

# Developing a Climate Action Plan for the Nicholas School of the Environment

By Master of Environmental Management Candidates, Spring 2018

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## List of Abbreviations and Acronyms

AC	Air conditioning
ACUPCC	American College & University Presidents' Climate Commitment
Btu	British thermal units
CAP	Climate action plan
CH <sub>4</sub>	Methane
CO <sub>2</sub>	Carbon dioxide
CO <sub>2</sub> eq	Carbon dioxide equivalents
DUML	Duke University Marine Laboratory
EH	Environment Hall
EPA	United States Environmental Protection Agency
EUI	Energy use intensity
FMD	Duke Facilities Management Division
Fpm	Feet per minute
FY	Fiscal year
GHG	Greenhouse gas
GIS	Geographic Information System
GJ	Gigajoule
GWP	Global warming potential
HDD	Heating degree day(s)
HFC	Hydrofluorocarbon
J	Joule
kBtu	kilo-British thermal units (1,000 Btu)
kWh	kilo-watt hours (1,000 Wh)
LEED	Leadership in Energy and Environmental Design
LED	Light-emitting diode
LSRC	Levine Science and Research Center
M&V	Measurement & Verification
N <sub>2</sub> O	Nitrous oxide
NOAA	National Oceanic and Atmospheric Administration
NSOE	Nicholas School of the Environment
PFC	Perfluorocarbon
SF <sub>6</sub>	Sulfur hexafluoride
W	Watt(s)
Wh	Watt hour(s)

## Introduction

As climate change effects become more impactful on the planet, it will be the responsibility of global citizens to commit to reducing their climate impacts. Colleges and universities should continue research on climate change, educate, and create commitments to climate action (Cortese, 2003). Campus sustainability is an important goal for both higher education institutions and for the communities in which they reside. Higher education institutions consist of education, research, outreach as well as university operations, all while interacting with external communities. Due to the complexity and reach these institutions have, they play a unique role in testing and understanding sustainability outcomes by combining various disciplines. Higher education institutions “can serve as a model of sustainability by fully integrating all aspects of campus life” (Cortese, 2003). As hubs of diverse disciplines and stakeholders, there are opportunities to create a fully integrated system of sustainability that cannot be found elsewhere.

Following this belief, in 2007, former Duke University President Richard H. Brodhead signed the American College & University Presidents Climate Commitment (ACUPCC), agreeing to conduct a greenhouse gas (GHG) emissions inventory and set targets and milestones to achieve climate neutrality. This provided a foundation for Duke University to strive toward climate neutrality by joining a network of climate leaders in higher education. In addition, Duke made a public pledge to integrate sustainability into the curriculum and create the Campus Sustainability Committee (CSC), tasked with the mission of setting climate targets for the University. The CSC developed Duke’s first climate action plan (CAP), which set the goal that Duke will be climate neutral by 2024.

As of 2016, over 600 institutions in 50 states and Washington D.C. have signed a formal climate commitment like the ACUPCC. The Climate Leadership Network reports that currently 18.9% of higher education institutions have formally signed this commitment (Second Nature, 2016). For those institutions that have implemented Climate Action Plans (CAPs) to benchmark current emissions and identify pathways to mitigate climate change, 47% have seen reductions in energy costs (Second Nature, 2016).

A CAP is a document that outlines current and past sustainability initiatives, emissions reduction goals, and strategies for future action to promote environmental sustainability on campus. In addition, CAPs are increasingly incorporating social sustainability into their planning as well looking at aspects such as wellness and diversity. CAPs also do not ignore economic sustainability as a part of the evaluation before implementing a strategy. Each university can create their own structure and methodology for creation of a CAP, but understanding the current landscape of the campus, the core values, and the barriers to climate action and sustainability are critical.

Nearly 10 years after Duke’s first CAP, the university continues to make progress on its commitment. Yearly progress reports are published and the most recent update for 2017 showing a 24% reduction in

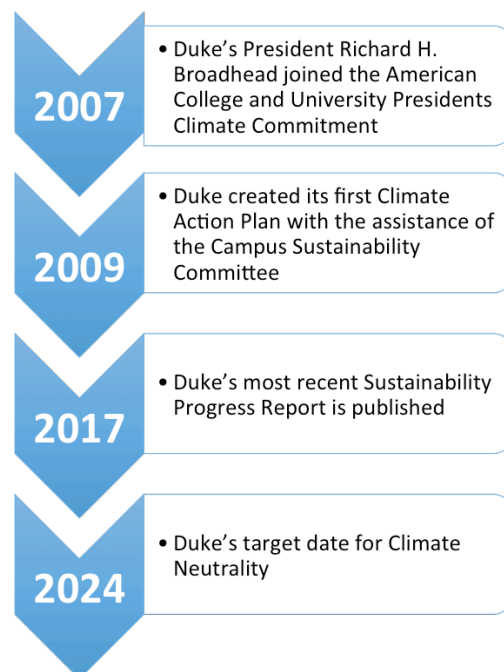


Figure 1. History of Climate Action at Duke University.

greenhouse gas emissions since 2007 (Sustainable Duke, 2018). To continue this progress, Sustainable Duke, the on-campus office dedicated to developing programs that positively influence campus sustainability behaviors and operations, is investigating the feasibility of each school (e.g., Trinity School of Arts and Sciences, School of Law, Nicholas School of the Environment, etc.) creating their own specific CAPs to complement the university-wide CAP. One potential pathway to determining this feasibility is starting with a pilot Climate Action Plan at the Nicholas School of the Environment (NSOE). The NSOE is one of ten graduate and professional schools at Duke University. The mission of the NSOE is to "create knowledge and global leaders for a sustainable future" (Nicholas School of the Environment, n.d.-a). This makes it the ideal pilot candidate for a school-specific sustainability-focused Climate Action Plan.

In addition to its presence on the main campus, the NSOE includes the Duke University Marine Lab, in Beaufort, North Carolina. The Duke University Marine Laboratory (DUML) is home to full-time faculty, staff, and students engaged in research, education, training, and outreach. Leadership at the DUML has expressed a keen interest in increasing sustainability on their campus with the goal of also reaching climate neutrality.

## Objectives

The objective of this project is to determine the feasibility of a Nicholas School Climate Action Plan and quantify the carbon emissions of the Nicholas School of the Environment. In addition, the results of this analysis will produce possible avenues for climate action, education, and energy efficiency. Although there are many steps involved in the development of CAPs, the focus of this project is mainly on knowledge gathering and creation of preliminary GHG emissions inventory (**Figure 2**). This project will cover the past three University fiscal years (FY) for this analysis and quantification: FY15, FY16, and FY17.



Figure 2. Steps of a climate action plan (CAP) development.

The team was comprised of three Nicholas School Master of Environmental Management students with the assistance of the Sustainable Duke and stakeholders at the DUML. The DUML Administration aims to learn more about current GHG emissions footprint and identify specific short- and long-term strategies. In addition, this study will provide insights into opportunities for improvement including energy efficiency and sustainability initiatives. At the conclusion, the results and recommendations will be delivered to various stakeholders at the NSOE such as the new incoming Dean of the NSOE, Directors of the DUML, the NSOE Board of Visitors, and facilities managers at the university. The results from this project will be used to advance climate action goals at Duke and will further tie into the University's overall Climate Action Plan.

The qualitative portion of this work identifies the

barriers and benefits of creating a school-specific climate action plan by collecting knowledge and insight on facilities operations, challenges, goals, and specific needs of the DUML. The quantitative aspect focuses on the creation of a GHG emission inventory. The results of these two analyses will inform the leadership and stakeholders to better understand the current GHG emissions footprint and provide a foundation to develop a climate action plan.

## Background

This section will provide a background on the Nicholas School of the Environment and the Duke University Marine Lab. Specifically; this section will provide information about the facilities on each campus.

### Nicholas School of the Environment

The NSOE was created in 1991 when the School of Forestry, the Division of Marine Science and Conservation, and the School of Environmental Studies came together to form the School of the Environment. Following a \$20 million gift in 1995, from Peter M. and Ginny Nicholas of Boston, the school was renamed the Nicholas School of the Environment. In 1997, Duke's Department of Geology joined the NSOE.

The school is motivated by the need to "restore and preserve" global environmental resources while also adapting to changing climate and population growth. With undergraduate, professional masters, and Ph.D. student programs, the school seeks to train environmental leaders, scholars, and scientists who will forge a sustainable future. As of the 2017 school year, the NSOE consists of over 850 combined faculty, staff, and students (Nicholas school of the Environment, n.d.-f).



*Figure 3. The Environment Hall is home to the Nicholas School of the Environment (NSOE) (Source: Warren Jagger Photography).*

Physically, the main campus elements of NSOE are located on West Campus are comprised of the Environment Hall and the A-Wing of the Levine Science Research Center (LSRC), with some faculty offices and classes taking place in other areas of campus. Most of the faculty and staff of the NSOE are

housed in Environment Hall (EH), a five-story, 70,000 square-foot, LEED Platinum certified building which opened in April 2014. As a LEED platinum certified building, EH incorporates sustainability features such as a green roof with a student-managed garden, innovative climate and water control systems, rooftop solar, and an emphasis on natural light and native landscaping (Payette, n.d.). EH is home to five classrooms, a large auditorium, offices for faculty and staff, and a computer lab, art gallery and common spaces (Nicholas school of the Environment, n.d.-e).

### Duke University Marine Laboratory Overview

In the early 1930s, Dr. A.D. Pearse and other colleagues from Duke used Pivers Island, in Beaufort, North Carolina, as a place to centralize their summer field studies. In 1938, the university acquired the land and buildings began to be built for summer training and research, formally establishing the marine laboratory. Although originally only used for the summer, the DUML currently operates year-round to provide educational training and research opportunities to around 3,500 people each year. This includes the undergraduate, professional and Ph.D. students from the university, but also comprises visiting student groups from across the country and scientists from across the globe (Nicholas school of the Environment, n.d.-d). During the academic year, the DUML is home to around 125 full-time faculty, staff, and students.



Figure 4. Aerial View of the Duke University Marine Laboratory (DUML) campus (Nicholas school of the Environment, n.d.-c)

Programs provided at the DUML are integral to the mission of the NSOE by providing interdisciplinary educational and research opportunities. The MSC “strives to be at the forefront of understanding marine environmental systems, their conservation, and their governance through leadership in research, training, and communication”. Since oceans comprise the majority of the Earth’s surface, it has a large effect on climate regulation, sustaining marine species, and supplies of food and mineral resources. In addition, the DUML is a member of the National Association of Marine Laboratories. This non-profit organization consists of 90 members who work together to provide research, education, and public service programming.

The DUML is located on Pivers Island in Beaufort, N.C., approximately 185 miles east of Durham. Beaufort is the third oldest town in North Carolina and the surrounding area is comprised of a system of barrier islands, sounds, and estuaries. On Pivers Island, Duke owns and operates 21 buildings including six dormitories, a dining hall, a library, and student center, along with laboratories for research and

classrooms for education, and two lecture halls for seminars and workshops. A detailed map of the DUML campus is shown in **Figure 5**.



Figure 5. A campus map of the Duke University Marine Laboratory (DUML) located in Beaufort, North Carolina. (Source: Duke University Marine Lab).

### Building Overview

The purpose of this section is to provide additional detail about the facilities on Pivers Island.

### *Marguerite Kent Repass Center (Repass)*

The Repass Center is one of the newer buildings, completed in November 2006 and LEED Platinum certified in 2013. The 5,600 square foot building serves one of the main teaching facilities on the island and is often used for seminars and public engagement events. The building overlooks the Rachel Carson Estuarine Research Reserve, Beaufort Inlet, and Taylor’s Creek (Nicholas school of the Environment, 2013). The center has a large lecture room and a teaching laboratory as well as environmental features including geothermal wells for heating and cooling, solar panels for hot water, and a green rooftop solar PV array and a garden. (Nicholas school of the Environment, n.d.-g).



*Figure 6. Repass with a view of solar panels, one of the buildings green features (Photo taken by: Yige Liu, 2017)*

### *Bookhout Laboratory*

The largest building on the island is Bookhout Research Laboratory. This laboratory was built in the 1960s. The building contains research labs, faculty and Ph.D. office space, and two classrooms. The second floor of this building houses the Marine Conservation Molecular Facility, which provides faculty and students access to molecular tools for marine science (Nicholas school of the Environment, n.d.-h).



