it is likely that HVAC, refrigeration, kitchen, and other equipment will reach the end of it's useful life. When these pieces of equipment retire, we recommend to: 1) ensure replacement equipment is electric powered, 2) install energy efficient equipment, and 3) investigate rebates through the local utility. While every building has equipment that can be upgraded at end-of-life, most utility savings are miniscule. The two buildings that offer the most potential for savings in upgrading equipment are the Craigville Inn and Beach House, mostly because of the refrigeration and kitchen equipment utilized at these locations.

In addition to the standard HVAC equipment at the Craigville Inn, there are walk-in coolers and freezers plus cooking equipment used to serve meals. Upgrading this equipment could result in potential electricity savings of around 2,000 kWh per year and a financial savings of $280. Implementing this equipment at the Beach House could result in potential electricity savings of around 1,500 kWh per year and a financial savings of approximately $210 per year.

**Electric Furnace And Hot Water Systems**

One of the simplest recommendations we researched is for the CCMA and Village residents to replace on-site natural gas fueled heating and hot water systems with electric heating and hot water systems. If the CCMA conducted a total fuel switch from gas to electric for hot water systems and furnace purposes, not only would it eliminate almost all of the CCMA's natural gas usage, but it would also eliminate a large portion (in the range of 40-50%) of the annual GHG Emissions generated by the CCMA's facilities. However, it is difficult to quantify the exact amount of expected GHG reductions, as the exact amount is still dependent on the source of electricity generation.

Furthermore, in order to meet the ambitious goal of achieving Net Zero GHG emissions by 2050, it is necessary to eliminate the natural gas used onsite to heat air and hot water. While this measure would not totally eliminate natural gas usage on-site, as it would not include any natural gas usage for cooking purposes, it would still eliminate a significant share of natural gas usage. The simplest method to deploy this measure is to replace the natural gas systems with electrical systems. Much of the associated systems (pipes, air ducts, etc) can remain in place and this is the cheapest recommendation to achieve the Net Zero GHG emissions goal.

During our site visit in February, we surveyed the existing equipment and determined the CCMA's furnace and hot water heating systems have 10-to-15 years left of useful life, therefore, the most cost effective recommendation to meet the goals of Net Zero by 2050 is to wait until the end of the equipment's useful life and then replace the natural gas equipment with electric equipment.

**Heat Pumps**

Yet another highly viable, and comparable, recommendation is for the CCMA to implement geothermal heat pumps, as they provide a substantial benefit in being able to reduce the heat requirement of a building. While this recommendation is expensive compared with other mitigation recommendations for most buildings, the cost is paid back for the Craigville Inn in reducing the subsequent electrical costs. Furthermore, just as with electric furnaces and hot water systems, implementing geothermal heat pumps is a necessary measure to eliminate the amount of natural gas used by CCMA facilities. Finally, geothermal heat pumps provide a marketable Net Zero project CCMA can utilize to attract sustainable and environmental groups to choose Craigville as a retreat destination.

The primary challenge associated with implementing this mitigation recommendation is that the lack of available land prevents the use of horizontal geothermal systems and the closeness of the water-line prevents the use of a vertical geothermal system. However, based on energy modeling and cost considerations, we have determined an air-source heat pump to be a viable option for the Craigville Inn. Air-source heat pumps operate similar to geothermal heat pumps except they use air as a source of heat sink. While not as efficient as geothermal heat pumps, they use less electricity than electric furnaces to provide the same amount of heat. However, the increased efficiency comes with a cost. A conversion from a natural gas furnace to heat pump would require extra piping and ductwork to be installed, increasing installation costs. Therefore, heat pumps are not the best option in all scenarios. We have conducted a financial analysis for the Craigville Inn, the most likely candidate for air-source heat pump conversion, comparing the total cost of ownership of an electric furnace versus air-source heat pump. This financial analysis is included in Appendix 4.

### Solar Thermal

Solar thermal is an interesting technology used to help heat hot water by utilizing the heat from the sun. The sun's heat is used to heat service water prior to being heated in a conventional hot water heater. While it doesn't eliminate the need for an electric hot water heater, it can reduce the amount of energy required to heat water. It can cut electrical use for domestic hot water heating in half; however, implementation costs are substantially higher than simply converting the building from a natural gas system to electric system. We evaluated all of the buildings for solar hot water; however, due to the large amount of hot water required for kitchen activities, the most viable locations are the Craigville Inn and Beach House.

The main benefit towards a Net Zero goal is the removal of natural gas for heating. An additional benefit is that these systems require less electricity to run than standard conversions to electric hot water systems. For example, the projected utility consumption and costs for the Craigville Inn are displayed below. Total cost of ownership is the expected cost to install and run the equipment for a 20-year lifespan. See Appendix 4 for the full financial model.

**Table 10:** Cost comparison of electric & solar powered hot water systems.

| Projected Utility Consumption & Implementation Costs for Craigville Inn<br>A Comparison of Electric & Solar Powered Hot Water Systems | | | |
|---|---|---|---|
| Type | Electric Consumption (kWh) | Upfront Cost | Total Cost of Ownership ($) |
| Electric Furnace | 34,710 | $5,000 | $118,598 |
| Solar Heating with Electric | 17,520 | $22,000 | $46,082 |

While the table above provided a cost comparison only for the Craigville Inn, installing solar thermal across all CCMA owned buildings is similar. At a cost of slightly more than $41,500, solar thermal would eliminate natural gas consumption, increase annual electricity consumption by 27,192 kWh, and result in utility cost savings of roughly $5,000 per year. In contrast, installing electric hot water heaters would increase electricity consumption by 68,783 kWh and cost $10,500 to implement.

**Electric Vehicles**

Prior to researching renewable energy opportunities for Craigville, we researched the potential adoption of electric vehicles by the CCMA. The CCMA currently owns two gasoline-powered vehicles, a 2009 Hyundai Santa Fe SUV with approximately 29,400 miles, and a 2006 Toyota Tundra pick-up truck with approximately 57,700 miles. The vehicles have several more years of useful life, as both are in good shape and are only used for light work, such as trips to the local shops and hauling trash.

While we recognize that switching to electric vehicles would result in a noticeable decrease in GHG Emissions, equaling approximately 4-5 t/CO2e on an annualized basis, the costs associated with switching from conventionally-fueled vehicles to electric vehicles is currently too high to be considered economically feasible for the CCMA. As such, we do not deem electric vehicles fit for the CCMA at this time due to the high upfront capital investment needed, and the relatively low usage of their existing vehicles. We suggest they reassess this recommendation when their current vehicles reach the end of their useful life, at which time the cost of electric vehicles may be cost competitive with conventionally-fueled vehicles.

**Solar Photovoltaic**

The most impactful mitigation recommendation for the CCMA to implement would be the development of a solar energy project onsite. Based on our research, the only viable location for onsite solar deployment is in the form of a parking lot canopy installation at the Craigville Beach Association's beach parking lot. From our site visit, and additional knowledge learned of the area, we were able to scope out a project proposal for the CCMA. This proposed project, which was designed using industry standards on Helioscope, a solar design software, is expected to generate approximately 856,000 kWh of energy to the grid annually, which is more than enough to offset the annual consumption of electricity for CCMA owned facilities, and is somewhere in the range of 12 to 22 times as much annual production as two solar projects previously proposed to the CCMA by GRIDMARKET and Cazeault Solar & Home.

The recommended canopy solar project would substantially decrease Craigville's GHG Emissions originating from the energy sector, displacing approximately ~42 t/$CO_2$e annually.

The costs associated with the recommended canopy solar project are substantial. While our analysis did not result in an all-in project development cost, the project will cost approximately $1.7m. The primary cost drivers associated with this project are the overall project size, and components involved, since it is a canopy solar project proposed for a sandy parking lot. Unfortunately, the CCMA is a non-profit entity and, thus, cannot take advantage of the Investment Tax Credit for solar (Solar Energy Industries Association, 2019). We recommend partnering with a third-party financier to resolve this issue and bring the upfront cost down to $1.3m.

While this recommended project does necessitate an upfront capital outlay that is substantially higher than the solar projects previously proposed, based on our preliminary financial analysis a 12-year payback can still be achieved with significant revenue continuing to be accrued by the CCMA after that payback. The Solar Massachusetts Renewable Target (SMART) program provides incentives for solar photovoltaic systems in Massachusetts for 20 years after the installation of the system (Massachusetts DOER, 2018). The recommended project would be eligible for an incentive of approximately $0.23 per kWh for the electricity generated by the solar canopy. This credit is greater than the current cost per kWh that the CCMA is paying for electricity so it represents a net profit for the CCMA for each kWh of energy they consume. Further, the solar canopy project could be developed as a community solar project in which the CCMA and the private residences of Craigville all receive solar credits from the canopy solar project, thus offsetting significant portions of their electricity use with clean solar energy. According to our calculations, if the project were to be community solar, the CCMA could offset all of their electricity use by subscribing to receive approximately 40% of the kWh of energy generated by the solar canopy. The remainder could be allocated to Craigville residents and could offset a total of 32% to 50% of the electricity used in private homes depending on how much electrification and solar hot water systems are implemented in the private homes.

private homes.

For additional information regarding the details of this proposed project, please see Appendix 5.

**Micro Wind-Turbine**

Another potential recommendation for on-site generation we researched was micro-wind-turbines. While we were hopeful that this would be a viable recommendation for the CCMA, unfortunately, our research led us to determine the introduction of micro-turbines at various places around the Village would not contribute enough production capacity to make a substantial difference for the CCMA's overall needs. Furthermore, given the high upfront costs associated with deploying micro-turbine projects, we do not consider this option to be economically viable for the CCMA.

**Renewable Energy Credits**

In order to fill the gap between the electricity demanded if all proposed implementation measures are fulfilled, and the amount of clean energy that can be deployed locally by the proposed solar project, we suggest that the CCMA purchase carbon offsets, in the form of Renewable Energy Certificates (REC's), from the New England Power Pool (NEPOOL) Generation Information System (GIS) (NEPOOL, 2019).

To reach Net Zero Energy by 2050, it is suggested that the CCMA delay the purchase of these offsets until 2049. This strategy ensures that other high-impact recommendations are prioritized, because by delaying the purchase of these offsets, the CCMA can invest in the proposed solar project and the facility improvement measures in the near-term, and invest in energy efficiency measures when appropriate, which will drive emissions reductions and energy savings, without placing an undue economic burden on the CCMA or Village residents. After the recommended measures have been implemented, then the CCMA should purchase offsets that equal the amount of consumed electricity that still originates from conventional fuel sources. Additionally, this strategy allows the CCMA to seek out alternative forms of renewable electricity supply, if they become available for local use.

Along those lines, it is important to note that the Vineyard Wind project is highly anticipated to come online in 2021, which may present a sustainable alternative for the CCMA's energy needs (Vineyard Wind, 2019). When the Vineyard Wind is officially online, the CCMA may not need to purchase offsets to achieve the goal of Net Zero Energy, however, it's suggested that the CCMA not rely on utilizing the Vineyard Project to fill the gap, as large-scale offshore wind projects in the US typically experience regulatory delays in reaching project completion.

The purchase of offsets has no direct impact on local energy use, but this recommendation does allow for the CCMA to 'bridge-the-gap' between the electricity demanded from full implementation of the recommended measures, and the amount of low-carbon energy that can be deployed locally. Furthermore, the use of offsets will enable the CCMA to neutralize the remaining amount of GHG emissions originating from non-renewable energy consumption.

While the specific costs of the offsets will vary based on geo-temporal and geo-spatial parameters, the total cost of offsetting the additional energy needs for CCMA and residential buildings are not expected to be a large expense. For more information on the process of buying the offsets provided by NEPOOL, we suggest that stakeholders refer to their online documentation (Ngo, 2018).

As stated previously, if these proposed measures are implemented, CCMA can achieve its goal of cutting greenhouse gas emissions to zero by reducing energy consumption through efficiency and conservation measures and by producing and/or buying enough clean energy to meet all remaining needs. The following figures provide a clear illustration of the changes in energy use in Craigville given our recommendations and the resultant Net Zero greenhouse gas emissions.

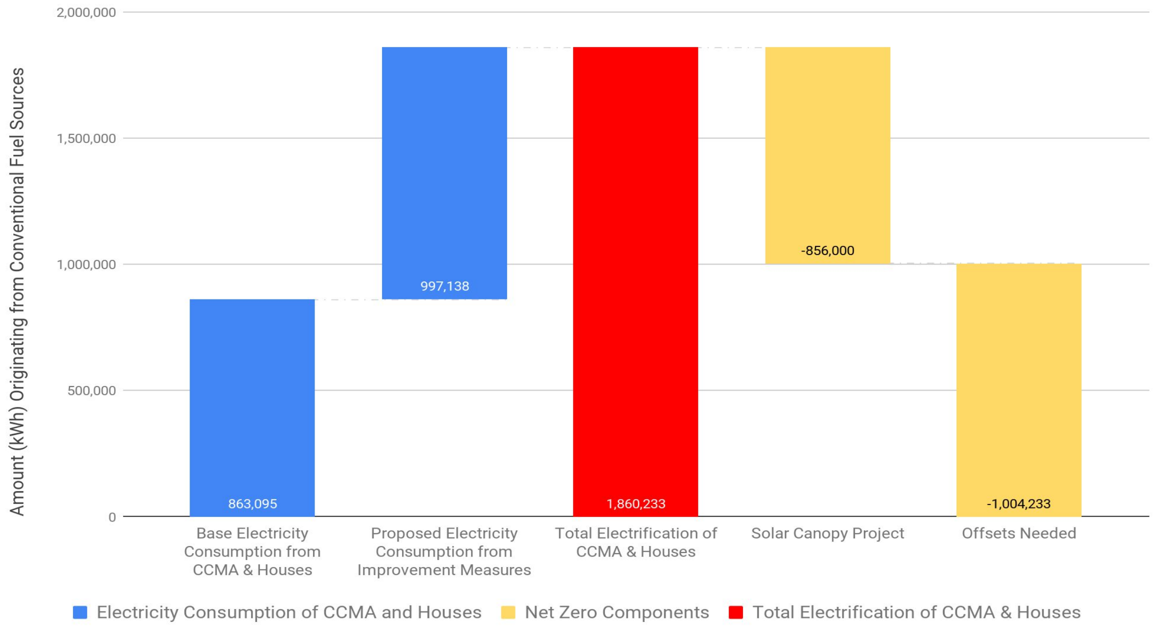



**Figure 7:** CCMA Electricity Consumption Profile for Net Zero (1)

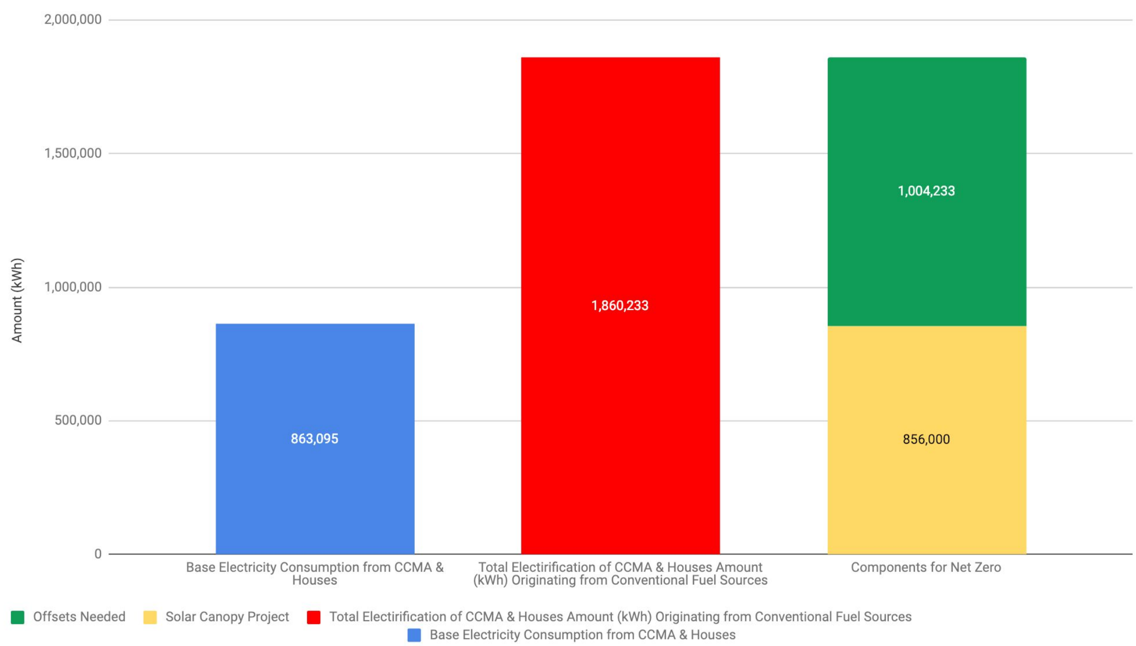



**Figure 8:** CCMA Electricity Consumption Profile for Net Zero (2)

## Financial Incentives

Beyond the quantitative analysis and recommendations list, we also conducted research on the multiple energy-related financial incentive programs that exist. Unfortunately, due to the CCMA's unique legal structure, we concluded that the CCMA, and most Village residents, is not eligible for many of the incentive programs, as many of them are only valid for taxable or commercial operations.

When conducting our research, we analyzed financial incentives for two primary user groups, commercial/non-profits and residents. For each user group, we researched viable incentive packages in three main categories, solar, heat pumps, and energy efficiency. We analyzed the incentives based on whether they were state or federal incentives, the value of each incentive package, eligible participants, expiration dates, and we provided summary notes based on our research. In total, we identified 12 different financial incentive packages that our client, or residents in the surrounding area, may be eligible for receiving. However, due to our client's unique legal entity structure, we are not able to assess, with any level of certainty, which incentive packages may apply for specific buildings, facility improvement measures, system upgrades, or new project deployments.

# NET ZERO WATER

## Net Zero Water

The CCMA defines Net Zero water as continuing "to support the efforts of the Red Lily Pond Project and working to preserve and protect the quality and availability of water needed to sustain the livability and beauty of the community" (Christian Camp Meeting Association, 2018). The Red Lily Pond is the physical heart of a historic community that has existed since the late nineteenth century, and survives today, but is currently suffering from invasive species and pollution (Horsley Witten Group, 2017). We will aim to preserve the pond and enhance the health of the ecosystem through our recommendations.