*Figure 7. Side view of Bookhout Laboratory (Photo taken by: Yige Liu, 2017).*

### Orrin Pilkey Laboratory

The Orrin Pilkey Research Laboratory opened in 2014 and is the newest building on the island, is a 12,000 square foot space with labs, office space, a conference room, a classroom, and large common area. In 2016, the building received its LEED Gold certification. Environmental features include water-efficient landscaping, a geothermal system for heating and cooling, locally sourced wood siding, and extensive use of natural lighting and ventilation (Nicholas school of the Environment, n.d.-i).



Figure 8. Back view of Pilkey Laboratory (Photo taken by: Yige Liu, 2017).

### Dining Hall

The Dining Hall is located on the main quad of the DUML. Mainly consisting of a large open dining space and a kitchen, the space is a hub of activity feeding the undergraduate student residents, visitors, faculty, and staff on a daily basis.



Figure 9. View of the Dining Hall at the DUML (Photo taken by: Taylor Price, 2017).

### *Library / Auditorium*

The Pearse Memorial Library is located within the I.E. Gray Library-Auditorium Building and is a part of the Duke University Library system. The library houses many collections on the coastal environment, oceanography, and marine biology. Per the Duke Libraries website, the library houses 12 computer stations along with printers and copiers for student and staff use. In addition to the library, the building has a large open auditorium space used for seminars, teaching, as well as large gatherings and events (Duke University, n.d.).



*Figure 10. Library at the DUML (Photo taken by: Yige Liu, 2017).*

## Background Literature

As of early 2014, over 670 higher education institutions were committed to mitigate climate change via the ACUPCC (Boscio, Teferra, and Du, 2014). In that same year, 58% of institutions that submitted at least two GHG reports showing a reduction in emissions since signing the agreement (Boscio, Teferra, and Du, 2014). It is also important to note that the ACUPCC does not cover all institutions that have committed to climate action. Other group commitments like the Talloires Declaration and the White House American Campuses Act on Climate Pledge exist in a similar fashion to the ACUPCC. In addition, some institutions have made individualized commitments to climate action (Eagan et al, 2008).

The “Guide to Climate Action Planning: Pathways to a Low-Carbon Campus”, published by the National Wildlife Federation in 2008, highlights that many campuses will begin their climate action planning process in the near future if they have not already. The organization believes this planning process should encompass three dimensions: people, process, and product (Eagan et al., 2008). “People” include the various levels of campus stakeholders incorporated as a part of the planning process. “Process” is the steps taken to commit, establish, develop, report, and review climate plans. Lastly, “Products” are the results of the planning processes including documents like GHG emissions inventory, targets, or a final climate plan. In the United States, one of the leading organizations that provide guidance to campuses that make sustainability commitments is Second Nature, the foundational organization of the President’s Climate Leadership Commitments (Second Nature, n.d.).

Peer-reviewed literature on campus sustainability shows that there are many elements that contribute to environmental sustainability. This study lists six main factors that are critical to campus sustainability:

1. Green campus operations
2. Campus wide actions and activities
3. Campus administration, organization, and leadership
4. Teaching, research, and service
5. Institutional assessment of sustainability
6. And established methods for overcoming barriers.

In addition to possessing these critical success factors, higher education institutions wishing to make an environmental change must be facilities driven (James and Card, 2012). Facilities staff leaders should not only be knowledgeable about how facilities and buildings function on campus, they must also be aware of the costs and energy consumption within those buildings. Furthermore, research suggests that campuses that have had success in greening their campus have “fostered an environment of shared governance, transparency, and open communication, as well as integrated key sustainability issues, into their strategic plan of the institution” (James and Card, 2012).

## Methods

This section will detail the methodology used for this analysis specifically, the GHG inventory, qualitative interview process and the quantitative emissions calculations.

Before detailing the methodology, it is important to identify the geographic boundaries for this analysis. This research will include GHG quantification for EH and the DUML. Although the student research team is aware that the NSOE is comprised of more than just these two physical spaces, they are the majority of the NSOE. In addition, the other spaces in which the NSOE can be found on campus are often shared with other departments of the university, making it difficult to parse out the emissions that could be attributed to the NSOE specifically. In addition, these spaces are not directly controlled by the NSOE, which makes the ability to formulate targeted recommendations for climate action difficult. A visual representation of the geographic boundary can be found in **Figure 11**.

Hereafter, the term NSOE references only the Environment Hall and the Duke Marine Lab.

### Nicholas School of the Environment’s Geographic Boundary

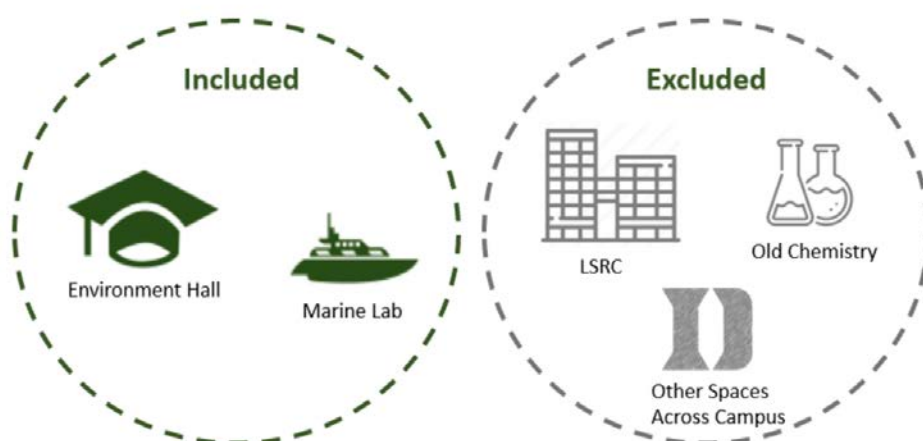


Figure 11. The Scope of the project excludes NSOE components in the Levine Science and Research Center (LSRC), Old Chemistry, and other spaces across the campus, while EH and the DUML are included.

## Greenhouse Gas Inventory

A GHG inventory is “a baseline quantification of GHG emissions, from which emissions reductions can be measured and progress towards climate neutrality can be tracked.”(Dautremont-Smith et al., 2009)

## Duke University's Included GHG Emissions



Figure 12. Duke University GHG emission inventory sources of emissions broken down by Scopes (Sustainable Duke, n.d.).

The first GHG inventory of Duke was conducted in 2004 to determine the quantity, sources and the trends of emissions from all campus operations. In 2008, following the signing of the ACUPCC commitment, Duke conducted another GHG inventory and used it as baseline for climate action planning (Duke University, 2009). Duke updates the GHG inventory annually. In the inventory, emission sources are categorized within three Scopes as shown in **Figure 12**.

### Methodology & Emissions Sources

The GHG inventory methodology for this analysis was modeled after the Duke University CAP. This GHG inventory is consistent with the GHG Protocol standards and tracks six GHGs: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbon (HFC), perfluorocarbon (PFC), and sulfur hexafluoride (SF<sub>6</sub>) (Duke University, 2009). These GHGs are quantified and calculated separately, then based on their global warming potential (GWP), aggregated into carbon dioxide equivalents (CO<sub>2</sub>-eq). (Duke University, 2009).<sup>1</sup> However, the Scope this study was narrower as the group chose to exclude synthetic and organic fertilizers, refrigerants (HFC-134a, HFC-404a, HCFC-22), and solid waste (incinerated and landfilled) due to data availability. For example, solid waste collection is not metered to quantify how much waste is generated per building or per trash collector.

Additionally, the use of fertilizers and refrigerants are not quantified at EH and at the DUML. Although fertilizers, refrigerants and solid waste are excluded, the total contribution of three categories within the larger Duke GHG inventory was only 0.83% of the total in FY17. Due to this small contribution of the university's overall GHG emissions, it can be assumed that this would also be a small amount of emissions at the NSOE.

<sup>1</sup> Global warming potential is a relative measurement of a greenhouse gas' potential to trap heat and is used to compare the heat amount trapped by a GHG to the heat amount trapped by similar-sized carbon dioxides.

The analysis for this project follows the Duke CAP’s GHG emissions inventory methodology and sources of emissions and separates items into three categories:

- Scope 1: – the direct GHG emissions from sources that are owned or controlled, which include:
  - natural gas, fuel oil, or propane used at campus steam plants and the associated fugitive emissions<sup>2</sup>, and
  - gasoline and diesel used by Duke-owned fleet vehicles
- Scope 2: – the indirect GHG emissions from electricity generation sources not owned or controlled, which include:
  - electricity purchased from Duke Energy or an equivalent energy provider, and
  - transmission losses<sup>3</sup>.
- Scope 3: – all other indirect emissions as a result of the institutions activities that occur from sources not owned or controlled, which include:
  - air travel paid for by the university,
  - faculty and employee commuting.

The GHG emissions inventory for this project can be summarized in **Table 1** below:

<i>Scope</i>	<i>Category</i>	<i>Sub-Category</i>	<i>Note</i>	<i>Data Sources</i>
Scope 1	Natural Gas	Actual consumption	Only used at EH	Energy Witness
		Fugitive emissions	11% of total consumption	Extrapolated based on Energy Witness data
	Owned Fleet Emissions	Gasoline	Boat fuel	Boat data from DUML marine operations
	On-Campus Stationary Fuel Sources	Propane	Heating and cooking at the DUML	Propane Records at DUML
Scope 2	Electricity	Generation	Purchased electricity from Duke Energy	Energy Witness
		Transmission loss	9% of total consumption	Extrapolated based on Energy Witness data
Scope 3	Air Travel		Includes all Durham-based and DUML-based faculty and staff (Not limited by geographic boundary)	Duke Employee Travel & Reimbursement
	Staff & Faculty Commuting		Includes all Durham-based and DUML-based faculty and staff (Not limited by geographic boundary)	Sustainable Duke; Transportation Survey

*Table 1. The greenhouse gas (GHG) emissions inventory and included items in this analysis.*

<sup>2</sup> In FY17, fugitive emissions from natural gas extraction/transportation were added to the Duke CAP.

<sup>3</sup> In FY17, transmission losses from electricity purchased from Duke Energy were added to the Duke CAP.

Energy Witness used by Duke Facilities Management (FMD) to provide robust tools for managing utility bills, utility data, and analytics (Duke Facilities Management, n.d.). The online platform is used by Duke University to track utility and building level electricity usage each month for on-campus buildings. Data is available on electricity, steam, chilled water, storm water, and water/sewer usages. This system, developed by Interval Data Systems, details historical energy consumption and allows for comparison to other buildings at the university. to track utility and building level electricity usage each month for on-campus buildings. Data is available on electricity, steam, chilled water, storm water, and water/sewer usages. This system, developed by Interval Data Systems, details historical energy consumption and allows for comparison to other buildings at the university.

### Qualitative Analysis

The initial phase of this project was a background literature review and interviews. The literature review began with an overview of Duke’s Climate Action Plan published in 2009, which provided the baseline and background methodologies for this project. The team then looked at the Annual Sustainability Progress Report for both 2016 and 2017, these documents provided an updated snapshot of Duke University’s progress towards climate neutrality. In addition, climate action plans from other peer universities that have implemented CAPs were reviewed. These institutions included Emory University, Stanford University, and the University of North Carolina at Chapel Hill (Emory University, 2011;

Stanford University, 2013; The University of North Carolina at Chapel Hill, 2009). This review framed questions for interviews.