Our approach to deliver on this definition of Net Zero started with benchmarking against communities across the U.S. that have also created Net Zero plans for their communities. While there is no consistent definition of "Net Zero water" across these plans, our team chose relevant practices from each community that were applicable to Craigville. The research revealed three themes common amongst these communities: (1) flood damage planning, (2) storm surge planning and (3) household water consumption reduction efforts.

## Initial Analysis

Analysis of the water usage of each CCMA building was conducted through shared water bills, which concluded that largely, the village of Craigville is not consuming an exceptional amount of water per household. In fact, on average, homes consumed 10,000 gallons per month compared to the national average of 12,000 gallons per month (US Geological Survey, 2016).

Additionally, our team surveyed Craigville's septic system during our site visit. It was discovered that 17 of Craigville's 97 residents address their wastewater through a cluster septic system, while all others are on a Title 5 septic system. The 17 homes on the cluster system effectively push wastewater away from the fragile pond ecosystems that directly affect the village's water source. In contrast, the remaining homes use localized septic tanks that slowly leach wastewater into the soil.

Finally, our team analyzed stormwater and wastewater runoff and the potential effects of sea level rise. Stormwater runoff in Craigville due to rain and flooding events has caused wastewater to pollute the Red Lily Pond and additional wetland areas. Due to the high water density in the village, high precipitation events cause the drainage system to back up into the town—causing flooding throughout areas where both CCMA buildings and residential homes are located. Our team reviewed sea level rise maps to understand the breadth of the low lying areas and discovered that due to the slight increase in elevation to approximately 50 feet above sea level in the center of the village, many residential homes and CCMA buildings within the area of higher elevation are not in immediate danger of physical damage caused by sea level rise. However, the homes near the beach will likely be affected in the near future, as a 4 foot increase in sea level will have detrimental effects on those low lying areas. We have conservatively estimated 4 feet of sea level rise based on the National Oceanic and Atmospheric Sea Level Rise Viewer, which states that by the year 2100 sea level rise has the potential to raise anywhere between 1.90 feet and 11.22 feet (National Oceanic and Atmospheric Administration, 2017a). One of the major issues associated with this flooding is the leaching of pollutants from the flooded areas into the wetlands adjacent to these flooding zones. In order to combat this, we will be recommending solutions to minimize flooding, in addition to solutions to rid the wetland areas of existing and ongoing pollutants.


**Figure 9**: Effects of 4 ft sea level rise in the Village of Craigville (National Oceanic and Atmospheric Administration, 2017b).

**Benchmarking**

Of the towns we benchmarked against, Kingston, NY, with a population of approximately 23,000 residents, was most similar to Craigville. According to the town's report, their risk of flooding from intense precipitation had increased the most within their region (City of Kingston Tidal Waterfront Flooding Task Force, 2013). The town took action by raising houses and renovating them so that electric panels, A/C units, and furnaces were placed on higher floors. They also hosted a climate-adaptive design open house in the city town hall to inform and educate the community about the issue and contacted Columbia University's Lamont-Doherty Earth Observatory to conduct studies and recommend planning strategies. The community came together as well as used outside experience in order to adapt to the harmful impacts of climate change.

Tybee island, an island off the coast of Savannah, Georgia, "has a single road that allows access on and off the island, so shoring up this road—U.S. Highway 80—and improving it to minimize traffic bottlenecks was a key part of the city's resilience plan" (Thead, 2016). The premium placed on reinforcing natural barriers to inland flooding directed us to consider this solution for Craigville as well. Rotterdam, in the Netherlands, has also invested in flood planning by building dikes around areas of the city. Unfortunately, over the years the structures have damaged the environment and aquatic ecosystems. In a more sustainable, ecologically sound, and physically robust plan, the government is now shoring up the natural coastline of the city by rebuilding sand dunes and expanding shores with sediment (Thead, 2016).

London's sustainability report focused on securing the availability of water for future generations in one of the most dynamic cities in the world and discussed key items such as pressure on water resources, managing water use, and more (Mayor of London, 2011). Boston's sustainability plan reinforced the need to "emphasize community awareness and education as critical tools for climate preparedness" (Thead, 2016). These cities' efforts, despite being on a much larger scale than that of Craigville, provide an ambitious goal for Craigville to strive towards.

## Recommendations

### Enhancing Wetland Preservation Plan (Red Lily Pond & Surrounding Wetlands)

Since the 1700s, 87% of global wetlands have been lost (The Ramsar Convention, 2018) — we aim to beat this trend in Craigville. One of the key features of the village is the Red Lily Pond. The Red Lily Pond Project Association (RLPPA) was created in order to ensure the preservation of this area. Our goal is to reinforce the work done by the association in order to further protect the ecological, the work done by the association in order to further protect the ecological, cultural, and aesthetic values of the pond.

The village of Craigville, and particularly the CCMA, has done excellent work in improving and maintaining the wetland, lake, and pond areas within the village. Through the work of the Red Lily Pond Project and the creation of cluster septic systems, the village has managed to largely restore these areas, which were once largely polluted by invasive species and wastewater runoff. Our approach to enhancing the work that has already been done to preserve the wetlands is to give additional direction regarding: (1) proper invasive species removal strategies, as well as the types of native plants the CCMA can plant to combat these invasive species, (2) raising residential homes to protect freshwater sources, (3) further filtering the wetland freshwater through the use of oysters, and lastly (4) coastal resilience via native planting.

In addition to ways to satisfy Craigvilles' Net Zero water definition, we've also created recommendations regarding water conservation. Below you will find a plan highlighting strategies for water conservation.

**Invasive Species Removal Strategies & Native Planting**

The CCMA has identified 2 major threats from invasive species within the Red Lily Pond area: purple loosestrife and phragmites. Both of these species are incredibly difficult to eradicate. Due to the amount of seeds purple loosestrife produce per season and the ease at which they spread, it is extremely difficult to remove. Phragmites on the other hand, thrive in waters that are polluted, so first focusing on the Red Lily Pond's pollution problem—for which the RLPPA has already begun—will be imperative to eradicating this invasive plant.

For purple loosestrife, we recommend attempting to focus on eradication in late June, July and early August, when it is in flower and the plant is easily recognized, and it has not yet gone to seed. We recommend pulling young plants out by hand and older ones out with a garden fork. It is important to remove as much of the root system as possible to ensure new plants do not sprout. If the plants have already gone to seed, the removal of all flowering spikes over a trash bag—preferably a paper bag used for lawn clippings as to avoid the use of plastic—is important so that further spreading does not occur from seed dispersal (Minnesota Sea Grant, 2017).

Proper disposal of plant material is just as important. It is recommended that all plant pieces are put in trash bags to expedite the rotting process and that all bags are disposed of at sanitary landfill sites. Note that it is ill advised to break open the bag for composting at the landfill site, as purple loosestrife spread extremely easily. If the option is available, the best course of action is to incinerate these plants.

An alternative way to remove purple loosestrife is to use biocontrol via the intentional introduction of natural predators, most often beetles. Additional details can be found within the Massachusetts Office of Coastal Zone Management Wetlands Restoration Program, which has outlined best practices for biocontrol via beetle release within the state of Massachusetts (Massachusetts Office of Coastal Zone Managemente, 2007).

In order to properly remove phragmites, it is imperative to address underlying environmental conditions prior to attempting to physically eradicate plants. Phragmites thrive in polluted ecosystems and are easily able to outcompete native crops. Once the underlying ecosystems are repaired, phragmites can be removed via cutting, burning, herbicides, hydrologic controls, and plastic covers (Tiner, 1995).

The implementation of this recommendation will be done by the CCMA, in collaboration with the RLPPA. We recommend that removal efforts be supported with help from local community volunteer programs, as well as enlisted outside aid from groups such as AmeriCorps. The Massachusetts Environmental Trust, a grant program whose mission is to support projects that enable innovative approaches to protect and restore natural resources, can also be leveraged by the CCMA (MET, 2019). The Red Lily Pond and surrounding wetlands will be the perfect projects to pitch to the trust, if it hasn't been approached yet.

After successful removal of invasives, the CCMA should follow with native planting. Our team has compiled a list of native plant options that can be found in Appendix 6.

**Oyster Farm Water Filtration**

Due to storm and wastewater runoff, the Red Lily Pond and other wetland areas have been subject to pollution from leached pollutants into those water bodies.

In order to combat this without overhauling the sewage and drainage systems, we recommend the use of oyster farms to help filter the water of any unwelcome chemicals that alter the natural ecosystems of the wetlands in the village of Craigville.

In accordance with Cape Cod Commissions Section 208 Watershed Protection Guidance, oysters provide a natural solution for dealing with meeting applicable nutrient reduction targets (Cape Cod Commission, 2018). “Oysters filter pollutants either by consuming them or shaping them into small packets, which are deposited on the bottom where they are not harmful. An adult oyster can filter as much as 50 gallons of water per day” (Chesapeake Bay Foundation, 2019). With regards to cost, a starter-sized oyster farm, with roughly 25 oyster bags, is equivalent to approximately 5,000 oysters-worth between $2500 and $3750. Investment for equipment, seeds and permitting are approximately $700 (Morse, n.d.).

In implementation, we recommend that oysters be used within the wetland areas to help filter any pollution out of this fragile ecosystem. This will help with the eradication of phragmites as well as help repair the natural ecosystem.

**Raising Homes**

Given the village of Craigville’s proximity to the coast and its partial location within the floodplain, several private homes’ foundations have been raised in order to avoid damages to livelihoods. The CCMA beach house and residential homes that have yet to be raised are currently at risk due to their proximity to the water. Using the National Oceanic and Atmospheric Administration’s (NOAA) Sea Level Rise Viewer, a flood zone analysis revealed that damaging sea level rise will affect residences and buildings by the year 2050 (National Oceanic and Atmospheric Administration, 2017b). The flood zone analysis conducted indicates an intermediate low to extreme high scenario range for potential sea level rise. Pictured below you will find sea level rise potential for the year 2020 through 2050 in ten-year increments.

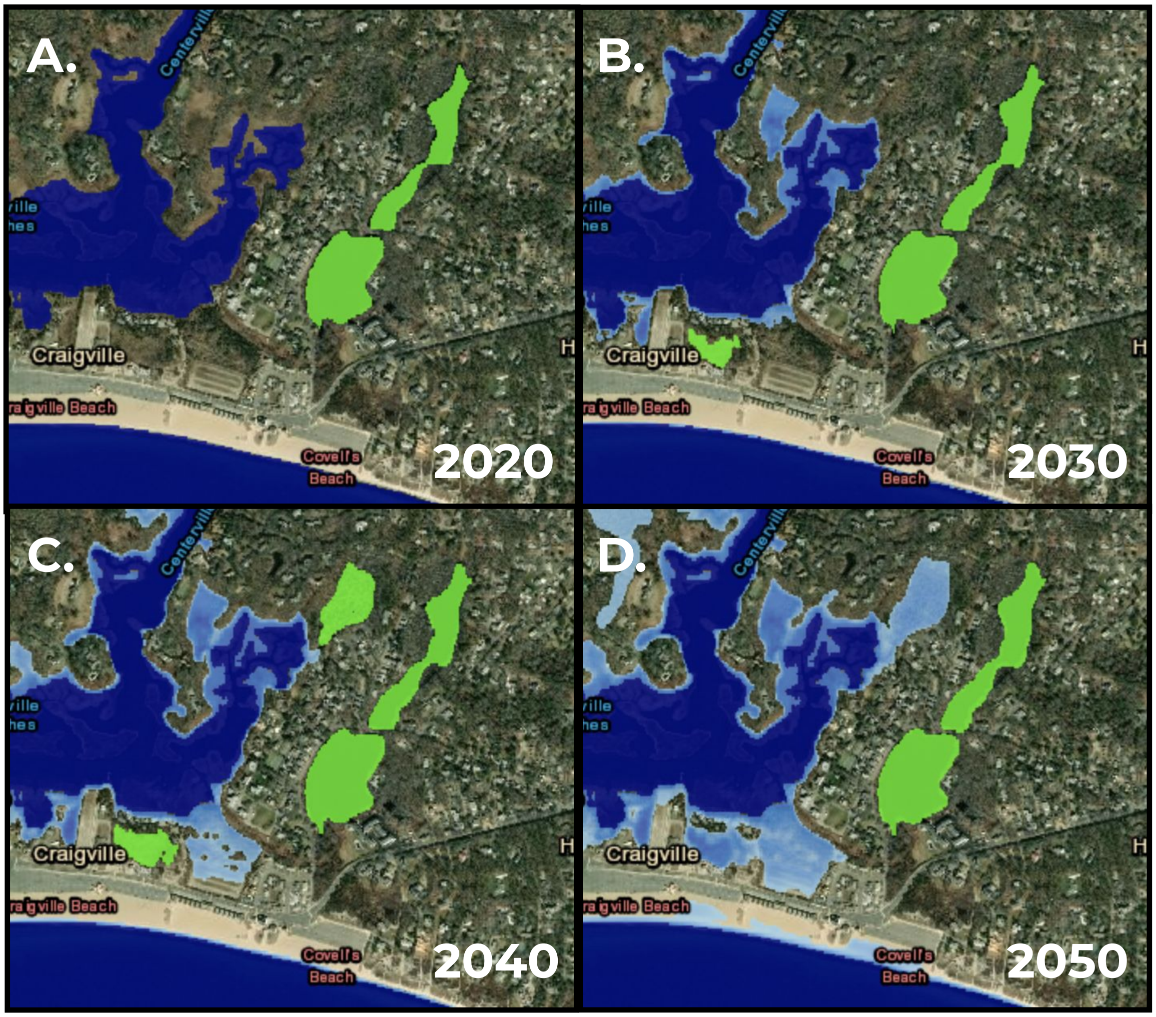



**Figure 10**: Potential Sea level rise in Craigville from 2020 to 2050.

By 2020, sea level rise potential is 0.39 to 0.95 feet as pictured above. By 2030, sea level rise potential is 0.59 to 1.61 feet as pictured above. By 2040, sea level rise potential is 0.79 to 2.46 feet as pictured above. By 2050, sea level rise potential is 1.02 to 3.48 feet as pictured above.

Although raising homes is indirectly tied to the CCMA definition of Net Zero, sea level rise and its effects on the homes and affected CCMA buildings is imminent. Sea level rise affects not only infrastructure, but drinking water as well. Following heavy inland flooding, the mixing of freshwater and saltwater can result in a decrease in the amount of potable drinking water. Similarly to hurricane flood damage, sea level rise can lead to sewage spills, and to pipes breaking, both of which can cause freshwater sources to become contaminated (Pure Water Technology, 2017).

This recommendation addresses quite literally the "livability" of the Craigville community. It is to be implemented on a need-basis, and the buildings located in the floodplain should be prioritized. The approximate time-frame to raise one house is two to four weeks from start to finish (Meier House Removals, 2019). The cost associated with raising individual homes should be evaluated on a case by case basis. An approximate cost to raise a private home or a CCMA-owned building is $8,000 based on ImproveNet's pricing calculation by zip code (ImproveNet, 2018). When raising a residence, we recommend that this expense be voluntarily co-financed between the owner of the home and the CCMA. Elevating a house just one foot above the base flood elevation often results in a 30% reduction in annual premiums on flood insurance. A homeowner with an elevated home with its first floor elevated three feet above the base flood elevation can expect to save 60% or more on annual flood insurance premiums (FEMA, 2019). Another source of financing that we recommend the CCMA look into further is FEMA's Flood Mitigation Assistance Program, which allows homeowners to lift their homes to mitigate future flood event (FEMA, 2018).

**Coastal Resilience Through Native Planting**

In order to further address the threat of flooding due to sea level rise and protect surrounding ecosystems, we also recommend planning for coastal resilience through native planting. In addition to protecting Craigville against invasive species, native planting will strengthen Craigville's shoreline and wetland ecosystems. For this recommendation, the same list of native plant species in Appendix 6 can be referenced. To implement this recommendation, we suggest focusing on three core areas within Craigville to plant native species around: the beachfront, wetland ecosystems, and Red Lily Pond area.

Properties in the low-lying areas of the Village of Craigville are most vulnerable to disastrous flooding caused by sea level rise (see Figure 11) and coastal storms. As observed previously, sea level rise by 4 feet will result in disastrous flooding—therefore, focusing efforts on those homes most vulnerable in between the beachfront and 50-foot elevation to the majority of CCMA buildings is critical. In order to protect those areas, we recommend native planting on the perimeter of the shorelines (Dadson et al., 2017). This includes surrounding the beachfront area as well as the low lying wetlands with as much live, native vegetation as possible. This will create a buffer to help absorb sea water, before it gets to the homes located in flood zones.


**Figure 11**: Potential extensive flooding from sea level rise.

Additionally, oyster reefs may be used as a natural hard barrier within beachfront areas (Arkema et al., 2013). This is a natural and cost effective alternative to artificial sea wall barriers—which could cost millions of dollars to build and maintain, and disrupt the CCMA's main economic driver, in addition to the natural beauty of the beachfront area and the ecosystems that rely on it (Smithsonian, 2018).

**Water Conservation Plan**

Water is essential for humanity's survival, and even though the world is largely covered by water, only a small percentage is potable for human utilization. The world's population is growing every year which raises demand and pressure on water. Only 2.5% of the Earth's water is freshwater, and 1.5% of that is either polluted or frozen. This means that people need to start conserving the remaining drinkable 1% and no longer take water for granted (National Geographic, 2019). Consumers need to change the way they perceive, use, and reuse water to ensure that there is enough when it is needed. However, responding to this challenge will mean that consumers can save money, ensure future generations have sufficient water infrastructure, and reduce environmental impacts.

The proposed strategy is intended to complement the plans and strategies of other organizations, such as the Horsley Witten Group, by presenting a

Craigville-specific approach to water management (Horsley Witten Group, 2017). This section includes three main pillars that will lead the village of Craigville to save more water, reduce its water bills, and reduce its impact on the environment.

**Water Refilling Stations**

Given the large number of plastic water bottles sold by the CCMA, especially at the beach, it is recommended that the CCMA installs water refilling stations to reduce the amount of disposable plastic bottles being consumed and to promote filtered tap water. Water refilling stations are designed to provide drinkable tap water to users with a refillable water bottle. Users simply place their own refillable bottle under the refilling station sensor and it dispenses water directly into the bottle. A key benefit of refilling stations is their ability to provide safe drinking water. The majority of stations use high-performance filters that remove common contaminants such as chlorine and lead. Elkay is one of the leading water bottle filling station manufacturers, and it offers filtered water refilling stations that remove on average 99.3% of lead from drinking water (Elkay, 2017).

A tandem sustainability benefit is the reduction of plastic waste. Plastic waste is one of the major issues of the 21st century and its management has become even more so of a critical issue. It is estimated that 8,300 million metric tons of virgin plastic have been produced and 79% of it is accumulated in landfills or the natural environment (Geyer, Jambeck, & Law, 2017). A significant amount of plastic waste has also polluted the oceans. It is estimated that 4.8–12.7 million metric tons of plastic waste was dumped into the ocean in 2010 because of insufficient plastic waste management. Due to this, there is a growing concern about the impact of plastic waste on both ourselves and our planet. Using the natural capital valuation approach, the United Nations Environmental Program (UNEP) estimated that the natural capital cost of plastic in the consumer goods sector alone was 75 billion USD per year and the natural cost of plastic in marine ecosystems was 13 billion USD per year (UNEP, 2014).

Several universities in the country have begun installing these refilling stations in an effort to reduce the number of plastic bottles used on campuses (Uehara & Ynacay-Nye, 2018). One example that demonstrates the effectiveness of using water refilling stations can be observed in the case of Washington University in St. Louis. The university installed water refilling stations in order to meet their campus sustainability goals. In 2014–2015, due to the campus wide plastic water bottle ban and the implementation of refilling stations, the university saw a reduction of 567,000 plastic bottle purchases (Keaggy, 2016). The university also reduced its carbon footprint levels by decreasing the production and transportation of plastic bottles as well as limited the number of unrecyclable plastic bottles ending up in landfills.

Although consumers generally prefer the taste of bottled water to tap water, water refilling stations avoid this problem because they are equipped with high-performance filters and cooling systems, making them capable of removing the usual causes of unpleasant tasting water, such as chlorine and particulates. The refilling stations purify water, making it taste clean and fresh. Moreover, regardless of whether the stations are placed outdoors or indoors, they are able to consistently deliver cool water.

Over the years, as the demand for cleaner water becomes higher, the price of household water purifiers and bottled water has become prohibitive. Water refilling stations offer a cheaper and more convenient solution to the public's drinking water needs than bottled water or the use of household filters. Based on the dynamics of the village of Craigville, it is recommended that water refilling stations are installed on the beach and in each one of the CCMA Retreat Center buildings. The beach is the most preferred destination for residents and visitors especially during warmer weather. When it is hot outside, people tend to drink more water to cool their bodies. The body also needs to compensate for the sweat it releases during warm weather. Therefore, having an accessible refilling station on the beach is imperative in order to ensure the wellbeing and safety of the public. Given that the CCMA Retreat Center buildings host a large number of guests, it is recommended to install water refilling stations in these buildings in order to ensure that visitors will avoid the consumption of plastic bottles and encourage them to use reusable bottles instead.

We recommend using the Elkay water refilling station considering it is one of the most popular and reliable refilling stations in the US (Elkay, 2017). Their "ezH2O" model looks and operates like a standard public drinking fountain, however, in addition to the regular water nozzle that can be operated with the push of a button, a motion sensor-activated bottle filling unit is also attached (Knowledge Center, 2016). It is important to note that in order to become compliant with the Americans with Disabilities Act (ADA), the station needs to be no higher than 36 inches above ground, as shown in Figure 12 (ADA Compliance, 2019).

Spout Height and Knee Clearance

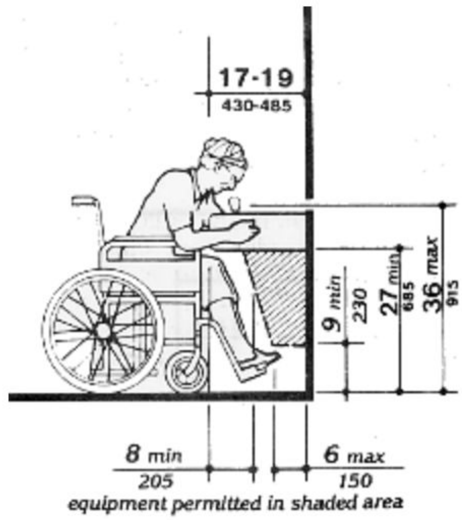



**Figure 12**: ADA Dimension Directory

**Water Efficient Appliances and Fixtures**

In order to ensure that Craigville becomes a sustainable community, resources need to be consumed as efficiently as possible. Therefore, the village of Craigville should turn to water efficiency as a source to save water to support current and future development. Efficiency differs from conservation, which asks consumers to consume less. Whereas conservation asks for sacrifice in order to get through a drought or another type of emergency, relying on individuals to change their behavior to achieve results, efficiency means doing more with less. It means using the best available technology and innovative ideas to achieve long-term water sustainability without sacrificing quality of life. Efficiency builds water savings into the infrastructure, and the savings are sustained even when individual stamina to change behavior begins to deteriorate. However, this does not mean that conservation should be set aside in favor of efficiency: both are needed to achieve sustainability. Water efficiency also contributes to environmental sustainability and promotes a healthy ecosystem. Unsustainable consumption of water depletes rivers, streams and wetlands. Healthy aquatic ecosystems need sufficient water supply, and water efficiency helps preserve and protect precious water resources and marine ecosystems.

Efficiency is an intelligent investment in the future of any society. It is the most inexpensive water management strategy and the best source of additional water supply. A study conducted by the National Resource Defense Council revealed that installing water-efficient fixtures can reduce water use up to 35% (National Resources Defense Council, 2009). If all U.S. households installed water-efficient appliances, that would save more than 8.2 billion gallons of clean water daily, equivalent to more than 12,000 Olympic-size swimming pools worth of water every single day, adding up to cost savings of more than $18 billion per year (Trice, 2016). Communities across the country have successfully deployed water efficiency measures to enhance reliability of domestic water supply, cut cost, and protect the environment. For example, Boston used efficiency approaches to supply safe, clean water to more than two million people while reducing its water consumption by 33%. These efficiency measures saved the city approximately $500 million because they eliminated the need to build a new dam to provide additional water supply (Trice, 2016). Seattle used efficiency to extend its water supply by 50 years. In an extreme drought that had left the city with water supply for only 3 hours per day, installation of efficiency measures that reduced consumption by 45% helped to rapidly restore the town's water service (Trice, 2016).

Installing water efficient appliances and fixtures will reduce the volume of water demand which in return will improve and elongate the lifespan of pipes, sewers, drinking water treatment facilities, and wastewater treatment facilities. Equipment wear and tear is also reduced where individual wells are used. Lowering water demand helps a community be better prepared for a drought or emergency. Efficiency also makes good financial sense for both individuals and communities as a whole. Most water efficient appliances pay for themselves in less than 5 years by saving water and thus saving money. These savings can also help reallocate public funds towards necessary upgrades to water infrastructure, including fixing leaks, improving drinking water quality, and improving wastewater treatment.

Many organizations across the world have adopted recommendations for water efficient appliances and fixtures, such as the U.S. EPA WaterSense program which was used as a benchmark in this report (US Environmental Protection Agency, 2019). To aid the CCMA in improving water efficiency, a list of appliances and fixtures can be found in Appendix 7. The list includes efficient models for bathroom, kitchen and laundry appliances, based on water and energy consumption.

**Individual Meter Systems To Allow For Monitoring**

In most sustainable communities, water metering is an essential practice which helps residents save water and promote conservation behavior. In 2017, the water metering market was primarily conquered by Automated Meter Reading (AMR) water meters due to benefits they offer such as limited meter-reading expenses, reduced billing errors and real-time billing information, among several others. Recent enhancements to improve water metering and communications technologies have the potential to improve the management of water resources and utility infrastructure, benefiting both residents and utilities. Already, water metering systems are now more cost-effective and easier to install. The highly detailed, real-time data and opportunity for automated control provided by these advanced systems results in operational benefits similar to energy motors which yields energy and cost savings.

Research has concluded that information provided by advanced metering can motivate behavioral reductions in consumption by improving ratepayers' awareness about their usage. Text messages alerts, in-home display, and web portals are some examples of communication methods used to make water consumption more transparent to residents. One 2013 study explored the impact of customer-specific water use information on consumption patterns and found that daily consumption data from smart water meters can reduce water consumption by an average of 9% (Berger, Hans, Piscopo, & Sohn, 2016). Moreover, the East Bay Municipal Utility District (EBMUD), which provides water throughout the San Francisco East Bay, conducted a pilot study in 2014 in which they installed water metering systems that supply hourly water consumption data to customers through an online web portal. The access to water consumption data resulted in a 15% reduction, on average, of water use amongst residential customers, due to both more conscientious use of water and customer-side leak repair (Berger et al., 2016). An additional benefit of this decreased water consumption is the decrease in embedded energy related to water consumption that would otherwise be used by the water utility to extract, treat, and distribute the water.

Because water pipes are generally placed underground, water main damages and degradation, whether from soil pressure, excavation and construction threats, tree root growth, freeze-thaw cycles, or earthquakes, are common occurrences that residents are not aware of. Studies have shown that leaks account for 13% of all residential indoor water consumption across the U.S. (Berger et al., 2016). The installation of water meters, then, is a prudent decision because they will allow the village of Craigville to detect leaks and improve water conservation efforts.

# NET ZERO WASTE

### Net Zero Waste

With regards to waste, the CCMA has defined their Net Zero goal as 100% diversion from landfill. This requires a combination of reduction, reuse, recycling, and composting efforts to both minimize the production of waste as well as ensure that any waste produced does not end up in a landfill.

To achieve this goal, our team first benchmarked against a variety of cities and towns to identify best practice and activities that Craigville could replicate. This research gave us insight into possible approaches to meeting a Net Zero waste goal and informed our understanding of waste management and the importance of a tailor-made solution, given the various constraints of different communities.

Background research provided context regarding the governance framework and the parameters within which the CCMA operates. Given that the CCMA does not have jurisdiction to enact law in Craigville, it is assumed that Barnstable's legislation is to be used, in addition to state-level and federal legislation. Massachusetts has strict laws for what can and cannot be recycled. A quick guide to Massachusetts recycling can be found in Appendix 8. One interesting revelation was that the CCMA is not able to recycle any of their recyclable waste at the local transfer station in Barnstable due to Board of Health regulations and permit restrictions that prevent the station from accepting commercial recyclable materials. Despite being part of Public Works, the Barnstable transfer station is actually an enterprise fund, which means that they don't benefit from any tax dollars; their revenue derives strictly from sticker sales which enable individual residents use of the facility. Conversations with the CCMA's waste hauler, Macombers Sanitary Refuse, provided insight into the waste journey post-pick up. The company hauls all the trash they collect across the Cape to a facility in Yarmouth, a town within Barnstable county whose central location on the Cape makes it an ideal transfer point. At the Yarmouth facility, the trash is transferred into train carts, after which the trash is brought by railway to an off-Cape incineration facility, where the trash is burned.

### Initial Analysis

As with energy and water, we conducted an analysis of the CCMA's bills, which revealed high waste hauling costs from Macombers. This high cost is reflective of the amount of recyclable content that, instead of being recycled, is being sent to landfill. A visual assessment of bins during the site visit to Craigville confirmed that the CCMA's waste stream does include a significant amount of recyclables, the majority of which is packaging materials, as well as a substantial amount of organic waste. Because we were unable to complete a waste audit during the site visit, we used the World Bank's data for the waste characterization of high-income countries as a proxy for Craigville's waste stream, as shown in Figure 13 (The World Bank Group, n.d.). We used the hauling costs to estimate that the CCMA produced 34.5 metric tons of waste in 2018. It is important to note that, in order to be able to properly assess progress towards their Net Zero waste goal, the CCMA must conduct a waste audit to understand both the composition of their waste and the volume of waste produced.

While observing the receptacles on site, we noticed a lack of proper labeling to indicate whether a bin is for recycling or trash. Only in one building were the receptacles clearly labeled. This inconsistency makes it difficult for guests and other community members to understand CCMA's sorting of waste and recyclable material. The site visit also revealed the lack of proper composting infrastructure and sound composting techniques in Craigville. The surrounding wetlands and their designation as a protected area limited the areas in which the CCMA can establish a composting site. Currently, the CCMA uses two plastic containers buried in the vegetable plot next to the Craigville Inn to collect their organic waste, though this has limited potential to create compost.

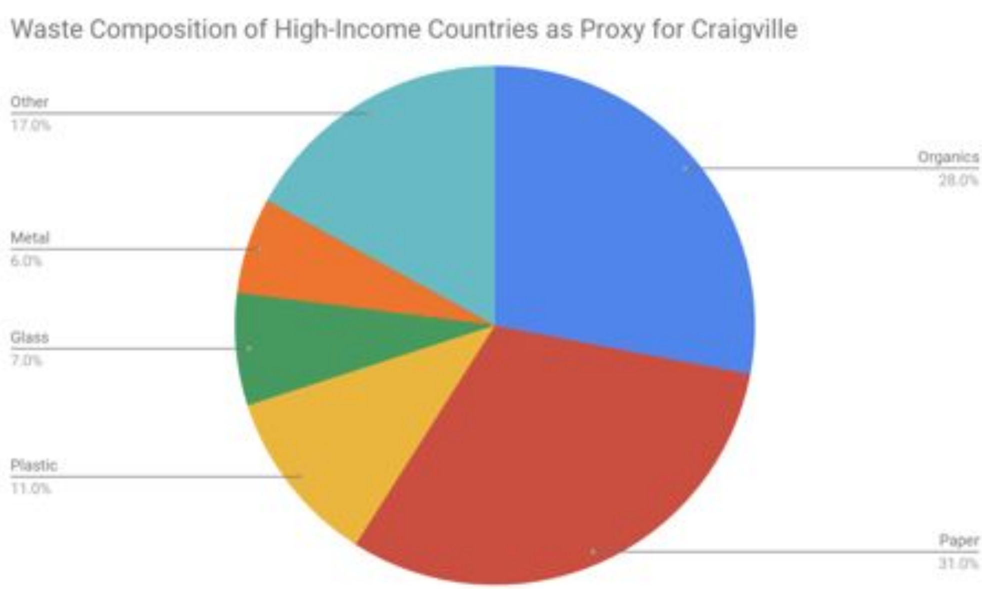



**Figure 13**: Waste Composition of High Income Countries.

**Benchmarking**

Our research into other communities' waste initiatives revealed an emphasis on proper waste sortation, composting programs, and community education and engagement. In 2003, San Francisco, a leader in the environmental space, set a Zero Waste by 2020 goal (US Environmental Protection Agency, n.d.). By 2012, the city had achieved nearly 80% diversion, the highest rate of any major U.S. city (SF Environment, 2012). San Francisco's success can be partially attributed to their innovative and first-of-its-kind three-bin sorting strategy that entails sorting waste into clearly labeled green, blue, and black carts for commingled recyclables, compostable materials, and trash (US Environmental Protection Agency, n.d.). The success of this program is largely due to the Department of Environment's team conducting extensive, door-to-door outreach to educate residents and businesses about the sorting process, as well as their monitoring of residential curbside bins throughout the city on a regular basis. If a visual inspection reveals waste materials in the wrong cart, those carts were flagged to notify the residents to correct their sorting practices ahead of the team's follow-up visit, thereby creating a system of accountability (SF Environment, 2019).

Vancouver, another city recognized for its urban sustainability leadership, has issued a Zero Waste by 2040 goal. Their plan includes a single-use item reduction strategy and a food waste strategy, both of which are relevant to Craigville given the significant amount of organic material and plastics in Craigville's waste stream (City of Vancouver, 2018b). However, unlike Craigville, Vancouver has jurisdictional authority to create legislation and is leveraging that to reduce both single-use plastics and divert organic waste from the waste stream to composting streams (City of Vancouver, 2018a, 2019).

We also researched the waste initiatives of smaller communities. Southampton, NY prioritized community education and engagement. The Southampton sustainability plan included education and outreach to "promote resource stewardship, waste reduction and diversion, and indicate the link between waste and other environmental issues such as water quality" (Southampton Town Board & Perkins+Will, 2013). Similarly, Fairport, New York, also incorporates an education and community engagement component. They distribute an annual community award for recycling and reduction of waste to incentivize their community members to recycle (Village of Fairport & Ingalls Planning and Design, 2010).

Lastly, outside of North America, the Japanese village of Kamikatsu was able to substantially divert their waste from both landfills and incinerators through education which propelled a major behavioral change amongst its local residents. According to a World Economic Forum (WEF) report, the village managed to encourage a lifestyle shift by organizing roundtables that aimed to facilitate the dialogue around the Village's goal and the waste management efforts that needed to take place in order to reach those goals (Gray, 2019)

## Recommendations

Our recommendations for achieving Net Zero waste align with the "Reduce, Reuse, and Recycle" waste hierarchy that encourages the disposal of waste using those three practices in that order. While it is helpful to recycle, it still requires energy and resources; therefore, reusing materials is the preferred practice to recycling. However, reducing and eliminating any materials you don't need, which ultimately allows for less materials to be made and later disposed of, is the gold standard with regards to waste management.

.