Interviews were conducted during a site visit to the DUML on November 2-3, 2017. Five semi-structured, 30-minute interviews were conducted with facilities managers at Duke’s Facilities Management Department, staff, faculty, and the Director and Assistant Director. Respondents were selected for an interview due to their knowledge of DUML

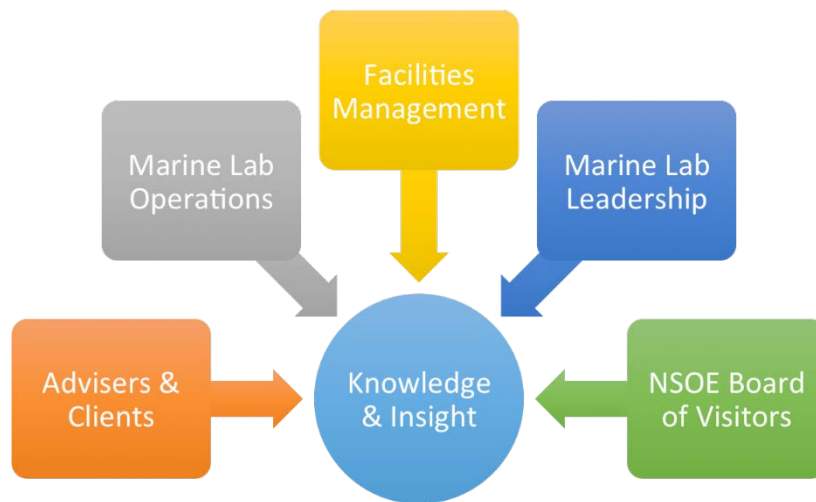


Figure 13. Qualitative interviews structure.

operations and job title as NSOE or DUML leadership. Respondents were asked about the campus of the DUML, building use, and goals of the current administration and leadership. In addition, when the team returned to Durham, 5 additional semi-structured interviews were conducted to learn about facilities management and operations on the Durham campus and at Environment Hall. The Qualitative Results section contains a detailed list of those interviewed.

The relevant literature, climate action plans, interview data in the form of transcribed notes, and photos from the DUML site visit were analyzed using NVivo 11, a software package used for qualitative analysis. The data were coded to highlight common themes related to energy use, challenges and successes of climate action, and education and renewable energy. Additional content related codes included boats,

carbon, climate action, funding, and transportation. Photos of buildings and other relevant features of the DUML were also collected to provide context for the qualitative data.

## Quantitative

The quantitative analysis includes data for the past three fiscal years including FY15, FY16, and FY17.<sup>4</sup> Duke's fiscal year runs from July 1<sup>st</sup> to June 30<sup>th</sup>. There were changes at the end of FY14 in methodology and calculation in the building energy data provided by Energy Witness that may significantly affect the analysis. Therefore, the timeframe for analysis was trimmed to include only after FY15 to maintain consistent methodology and calculation.

### Scope 1

Scope 1 includes all direct GHG emissions from sources that are owned or controlled by the institution. This analysis includes natural gas, fugitive emissions from natural gas, propane, and gasoline.

#### *Natural Gas*

Natural gas is used as one of the primary fuels on Durham campus' central steam plants to produce steam for heating and hot water. However, natural gas is not used on the DUML campus, therefore, the total natural gas consumption is isolated to EH. On-campus, there is no individual meter that monitors the precise consumption at each building. Therefore, the estimated usage was calculated using historical data reported on Energy Witness. The data provides total monthly consumption and detailed methods are discussed further in the **Appendix – Natural Gas Consumption**. Beginning in FY17, natural gas fugitive emissions were added to the GHG inventory in the Duke CAP. Fugitive emissions include emissions from the natural gas supply chain and include leakages and transportation losses. These fugitive emissions are calculated as 11% of the total natural gas consumption.

#### *Propane*

Propane is used at the DUML for cooking in the dining hall, heating the library building, and for dryers in the laundry. The tanks are checked on a weekly basis and are refilled when needed. For this analysis, consumption of propane was derived from purchase invoices for each tank. Propane purchase data for maintenance building and laundry were obtained from the end of 2014. Data for the dining hall and library tanks were only available for calendar year 2017, therefore the team assumed that the dining hall serves similar numbers of people from year to year, and thus that the cooking in dining hall consumed the same amount of propane from years 2015 to 2017.

Energy demand for heating in the library depends on various parameters, mainly the external temperature. The degree-day method is a straightforward way to obtain the trends of energy consumption for small buildings. Heating degree-day (HDD) represents how many degrees that the average temperature of the day is below 65°F. The basic assumption for this method is that the energy consumption for heating is proportional to the difference between the average temperature and reference temperature of 65°F. This means a year with more heating degree-days equates to a higher energy consumption. For example, a year with colder than average temperatures will use more energy for heating than a year with higher than average temperatures.

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<sup>4</sup> Some data from FY18 is included when detailing the building level analysis for Scope 2.

A simplified equation to calculate monthly energy consumption for heating based on degree-day method is (De Rosa et al., 2014):

$$E = \frac{H \cdot HDD \cdot t}{\eta}$$

where  $H$  is the building transmission coefficient,  $t$  is the heating time which is 24 if heating is provided constantly,  $\eta$  is the equipment efficiency and HDD is the heating degree-days. Thus, the propane demands for heating in the library in 2015 and 2016 were calculated based on HDD which can be collected from a National Oceanic and Atmospheric Administration (NOAA) database while all other parameters remain the same (NOAA, n.d.). After total consumption was determined, the CO<sub>2</sub>eq emissions were estimated for the GHG analysis.

### *Boat Fuel – Gasoline*

Scope 1 also includes emissions from Duke-owned fleet fuel usage. For Duke University as a whole, the fleet is mainly comprised of the busses, shuttles, and other vehicles owned and operated by the university. The NSOE does not directly own any vehicles. However, the DUML currently owns and operates a boat fleet consisting of 4 university owned vessels (Nicholas school of the Environment, n.d.-b). This fleet is used for used for research, education, and outreach off the North Carolina coast.

Historically, the amount of gasoline used for boats has not been tracked, however, there are detailed usage logs for each vessel trip taken. This log details the vessel name, date, reason for the trip, and trip duration. In addition, technical documentation from Yamaha, the boat engine manufacturer, allowed for estimates on boat consumption for average boat trips. The technical data was based on the same or similar boat hulls allowing for an assumption to be made that DUML owned boats would also perform similarly under these conditions. This information is detailed in **Table 2**.

Although fuel use per trip varies depending on weather, vessel speed, and trip type, John Wilson, Dr. Jim Hench, and Zack Swaim from the DUML estimated the average amount of gasoline used per trip. These estimates were then paired with the historic boat log for FY15, FY16, and FY17. This resulted in the total gallons of gasoline consumed per fiscal year.

In addition to the vessels currently owned by the DUML, it was announced in the summer of 2017 that the university received \$11 million for the construction and operation of a new research vessel. The vessel will be much larger than the current vessels and will have the capability to conduct extended and overnight trips. In addition, the vessel will carry oceanographic equipment, including wet/dry labs, and a galley (Nicholas school of the Environment, 2017). As an addition to the analysis of current boat fuel usage, the analysis will also look at technical specifications to predict future consumption to determine its effect on the DUML's current GHG emissions. This analysis will be calculated in the same manner as the current boat fleet.



<i>Boat Name</i>	<i>Characteristics</i>
 <p><i>R/V Kirby-Smith</i></p>	28 ft. Carolina Skiff, 2790 DLX EW 1 x 250 hp Yamaha 4-stroke outboard 18 Passenger Fuel Capacity: 24 gal
<p><i>R/V Willem</i></p>	21 ft. Carolina Skiff, 218DLV 1 x 115 hp Yamaha 4-stroke outboard Fuel Capacity: 30 gal
<p><i>R/V Exocetus</i></p>	19 ft. Ribcraft, RHIB 1 x 90 hp Honda 4-stroke outboard Research Vessel Fuel Capacity: 46 gal
 <p><i>R/V Richard T. Barber</i></p>	30 ft. Safe Boat 27, walk-around-cabin 2 x 300 hp Yamaha 4-stroke outboards Research Vessel Fuel Capacity: 200 gal

Table 2. Duke Marine Laboratory boat fleet and characteristics (Source: SAFE Boats International).

## Scope 2

Scope 2 includes the indirect GHG emissions from electricity generation sources not owned or controlled by the institution. Electricity usage and the transmission losses, calculated at 9% of the total electricity used, are included.<sup>5</sup>

## Building Survey

The energy use intensity (EUI) was used as a metric to benchmark a building's energy use. This metric is calculated by dividing the total energy use (usually measured in kBtu or GJ) by the total gross floor area of the building in a given year (U.S. Environmental Protection Agency, 2016). EUI was used in this analysis to identify high energy consuming buildings, as it is a simple way to compare energy use per square foot. EUI is particularly useful to benchmark a building's energy consumption to other same or similar property type to understand the consumption levels.

<sup>5</sup> Transmission loss was added to the Duke CAP in FY17 to capture the power loss that occurs from point of generation to end-user consumption.

EUI was used to determine the building on the DUML campus that consumed the most energy per square foot. These top 5 buildings, along with several smaller buildings on the DUML campus were surveyed to better understand where energy was used within the building. This allowed for the team to estimate what percentage of energy was used for lighting or other sources, such as the plug load from lab equipment, computers, refrigerators, or other things found in the buildings. This process was also repeated for EH.

A lighting and plug load inventory was made by visual inspections on December 03, 2017 for the DUML and on March 10, 2018 for EH. The objective was to quantify the number of fixtures and equipment in each building, then estimate the associated energy use. For the lighting load, they type and quantity of each lighting fixture in the building was identified and recorded. However, a very few fixtures are hidden behind concaved areas or concealed within the fixture, preventing accurate assessment. For example, the Repass Center common area has lighting fixtures that are tucked away from an occupant's point of view, making an assessment difficult without the aid of architectural plans or lighting schedules (**Figure 14**). Although such instances were not common, floor plans and electrical maps were used to aid the assessment.



*Figure 14. The Repass Center common area has lighting fixtures hidden behind recessed areas that render visual assessments difficult. Floor plans and other information were used to identify and estimate the lighting fixtures.*

For the plug load, the same technique was applied – a manual survey was conducted identify the quantity and type of various items. For each item, the power rating (or wattage) was researched using product information and the manufacturer's published information. In cases where there no published technical documents or rated power ratings, similar-sized products from a different manufacturer were used as a proxy. For example, Pilkey Laboratory has several centrifuges manufactured by USA Scientific, however, electrical information was not included in the technical documents. Therefore, power ratings from similar-sized centrifuges made by another manufacturer were used instead.

#### [Establishing Load Profiles for Buildings](#)

After the power rating for plug and lighting loads were identified, the team estimated typical hours of use to calculate the annual electricity consumption for each item. To determine approximate use hours, benchmark data were used as proxies (Norberg, 2015; University of California Santa Cruz Office of Sustainability, n.d.; Sahai, n.d.). This process was based on a simplified model that uses the rated power (W) at the active state and the rated power at idle state. This was done to account for any fluctuations in electricity consumption. For instance, a desktop computer's consumption with a rated power of 2,000 W

will not be drawing a constant 2,000 W over a typical 24-hour period but fluctuate between peak and idle load depending on use patterns. Therefore, using 2,000 W will most likely overestimate the annual consumption. Ideally, a true load profile would have a more granular and robust set of rated powers to account for the load fluctuations. However, this analysis used a simplified model with two sets of rated powers as these detailed load profiles can only be obtained by installing a meter to the appliance.

Once the active usage hours were established, the following formula was used to determine the total annual electricity consumption:

$$= (\text{rated power at active state}(W) \times \text{active usage hours}) \\ + (\text{rated power at idle state}(W) \times (8,760 \text{ hours} - \text{active usage hours}))$$

The active state and idle state were separated to reflect the energy use of appliances even when it is not being actively used. Although the idle energy load may be insignificant for some appliances, this can be high for laboratory equipment. A more detailed explanation of this process can be found in the **Appendix – Estimating Building Load Profile**.

### Scope 3

Scope 3 emissions are all indirect emissions that are a consequence of the activities of the institution but are from sources that are not owned or controlled by Duke or the NSOE. Following the direction of the AUCPCC, Duke University includes emissions from employee commuting and for air travel that is paid for by the institution.

#### *Employee Commuting*

Per the ACUPCC, commuting is defined as travel to and from campus on a daily basis. These emissions are generated from students, faculty, and staff who drive their personal vehicles to and from Duke each day. In the Duke 2007 GHG emissions inventory, the university only included emissions from commuting for faculty and staff. Keeping consistent with this methodology, this analysis of the NSOE also includes only emission data from these two groups.

Annually, Duke completes a survey to assess the ways in which employees commute to and from work. This results in an estimation in the proportion of faculty and staff driving alone, carpooling, or using public or alternate forms of transportation. For this study, emissions for Durham-based faculty and staff were estimated using these Duke estimates. However, for the DUML the team created Beaufort-specific estimates based on a transportation survey.