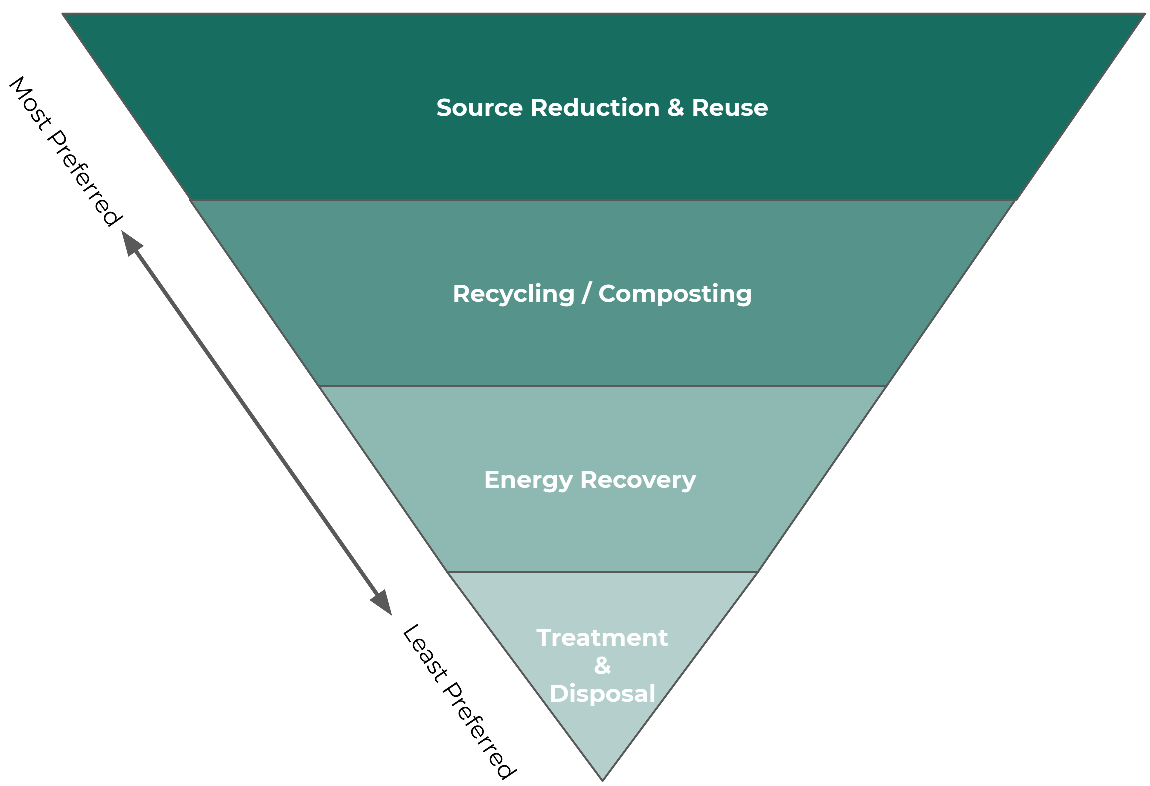



**Figure 14**: Waste Management Hierarchy

As per the above graphic, another option within the waste hierarchy is energy recovery (US Environmental Protection Agency, 2017). According to research conducted by students from Columbia University on “Improving the State of NYC’s Waste and Energy System” there are tangible benefits to transforming waste to energy (WtE). For instance, WtE reduces the volume of solid waste by approximately 87% and is a source of clean energy: “one ton of municipal solid waste burned by WtE generates approximately 474 kWh, and avoids approximately one ton of GHG emissions” (Blake, Mazars, Prado, & Wilson, 2018). WtE, however, is incredibly expensive and therefore not a feasible option for the CCMA.

**Waste Reduction Initiatives**

Our first set of recommendations focuses on reducing the amount of waste generated in Craigville. To combat the high volume of cardboard, plastics and other packaging materials we observed in the dumpster, we are recommending reducing packaging materials by partnering with local farmers who can use totes and crates in lieu of standard disposable packaging. Not only would the new source help eliminate packaging waste, but it would also allow the CCMA to source more sustainably as compared to purchasing from companies located farther away. Local farmers we reached out to, such as Apponagansett Farm and Cape Cod Organic Farm, were open to this implementation and some even had their own reusable totes and crates that they utilize with customers. For farmers who don’t have their own reusable containers, we estimate an upfront cost of approximately $750 to purchase approximately 40-50 crates and totes (Plastic Pallets and Bins, 2019). The implementation of this initiative, managed directly by the CCMA, will contribute towards reducing the current volume of packaging being discarded; approximately 42% between paper and plastic is estimated to be diverted from landfills with this recommendation.

Another significant area of reduction in Craigville, and especially at the beach, is plastic water bottles. According to the WEF, “eight million metric tons of plastic waste enter the marine environment each year” (van Sebile, 2016). For this reason, our next recommendation is to reduce the volume of plastic water bottles being discarded by replacing the sale of disposable water bottles with the sale of reusable CCMA-branded water bottles, which will be complement to the Net Zero water recommendation for a reusable water bottle refilling station. We believe the Craigville motto branded on a reusable water bottles would not only convey Craigville’s commitment to sustainability, but would also generate revenue from their sales. Upfront costs range from ($0.42 x 1000 units) $420 - $3,490, depending on the size and material of the water bottles, but the profit from these bottles should offset the upfront cost fairly quickly (Custom Earth Promos, 2019b). Replacing disposable water bottles with reusable water bottles is easy to implement and can be deployed as early as the Summer of 2019. This recommendation will help reduce the estimated 11% of plastics being discarded in Craigville and will help reduce coastal and ocean pollution.

Similar to the plastic water bottle reduction strategy, we also recommend the elimination of single use materials such as plastic bags, plates, and straws. Discarded plastic should be considered a resource for capture and reuse, rather than simply a disposable convenience. To that end, we recommend eliminating and replacing single-use materials with reusable or compostable alternatives, such as tote bags, stainless steel or bamboo straws, and reusable cutlery. Implementation of this recommendation can be paired with education through distribution of reusable tote bags during educational roundtable meetings, community gatherings, and events. The CCMA can also sell the totes bags at any CCMA-managed facility to help cover the upfront cost, which is estimated to range from ($0.59 x 1000 units) $590 - $5000 depending on material and logo size (Custom Earth Promos, 2019a). This proactive approach will help not only change behavior towards the use of single plastic materials, but will also signal the efforts the CCMA is making towards becoming a sustainable destination.

Another potential area of reduction in waste is organics. Numerous studies show that eliminating trays in a dining hall can help eliminate food waste as a result of the inability to take more food than a person can eat. Going tray-less is a simple solution to encourage people to waste less. A co-benefit of this recommendation is the water savings attributable to fewer dishes that require cleaning. A study released by the Journal of Hunger & Environmental Nutrition documented a 32% reduction in food waste and a 27% reduction in dish use when trays were made unavailable at a university dining facility (Kim & Morawski, 2012). These findings suggest that tray-less cafeterias are a simple solution for universities and other dining facilities looking to reduce waste and save money. The tray-less initiative should be implemented primarily at the Craigville Retreat Center, with the CCMA staff in charge of deploying and administering this initiative. Implementing this change would be extremely easy as it requires no work or cost to implement. We suggest that the CCMA staff discontinue using trays, but keep them stored for extenuating circumstances. This initiative would contribute towards reducing organic waste, which makes up 28% of the CCMA's waste stream.

**Composting Initiatives**

The team also evaluated various options for diverting food waste, which typically accounts for approximately 28% of total waste in high-income countries. We recommend that the CCMA incorporate composting into its waste management process to account for the large amount of organic waste in their waste stream, stemming mostly from kitchen operations in the Craigville Inn. Composting uneaten food helps to save money by avoiding disposal costs and returns the nutrients from the food back to the soil. Given the limited amount of space where a composting site can be set up, we recommend that compost bins, such as the one in Figure 15, be installed in the fenced-in dumpster area adjacent to the Craigville Inn. The implementation of this initiative would require the purchase of composting bins, the upfront cost of which can range from $400 to $1,200, depending on type and size (Gardener's Supply Company, 2019).

**Figure 15**: Compost Bin

This is a relatively easy solution to implement and it will take up to month to roll out. To achieve optimal composting, we would recommend that CCMA mix high carbon food waste with lower carbon plant waste (grass clippings, leaves, wood chips) in layers, and also introduce earthworms into the bins. On a regular (weekly) basis, the contents of the bins should be turned and agitated to ensure proper mixing of the material. CCMA should ensure that the bins are large enough to facilitate the composting process (testable by confirming there is a large hot center) but small enough to allow air to pass through (testable by odor – the bins should not have a bad odor). In addition, CCMA should ensure the composting remains damp. This recommendation would require minimal upkeep on the part of CCMA and would contribute towards annually diverting 21,335 lbs of waste (organics) from landfills. However, because regular compost bins cannot break down meat and bones, this cannot be the only solution for composting.

One technologically advanced option that accounts for meat and bones is a digester. Two types of digesters exist: anaerobic and aerobic. An aerobic digester is an industrial food composting system solution able to produce compost in as little as five days. The use of this technology is an environmentally responsible and sustainable alternative to landfilling and incineration. The digester is a biologically and energy efficient option that will not attract pests, requires very little maintenance, and is virtually odorless. Furthermore, it does not require any bacterial adders, enzymes, water, or heat. Similarly, anaerobic digestion occurs naturally, in the absence of oxygen, as bacteria break down organic materials and produce biogas. Many local governments and municipalities are interested in processing food waste in anaerobic digesters at treatment facilities, however, cost is a limiting factor (E3A, 2019).

One model we considered for analysis – the FOR Solutions Model 500 Composting System – is an aerobic system that requires 2,500 lbs/week of materials such as uneaten food which includes raw and cooked meat, produce, dairy, bones and shells, napkins and or paper towels, and compostable plates (FOR Solutions, 2019). The estimated annual energy use is of 6,000 - 8,300 kWh. Although the CCMA alone does not produce a sufficient amount of food waste for this system, we still recommend this technology as a solution for meat and bones diversion. Because of the lack of enough food waste as well as the hefty investment, often upwards of $400,000, this recommendation ranks low in comparison with other recommendations. However, we recommend that the CCMA partner with other local businesses to invest in the technology to make it more cost effective as well as to have enough food waste to make it a feasible option. In the meantime, we recommend composting with the composting bins recommended above.

**Recycling Initiatives**

Regarding recycling initiatives, we recommend CCMA partners with Recyclops, a recycling company that can assist in the recycling of plastics, metal, glass, and other recyclable materials (Recyclops, n.d.). Recyclops focuses on bringing recycling to communities that have been historically underserved by recycling infrastructure. They leverage the gig economy by hiring local independent contractors to do pick-ups. The cost of the contract can be negotiated and the benefit of establishing these partnerships is that they often do all the legwork which entails finding a hauler and a material recovery facility (MRF). An additional benefit is that they typically provide the recycling bins with an option that enables the customer to use their own bin as long as they meet certain specifications, i.e. appropriate size and labeling. Recyclops indicated that they are willing to meet with the CCMA to work on a mutually agreeable solution.

They often can launch recycling programs within 30 days, depending on the scale of the program. Therefore, our recommendation is to establish a partnership to contribute towards diverting 7% of glass, 6% of metals and 17% of other recyclable materials from landfills.

Alternatively, the CCMA could explore contracting with a local waste hauler directly for the removal of recyclable materials. This would be more complicated, but more cost effective than working with an intermediary like Recyclops. However, given the CCMA's limited recycling activities today, we would recommend at least starting with Recyclops until the CCMA has developed the internal expertise to manage a recycling program.

**Community Engagement and Education Initiatives**

Our final recommendation to help achieve Net Zero waste is education and community engagement. Educating and engaging Craigville's community and visitors about waste are important to ensure participation and success of all the previously mentioned recommendations. One way to encourage the community to recycle more is to improve the labeling of bins so that they are consistent across the town and are easy and intuitive for people to utilize. Recycling can also be encouraged by using town meetings to educate the residents about proper recycling etiquette and through the creation and distribution of pamphlets and posters. To help with educating residents about recycling habits, MassDEP provides funding to selected communities to educate residents on recycling habits, using their Recycling IQ Kit (Massachusetts DEP, 2019).

The composting initiative also provides the opportunity to engage the community through the creation of a volunteer program to collect and monitor the composting sites. Furthermore, community volunteers could use the finished compost on Village beautification efforts or gardening. By engaging the community in Craigville's waste reduction efforts, the CCMA could expect increased participation, higher probability of success, and a greater sense of community. While this recommendation is inexpensive, it is one that requires almost constant consideration.

# IMPLEMENTATION PLAN

**Implementation Plan**

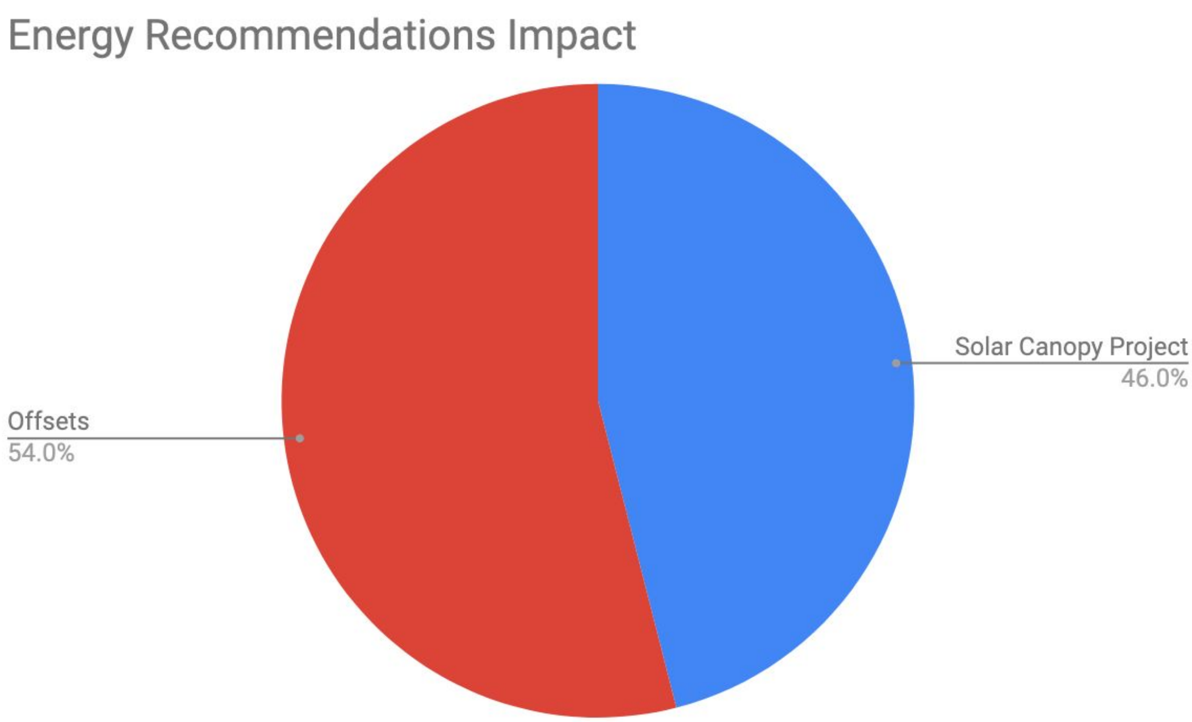
This report should be used by the CCMA and associated stakeholders to inform conversations, identify opportunities for action, and project plan implementation. Given the unique governance structure of Craigville, three ambitious Net Zero goals, and limited financial capability, this report organizes our recommendations into three tranches, or distinct 10-year periods, between 2020 and 2050 to provide the CCMA with a potential timeframe for implementation. While some actions can be implemented right away, others will lay the groundwork for progress over time.

Achieving Craigville's 2050 Net Zero energy goal will be accomplished in three phases, as illustrated in Table 11 below. The first tranche should be exclusively dedicated to installing the large solar canopy. During the second tranche, we recommend complete replacement of natural gas burning equipment with electric or solar-powered alternatives. Finally, in 2049, we recommend purchasing offsets for the remaining amount of greenhouse gas emissions. While we recommend energy efficiency improvements be implemented in all tranches, these improvements should be done on a case-by-case basis when normal equipment replacement is occurring and they are economically beneficial to do so.

**Table 11:** All Total Net Zero Energy Recommendations

| Net Zero Energy Recommendations | | | | | |
|---|---|---|---|---|---|
| **Recommendation Name** | **Upfront Cost** | **Ease of Implementation** | **Implementation Timeline** | **Net Zero Impact** | **Net Zero Installation Period** |
| Canopy Solar Project | $1,700,000 | *Medium* | 0-2 years | High | *Tranche 1: 2020-2030* |
| Beach House - Electric HW | $2,000 | *Easy* | 0-2 years | Medium | *Tranche 2: 2030-2040* |
| Beach House - Solar HW | $8,000 | *Medium* | 0-2 years | Medium | *Tranche 2: 2030-2040* |
| Craigville Inn - Electric Furnace | $15,000 | *Easy* | 0-2 years | Medium | *Tranche 2: 2030-2040* |
| Craigville Inn - Electric HW | $5,000 | *Easy* | 0-2 years | Low | *Tranche 2: 2030-2040* |
| Manor - Electric Furnace | $7,500 | *Easy* | 0-2 years | Low | *Tranche 2: 2030-2040* |
| Manor - Electric HW | $1,500 | *Easy* | 0-2 years | Low | *Tranche 2: 2030-2040* |
| Large House Year-round - Electric Furnace | $13,500 | *Easy* | 0-2 years | Low | *Tranche 2: 2030-2040* |
| Large House Year-round - Electric HW | $2,700 | *Easy* | 0-2 years | Low | *Tranche 2: 2030-2040* |
| Medium House Year-round - Electric Furnace | $8,625 | *Easy* | 0-2 years | Low | *Tranche 2: 2030-2040* |
| Medium House Year-round - Electric HW | $1,725 | *Easy* | 0-2 years | Low | *Tranche 2: 2030-2040* |
| Small House Year-round - Electric Furnace | $4,875 | *Easy* | 0-2 years | Low | *Tranche 2: 2030-2040* |
| Small House Year-round - Electric HW | $975 | *Easy* | 0-2 years | Low | *Tranche 2: 2030-2040* |
| Energy Efficiency Measures for all buildings | $25,000 | *Medium* | 0-2 years | High | *ALL* |
| Carbon Offsets (Renewable Energy Certificates) | $1,500 | *Medium* | 3-5 years | High | *Tranche 3: 2040-2050* |

Since the majority of Craigville's Net Zero energy recommendations focus on eliminating natural gas use, reducing the community's greenhouse gas emissions to zero is achieved through the development of a solar canopy and the procurement of offsets. As previously discussed, due to Craigville's limited opportunities for additional forms of renewable energy development, offsets will likely represent a significant portion of the community's Net Zero energy effort as shown below.




Craigville's Net Zero water goal is the least quantifiable of the three. With that in mind, our recommendations seek to address water from a holistic resource perspective. During tranche 1, we recommend addressing invasive species in parallel with restoring native species, planting an oyster farm, and installing reusable water bottle refill stations. Within tranche 2, we recommend installing plant buffers to protect the community from risks associated with sea level rise and increased flood propensity. We recommend the installation of water efficient appliances and water metering equipment across all tranches as access to capital allows.

**Table 12:** All Total Net Zero Water Recommendations

| Net Zero Water Recommendations | | | | | |
|---|---|---|---|---|---|
| Recommendation Name | Upfront Cost | Ease of Implementation | Implementation Time | Net Zero Impact | Net Zero Installation Period |
| Eradicating Invasives & Native Planting | $4,279 | Medium | 2-5 years | Low | Tranche 1: 2020-2030 |
| Oysters Farming | $4,450 | Easy | 2-5 years | High | Tranche 1: 2020-2030 |
| Water Refill Stations | $3,718 | Easy | 0-2 years | Medium | Tranche 1: 2020-2030 |
| Water Efficient Appliances | $329,670 | Easy | 5-10 years | Medium | All |
| Water Metering | $42,598 | Easy | 5-10 years | Medium | All |
| Plant Buffers | 25,000 | Medium | 0-2 years | Medium | Tranche 2: 2030-2040 |

As stated above, the qualitative nature of the Net Zero water goal made it difficult to quantify the potential impact of our recommendations. Therefore, the figure below is an estimate based on the definition of Net Zero water provided by the CCMA.

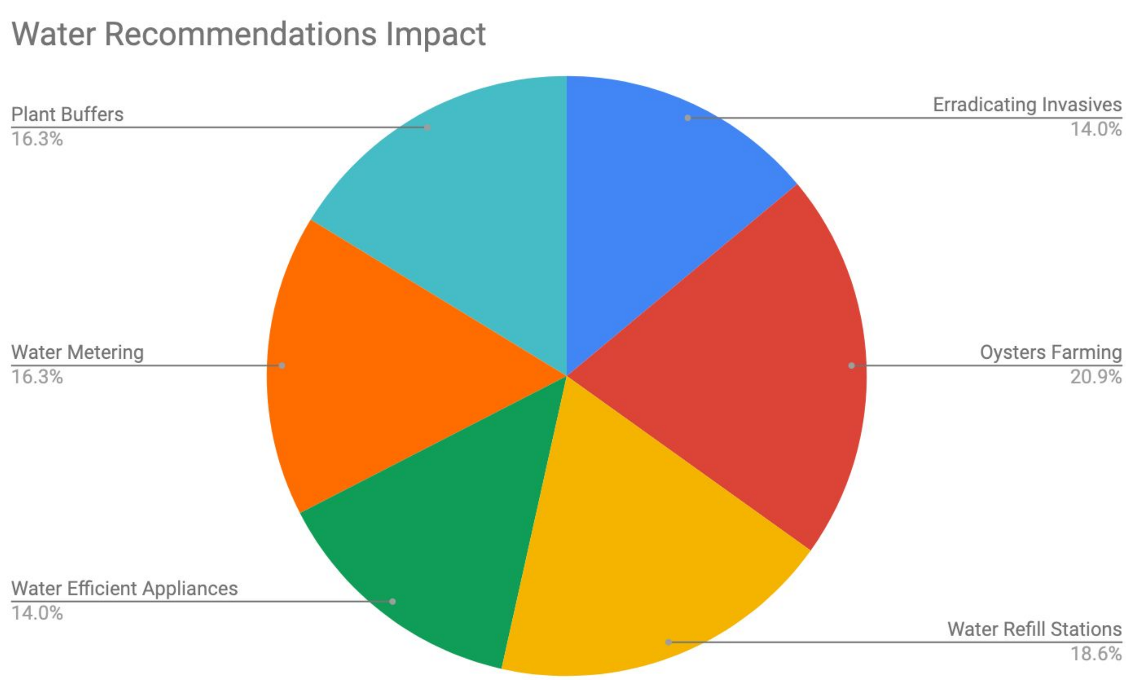


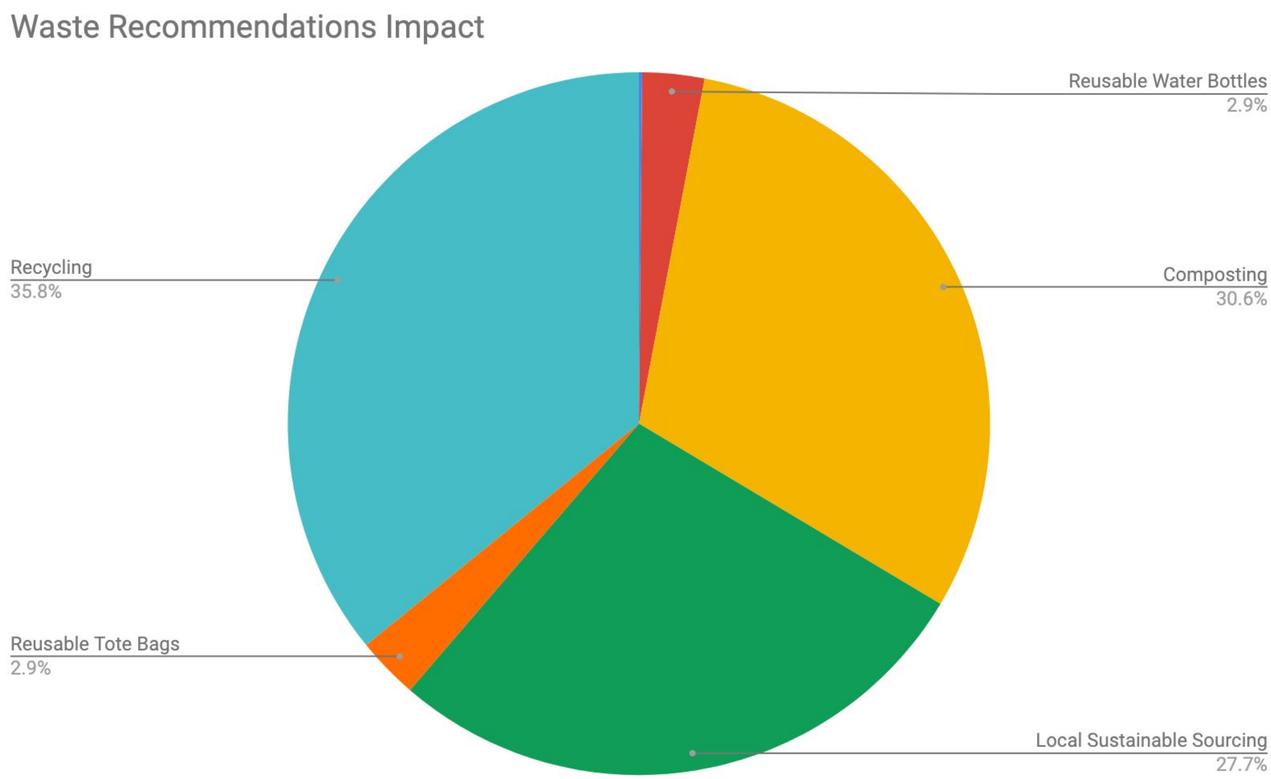

**Figure 17:** Water Recommendations Impact

In comparison to the other two Net Zero goals, Craigville's Net Zero Waste goal and the accompanying recommendations are less expensive and relatively easier to implement. Because of this, most recommendations, such as reduction initiatives and the installation of composting bins, can be implemented within the first tranche. Despite a higher upfront cost, partnering with Recyclops to deploy recycling should still be attempted in Tranche 1, given it creates the largest impact in making progress towards achieving Net Zero waste, as illustrated in Figure 18 below. We recommend that an aerobic composting system be installed in Tranche 3, at which point the CCMA should have a better understanding of its waste stream and composting needs. Lastly, education and community engagement are paramount to ensuring the success of all other recommendations; therefore, this activity should be ongoing throughout all three tranches. The impact of this goal is not represented as a slice of the pie chart because its impact would instead decrease the size of the overall Net Zero waste goal.

**Table 13:** All Total Net Zero Waste Recommendations

| Net Zero Waste Recommendations | | | | | |
|---|---|---|---|---|---|
| Recommendation Name | Upfront Cost | Ease of Implementation | Implementation Time | Net Zero Impact | Net Zero Installation Period |
| Eliminating Trays | 0 | Easy | 0-2 years | Low | Tranche 1: 2020-2030 |
| Reusable Water Bottles | $420 - $3,490 | Easy | 0-2 years | Medium | Tranche 1: 2020-2030 |
| Composting (Bins) | $400 - $1,200 | Easy | 0-2 years | Medium | Tranche 1: 2020-2030 |
| Local Sustainable Sourcing | $750 | Easy | 0-2 years | Low | Tranche 1: 2020-2030 |
| Reusable Tote Bags | $590 - $5,000 | Easy | 0-2 years | Low | Tranche 1: 2020-2030 |
| Recyclops | $12,000-$24,000 | Easy | 0-2 years | Low | Tranche 1: 2020-2030 |
| Education and Community Engagement | $1,000 | Medium | 0-2 years | Medium | All |
| Aerobic Composting System | $400,000-$1.2 million | Medium | 0-2 years | Low | Tranche 3: 2040-2050 |

**Figure 18:** Waste Recommendations Impact




We recognize that the CCMA is the single organization responsible for implementing initiatives in pursuit of all three Net Zero goals simultaneously. Therefore, the CCMA will have to prioritize our recommendations against one another. To assist the CCMA with accomplishing this task, we have developed Appendix 1. This Appendix ranks all of the Net Zero recommendations across a common set of metrics. The ranking metrics include a range for estimated upfront cost, ease of implementation, and Net Zero impact within each goal. To further assist with the most efficient allocation of CCMA's annual funds, three separate cost ranges for upfront costs were developed in consideration of Craigville's current access to capital, as stated during conversations with the CCMA Board. These three ranges are as follows: recommendations with an upfront cost between: 1) 0-$24,999, 2) $25,000 - $49,999, 3) $50,000 and above. In combination with each Net Zero goal's implementation chart, Appendix 1 should be referenced for planning purposes.

Given that the costs in this report are estimates, we hope the CCMA uses our recommendations and implementation plan to contact contractors for work estimates, as well as to apply to the relevant grants we identified, and for future budget planning.

We suggest CCMA actively engage their residents and visitors in their Net Zero plans and initiatives. The creation of a marketing campaign will encourage Craigville residents to participate in Net Zero initiatives and attract new visitors to the retreat center, as well as create partnerships with volunteer organizations to accomplish the recommendations. We strongly believe such efforts will yield synergistic benefits across all Net Zero goals.

Lastly, achieving Net Zero by 2050 is an ambitious effort, but it establishes a goal more than 30 years away. Considering that timeframe, the rapid pace with which science and technology have been advancing, we recommend re-assessing Craigville's opportunities at a minimum every three years. Increases in Craigville's population, visitors, or building stock would also be factors to consider when revisiting this report.

# CONCLUSION

## Conclusion

The CCMA's commitment to make Craigville a Net Zero community by 2050 is an ambitious goal. Threats from sea-level rise, limited access to capital, and a local economy dependent upon spring and summer visitors are not unique to Craigville. These obstacles mirror what all coastal communities are will face in the coming decades. Though only a small Village in Cape Cod, Craigville has the potential to become a leader among the cities and various municipal entities taking action against anthropogenic climate change.

Based on our analysis and benchmarking across Net Zero energy, water, and waste, it is our belief that making Craigville Net Zero by 2050 is possible. We believe our individual Net Zero recommendations, in conjunction with the implementation plan we have developed, provide the CCMA with the information necessary to engage stakeholders and the community as they develop and implement their Sustainability Action Plan. With our roadmap to making Craigville Net Zero by 2050, we believe Craigville can stay true to its motto: "Preserving the Past, Providing for the Future."


Infographics
39.42
25.8K
122 841
992
Visibility
Organic Keywords

# APPENDIX

## **Appendix 1a:** All Net Zero Recommendations Ranked by Cost, Ease of Implementation, and Net Zero Impact

| All Net Zero Recommendations Ranked by Cost, Ease of Implementation, and Net Zero Impact | | | | | | |
|---|---|---|---|---|---|---|
| Name | Upfront Cost | Ease of Implementation | Impact Category | | | Total Points |
| | | | Energy | Water | Waste | |
| Oysters Farming | *$0-$24,999* | *Easy* | *None* | *High* | *None* | 9 |
| Craigville Inn - Electric Furnace | *$0-$24,999* | *Easy* | *Medium* | *None* | *None* | 8 |
| Beach House - Electric HW | *$0-$24,999* | *Easy* | *Medium* | *None* | *None* | 8 |
| Reusable Water Bottles | *$0-$24,999* | *Easy* | *None* | *None* | *Medium* | 8 |
| Eliminating Trays | *$0-$24,999* | *Easy* | *None* | *Low* | *Low* | 8 |
| Composting | *$0-$24,999* | *Easy* | *None* | *None* | *Medium* | 8 |
| Water Refill Stations | *$0-$24,999* | *Easy* | *None* | *Medium* | *None* | 8 |
| Water Metering | *$0-$24,999* | *Easy* | *None* | *Medium* | *None* | 8 |
| Craigville Inn - Electric HW | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Manor - Electric Furnace | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Manor - Electric HW | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Lodge - Electric Furnace | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Lodge - Electric HW | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Yale (6) - Electric Furnace | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Beach House - Solar HW | *$0-$24,999* | *Medium* | *Medium* | *None* | *None* | 7 |
| Large House Year-round - Electric Furnace | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Large House Year-round - Electric HW | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Large House Seasonal - Electric Furnace | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Large House Seasonal - Electric HW | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Medium House Year-round - Electric Furnace | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Medium House Year-round - Electric HW | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Medium House Seasonal - Electric Furnace | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Medium House Seasonal - Electric HW | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Small House Year-round - Electric Furnace | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Small House Year-round - Electric HW | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Small House Seasonal - Electric Furnace | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Small House Seasonal - Electric HW | *$0-$24,999* | *Easy* | *Low* | *None* | *None* | 7 |
| Local Sustainable Sourcing | *$0-$24,999* | *Easy* | *None* | *None* | *Low* | 7 |
| Reusable Tote Bags | *$0-$24,999* | *Easy* | *None* | *None* | *Low* | 7 |
| Recyclops | *$0-$24,999* | *Easy* | *None* | *None* | *Low* | 7 |

## **Appendix 1b:** All Net Zero Options Ranked by Cost, Ease of Implementation, and Net Zero Impact

| All Net Zero Options Ranked by Cost, Ease of Implementation, and Net Zero Impact | | | | | | |
|---|---|---|---|---|---|---|
| Name | Upfront Cost | Ease of Implementation | Impact Category | | | Total Points |
| | | | Energy | Water | Waste | |
| Education and Community Engagement | *$0-$24,999* | *Medium* | *None* | *None* | *Medium* | 7 |
| Plant Buffers | *$0-$24,999* | *Medium* | *None* | *Medium* | *None* | 7 |
| GhG Offsets | *$25,000-$49,999* | *Medium* | *High* | *None* | *None* | 7 |
| Craigville Inn - Air-source Heat Pump | *$25,000-$49,999* | *Difficult* | *High* | *None* | *None* | 6 |
| Craigville Inn - Solar HW | *$0-$24,999* | *Medium* | *Low* | *None* | *None* | 6 |
| Manor - Solar HW | *$0-$24,999* | *Medium* | *Low* | *None* | *None* | 6 |
| Lodge - Solar HW | *$0-$24,999* | *Medium* | *Low* | *None* | *None* | 6 |
| Yale (6) - Solar HW | *$0-$24,999* | *Medium* | *Low* | *None* | *None* | 6 |
| Large House Year-round - Solar HW | *$0-$24,999* | *Medium* | *Low* | *None* | *None* | 6 |
| Large House Seasonal - Solar HW | *$0-$24,999* | *Medium* | *Low* | *None* | *None* | 6 |
| Medium House Year-round - Solar HW | *$0-$24,999* | *Medium* | *Low* | *None* | *None* | 6 |
| Medium House Seasonal - Solar HW | *$0-$24,999* | *Medium* | *Low* | *None* | *None* | 6 |
| Small House Year-round - Solar HW | *$0-$24,999* | *Medium* | *Low* | *None* | *None* | 6 |
| Small House Seasonal - Solar HW | *$0-$24,999* | *Medium* | *Low* | *None* | *None* | 6 |
| Erradicating Invasives & Native Planting | *$0-$24,999* | *Medium* | *None* | *Low* | *None* | 6 |
| Water Efficient Appliances | *$50,000 & above* | *Easy* | *None* | *Medium* | *None* | 6 |
| Canopy Solar Project | *$50,000 & above* | *Medium* | *High* | *None* | *None* | 6 |
| Manor - Air-source Heat Pump | *$0-$24,999* | *Difficult* | *Low* | *None* | *None* | 5 |

**Appendix 2:** CCMA Facility Improvement Measures Cont.

| Craigville Facility Improvement Measures | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Building | Description | For Rec | Cost | Electric Baseline | Natural Gas Baseline | Baseline Annual Utility Cost | Measure Electric | Measure Natural Gas | Measure Utility Cost | Electric Impact | Natural Gas Impact | Cost Impact |
| Large House Year-round | Electric Furnace | Large House Year-round - Electric Furnace | $13,500 | 16,240 | 984 | 3,269 | 30,000 | 262 | 4,594 | 13,760 | -722 | 1,324 |
| Large House Year-round | Electric HW | Large House Year-round - Electric HW | $2,700 | 16,240 | 984 | 3,269 | 21,840 | 722 | 3,838 | 5,600 | -262 | 569 |
| Large House Year-round | Solar HW | Large House Year-round - Solar HW | $6,300 | 16,240 | 984 | 3,269 | 18,720 | 722 | 3,386 | 2,480 | -262 | 116 |
| Large House Seasonal | Electric Furnace | Large House Seasonal - Electric Furnace | $7,500 | 9,710 | 94 | 1,495 | 9,500 | 92 | 1,463 | -210 | -2 | -32 |
| Large House Seasonal | Electric HW | Large House Seasonal - Electric HW | $1,500 | 9,710 | 94 | 1,495 | 11,680 | 2 | 1,695 | 1,970 | -92 | 200 |
| Large House Seasonal | Solar HW | Large House Seasonal - Solar HW | $3,500 | 9,710 | 94 | 1,495 | 10,310 | 2 | 1,497 | 600 | -92 | 2 |
| Medium House Year-round | Electric Furnace | Medium House Year-round - Electric Furnace | $8,625 | 11,830 | 795 | 2,454 | 24,020 | 172 | 3,643 | 12,190 | -623 | 1,189 |
| Medium House Year-round | Electric HW | Medium House Year-round - Electric HW | $1,725 | 11,830 | 795 | 2,454 | 15,510 | 622.7 | 2,828 | 3,680 | -172 | 374 |
| Medium House Year-round | Solar HW | Medium House Year-round - Solar HW | $4,025 | 11,830 | 795 | 2,454 | 13,660 | 622.7 | 2,560 | 1,830 | -172 | 106 |
| Medium House Seasonal | Electric Furnace | Medium House Seasonal - Electric Furnace | $5,625 | 6,910 | 64 | 1,061 | 6,860 | 61 | 1,051 | -50 | -3 | -10 |
| Medium House Seasonal | Electric HW | Medium House Seasonal - Electric HW | $1,125 | 6,910 | 64 | 1,061 | 8,220 | 2 | 1,194 | 1,310 | -62 | 133 |
| Medium House Seasonal | Solar HW | Medium House Seasonal - Solar HW | $2,625 | 6,910 | 64 | 1,061 | 7,720 | 2 | 1,121 | 810 | -62 | 60 |
| Small House Year-round | Electric Furnace | Small House Year-round - Electric Furnace | $4,875 | 5,556 | 626 | 1,387 | 16,790 | 80 | 2,509 | 11,234 | -546 | 1,122 |
| Small House Year-round | Electric HW | Small House Year-round - Electric HW | $975 | 5,556 | 626 | 1,387 | 7,286 | 544 | 1,562 | 1,730 | -82 | 175 |
| Small House Year-round | Solar HW | Small House Year-round - Solar HW | $2,275 | 5,556 | 626 | 1,387 | 6,550 | 544 | 1,456 | 994 | -82 | 68 |
| Small House Seasonal | Electric Furnace | Small House Seasonal - Electric Furnace | $1,800 | 2,456 | 37 | 391 | 2,666 | 8 | 394 | 210 | -29 | 3 |
| Small House Seasonal | Electric HW | Small House Seasonal - Electric HW | $360 | 2,456 | 37 | 391 | 3,075 | 29 | 473 | 619 | -8 | 82 |
| Small House Seasonal | Solar HW | Small House Seasonal - Solar HW | $840 | 2,456 | 37 | 391 | 2,756 | 29 | 427 | 300 | -8 | 36 |