In addition, the university completes an annual estimation of average commute distance using geospatial analysis (GIS) and employee home address, resulting in an average commute distance in miles for those based in Durham. For the DUML, a GIS analysis of employee address data was individually computed to find a Beaufort area-specific average daily commute. These averages, combined with the faculty and staff population at each location, and average fuel efficiency data from the U.S. Department of Transportation allowed total miles driven for each year of this analysis to be calculated. This resulted in an estimate of miles traveled by faculty and staff each year and the equivalent GHG emissions.

The DUML is located about 3 hours away from Duke's main campus in Durham. To complement the commute distance analysis, the team developed a transportation survey for all members of the DUML community. The purpose of this survey was to better understand the differences between the DUML and main campus on transportation. The 14-question transportation survey was administered using the

Qualtrics online platform and distributed via email to the DUML community in early December 2017. Questions focused on how students, staff, and faculty, commute to and from the DUML, frequency of travel to Duke's main campus in Durham, and impressions of transportation options in Beaufort.

The survey also included a section that asked about Gallants Channel Bridge project, which may have an impact on the DUML. The North Carolina Department of Transportation will complete construction in spring 2018 on the Gallants Channel Bridge, built at a cost of a \$66 million. This 65-foot high-rise bridge will replace the existing drawbridge that residents often use to gain access to Beaufort (North Carolina Department of Transportation, n.d.). The new bridge and access roads will most likely change the routes that many motorists and cyclists will travel to the DUML daily. Due to the possible concern from DUML Administration on the impacts that the bridge may have on access to the lab, the team used this opportunity to understand the perceptions of this new infrastructure. The transportation survey included questions about the effect this new bridge may have on their daily commute.

### *Employee Air Travel*

As defined by the ACUPCC, Duke only includes emissions from air travel paid for and logged into the university travel system. Duke University estimates total miles traveled using the cost of the air travel ticket as the total miles for each trip is not recorded. This methodology was also used for this analysis to stay consistent with the 2007 GHG analysis. Data for all air travel expenses of Nicholas School including the DUML from FY15 to FY17 were available for this analysis. The total miles traveled is found by dividing the total spent on air travel by the average price per passenger air mile provided by American Airlines. Related fees for airline travel are also reported via the air travel system, but these were not considered in this analysis as they are assumed to have little contribution to GHG emissions. This factor was \$0.27 per mile in FY15 and FY16 and increased to \$0.28 per mile in FY17. Using the miles flown and emissions factors of 0.00048 MTCO<sub>2</sub>eq per mile, GHG emissions from air travel can be estimated (Sustainable Duke, n.d.).

To better understand the composition of air travel at the Nicholas School, trips were also categorized into six different travel types: conference, research, research related meeting, education-related activities, others (includes recruiting and alumni events) and unspecific trips which have no detail documented. Dividing air travel into these categories will allow for the team to have more detail into the purpose behind each flight, providing context for the data.

## Results

The sections following will detail the results of the qualitative and quantitative analyses detailed in the methods above.

### Qualitative

This section presents the analysis of interviews with DUML operations leadership and members of Duke's Facilities Management Department. The majority of the interviews took place November 2-3, 2017. Main topics include operations and functionality of the buildings at the DUML and insight on electricity, propane, and renewable energy features of many of the buildings. In addition, the data provide information regarding building function, renewable energy present on the island, boat use, and sustainability education.

For this study, we interviewed key stakeholders within Duke and the NSOE (**Table 3**).

<i>Name</i>	<i>Title</i>
<i>Casey Collins</i>	Energy Manager – Duke University
<i>Dr. Andy Read</i>	Director of Marine Lab
<i>Rebecca Smith</i>	Associate Director of Marine Lab
<i>Dominick Brugnolotti</i>	Director of Campus Services – DUML
<i>Steve Palumbo</i>	Director of Facility Operations – Duke
<i>Dana Gillikin</i>	FMD Staff – DUML
<i>John Wilson</i>	Manager of Marine Operations
<i>Dr. Tom Schultz</i>	Assistant Professor of the Practice – DUML
<i>John Robinson</i>	Assistant Dean, IT and Facilities – NSOE
<i>Abhishek Bathula</i>	Energy Engineer – Duke University

*Table 3. List of Interviewees and their affiliation to Duke.*

### *The Community*

The team began the visit to the DUML with an interview with Marine Lab Director, Dr. Andy Read, and Assistant Director, Rebecca Smith. The two outlined how decisions are made for operations on the island. Although cost considerations for projects are important, the DUML sense of community and history is always a central consideration. Ms. Smith Rebecca mentioned “architectural integrity” when speaking on building and renovation. She noted that the alumni of the DUML love coming back to visit and seeing that the island has not changed much through the years. The dorms and dining hall were built in a traditional style that is familiar although the building interiors have been renovated while retaining the historical look. In addition, Dr. Read emphasized that the DUML community is small and tight-knit, with about 125 full-time people on-island each semester. In light of this fact, as the director, he feels that all groups represented on the island are important from undergraduate, masters, and Ph.D. students to the faculty, staff, and researchers who call the island home. As the team works to create recommendations for climate action, these insights will be helpful.

### *Transportation*

Director of Campus Services, Dominick Brugnolotti was very concerned about the issue of transportation and carpooling at the DUML. He was interested in the feasibility of a carpooling service or an electric vehicle on campus at the DUML. Dr. Read also stressed that relative to other academic units at Duke, the DUML is unusual in its location and size. For example, many of the transportation and commuting options available on the main campus in Durham cannot be translated to the DUML. In Eastern North Carolina, public transportation options are limited. Identifying ways to get students, faculty, and staff onto the island safely and efficiently where public bus routes do not exist is difficult. In addition, because the DUML is a satellite campus to Durham, many students are traveling back and forth on the nearly three-hour drive back and forth for meetings and events on the main campus (R. Smith, personal communication, December, 2017).

### *Laboratory Operations*

The team completed a walkthrough of the lab spaces at the DUML with Dr. Tom Shultz. Dr. Shultz is an Assistant Professor of the Practice and the Director of the Marine Conservation Molecular Facility. Unofficially, he serves as the DUML’s current lab safety compliance officer. This role gives him a broad

overview of research spaces and equipment used in each building. Dr. Schultz shared that many lab spaces at the DUML have equipment like fume hoods and freezers running 24 hours of the day. This results in extensive energy use and loss of energy efficiency for the building. When looking at the quantitative data for the labs, he noted that it should not be surprising to see a much higher energy use per square foot for these buildings given the nature of their function. This information was important to the team moving into the data collection phase.

### *Boats*

John Wilson, Director of Marine Operations at the DUML offered information to the team on the current boat fleet. The DUML has four Duke-owned boats currently in the fleet, and two of the Duke-owned boats account for 95% of the boat fuel usage (J. Wilson, personal interview, December 2017). This will be a factor of consideration in the carbon output for the DUML, but Wilson explained to the team that there might not be much that can be done to reduce this impact, as boat technologies can often not be updated unless a new vessel is purchased. Wilson also detailed specifications of the new vessel that is projected to be completed in 2019. The current fleet contains all gasoline powered outboard boats, while the new vessel will use diesel fuel. In addition, the new vessel will be much larger and can carry 1,500 gallons of fuel at a time, but also will be more fuel efficient relative to the smaller older boats. Wilson also provided the team with technical documents that informed the data analysis and projection phase.

### *Coastal Environment*

The coastal environment constrains many of the solutions and recommendations that can be made. This was exemplified when discussing the green roof on top of the Repass Center with the FMD staff members Steve Palumbo and Dana Gilikin. The green roof was originally planted with native wildflowers and plants to minimize heating, cooling, and water drainage. However, the harsh coastal climate and salty air make the roof more difficult to maintain. The majority of the initially planted greenery was succeeded by the seagrasses deposited by wind and birds (D. Gillikin, personal interview, December 2017). This has now caused there to be leaks in the mechanical room directly under the green roof as sea grasses do not absorb as much water.

### *Conclusion*

While sustainability successes have been accomplished over the years, there is still more to do at the NSOE, particularly when it comes to quantifying and reducing GHG emissions. Conducting formal interviews allowed for a deeper understanding of the main goals of many stakeholders to climate action at the NSOE. Of the main interview topics, it was critical for the team to gain knowledge on campus operations before moving forward in the project. In addition, none of the student team was based at the DUML, so insight on Beaufort and campus operations were necessary. These interviews set the stage for the quantitative portion of the analysis by detailing issues of importance and identifying data gaps. Specifically, these interviews prompted the team to conduct building audits, developed a transportation survey, and completed an analysis of the new vessel.

### *GHG Inventory*

This section details the results of the GHG inventory for the DUML and EH, followed by sections that will detail the Scope 1, 2, and 3 emissions as outlined in the Methods section.

In summary, for FY17, the total emissions for the DUML and EH were 3,295 MTCO<sub>2</sub>eq, approximately 1.26% of Duke University’s entire emissions (compared to 258,582 MTCO<sub>2</sub>eq in FY17). This is approximately equivalent to 706 passenger cars driven for a year (**Figure 15**) (U.S. Environmental Protection Agency, 2017).

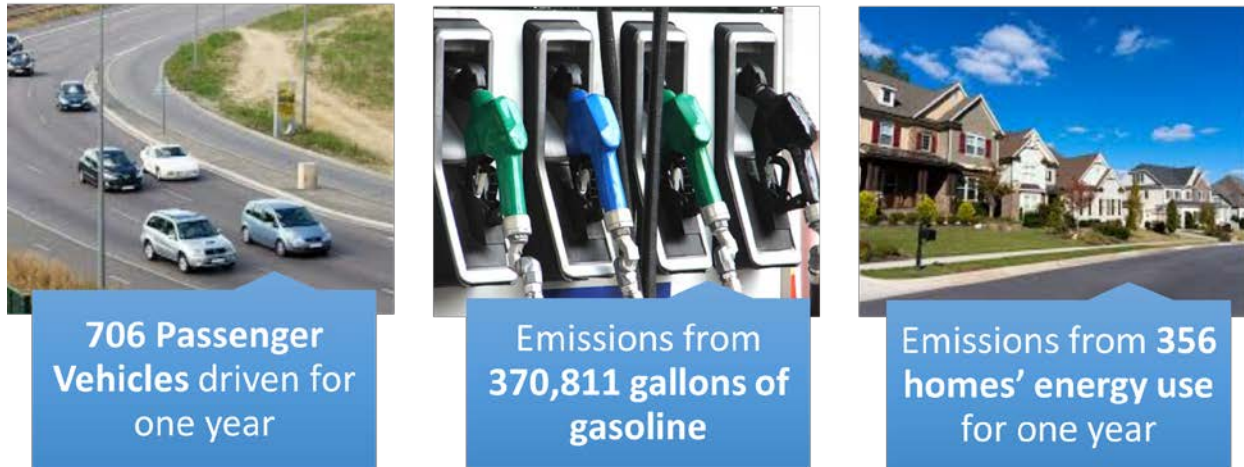


Figure 15. Total greenhouse gas (GHG) emissions at the Environment Hall and the Duke Marine Lab combined is 3,295 MTCO<sub>2</sub>eq (FY17). The equivalent GHG emissions would result from 706 passenger vehicles driven for a year, 370,811 gallons of gasoline, or operating 356 residential homes for a year.

**Figure 16** summarizes the trend of GHG emissions for the NSOE as a whole, DUML and EH combined. As shown, there has been a 17% decrease in emissions from FY15 to FY17. This decreasing trend is also seen overall in the University’s Sustainability Progress Report. For the NSOE overall, Scope 2 emissions, purchased electricity, make up the majority of the emissions for each fiscal year in this analysis. Although there is a decrease in MTCO<sub>2</sub>eq each year, purchased electricity, Scope 2 emissions, have been the majority share each year.

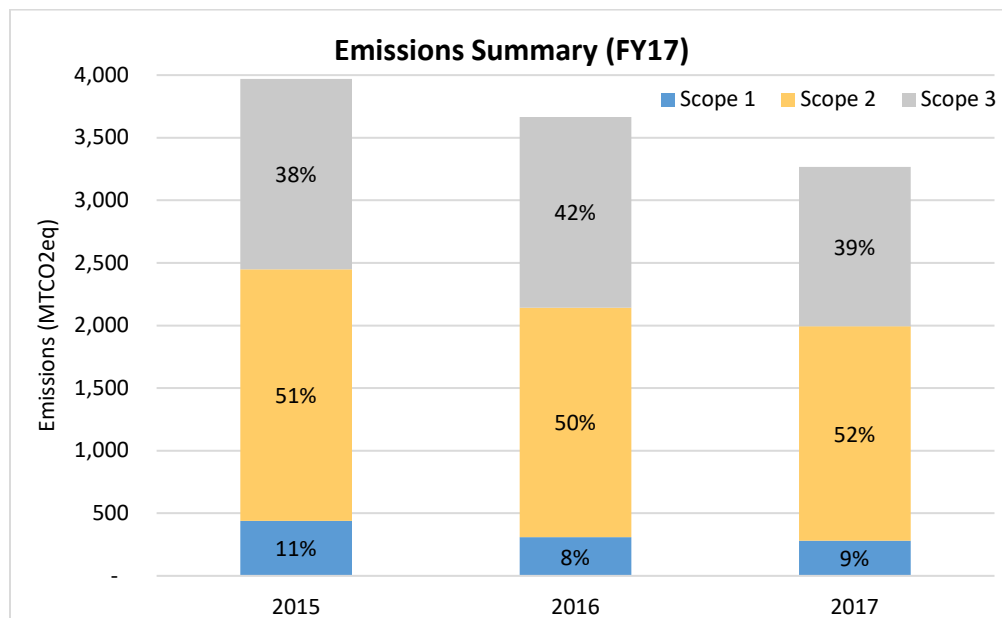
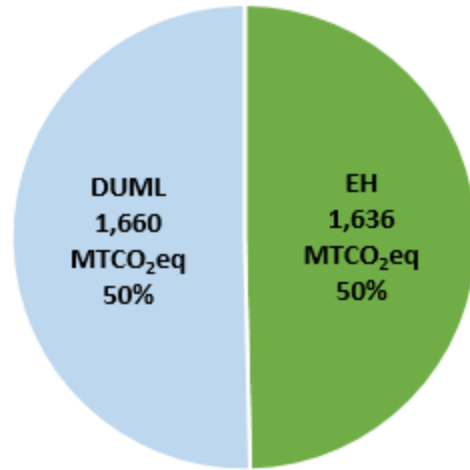


Figure 16. Comparison of GHG emission for the NSOE in total (DUML and EH) for FY15-FY17. Emissions are broken down by Scope 1, 2, and 3. Overall there has been a 17% decrease from FY15 to FY17.

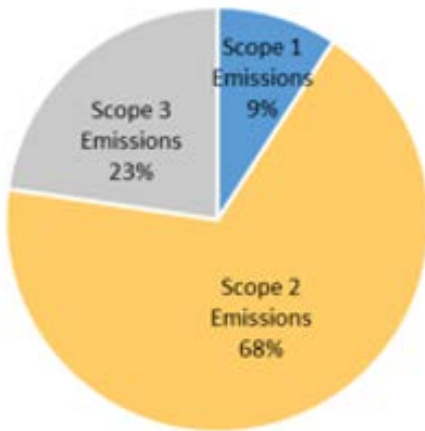
As shown in **Figure 17**, the GHG analysis showed an even split between emissions from the DUML and EH, both with around 1,600 MTCO<sub>2</sub>eq for FY17. However, the categories of where these emissions come from greatly differ depending on the location (**Figure 18**). For the DUML, the majority of emissions are from Scope 2, purchased electricity, while on the main campus in EH, the majority of emission is a result of employee air travel and daily commute. In context, these differences are explainable by the data. The DUML is comprised of 21 different buildings, all of which need electricity. Therefore, it would make sense that this purchased demand would make up most of the emissions. Although EH is only one building in Durham, it is quite large. However, Scope 3 emissions dominate in this analysis because, when calculating employee commuting, the team used the total of Durham-based faculty and staff. This number not only includes those housed in EH but also in LSRC.

**Total Emissions Breakdown (FY17)**

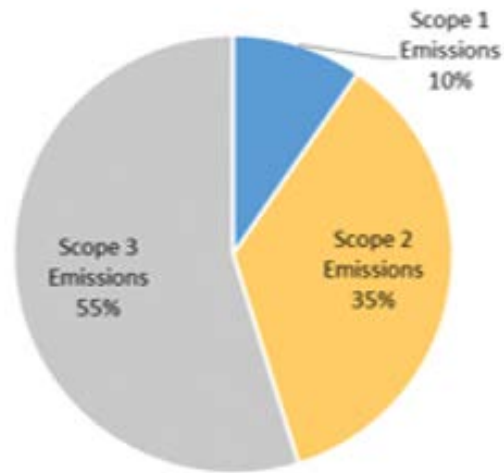


*Figure 17. The breakdown of emissions of the NSOE by location. With EH making up 50% and the DUML making up 50% of total emissions for FY17.*

**Duke Marine Lab Breakdown (FY17)**



**Environment Hall Breakdown (FY17)**



*Figure 18. The breakdown of emissions by Scope for the DUML and EH for FY17.*

## Scope 1

This section will detail the results of Scope 1 emissions for the DUML and EH. This includes the direct emissions from owned or controlled sources such as vehicle fleets. For this analysis, this includes natural gas, propane, and gasoline from the boat fleet.

The GHG inventory results showed the total Scope 1 emissions in FY17 was 310 MTCO<sub>2</sub>eq or equivalent to 66 vehicles driven for a year. This is 9.4% of the total GHG emissions at the NSOE. The breakdown shows natural gas and its fugitive emissions make up 50.7% of total Scope 1 emissions followed by gasoline (26.7%) and propane (22.5%) (**Figure 19**).

**Figure 20** details the total Scope 1 emissions for the NSOE in total for the years included in this analysis. As shown, there has been a decrease overall of 190 MTCO<sub>2</sub>eq from FY15 to FY17.

**Scope 1 Emissions Breakdown (FY17)**

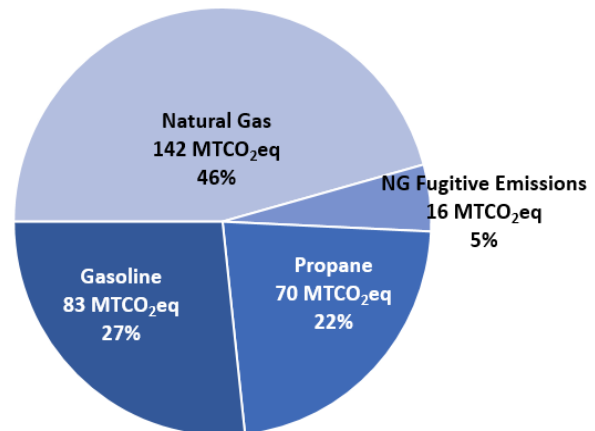


Figure 19. Scope 1 emissions breakdown in FY17 shows natural gas consumption takes up more than 50% of the Scope 1 emissions.

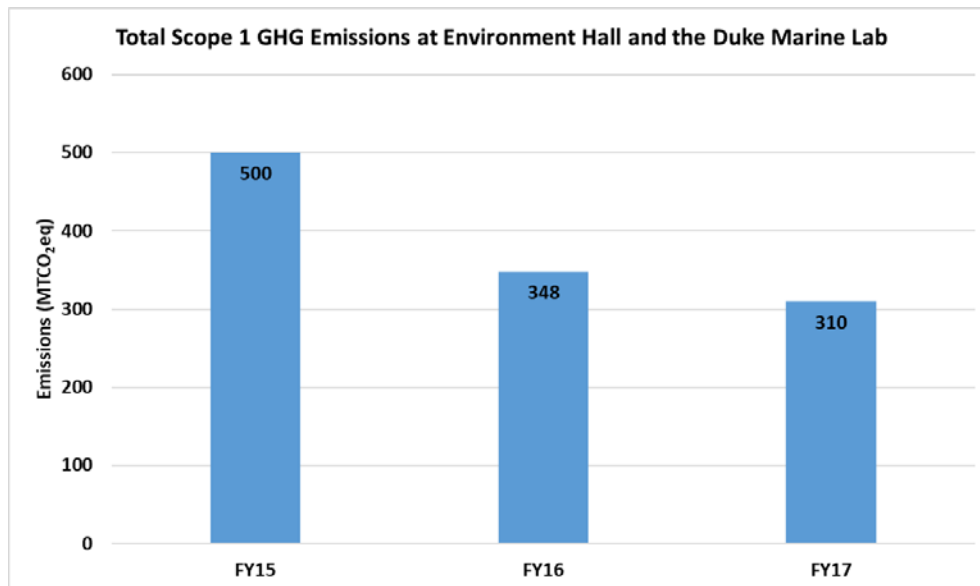


Figure 20. The total Scope 1 emissions showed a decreasing trend since FY15 driven by reduction in heating load at Environment Hall.

## Natural Gas

Natural gas is used on the Durham campus to produce steam for heating and hot water, but not on the DUML campus. Emissions from natural gas were 4.77% of total EH emissions in FY17. Overall, the results of this analysis, detailed in **Figure 21**, show there has been a significant reduction in natural gas consumption in the past two fiscal years. This decrease can most likely be attributed to an improved

building management system and optimizations implemented by the Duke FMD. The total consumption during FY17 decreased by 52% since FY15 even with the addition of fugitive emissions in FY17.

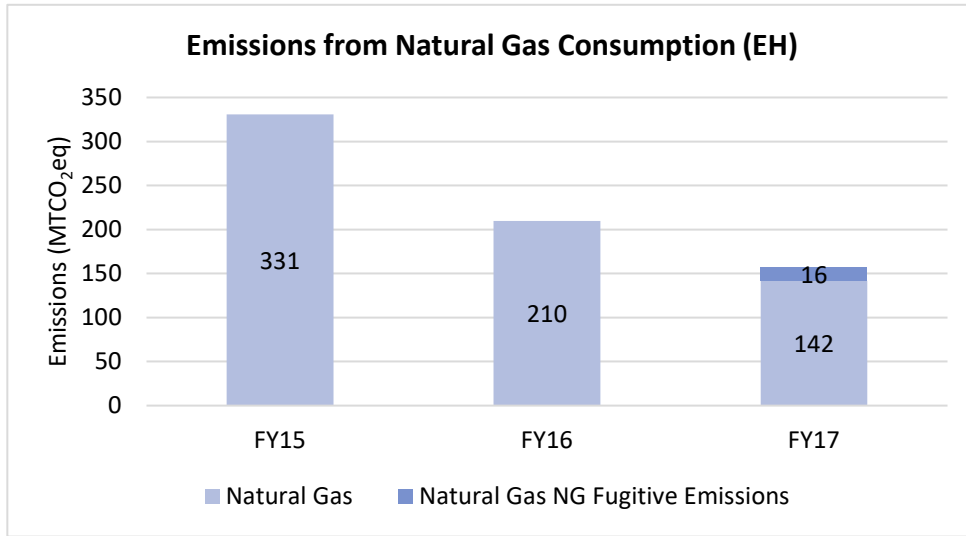


Figure 21. GHG emissions from natural gas consumption at Environment Hall. A 52% reduction in consumption was achieved since FY15.

### Propane

Propane is only used on the DUML campus at the NSOE. Emissions from propane usage were 4% of total DUML emission in FY17, among which heating in the library / auditorium made up 65% and cooking in the dining hall accounted for 33%. **Figure 22** details the breakdown of propane usage as it relates to the total emissions for the DUML during the most recent fiscal year. A very small amount of propane (1%) is used in the laundry room dryers for undergraduate students who do laundry on campus. About 1% of the total usage is also used in the maintenance building to fuel a forklift.