**Appendix 3a:** CCMA Property Data

| Craigville Properties | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Street Number | Street Name | Owner | Type | Square Footage | | Heat | A/C | Baths |
| | | | | Living | Gross | | | |
| 6 | Butler Avenue | Underwood | Private | 2,861 | 4,736 | Nat Gas | None | 2.5 |
| 12 | Butler Avenue | Shoemaker | Private | 1,896 | 3,664 | Nat Gas | None | 2.5 |
| 22 | Butler Avenue | Greene | Private | 4,369 | 7,337 | Nat Gas | None | 3.5 |
| 33 | Butler Avenue | Greene | Private | 1,539 | 3,170 | Nat Gas | None | 2.0 |
| 2 | Clark Avenue | Carpenter | Private | 1,526 | 2,836 | Nat Gas | Yes | 2.0 |
| 45 | Lake Elizabeth Drive | Croteau | Private | 2,466 | 4,144 | Nat Gas | None | 3.0 |
| 55 | Lake Elizabeth Drive | Kumar | Private | 2,369 | 3,799 | Nat Gas | None | 3.0 |
| 67 | Lake Elizabeth Drive | Gavitt | Private | 2,883 | 4,263 | Nat Gas | Yes | 2.5 |
| 89 | Lake Elizabeth Drive | Kirk | Private | 2,079 | 4,276 | Oil | None | 2.5 |
| 105 | Lake Elizabeth Drive | Herzog | Private | 1,608 | 3,404 | Electric | None | 2.5 |
| 109 | Lake Elizabeth Drive | Troy | Private | 1,582 | 3,381 | None | None | 2.0 |
| 117 | Lake Elizabeth Drive | Crory | Private | 880 | 3,068 | Nat Gas | Yes | 2.5 |
| 123 | Lake Elizabeth Drive | Gates | Private | 1,996 | 3,998 | Nat Gas | Yes | 3.0 |
| 127 | Lake Elizabeth Drive | Oates | Private | 1,672 | 3,119 | Nat Gas | None | 2.5 |
| 131 | Lake Elizabeth Drive | Delany | Private | 2,141 | 2,898 | Nat Gas | None | 2.5 |
| 135 | Lake Elizabeth Drive | Parke | Private | 1,972 | 2,570 | Nat Gas | None | 2.5 |
| 149 | Lake Elizabeth Drive | Walters | Private | 853 | 3,100 | Oil | None | 3.0 |
| 163 | Lake Elizabeth Drive | Barksdale | Private | 1,549 | 2,778 | Nat Gas | None | 1.5 |
| 173 | Lake Elizabeth Drive | Brown | Private | 1,762 | 2,272 | Nat Gas | None | 2.0 |
| 177 | Lake Elizabeth Drive | Hanson | Private | 2,279 | 2,924 | Nat Gas | Yes | 2.5 |
| 186 | Lake Elizabeth Drive | Coughlin | Private | 1,374 | 2,984 | Nat Gas | None | 1.5 |
| 194 | Lake Elizabeth Drive | *Boston* | CCMA | | | | | |
| 198 | Lake Elizabeth Drive | *Yale* | CCMA | | | | | |
| 202 | Lake Elizabeth Drive | *Andover* | CCMA | | | | | |

**Appendix 3b:** CCMA Property Data

| Craigville Properties | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Street Number | Street Name | Owner | Type | Square Footage | | Heat | A/C | Baths |
| | | | | Living | Gross | | | |
| 208 | Lake Elizabeth Drive | *Inn* | CCMA | 10,516 | 13,977 | Nat Gas | None | 16.0 |
| 222 | Lake Elizabeth Drive | *Union* | CCMA | | | | | |
| 228 | Lake Elizabeth Drive | Kirk | Private | 1,050 | 2,882 | None | None | 1.0 |
| 234 | Lake Elizabeth Drive | Schumacher | Private | 1,038 | 1,902 | None | None | 1.5 |
| 238 | Lake Elizabeth Drive | Kirk | Private | 1,225 | 2,310 | None | None | 2.0 |
| 242 | Lake Elizabeth Drive | Beal | Private | 1,082 | 1,366 | Electric | None | 1.0 |
| 246 | Lake Elizabeth Drive | Lahey | Private | 1,249 | 2,410 | Oil | None | 2.0 |
| 248 | Lake Elizabeth Drive | Price | Private | 576 | 992 | Nat Gas | None | 1.0 |
| 251 | Lake Elizabeth Drive | *Tabernacle* | CCMA | 3,750 | 3,785 | None | None | 0.0 |
| 260 | Lake Elizabeth Drive | Lyons | Private | 1,437 | 3,422 | Nat Gas | Yes | 3.0 |
| 295 | Lake Elizabeth Drive | Fackre | Private | 876 | 2,542 | Oil | None | 2.0 |
| 297 | Lake Elizabeth Drive | Gandy | Private | 990 | 2,122 | Electric | None | 1.5 |
| 306 | Lake Elizabeth Drive | Lacoy | Private | 1,014 | 2,178 | Nat Gas | None | 1.0 |
| 308 | Lake Elizabeth Drive | Schultz | Private | 952 | 2,000 | Nat Gas | None | 1.0 |
| 309 | Lake Elizabeth Drive | Hofmann | Private | 2,880 | 3,609 | Nat Gas | Part | 2.0 |
| 310 | Lake Elizabeth Drive | Bergeron | Private | 792 | 2,340 | Nat Gas | None | 1.5 |
| 319 | Lake Elizabeth Drive | Peterson | Private | 1,172 | 2,524 | Electric | None | 1.0 |
| 320 | Lake Elizabeth Drive | Anastas | Private | 1,568 | 2,640 | Nat Gas | Yes | 2.0 |
| 327 | Lake Elizabeth Drive | McKinney | Private | 960 | 2,253 | Nat Gas | None | 1.0 |
| 330 | Lake Elizabeth Drive | Hoffman | Private | 1,680 | 4,038 | Nat Gas | None | 2.0 |
| 335 | Lake Elizabeth Drive | Balsamo | Private | 1,627 | 3,400 | Nat Gas | None | 2.5 |
| 342 | Lake Elizabeth Drive | Keedy | Private | 640 | 1,408 | Nat Gas | None | 1.0 |
| 344 | Lake Elizabeth Drive | Castaldi | Private | 1,210 | 3,255 | Oil | None | 2.0 |
| 347 | Lake Elizabeth Drive | Aeschliman | Private | 816 | 916 | Nat Gas | None | 1.0 |

## **Appendix 3c:** CCMA Property Data

| Craigville Properties | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Street Number | Street Name | Owner | Type | Square Footage | | Heat | A/C | Baths |
| | | | | Living | Gross | | | |
| 351 | Lake Elizabeth Drive | Liu | Private | 864 | 1,906 | Nat Gas | None | 1.0 |
| 359 | Lake Elizabeth Drive | Leone | Private | 1,096 | 2,927 | Nat Gas | None | 2.0 |
| 360 | Lake Elizabeth Drive | Whalen | Private | 2,140 | 4,087 | Nat Gas | Yes | 2.5 |
| 367 | Lake Elizabeth Drive | Dadashev | Private | 1,968 | 2,112 | Nat Gas | None | 2.0 |
| 368 | Lake Elizabeth Drive | Henderson | Private | 1,585 | 4,296 | Nat Gas | None | 2.0 |
| 375 | Lake Elizabeth Drive | Hodges | Private | 1,294 | 2,699 | Nat Gas | None | 2.5 |
| 386 | Lake Elizabeth Drive | Henderson | Private | 836 | 1,856 | Nat Gas | None | 1.0 |
| 387 | Lake Elizabeth Drive | Werner | Private | 816 | 816 | Oil | None | 1.0 |
| 395 | Lake Elizabeth Drive | Itkis | Private | 1,752 | 4,896 | Nat Gas | None | 3.0 |
| 396 | Lake Elizabeth Drive | Dallos | Private | 1,734 | 2,818 | Nat Gas | Yes | 2.0 |
| 402 | Lake Elizabeth Drive | Overlock | Private | 1,134 | 2,625 | Nat Gas | Yes | 2.0 |
| 406 | Lake Elizabeth Drive | Walsh | Private | 454 | 930 | Nat Gas | None | 1.0 |
| 9 | Laurel Avenue | McCormick | Private | 1,117 | 1,834 | None | None | 1.0 |
| 17 | Laurel Avenue | Vester | Private | 1,380 | 2,306 | Electric | None | 2.0 |
| 23 | Laurel Avenue | Gerardin | Private | 1,347 | 1,966 | Oil | None | 2.5 |
| 28 | Laurel Avenue | Connolly | Private | 1,096 | 2,540 | Nat Gas | None | 1.5 |
| 44 | Laurel Avenue | Swanson | Private | 1,008 | 2,480 | Nat Gas | None | 1.0 |
| 54 | Laurel Avenue | Norwood | Private | 648 | 1,280 | Electric | None | 1.0 |
| 47 | Ocean Avenue | Maddalena | Private | 1,674 | 3,498 | Nat Gas | Yes | 3.0 |
| 57 | Ocean Avenue | Ireland | Private | 2,240 | 3,161 | Oil | None | 3.0 |
| 63 | Ocean Avenue | Buffington | Private | 1,758 | 3,177 | Electric | None | 2.5 |
| 84 | Ocean Avenue | Hartunian | Private | 1,364 | 3,192 | Nat Gas | None | 2.5 |
| 93 | Ocean Avenue | Currier | Private | 1,938 | 2,823 | Nat Gas | Yes | 2.0 |
| 351 | Lake Elizabeth Drive | Liu | Private | 864 | 1,906 | Nat Gas | None | 1.0 |

## **Appendix 3c:** CCMA Property Data

| Craigville Properties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Street Number | Street Name | Owner | Type | Square Footage | | Heat | A/C | Baths |
| | | | | Living | Gross | | | |
| 101 | Ocean Avenue | Cardarelli | Private | 900 | 1,681 | Nat Gas | None | 0.5 |
| 125 | Ocean Avenue | *Groves* | CCMA | 2,100 | 3,552 | Nat Gas | None | 5.0 |
| 129 | Ocean Avenue | Almy | Private | 635 | 1,050 | None | None | 1.0 |
| 145 | Ocean Avenue | Gooding | Private | 1,944 | 2,713 | Nat Gas | Part | 2.0 |
| 151 | Ocean Avenue | Lahey | Private | 1,219 | 2,712 | Nat Gas | Yes | 1.0 |
| 153 | Ocean Avenue | Lahey | Private | 1,084 | 1,346 | None | None | 1.0 |
| 12 | Prospect Avenue | Twichell | Private | 1,444 | 3,220 | None | None | 3.5 |
| 25 | Prospect Avenue | *Manor* | CCMA | 3,115 | 5,043 | Nat Gas | None | 7.0 |
| 26 | Prospect Avenue | Williams | Private | 3,434 | 7,868 | Nat Gas | Yes | 3.5 |
| 39 | Prospect Avenue | *Lodge/Marshview* | CCMA | 10,207 | 13,917 | Nat Gas | None | 11.0 |
| 28 | Summerbell Avenue | Carpenter | Private | 2,318 | 4,666 | Nat Gas | Yes | 3.0 |
| 29 | Summerbell Avenue | *Tennis* | CCMA | | | None | None | 0.0 |
| 34 | Summerbell Avenue | Dalessandro | Private | 1,744 | 3,622 | Nat Gas | None | 2.0 |
| 42 | Summerbell Avenue | Shea | Private | 2,232 | 4,031 | Nat Gas | Yes | 2.0 |
| 57 | Summerbell Avenue | Power | Private | 1,058 | 1,812 | Nat Gas | None | 1.0 |
| 58 | Summerbell Avenue | Reilly | Private | 1,642 | 2,912 | Nat Gas | None | 2.5 |
| 67 | Summerbell Avenue | Caldera | Private | 840 | 1,368 | Nat Gas | None | 1.0 |
| 68 | Summerbell Avenue | Plonowski | Private | | | | | |
| 74 | Summerbell Avenue | Kay | Private | 1,424 | 2,976 | Nat Gas | None | 3.0 |
| 55 | Summerbell Avenue | Longo | Private | 1,800 | 2,386 | Nat Gas | None | 1.5 |
| 86 | Summerbell Avenue | Lane | Private | 1,806 | 3,906 | Oil | None | 3.0 |
| 94 | Summerbell Avenue | Farquar | Private | 1,782 | 2,864 | Nat Gas | Yes | 2.0 |
| 95 | Summerbell Avenue | Gahan | Private | 1,085 | 2,674 | Nat Gas | Yes | 2.0 |
| 101 | Ocean Avenue | Cardarelli | Private | 900 | 1,681 | Nat Gas | None | 0.5 |

**Appendix 3d:** CCMA Property Data

| Craigville Properties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Street Number | Street Name | Owner | Type | Square Footage | | Heat | A/C | Baths |
| | | | | Living | Gross | | | |
| 3 | Valley Avenue | Matthijssen | Private | 1,069 | 2,922 | None | None | 1.5 |
| 5 | Valley Avenue | Lynch | Private | 2,338 | 3,224 | Nat Gas | None | 3.0 |
| 7 | Valley Avenue | Oates | Private | 1,760 | 3,096 | Oil | None | 2.5 |
| 13 | Valley Avenue | Mascia | Private | 1,138 | 1,938 | None | None | 2.0 |
| 17 | Valley Avenue | Lebel | Private | 1,104 | 1,608 | Nat Gas | None | 1.5 |
| 35 | Valley Avenue | Duckworth | Private | 1,234 | 1,582 | Nat Gas | None | 1.0 |
| 43 | Valley Avenue | *Post Office* | CCMA | 320 | 320 | None | None | 0.5 |
| 7 | Vine Avenue | Hansen | Private | 1,712 | 2,835 | Nat Gas | None | 1.5 |
| 19 | Vine Avenue | Shea | Private | 3,491 | 8,848 | Nat Gas | None | 7.0 |
| 29 | Vine Avenue | Trull | Private | 1,915 | 4,002 | Nat Gas | Yes | 2.0 |
| 39 | Vine Avenue | Wright | Private | 2,525 | 3,164 | None | None | 3.0 |
| 44 | Vine Avenue | Pinto | Private | 2,050 | 2,577 | Mixed | None | 2.5 |
| 47 | Vine Avenue | Goroll | Private | 3,111 | 6,141 | Nat Gas | Yes | 3 + 2 |
| 58 | Vine Avenue | Deyton | Private | 2,902 | 5,010 | Nat Gas | Yes | 5.0 |
| 64 | Vine Avenue | Quirk | Private | 1,024 | 1,770 | None | None | 1.0 |

## **Appendix 4a:** Energy Financial Model - 20 YEAR FINANCIAL MODEL COMPARING ELECTRIC FURNACE AND HEAT PUMP AT CRAIGVILLE INN

| Constants | | | |
|---|---|---|---|
| Heat Pump Electric (kWh) | 39,340 | Utility Escalation | 2% |
| Heat Pump Cost | $ 30,000 | Elec Rate ($/kWh) | 0.14 |
| Heat Pump De-escalation | 5% | Equity Cost | 8% |
| Elec Furnace Electric | 71,470 | | |
| Elec Furnace Cost | $ 15,000 | | |
| Elec Furnace De-escalation | 2% | | |

| *Category* | *Start* | *Year 1* | *Year 2* | *Year 3* | *Year 4* | *Year 5* | *Year 6* | *Year 7* | *Year 8* | *Year 9* | *Year 10* | *Year 11* | *Year 12* | *Year 13* | *Year 14* | *Year 15* | *Year 16* | *Year 17* | *Year 18* | *Year 19* | *Year 20* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Electric Furnace | | | | | | | | | | | | | | | | | | | | | |
| Electric kWh | | 71,470 | 72,899 | 74,357 | 75,845 | 77,361 | 78,909 | 80,487 | 82,097 | 83,738 | 85,413 | 87,122 | 88,864 | 90,641 | 92,454 | 94,303 | 96,189 | 98,113 | 100,075 | 102,077 | 104,118 |
| Electric Cost | | $ (10,006) | $ (10,206) | $ (10,410) | $ (10,618) | $ (10,831) | $ (11,047) | $ (11,268) | $ (11,494) | $ (11,723) | $ (11,958) | $ (12,197) | $ (12,441) | $ (12,690) | $ (12,944) | $ (13,202) | $ (13,466) | $ (13,736) | $ (14,011) | $ (14,291) | $ (14,577) |
| Capital Cost | $ (15,000) | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| Cash Flow | $ (15,000) | $ (10,006) | $ (10,206) | $ (10,410) | $ (10,618) | $ (10,831) | $ (11,047) | $ (11,268) | $ (11,494) | $ (11,723) | $ (11,958) | $ (12,197) | $ (12,441) | $ (12,690) | $ (12,944) | $ (13,202) | $ (13,466) | $ (13,736) | $ (14,011) | $ (14,291) | $ (14,577) |
| NPV | $ (15,000) | $ (9,265) | $ (8,750) | $ (8,264) | $ (7,805) | $ (7,371) | $ (6,962) | $ (6,575) | $ (6,210) | $ (5,865) | $ (5,539) | $ (5,231) | $ (4,940) | $ (4,666) | $ (4,407) | $ (4,162) | $ (3,931) | $ (3,712) | $ (3,506) | $ (3,311) | $ (3,127) |
| Total Cost of Ownership | $ (128,598) | | | | | | | | | | | | | | | | | | | | |
| Heat Pump | | | | | | | | | | | | | | | | | | | | | |
| Electric kWh | | 39,340 | 41,307 | 43,372 | 45,541 | 47,818 | 50,209 | 52,719 | 55,355 | 58,123 | 61,029 | 64,081 | 67,285 | 70,649 | 74,181 | 77,891 | 81,785 | 85,874 | 90,168 | 94,676 | 99,410 |
| Electric Cost | | $ (5,508) | $ (5,783) | $ (6,072) | $ (6,376) | $ (6,695) | $ (7,029) | $ (7,381) | $ (7,750) | $ (8,137) | $ (8,544) | $ (8,971) | $ (9,420) | $ (9,891) | $ (10,385) | $ (10,905) | $ (11,450) | $ (12,022) | $ (12,624) | $ (13,255) | $ (13,917) |
| Capital Cost | $ (30,000) | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| Cash Flow | $ (30,000) | $ (5,508) | $ (5,783) | $ (6,072) | $ (6,376) | $ (6,695) | $ (7,029) | $ (7,381) | $ (7,750) | $ (8,137) | $ (8,544) | $ (8,971) | $ (9,420) | $ (9,891) | $ (10,385) | $ (10,905) | $ (11,450) | $ (12,022) | $ (12,624) | $ (13,255) | $ (13,917) |
| NPV | $ (30,000) | $ (5,100) | $ (4,958) | $ (4,820) | $ (4,686) | $ (4,556) | $ (4,430) | $ (4,307) | $ (4,187) | $ (4,071) | $ (3,958) | $ (3,848) | $ (3,741) | $ (3,637) | $ (3,536) | $ (3,438) | $ (3,342) | $ (3,249) | $ (3,159) | $ (3,071) | $ (2,986) |
| Total Cost of Ownership | $ (109,078) | | | | | | | | | | | | | | | | | | | | |

**Appendix 4b:** Energy Financial Model - Solar PV 20 Year Model

| *Category* | *Start* | *Year 1* | *Year 2* | *Year 3* | *Year 4* | *Year 5* | *Year 6* | *Year 7* | *Year 8* | *Year 9* | *Year 10* | *Year 11* | *Year 12* | *Year 13* | *Year 14* | *Year 15* | *Year 16* | *Year 17* | *Year 18* | *Year 19* | *Year 20* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Solar PV | | | | | | | | | | | | | | | | | | | | | |
| Capital Cost | $ (1,772,500) | | | | | | | | | | | | | | | | | | | | |
| Revenue | | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 | $ 146,871 |
| Present Value | $ (1,772,500) | $ 139,877 | $ 133,216 | $ 126,873 | $ 120,831 | $ 115,077 | $ 109,597 | $ 104,378 | $ 99,408 | $ 94,674 | $ 90,166 | $ 85,872 | $ 81,783 | $ 77,889 | $ 74,180 | $ 70,647 | $ 67,283 | $ 64,079 | $ 61,028 | $ 58,122 | $ 55,354 |
| **Total Cost of Ownership** | | | | | | | | | | | | | | | | | | | | | $ 57,837 |

**Appendix 4c:** Energy Financial Model - 20 YEAR FINANCIAL MODEL COMPARING ELECTRIC HW AND SOLAR HW HEATING SYSTEMS

| Constants | | | |
|---|---|---|---|
| Solar HW kWh | 17,520 | Utility Escalation | 2% |
| Solar HW Cost | $ 22,000 | Elec Rate ($/kWh) | 0.14 |
| Solar HW De-escalation | 0% | Equity Cost | 8% |
| Elec HW kWh | 34,710 | | |
| Elec Furnace Cost | $ 5,000 | | |
| Elec Furnace De-escalation | 2% | | |

| *Category* | *Start* | *Year 1* | *Year 2* | *Year 3* | *Year 4* | *Year 5* | *Year 6* | *Year 7* | *Year 8* | *Year 9* | *Year 10* | *Year 11* | *Year 12* | *Year 13* | *Year 14* | *Year 15* | *Year 16* | *Year 17* | *Year 18* | *Year 19* | *Year 20* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Elec HW** | | | | | | | | | | | | | | | | | | | | | |
| Electric kWh | | 71,470 | 72,899 | 74,357 | 75,845 | 77,361 | 78,909 | 80,487 | 82,097 | 83,738 | 85,413 | 87,122 | 88,864 | 90,641 | 92,454 | 94,303 | 96,189 | 98,113 | 100,075 | 102,077 | 104,118 |
| Electric Cost | | $ (10,006) | $ (10,206) | $ (10,410) | $ (10,618) | $ (10,831) | $ (11,047) | $ (11,268) | $ (11,494) | $ (11,723) | $ (11,958) | $ (12,197) | $ (12,441) | $ (12,690) | $ (12,944) | $ (13,202) | $ (13,466) | $ (13,736) | $ (14,011) | $ (14,291) | $ (14,577) |
| Capital Cost | $ (5,000) | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| Cash Flow | $ (5,000) | $ (10,006) | $ (10,206) | $ (10,410) | $ (10,618) | $ (10,831) | $ (11,047) | $ (11,268) | $ (11,494) | $ (11,723) | $ (11,958) | $ (12,197) | $ (12,441) | $ (12,690) | $ (12,944) | $ (13,202) | $ (13,466) | $ (13,736) | $ (14,011) | $ (14,291) | $ (14,577) |
| NPV | $ (5,000) | $ (9,265) | $ (8,750) | $ (8,264) | $ (7,805) | $ (7,371) | $ (6,962) | $ (6,575) | $ (6,210) | $ (5,865) | $ (5,539) | $ (5,231) | $ (4,940) | $ (4,666) | $ (4,407) | $ (4,162) | $ (3,931) | $ (3,712) | $ (3,506) | $ (3,311) | $ (3,127) |
| Total Cost of Ownership | $ (118,598) | | | | | | | | | | | | | | | | | | | | |
| **Solar HW** | | | | | | | | | | | | | | | | | | | | | |
| Electric kWh | | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 | 17,520 |
| Electric Cost | | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) |
| Capital Cost | $ (22,000) | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| Cash Flow | $ (22,000) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) | $ (2,453) |
| NPV | $ (22,000) | $ (2,271) | $ (2,103) | $ (1,947) | $ (1,803) | $ (1,669) | $ (1,546) | $ (1,431) | $ (1,325) | $ (1,227) | $ (1,136) | $ (1,052) | $ (974) | $ (902) | $ (835) | $ (773) | $ (716) | $ (663) | $ (614) | $ (568) | $ (526) |
| Total Cost of Ownership | $ (46,082) | | | | | | | | | | | | | | | | | | | | |

## Appendix 5a: CCMA Proposed Solar PV Design

Annual Production Report

# Prelim Carport

915 Craigville Beach Rd Centerville, MA 02632

**Report**

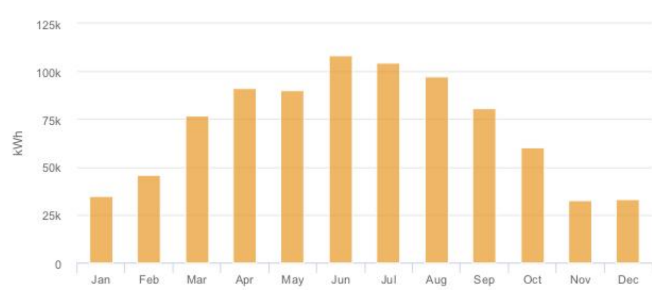
| | |
|---|---|
| Project Name | |
| Project Address | 915 Craigville Beach Rd Centerville, MA 02632 |
| Prepared By | |

**System Metrics**

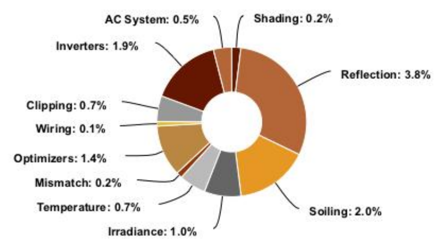
| | |
|---|---|
| Design | Prelim Carport |
| Module DC Nameplate | 709.1 kW |
| Inverter AC Nameplate | 567.8 kW<br>Load Ratio: 1.25 |
| Annual Production | 856.0 MWh |
| Performance Ratio | 88.1% |
| kWh/kWp | 1,207.1 |
| Weather Dataset | TMY, BARNSTABLE MUNI BOA, NSRDB (tmy3, II) |
| Simulator Version | b1ac4d4bc7-128e12e344-bc007dbd94-7d446903b9 |

**Project Location**


**Monthly Production**




**Sources of System Loss**




**Annual Production**

| | Description | Output | % Delta |
|---|---|---|---|
| Irradiance (kWh/m²) | Annual Global Horizontal Irradiance | 1,317.8 | |
| | POA Irradiance | 1,370.7 | 4.0% |
| | Shaded Irradiance | 1,367.3 | -0.2% |
| | Irradiance after Reflection | 1,315.1 | -3.8% |
| | Irradiance after Soiling | 1,288.8 | -2.0% |
| | **Total Collector Irradiance** | **1,288.8** | **0.0%** |
| Energy (kWh) | Nameplate | 914,488.4 | |
| | Output at Irradiance Levels | 905,307.5 | -1.0% |
| | Output at Cell Temperature Derate | 898,678.3 | -0.7% |
| | Output After Mismatch | 897,190.2 | -0.2% |
| | Optimizer Output | 884,627.9 | -1.4% |
| | Optimal DC Output | 883,547.7 | -0.1% |
| | Constrained DC Output | 877,319.6 | -0.7% |
| | Inverter Output | 860,265.0 | -1.9% |
| | **Energy to Grid** | **855,963.0** | **-0.5%** |
| Temperature Metrics | | | |
| | Avg. Operating Ambient Temp | | 13.0 °C |
| | Avg. Operating Cell Temp | | 19.6 °C |
| Simulation Metrics | | | |
| | | Operating Hours | 4337 |
| | | Solved Hours | 4337 |

## Appendix 5b: CCMA Proposed Solar PV Design

### Annual Production Report

#### Condition Set

| | |
|---|---|
| Description | Condition Set 2 |
| Weather Dataset | TMY, BARNSTABLE MUNI BOA, NSRDB (tmy3, II) |
| Solar Angle Location | Meteo Lat/Lng |
| Transposition Model | Perez Model |
| Temperature Model | Sandia Model |

Temperature Model Parameters

| Rack Type | a | b | Temperature Delta |
|---|---|---|---|
| Fixed Tilt | -3.56 | -0.075 | 3°C |
| Flush Mount | -2.81 | -0.0455 | 0°C |
| East-West | -3.56 | -0.075 | 3°C |
| Carport | -3.56 | -0.075 | 3°C |

Soiling (%)

| J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |

| | |
|---|---|
| Irradiation Variance | 5% |
| Cell Temperature Spread | 4° C |
| Module Binning Range | -2.5% to 2.5% |
| AC System Derate | 0.50% |

Module Characterizations

| Module | Characterization |
|---|---|
| LG320N1C-G4 (LG Electronics) | Spec Sheet Characterization, PAN |

Component Characterizations

| Device | Characterization |
|---|---|
| SE33.3KUS (SolarEdge Technologies) | CEC Efficiency Curve 2015-09-05 |
| P800S (SolarEdge) | Mfg Spec Sheet |

#### Components

| Component | Name | Count |
|---|---|---|
| Inverters | SE33.3KUS (SolarEdge Technologies) | 17 (567.8 kW) |
| Strings | 10 AWG (Copper) | 48 (9,376.5 ft) |
| Optimizers | P800S (SolarEdge) | 1,112 (889.6 kW) |
| Module | LG Electronics, LG320N1C-G4 (320W) | 2,216 (709.1 kW) |

#### Wiring Zones

| Description | Combiner Poles | String Size | Stringing Strategy |
|---|---|---|---|
| Wiring Zone | 12 | 13-47 | Along Racking |

#### Field Segments

| Description | Racking | Orientation | Tilt | Azimuth | Intrarow Spacing | Frame Size | Frames | Modules | Power |
|---|---|---|---|---|---|---|---|---|---|
| Field Segment 1 | Carport | Portrait (Vertical) | 5° | 196.65° | 0.1 ft | 1x1 | 372 | 372 | 119.0 kW |
| Field Segment 2 | Carport | Portrait (Vertical) | 5° | 196.65° | 0.1 ft | 1x1 | 736 | 736 | 235.5 kW |
| Field Segment 2 (copy) | Carport | Portrait (Vertical) | 5° | 196.65° | 0.1 ft | 1x1 | 736 | 736 | 235.5 kW |
| Field Segment 1 (copy) | Carport | Portrait (Vertical) | 5° | 196.65° | 0.1 ft | 1x1 | 372 | 372 | 119.0 kW |

## Appendix 5c: CCMA Proposed Solar PV Design

Annual Production Report

Detailed Layout

## Appendix 5d: CCMA Proposed Solar PV Design - Financials

| *Based on Julia's Design* | | |
|---|---|---|
| Carport Size | 709 | kW DC |
| Cost per Watt | $2.50 | per W |
| Total Cost (before incentives) | $1,772,500.00 | |
| *With Incentives* | | |
| 30% ITC (2019 only) | $1,240,750.00 | |
| 26% ITC (2020 only) | $1,311,650.00 | |
| | | |
| Annual Generation | 856000 | kWh |
| | | |
| *SMART Compensation* | | |
| Block 3 | $0.17234 | per kWh |
| Tranche 1 Canopy | $0.06 | per kWh |
| Total Compensation | $0.23234 | |
| Total Annual Compensation | $198,883.04 | |
| | | |
| Shared Community Solar | | |
| CCMA Portion (43%) | 371515 | kWh |
| Resident Subscriber Portion (total 57%) | 484485 | kWh |
| Electricity Supply for CCMA | $0.14 | per kWh |
| Electricity Supply for Residents | $0.18 | |
| Total Electricty Cost | $139,219.40 | |
| | | |
| Total Annual Income | $146,870.94 | |
| Payback | 12.07 | years |

## Appendix 6: Native Plant Options & Pricing

| Common Name | Scientific Name | Habitat | Bloom Time | Cost | Est. # of Plants Ordered Per Seaon | Plant Size | Source | Total Cost Per Year |
|---|---|---|---|---|---|---|---|---|
| Cardinal Flower | *Lobelia cardinalis* | Pond Shore | Summer-Fall | $6.98 | 10 | 1 Gallon | Lowes | $69.80 |
| Joe Pye Weed | *Eupatorium spp.* | Pond Shore | Summer-Fall | $10.98 | 10 | 1 Gallon | Lowes | $109.80 |
| Boneset | *Eupatorium perfoliatum* | Pond Shore | Summer-Fall | $5.49 | 10 | 5000 Seeds | Amazon | $54.90 |
| Goldenrod | *Euthamia tenuifolia* | Pond Shore | Summer-Fall | $6.49 | 10 | 5000 Seeds | Amazon | $64.90 |
| Plymouth Gentian | *Sabatia kennedyana* | Pond Shore | Summer-Fall | $5.49 | 10 | 500 Seeds | Amazon | $54.90 |
| Cinnamon Fern | *Osmunda cinnamomea* | Swamps | May-June | $14.99 | 10 | Set of 3 roots | Amazon | $149.90 |
| Royal Fern | *Osmunda regalis* | Swamps | Spring | $8.00 | 10 | 1000 Seeds | Amazon | $80.00 |
| Highbush Blueberry | *Vaccinium corymbosum* | Swamps; Wet Woods | May | $19.98 | 10 | 1.5 Gallon | Lowes | $199.80 |
| Winterberry | *Ilex verticillata* | Swamps; Wet Woods | June | $31.99 | 10 | 2 Gallon | Amazon | $319.90 |
| Sweet Gale | *Myrica gale* | Swamps; Wet Woods | May (Catkins) | $5.99 | 10 | 10 Seeds | Amazon | $59.90 |
| Mountain Holly | *Nemopanthes mucronata* | Swamps; Wet Woods | June | $199.60 | 10 | 10 saplings | fastgrowingtrees.com | $1,996.00 |
| Swamp Azalea | *Rhododendron viscosum* | Swamps; Wet Woods | June | $16.96 | 10 | 1 gallon | fastgrowingtrees.com | $169.60 |
| Elderberry | *Sambucus canadensis* | Swamps | June | $24.98 | 10 | 2.25 gallon | Lowes | $249.80 |
| Red Maple | *Acer rubrum* | Swamps; Wet Woods | April | $69.98 | 10 | 8.75 gallon | Lowes | $699.80 |
| | | | | | | | Total | $4,279.00 |

## Appendix 7: Water Efficient Appliances

| Room | Item | Brand | Specs | Colors | Price | Link | ADA | Notes |
|---|---|---|---|---|---|---|---|---|
| Bathroom | **Bathroom Faucet** | American Standard (Touchless)* | Flow rate = 0.5 gpm<br>Single hole installation | Up to interiors | $449.8 | http://www.homedepot.com/p/American-Standard-Moments-Selectronic-DC-Powered-Single-Hole-Touchless-Bathroom-Faucet-in-Polished-Chrome-2506155-002/205445329 | Yes | |
| | **Toilet** | Niagra N7717EB-DF | Dual Flush<br>Flow rate = 0.5/0.95 gpm | White | $200 | https://niagaracorp.com/products/original-stealth-dualflush-elongated/ | No, but can be if installed to be compliant | http://www.niagaracorp.com/resources/dyn/files/1173050zfe781333/_fn/Stealth_Dual-Elongated-12RoughIn_N7717-N7714T-DF.pdf |
| | **Shower Head** | Delta 59462-B15-BG | Flow rate = 1.5 gpm | White | $33 | http://www.build.com/delta-51400/s1188687?uid=2870810 | Yes | |
| Kitchen | **Kitchen Faucet** | American Standard | Flow rate = 1.5 gpm<br>Deck mounted installation | Up to interiors | $591 | http://www.americanstandard-us.com/kitchen-faucets/Edgewater-Semi-Professional-Kitchen-Faucet-with-SelectFlo/ | Yes | |
| | **Dishwasher** | Bosch SGE63E06UC | Gallons per cycle = 1.95<br>Annual Energy consumption in kWh = 234<br>Annual water consumption in gallons = 477<br>120V, 12A | Black | $930 | http://www.bosch-home.com/Files/bosch2/us/us_en/Document/Spec_Sheets/SGE63E06UC.pdf | Yes | |
| Laundry | **Clothes Washer** | Bosch WM77120 | Volume = 2.2 cubic ft<br>Annual Energy Use (kWh/yr) = 67<br>Annual Water Use (gal/yr) = 2013<br>240V, 15A | White | $849 | https://www.appliancesconnection.com/blomberg-wm77120.html?ref=nextag | Yes | |

## Appendix 8: Massachusetts Recycling Quick Guide

## Appendix 9b: CCMA Board Resolution

**Sustainability Plan Committee** – On April 14, 2018 the CCMA Board passed a resolution committing the Village to becoming a "Net Zero Community" (the complete wording of the agreed motion is attached below). The aspiration of the Board is to achieve this goal in terms of energy, water and waste by the year 2050. A Sustainability Committee has been formed to advance this initiative. The Committee will be looking for volunteers to help regarding energy & waste and will coordinate with the Red Lily Pond Committee regarding water (the hope is Red Lily Pond will continue their great work and will be in charge of any aspects of the Sustainability Plan that are associated with water).