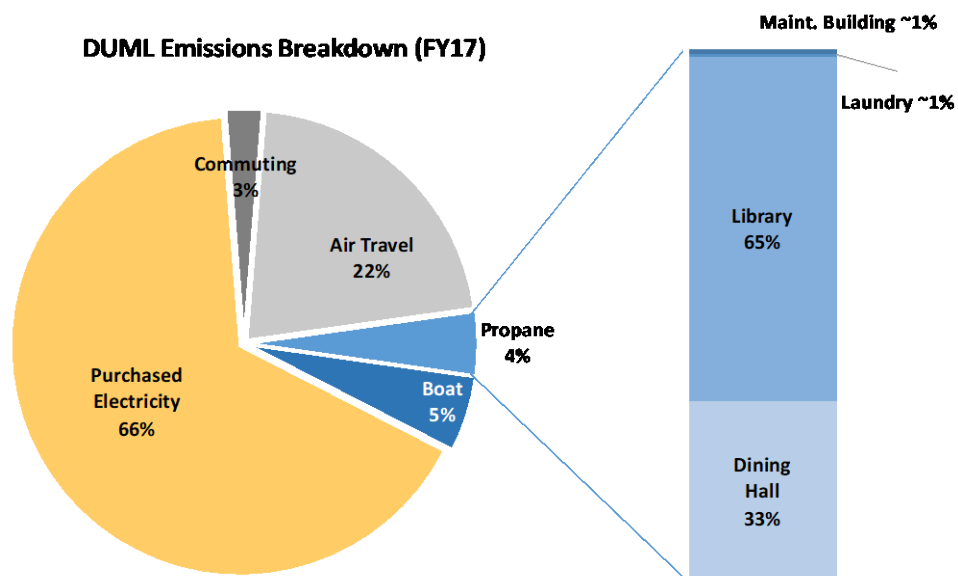


Figure 22. Total DUML Emission Breakdown for FY17 with a detailed view of propane usage (4%).

Due limited data availability, propane consumption for library heating for FY15 and FY16 was estimated using the heating degree-day method detailed in the methods section. 2015 was a colder year than average, so the estimated propane usage was rather high compared to the other years included in this analysis. This resulted in an estimated increase in emissions of 2% for FY15. **Table 4** documents the results of the total heating degree days, estimated propane usage, and the relative emissions for each year of analysis.

<i>Fiscal Year</i>	<i>Total HDD</i>	<i>Propane (Gal)</i>	<i>Emissions (MTCO<sub>2</sub>eq)</i>
2015	3,110	11,074	60
2016	2,259	8,044	44
2017	2,343	8,343	46

Table 4. Results of the heating degree day (HDD) and emissions analysis for FY15, FY16, and FY17 for the DUML.

It is important to note that the DUML is planning on renovating the library in the next few years. Since the library / auditorium building accounts for 65% of the propane use and in turn 2.6% of the total DUML emissions, increasing building efficiency could reduce propane consumption for the library. By adopting building efficient technologies, in addition to propane usage, other energy source consumption would also be reduced. For example, changing single pane windows to more efficient double pane windows could save approximately 20 to 30 percent on energy cost (U.S. Department of Energy, 2015).

#### Boat Fuel

Two research vessels, the R/V Richard Barber and the R/V Kirby Smith, make up nearly 96% of total gasoline usage for the fleet. This matches the qualitative description given by John Wilson during the DUML site visit. **Table 5** below details the gallons of gasoline used per boat for each year of analysis. For the fiscal years included in this analysis, the average gasoline consumption was 8,468 gallons. Mirroring the emissions factors from the Duke GHG emissions inventory, one gallon of gasoline is equivalent to 0.0089 MTCO<sub>2</sub>eq. This means that on average, current emissions from gasoline used by the Duke-owned boat fleet at the DUML is about 75.4 MTCO<sub>2</sub>eq. These emissions are equivalent to 16 passenger cars driven for a year.

<i>Boat</i>	<i>FY 15 (gal/year)</i>	<i>FY 16 (gal/year)</i>	<i>FY 17 (gal/year)</i>
R/V Exocetus	51	0	202
R/V Richard Barber	6,481	5,653	7,584
R/V Kirby Smith	843	1,684	1,320
Other Boats	1,318	106	160
<b>Total</b>	<b>8,694</b>	<b>7,444</b>	<b>9,268</b>

Table 5. Current boat fleet gallons of gasoline used per year for FY15, FY16, and FY17.

#### Projected Boat Emissions

As mentioned in the Methods section, the DUML is currently in the process of adding a new vessel to the current fleet. The boat builder for the planned 72' research catamaran, All American Marine, estimated total fuel usage for one year of use based on an estimate of vessel use from DUML staff and technical specifications for various engine loads. After one year of service, with an estimated 108 total days at sea, about 2,600 operating hours, the new vessel is estimated to use 101,351 gallons of fuel per year. The new board will use marine diesel. When using the conversion factor for marine diesel, 0.0096 MTCO<sub>2</sub>eq, this will equate to about 973 MTCO<sub>2</sub>eq per year (Sailors for the Sea, n.d.). If these emissions

were included in a GHG emissions inventory for the DUML in the future, it would result in a 1,997% increase in emissions for the fleet.

## Scope 2

Scope 2 emissions include the indirect emissions from electricity generation and transmission loss. These made up 52% of total GHG emissions at the NSOE, making it the largest contributor to total emissions for the years included in this analysis. The total electricity use at the NSOE in FY17 was 4.7 million kWh and the equivalent emission is 1,712 MTCO<sub>2</sub>eq or 367 passenger vehicles driven for a year. Compared to FY15, consumption levels have decreased 18% largely driven by the reduction at the Environment Hall (**Figure 23**). As it related to the DUML and EH, electricity generation is a 2:1 ratio with the DUML using 66% of total electricity use and EH using 34% of the total electricity use. This is most likely because the DUML campus has 21 small buildings while EH is one large building. For comparison, the total gross square feet of all DUML buildings is 108,211 ft<sup>2</sup> while the EH is 73,515 ft<sup>2</sup>.

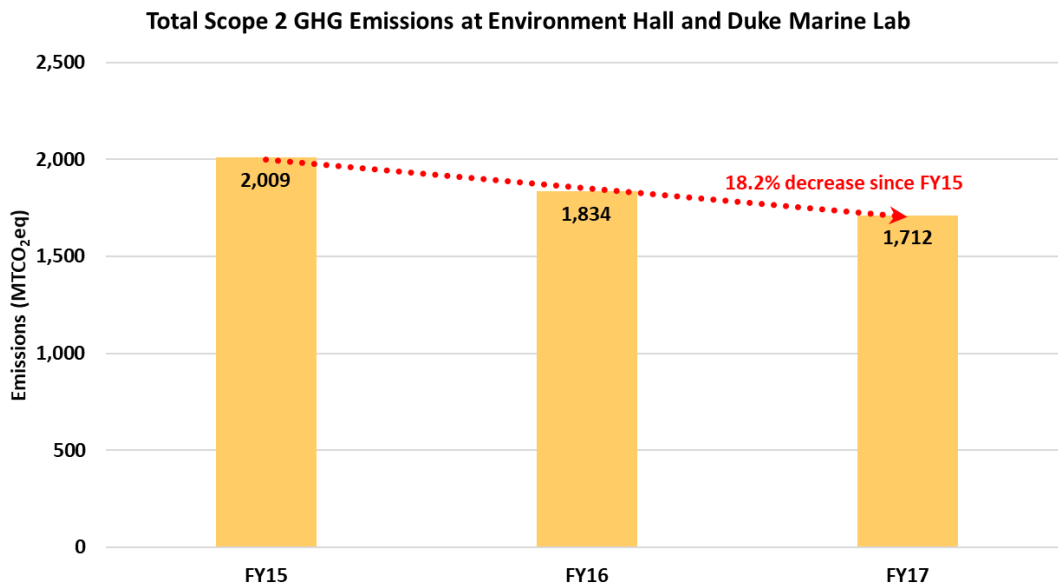


Figure 23. Total Scope 2 emissions at combined EH and DUML shows a decreasing trend since FY15.

For this analysis, following the methodology used by Duke University, Scope 2 emissions can be broken down into two parts: Electricity Generation (92%) and Transmission Loss (8%). In addition, **Figure 24** details the breakdown of Scope 2 emissions as related to total NSOE emissions.

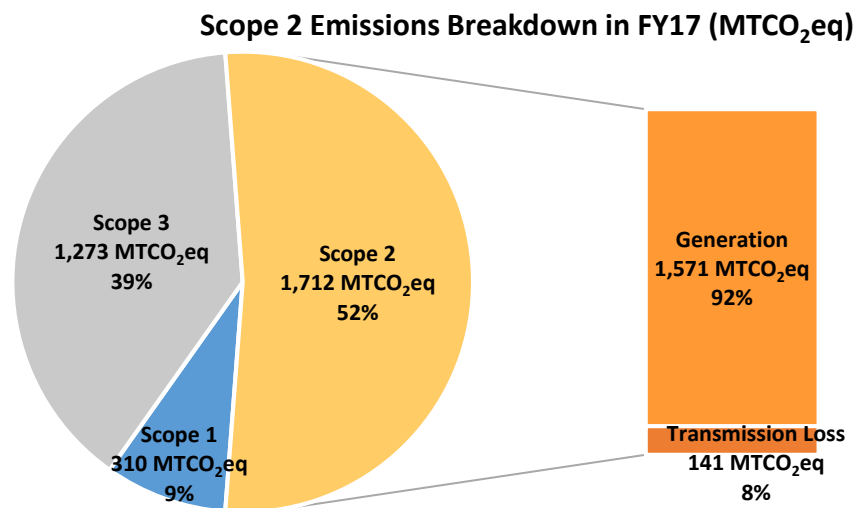


Figure 24. The total emissions from Scope 2 at Environment Hall and the Duke Marine Lab makes up 1,712 MTCO<sub>2</sub>eq and 52% of the total emissions.

The following sections will detail the results of the building level energy analysis for EH and the notable energy consumers at the DUML. Results will include breakdowns of building level electricity consumption and the results of the building audits.

### Energy Use Intensity

Energy use intensity (EUI) is a metric to benchmark a building's energy use and performance against other buildings which is calculated by taking the total energy use and dividing it by the gross floor area (U.S. Environmental Protection Agency, 2016). Sustainable Duke provided the team with the average EUIs for typical laboratories, classrooms/offices, and housing at Duke in F17 for benchmark purposes. These average EUIs were determined via work with FMD and Sustainable Duke to analyze Energy Witness Data to benchmark energy use with peer institutions.

**Figure 25** details the EUI comparison for the NSOE as it related to the Duke average and the US median for colleges and universities. For the DUML, the EUI comparison for FY17 shows the Library/Auditorium (278 kBtu/ft<sup>2</sup>) and the Dining Hall (189 kBtu/ft<sup>2</sup>) have the highest EUIs on the island. These buildings surpass the average EUI for laboratories at Duke University (**Figure 25**). Incidentally, both buildings consume propane: heating at the Library and cooking at the Dining Hall. In Durham, EH (105 kBtu/ft<sup>2</sup>) is performing below the national median and the average for Duke's classroom/office EUI.

Looking at laboratory spaces at the DUML, compared to the Duke Laboratories average (180 kBtu/ft<sup>2</sup>), Bookhout laboratory performs better despite being the largest energy consumer at the DUML. Similarly, the Pilkey Laboratory has a lower EUI of 158 kBtu/ft<sup>2</sup>. One reason these two buildings have better EUIs than the Duke average is that these buildings have a mixed use of both laboratories and offices. For example, Bookhout is the primary location for faculty and researcher offices but also used as the main lab space. Office space consumes substantially less energy than a laboratory, and a mixed-use building would be expected to have lower energy use than a fully dedicated laboratory building.

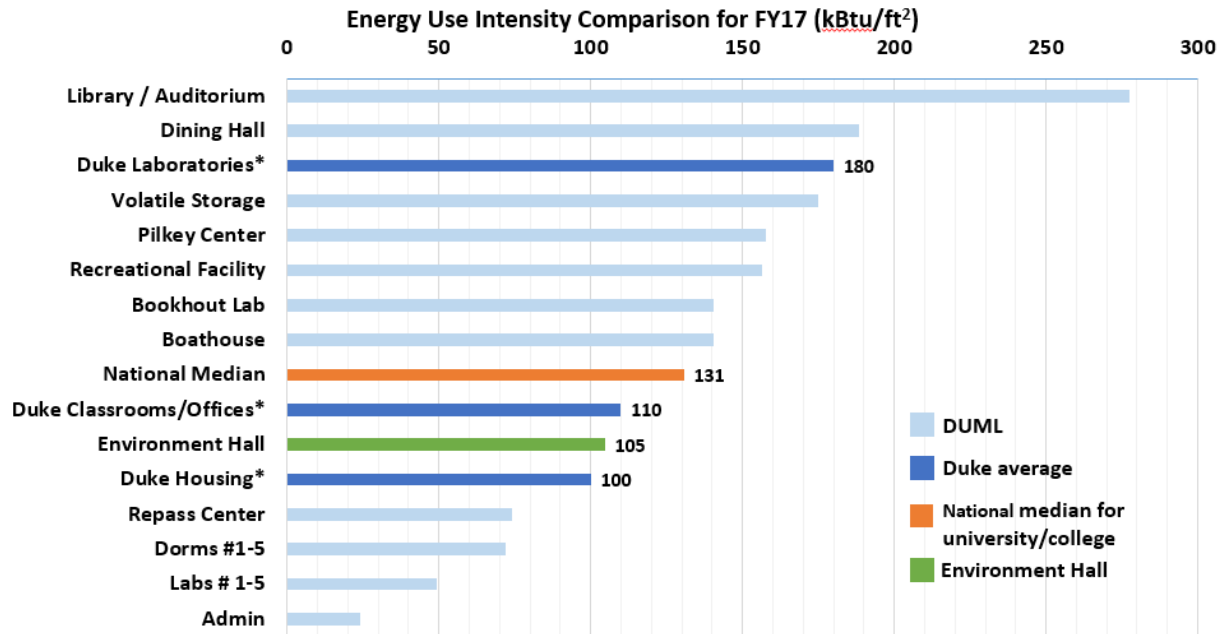


Figure 25. Energy use intensity (EUI) comparison for fiscal year 2017 provides a benchmark metric to determine which buildings are performing poorly.

### Environment Hall

The total energy consumption in EH for FY17 was equivalent to 582 MTCO<sub>2</sub>eq or 344 passenger vehicles driven for a year. EH had an EUI of 105 kBtu/ft<sup>2</sup> in FY17, a 39% reduction compared to FY15's 171 kBtu/ft<sup>2</sup>. This decrease was driven by a reduction in all cooling, heating, and electricity loads. The largest reduction resulted from the heating load, which decreased by 57% since FY15, as discussed in the Scope 1 – Natural Gas.

Figure 26 details the breakdown of energy for this building for FY17 and shows cooling and heating combined encompassed more than 85% of the total energy consumption. Compared to the buildings at the DUML, EH is different as cooling and heating use chilled water and steam from central plants. While at the DUML, buildings mainly use electricity for heating and cooling.

Although EH is LEED Platinum certified, the use of LED lights is limited to bathrooms, cabinet lights in the kitchenettes, and in Field Auditorium. Fluorescent bulbs (F28T5 and F14T5) and compact fluorescent bulbs are used elsewhere. The total bulb count is approximately 874.

The total electricity consumption in FY17 for EH has declined 26% compared to FY15. The

### Environment Hall Energy Use Breakdown (FY17)

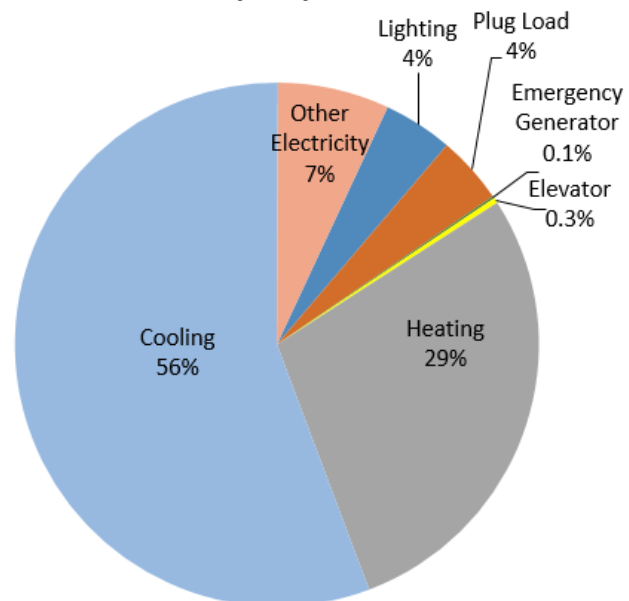


Figure 26. Environmental Hall energy use breakdown shows 85% of the load comes from heating and cooling.

consumption trend showed no distinct seasonal components and displayed a relatively uniform distribution of consumption throughout the year (**Figure 27**). The number of anomalies was more pronounced during FY15 and FY16, but the latest trend showed no significant outliers.

### Environment Hall Electricity Consumption

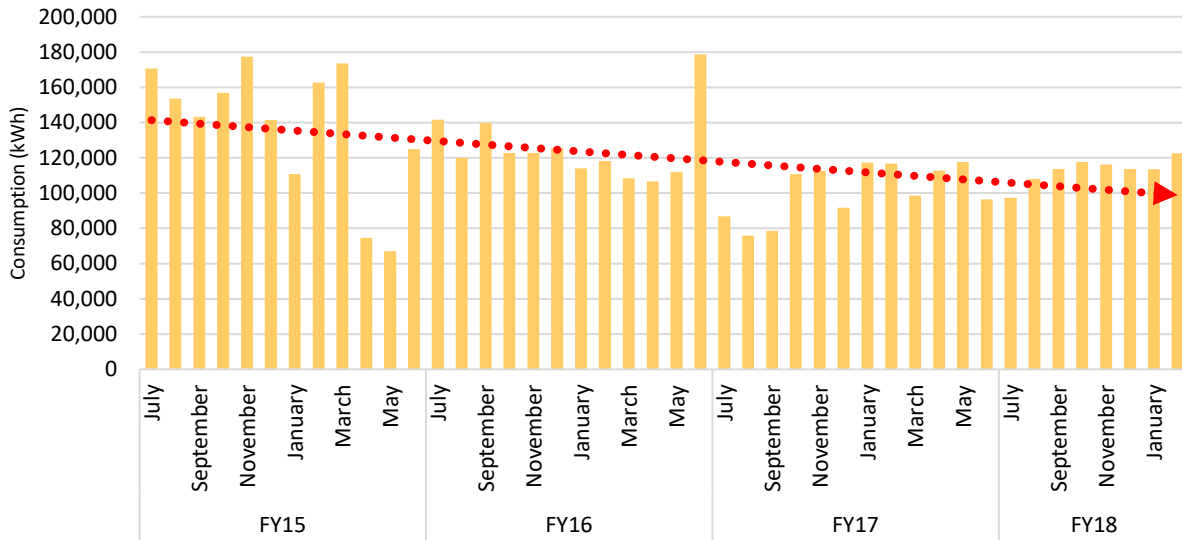


Figure 27. Environment Hall electricity consumption shows a decreasing trend with a 26% reduction comparing FY15 to FY17.

The cooling load, supplied with chilled water, shows a 27% reduction from FY15 to FY17 and continues the decreasing trend (**Figure 28**). The consumption pattern has a clear seasonal component, cycling between peak load during late summer and off-peak load during the winter.

### Environment Hall Cooling Consumption

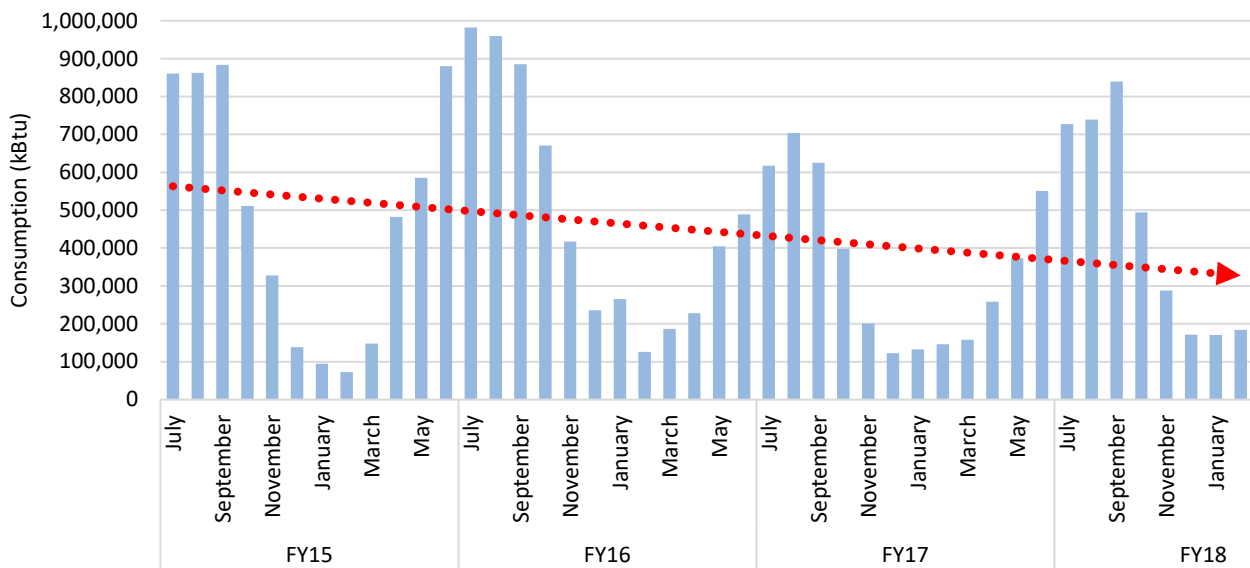


Figure 28. Environment Hall historical cooling load.

The heating load also had a seasonal pattern with peak loads during winter (**Figure 29**). The overall decrease in consumption was primarily driven by building optimizations and system corrections

implemented by the FMD. These changes included correcting the air handling units (AHUs) to prevent heating and cooling simultaneously and trimming the occupancy schedule. As a result, the total annual heating load decreased by 57% in FY17 compared to FY17.

### Environment Hall Heating Consumption

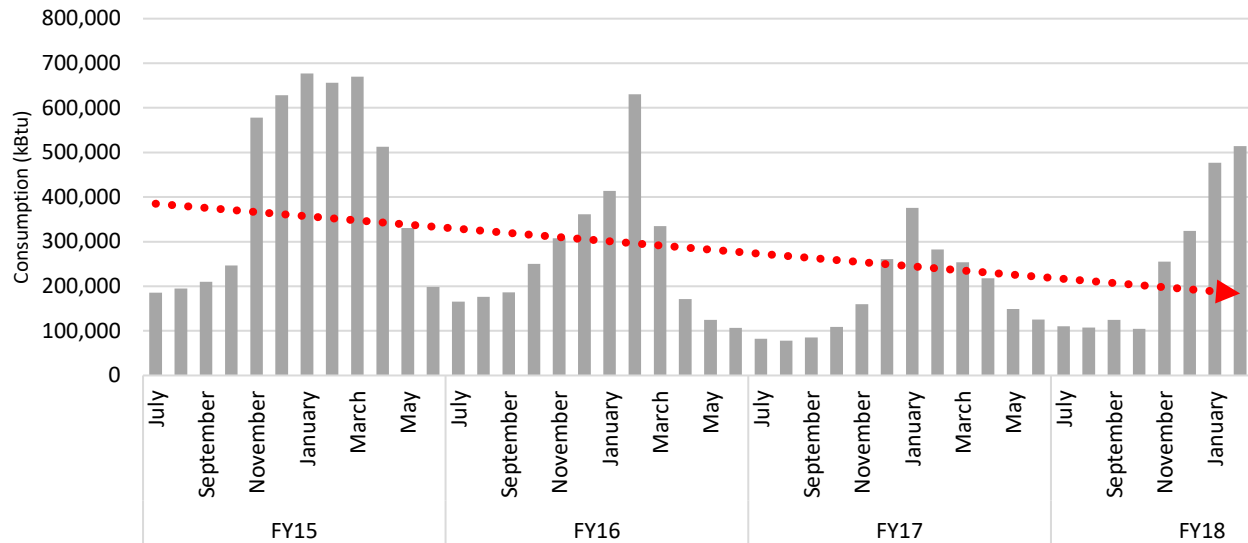


Figure 29. Environment Hall historical heating load.

### Duke University Marine Laboratory

The total electricity consumption at the DUML in FY17 was 10 million kBtu. This is equivalent to 1,037 MTCO<sub>2</sub>eq or 222 passenger vehicles driven for a year. Electricity makes up two-thirds of total emissions (**Figure 30**).