Preliminarily (this summer) the Committee will be looking to gather data on the present usage of energy, water and the production of solid waste. The goal of the data gathering is to:

a) Establish baselines (while the ultimate goal is to get to zero, baselines will help measure progress) and
b) To use said data to help prioritize activities.

To further help with priorities, we have approached Columbia University's Earth Institute in the hopes they might send a team of graduate students to help with the basic format of our Sustainability Plan (Columbia seems interested but has said, as anyone in their position would say, they would need baseline data to commence such an effort).

Furthermore, subsequent to the passage of the motion below, it has also been suggested the Sustainability Plan Committee add to their scope an assessment of the potential risk to Craigville associated with sea level rise. The committee also plans to study that issue (in coordination with Red Lily Pond).

## Appendix 9b: CCMA Board Resolution

Motion passed by CCMA Board on 14 April 2018:

"The climate is a common good, belonging to all and meant for all."*

In recognition of its Mission to ensure the continued beauty of our beloved Village for future generations, the CCMA acknowledges it must meet the needs of the present without compromising the ability of future generations to enjoy the splendor of Craigville and must reinforce the ongoing noble works of the Red Lily Pond Project. Accordingly, it is moved that the CCMA will use its best efforts to become a "Net Zero Community" by the year 2050. In doing so, the CCMA will reduce its impacts across the key resources of energy, water and waste, using approaches that are economically viable, socially beneficial and environmentally responsible.

CCMA further acknowledges that:

- Net-Zero energy means cutting the community's greenhouse gas emissions to zero by reducing energy consumption through efficiency & conservation measures and by producing and/or buying enough clean energy to meet all remaining needs. Energy supply may include energy produced by fossil fuels, but only to the extent the Village's natural habitat can absorb the effects of said purchases.
- Net-Zero water means continuing to support the efforts of the Red Lily Pond Project and working to preserve and protect the quality and availability of water needed to sustain the livability and beauty of the community.
- Net-Zero waste means reducing waste to a minimum, reusing and/or composting what we can, recycling the rest, and sending zero waste to landfill.

In order to accomplish the above, the CCMA recognizes it must commit to creating a series of "sub-plans" that together will form the CCMA's "Sustainability Plan". Such "sub-plans" should incorporate strategies for both the CCMA & individual homeowners and may include:

- Energy Conservation Plan
- Renewable Energy Production Plan
- Drinking Water Conservation Plan
- Wastewater and Stormwater Management Plan
- Wetlands Preservation Plan (which already exist - Red Lily Pond Project)
- Open Space Preservation & Landscaping Plan
- Recycling and Composting Plan
- Transportation Plan (encouraging walking & biking and use of EVs)
- Education & Outreach Plan

* *Laudato si'* (24 May 2015). Pope Francis. Available at http://w2.vatican.va/content/francesco/en/encyclicals/documents/papa-francesco_20150524_enciclica-laudato-si.html. Accessed 10 February 2018.

# REFERENCES

**References**

ADA Compliance. (2019). Drinking Fountains and Water Coolers. Retrieved April 27, 2019, from https://www.ada-compliance.com/ada-compliance/drinking-fountain-water-coolers.html

Arkema, K. K., Guannel, G., Verutes, G., Wood, S. A., Guerry, A., Ruckelshaus, M., … Silver, J. M. (2013). *Coastal habitats shield people and property from sea-level rise and storms*. Retrieved from http://ww1.prweb.com/prfiles/2013/07/14/10925480/kareiva report.pdf

Berger, M. A., Hans, L., Piscopo, K., & Sohn, M. D. (2016). *Exploring the energy benefits of advanced water metering. Energy Analysis and Environmental Impacts Division Energy Technologies Area*. Retrieved from https://www.energy.gov/sites/prod/files/2017/01/f34/Exploring the Energy Benefits of Advanced Water Metering.pdf

Blake, L., Mazars, G., Prado, K., & Wilson, S. (2018). *Improving the State of NYC's Waste and Energy System* (Environmental Infrastructure for Sustainable Cities). New York, NY.

Cape Cod Commission. (2018). *Guidance on Section 208 Plan Update - Obtaining a Consistency Determination*. Retrieved from http://www.capecodcommission.org/resources/208/guidance/Guidance on Section 208 Plan Update Obtaining a Consistency Determination.pdf

Chesapeake Bay Foundation. (2019). Oyster Fact Sheet. Retrieved April 27, 2019, from https://www.cbf.org/about-the-bay/more-than-just-the-bay/chesapeake-wildlife/eastern-oysters/oyster-fact-sheet.html

Christian Camp Meeting Association. (2018). *Motion passed by CCMA Board on 14 April 2018*. Craigville, Massachusetts.

City of Kingston Tidal Waterfront Flooding Task Force. (2013). Planning for Rising Waters: Final Report of the City of Kingston Tidal Waterfront Flooding Task Force. City of Kingston, NY. Retrieved from https://kingston-ny.gov/filestorage/8463/8511/8682/8690/Kingston_Tidal_Waterfront_Flooding_Task_Force_-_Final_Report_September_2013.pdf

City of Vancouver. (2018a). Policy Report RE: Zero Waste 2040. Retrieved from https://council.vancouver.ca/20180516/documents/pspc2a.pdf

City of Vancouver. (2018b). Zero Waste 2040. Retrieved April 27, 2019, from https://vancouver.ca/green-vancouver/zero-waste-vancouver.aspx

City of Vancouver. (2019). Single-Use Item Reduction Strategy. Retrieved April 27, 2019, from https://vancouver.ca/green-vancouver/single-use-items.aspx

Custom Earth Promos. (2019a). Eco-Friendly Reusable Bags. Retrieved April 27, 2019, from https://www.customearthpromos.com/eco-friendly-reusable-bags.html

Custom Earth Promos. (2019b). Personalized Reusable Water Bottles. Retrieved April 27, 2019, from https://www.customearthpromos.com/reusable-water-bottles.html

Dadson, S. J., Hall, J. W., Murgatroyd, A., Acreman, M., Bates, P., Beven, K., … Wilby, R. (2017). A restatement of the natural science evidence concerning catchment-based ‘natural’ flood management in the UK. Proceedings of the Royal Society, 473(20160706). Retrieved from https://www.oxfordmartin.ox.ac.uk/downloads/academic/Oxford_Martin_Restatement4_Natural_Flood_Management.pdf

DOE-2. (2009). eQuest: the Quick Energy Simulation Tool. Retrieved April 27, 2019, from http://www.doe2.com/equest/

E3A. (2019). Anaerobic Digesters. Retrieved April 29, 2019, from http://www.e3a4u.info/energy-technologies/anaerobic-digesters/economics/

Elkay. (2017). Elkay. Retrieved April 28, 2019, from http://www.elkay.com

FEMA. (2018). Flood Mitigation Assistance Grant Program. Retrieved April 27, 2019, from https://www.fema.gov/flood-mitigation-assistance-grant-program

FEMA. (2019). The National Flood Insurance Program. Retrieved April 28, 2019, from https://www.fema.gov/national-flood-insurance-program

Fong, W. K., Sotos, M., Doust, M., Schultz, S., Marques, A., & Deng-Beck, C. (2014). *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories*. Retrieved from http://c40-production-images.s3.amazonaws.com/other_uploads/images/143_GHGP_GPC_1.0.original.pdf?1426866613

FOR Solutions. (2019). Home: Ending Food Waste. Retrieved April 27, 2019, from https://www.forsolutionsllc.com

Gardener's Supply Company. (2019). Exaco Thermo Star 1000 Recycled Plastic XXL Compost Bin. Retrieved April 27, 2019, from https://www.gardeners.com/buy/exaco-thermo-star-1000-xxl-compost-bin/8598982.html

Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science Advances*, *3*(7). https://doi.org/10.1126/sciadv.1700782

Gray, A. (2019, January 21). The inspiring thing that happened when a Japanese village went almost waste-free. *World Economic Forum*. Retrieved from https://www.weforum.org/agenda/2019/01/the-inspiring-thing-that-happened-when-a-japanese-village-went-almost-waste-free/

Horsley Witten Group. (2017). Red Lily Pond/Lake Elizabeth Hydrologic and Hydraulic Assessment. Sandwich, MA.

ICLEI. (2013). US Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions (1.1). Retrieved from http://icleiusa.org/publications/us-community-protocol/

ImproveNet. (2018). How Much Will it Cost to Raise a House Foundation? Retrieved April 27, 2019, from https://www.improvenet.com/r/costs-and-prices/raise-foundation-cost-estimator

Intergovernmental Panel on Climate Change. (2007). *AR4 Climate Change 2007 Reports*. Retrieved from https://www.ipcc.ch/assessment-report/ar4/

International System of Units. (2019). Retrieved April 25, 2019, from https://en.wikipedia.org/wiki/International_System_of_Units

Keaggy, D. T. (2016, April 20). Water bottle ban a success; bottled beverage sales have plummeted. *Washington University in St. Louis TheSource*. Retrieved from https://source.wustl.edu/2016/04/water-bottle-ban-success-bottled-beverage-sales-plummeted/

Kim, K., & Morawski, S. (2012). Quantifying the Impact of Going Trayless in a University Dining Hall. *Journal of Hunger & Environmental Nutrition*, *7*(4), 482–486. https://doi.org/10.1080/19320248.2012.732918

Knowledge Center. (2016). The Benefits of Elkay's EZH2O Bottle Filling Stations. Retrieved April 28, 2019, from https://learn.supply.com/featured-products/benefits-elkays-ezh2o-bottle-filling-stations/

Massachusetts DEP. (2019). Get the MassDEP Recycling IQ Kit. Retrieved April 28, 2019, from https://www.mass.gov/how-to/get-the-massdep-recycling-iq-kit

Massachusetts DOER. (2018). Solar Massachusetts Renewable Target (SMART) Program. Retrieved April 25, 2019, from http://masmartsolar.com

Massachusetts Office of Coastal Zone Managemente. (2007). *Wetlands Restoration Program: Guidance Document for the Purple Loosestrife Biocontrol Project*. Retrieved from https://www.mass.gov/files/documents/2016/08/wi/pblc-guidance-document-2007.pdf

Mayor of London. (2011). *Securing London's Water Future: The Mayor's Water Strategy*. London, UK. Retrieved from https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/water-strategy-oct11.pdf

Meier House Removals. (2019). How Long Does It Take To Raise A Home? Retrieved April 27, 2019, from https://meierhouseremovals.com.au/how-long-raise-home/

MET. (2019). Massachusetts Environmental Trust. Retrieved April 27, 2019, from https://www.mass.gov/orgs/massachusetts-environmental-trust

Minnesota Sea Grant. (2017). Purple Loosestrife: What you should know, what you can do. Retrieved April 26, 2019, from http://www.seagrant.umn.edu/ais/purpleloosestrife_info

Morse, D. L. (n.d.). *Eastern Oyster Production in Maine: A Basic Review*. Retrieved from https://www.seagrant.umaine.edu/files/Dana Morse/Oyster Prod Overview FINAL.pdf

National Geographic. (2019). Freshwater Crisis. Retrieved April 27, 2019, from https://www.nationalgeographic.com/environment/freshwater/freshwater-crisis/

National Oceanic and Atmospheric Administration. (2017a). Sea Level Rise Viewer. Retrieved April 27, 2019, from https://coast.noaa.gov/slr/#/layer/slr

National Oceanic and Atmospheric Administration. (2017b). Sea Level Rise Viewer - 4ft in Craigville, MA. Retrieved April 27, 2019, from https://coast.noaa.gov/slr/#/layer/slr/4/-7829712.533547545/5106997.475647872/15/satellite/none/0.8/2050/interHigh/midAccretion

National Oceanic and Atmospheric Administration. (2019, February 6). 2018 was 4th hottest year on record for the globe. Retrieved April 27, 2019, from https://www.noaa.gov/news/2018-was-4th-hottest-year-on-record-for-globe

National Resources Defense Council. (2009). *Water Efficiency Saves Energy: Reducing Global Warming Pollution Through Water Use Strategies*. Retrieved from https://www.nrdc.org/sites/default/files/energywater.pdf

NEPOOL. (2019). New England Power Pool Generation Information System. Retrieved April 25, 2019, from https://www.nepoolgis.com

Ngo, B. (2018). Buying Certificates in NEPOOL GIS. Retrieved April 25, 2019, from https://nepoolgis.zendesk.com/hc/en-us/articles/360011036633-Buying-Certificates-in-NEPOOL-GIS

Plastic Pallets and Bins. (2019). Returnable Plastic Crate. Retrieved April 27, 2019, from https://www.plasticpalletsandbins.com/product/rpc-64x19

Pope Francis. (2015, May 24). Encyclical Letter: Laudato Si' Of the Holy Father Francis on Care for Our Common Home. *Libreria Editrice Vaticana*. Retrieved from http://w2.vatican.va/content/francesco/en/encyclicals/documents/papa-francesco_20150524_enciclica-laudato-si.html

Pure Water Technology. (2017). How do Hurricanes affect our Drinking Water? Retrieved April 27, 2019, from https://purewatertech.com/corporate/hurricanes/

Recyclops. (n.d.). Reclyclops. Retrieved April 28, 2019, from https://recyclops.com

SF Environment. (2012). San Francisco Sets North American Record for Recycling & Composting with 80 Percent Diversion Rate. Retrieved April 27, 2019, from https://sfenvironment.org/news/update/san-francisco-sets-north-american-record-for-recycling-composting-with-80-percent-diversion-rate

SF Environment. (2019). San Francisco Zero Waste - Frequently Asked Questions (FAQs). Retrieved from https://sfenvironment.org/zero-waste-faqs#other-cities

Smithsonian. (2018). Sea Level Rise. Retrieved April 27, 2019, from https://ocean.si.edu/through-time/ancient-seas/sea-level-rise

Solar Energy Industries Association. (2019). Solar Investment Tax Credit (ITC). Retrieved April 27, 2019, from https://www.seia.org/initiatives/solar-investment-tax-credit-itc

Southampton Town Board, & Perkins+Will. (2013). *Southampton 400+ Sustainability Element: Addendum to the Town of Southampton Comprehensive Plan*. Southampton, NY. Retrieved from https://www.southamptontownny.gov/DocumentCenter/View/1090/Sustainability-Plan-Final-Adopted---December-19-2013-PDF

The Ramsar Convention. (2018). *The Global Wetland Outlook*. Gland, Switzerland. Retrieved from https://www.global-wetland-outlook.ramsar.org

The World Bank Group. (n.d.). *Urban Development Series - Knowledge Papers: Waste Composition*. Retrieved from http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/Chap5.pdf

Thead, E. A. (2016). Sea Level Rise: Risk and Resilience in Coastal Cities. Retrieved April 28, 2019, from http://climate.org/sea-level-rise-risk-and-resilience-in-coastal-cities/

Tiner, R. (1995). *Phragmites: Controlling the All-Too-Common Common Reed*. Retrieved from https://www.massaudubon.org/content/download/9330/155607/file/Salt-Marsh-Phragmites-Tiner-English.pdf

Trice, A. (2016). *Daylighting Streams: Breathing Life into Urban Streams and Communities*. Retrieved from http://americanrivers.org/wp-content/uploads/2016/05/AmericanRivers_daylighting-streams-report.pdf

Uehara, T., & Ynacay-Nye, A. (2018). How Water Bottle Refill Stations Contribute to Campus Sustainability: A Case Study in Japan. *Sustainability* . https://doi.org/10.3390/su10093074

UNEP. (2014). *Valuing Plastic: The Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry*. Retrieved from http://wedocs.unep.org/bitstream/handle/20.500.11822/9238/-Valuing plastic%3A the business case for measuring%2C managing and disclosing plastic use in the consumer goods industry-2014Valuing plasticsF.pdf?sequence=8&isAllowed=y

US Energy Information Administration. (2016). Commercial Buildings Energy Consumption Survey (CBECS). Retrieved April 26, 2019, from https://www.eia.gov/consumption/commercial/data/2012/c&e/cfm/e2.php

US Environmental Protection Agency. (n.d.). Zero Waste Case Study: San Francisco. Retrieved April 27, 2019, from https://www.epa.gov/transforming-waste-tool/zero-waste-case-study-san-francisco

US Environmental Protection Agency. (2017). Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy. Retrieved April 27, 2019, from https://www.epa.gov/smm/sustainable-materials-management-non-hazardous-materials-and-waste-management-hierarchy

US Environmental Protection Agency. (2019). WaterSense Products. Retrieved April 28, 2019, from https://www.epa.gov/watersense/watersense-products

US Geological Survey. (2016). Water Questions & Answers. Retrieved April 26, 2019, from https://water.usgs.gov/edu/qa-home-percapita.html

van Sebile, E. (2016, January 12). How much plastic is there in the ocean? *World Economic Forum*. Retrieved from https://www.weforum.org/agenda/2016/01/how-much-plastic-is-there-in-the-ocean/

Village of Fairport, & Ingalls Planning and Design. (2010). *Village of Fairport Sustainability Plan*. Fairport, New York. Retrieved from https://www.village.fairport.ny.us/uploads/1/7/6/5/17656211/dbl_sided_print_version_-_final_fairport_sustainability_plan_08.04.10.pdf

Vineyard Wind. (2019). Vineyard Wind. Retrieved April 25, 2019, from https://www.vineyardwind.com