The main difference between the DUML campus and Durham campus is the absence of centralized heating and cooling system at the DUML. The lack of a centralized system increases the electricity load at the individual building level because cooling and heating are relatively inefficient compared to a centralized system that has higher energy efficiency. Therefore, the electricity use takes up a larger portion of the DUML compared to the EH.

### Greenhouse Gas Emissions Breakdown at DUML (FY17)

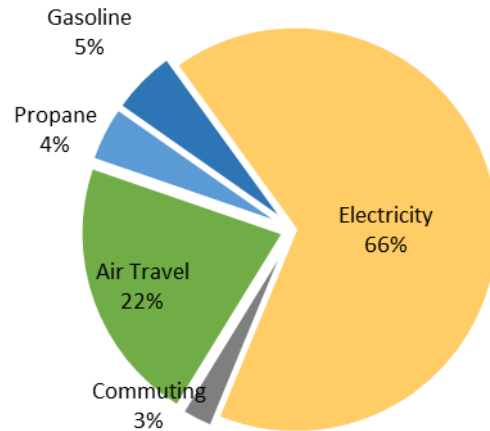


Figure 30. DUML total greenhouse gas emissions breakdown in FY17 shows electricity takes up two-third of the total emissions.

Building	Emissions (MTCO <sub>2</sub> eq)	EUI (kBtu/ft <sup>2</sup> )
Library / Auditorium	230	278
Volatile Storage	9	175
Pilkey Center	221	158
Recreational Facility	30	156
Bookhout Lab	428	140
Boathouse	10	140
Environment Hall	582	105
Dining Hall	36	91
Repass Center	44	74
Dorm #1	10	72
Dorm #5	22	52
Ocngrph Storage	10	50
Lab # 2	15	49
Garage	5	48
Service Bldg	23	47
Lab # 1	8	47
Maintenance & Storage Bldg	35	39
Dorm #4	5	29
Seawater Tank Facility	6	28
Lab # 5	12	26
Administration Bldg	11	24
Dorm #2	2	14
Dorm #3	2	13
Caretaker Residence	0.4	1.4

Table 6. The total GHG emissions and the energy use intensities by buildings at the DUML in FY17. The EUI for Library includes propane used for heating.

The total annual consumption has decreased by 4.3% from FY15 to FY17. This was driven by reductions in consumption in most buildings on the island. There were several buildings that showed an increase in consumption from FY15 to FY17. These building were: Library / Auditorium (+14%), Repass (+8%), Pilkey Lab (+5%), Bookhout (+3%), Recreational Facility (+3%), and Volatile Storage (+3%). Consumption at most buildings has decreased, however, this may be due to changes in the methodology rather than an actual decrease in consumption.

For instance, electricity consumption at Caretaker Residence decreased by 85% from FY15 to FY17 which resulted in an unusually low EUI of 1.4 kBtu/ft<sup>2</sup> (Table 6). The Volatile Storage had an EUI of 175 kBtu/ft<sup>2</sup>, putting it close level to the average Duke Laboratories of 180 EUI (kBtu/ft<sup>2</sup>). Considering this is a very small building with a floor area of 465 ft<sup>2</sup> with minimal electrical loads, it is highly likely the actual consumption is significantly lower than what is reported in the Energy Witness.

Furthermore, the DUML electrical plan showed the Volatile Storage, the Recreational Facility, and the Caretaker Residence had no meters, reinforcing the hypothesis that the consumption changes in these buildings are driven by changes in data collection and methodology.

### Bookhout Laboratory

The Bookhout laboratory is the largest electricity consuming building on the DUML campus using 38% of total electricity with an EUI of 140.5 kBtu/ft<sup>2</sup>. The total emissions in FY17 were 428 MTCO<sub>2</sub>eq which is equivalent to driving 92 passenger vehicles for a year. The historical consumption patterns displayed



Figure 31. A chiller unit is shared between Bookhout Laboratory and Library / Auditorium. Uneven cooling load may be negatively impacting the Library.

seasonality with a peak during winter months (Figure 32). Since both cooling and heating are electric-powered, this pattern suggests the heating load is greater than the cooling load. Additionally, the building shares a chiller unit with the Library / Auditorium for cooling purposes and it is assumed the costs are equally shared (Figure 31). The cooling load at Bookhout is significantly higher than the Library and this may be negatively affecting the electricity consumption at the Library/Auditorium (or vice versa). However, without a submeter, it is difficult to quantify the precise impact of sharing a chiller unit.

### Bookhout Lab Electricity Consumption

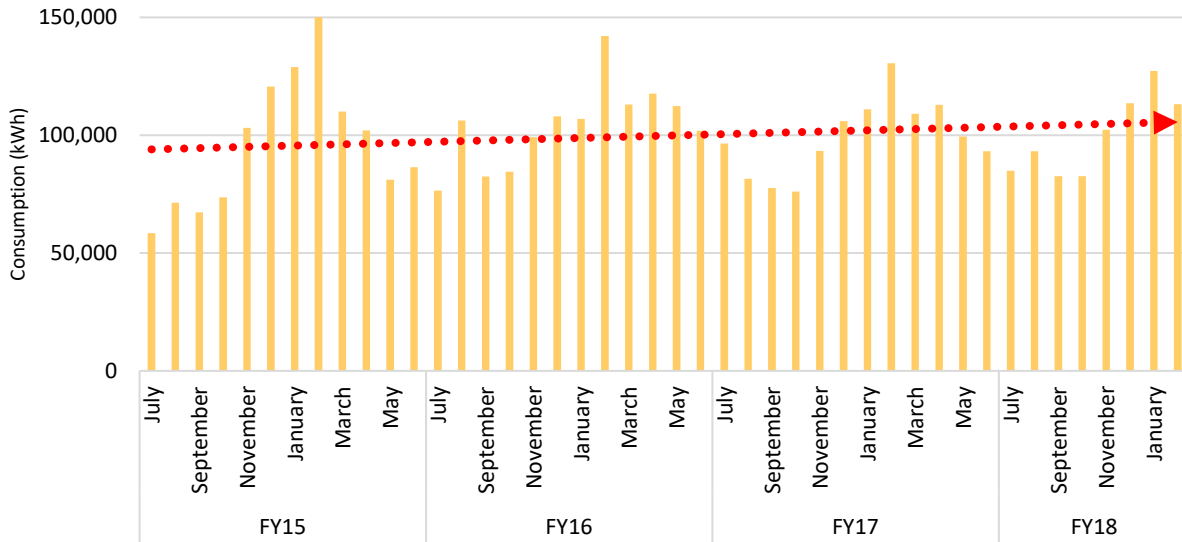


Figure 32. Bookhout historical electricity consumption pattern displays seasonality with peak load during the winter months. Overall consumption has increased 4% since FY15.

### Bookhout Laboratory Breakdown (FY17)

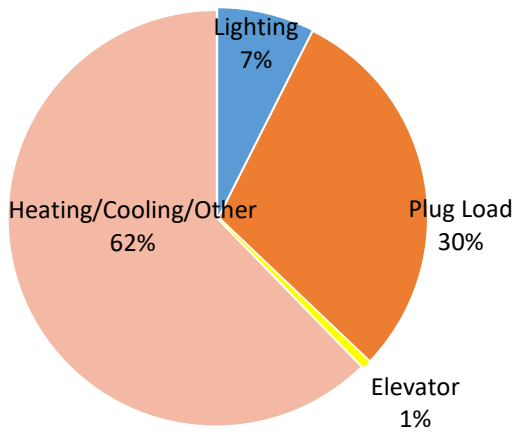


Figure 33. Bookhout breakdown in FY17 shows heating, cooling, and other make up 62%.

The end-use energy use breakdown in FY17 showed the heating, cooling, and other load accounted for 62% of the total load while lighting and plug loads combined accounted for 37% (Figure 33). The lighting fixtures were comprised of fluorescent light bulbs (F32T8 and F25T8) and the total estimated bulb count was 1,220. These are commonly used plug-in fluorescent tubes that consume 32W and 25W respectively. The building also had a variety of equipment including temperature freezers, refrigerators, incubators, environmental growth chambers, fume hoods, and other laboratory equipment.<sup>6</sup> Most refrigerators and freezers were scattered across the corridors of the building. Since those equipment are significant sources of heat, they may be contributing to the overall cooling load.

### Orrin Pilkey Laboratory

The Orrin Pilkey Laboratory is the second-highest electricity consumer drawing 19% of total DUML electricity consumption and has an EUI of 158 kBtu/ft<sup>2</sup>. The total emissions for FY17 were 221 MTCO<sub>2</sub>eq which is equal to 47 passenger vehicles driven for a year. Historical consumption patterns showed a 5% increase since FY15 with seasonality and peak loads occurring during the summer months, indicating the cooling load is greater than the heating load (Figure 34). This is consistent with the findings from the

<sup>6</sup> Laboratory equipment in the building included centrifuge, autoclave, spectrophotometer, PCR machines, heating block, circulator, cell sorter, osmometer, incubator, mixer, homogenizer, microscope, shaker, and circulator.

building survey as it houses a room with four ultra-low temperature freezers and two wall-mounted air conditioning (AC) units as well as a hallway with multiple freezers, refrigerators, incubators, and two wall-mounted AC units. The wall-mounted AC units were added to control for the additional heat produced from all the refrigerators and freezers and are running constantly throughout the year. This requires a significant amount of electricity considering each AC unit is estimated to consume 2,500 to 2,823 W.

### Pilkey Electricity Consumption

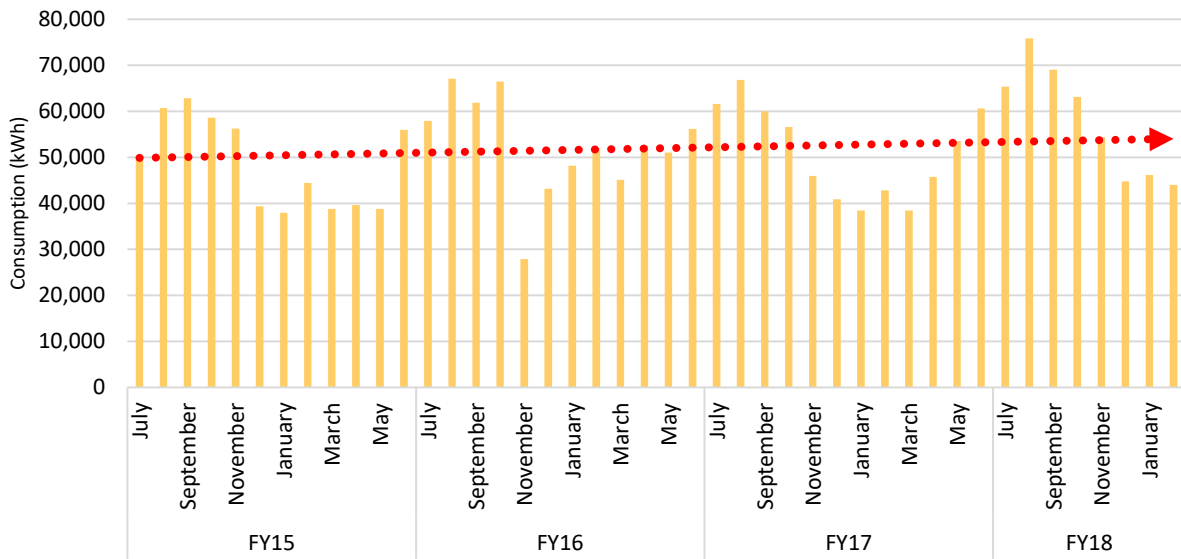


Figure 34. Pilkey Center historical electricity consumption displays seasonality with a 5% increase since FY15.

**Figure 35** shows the breakdown of the electricity usage which showed the heating/cooling load is the largest (52%) followed by plug load (40%), lighting load (7%), and the elevator (1%). The main lighting fixtures were comprised of fluorescent light bulbs (F32T8 and F25T8) and the total bulb count was 438. Even though Pilkey is a LEED Gold certified building, LED light bulbs were not used as a primary type of light bulbs. This represents an opportunity for energy efficiency through a lighting retrofit. Furthermore, several exterior lighting fixtures including the second-floor outdoor deck were illuminated during the day, indicating some of the sensor-activated lighting systems are not properly functioning.

### Pilkey Center Breakdown (FY17)

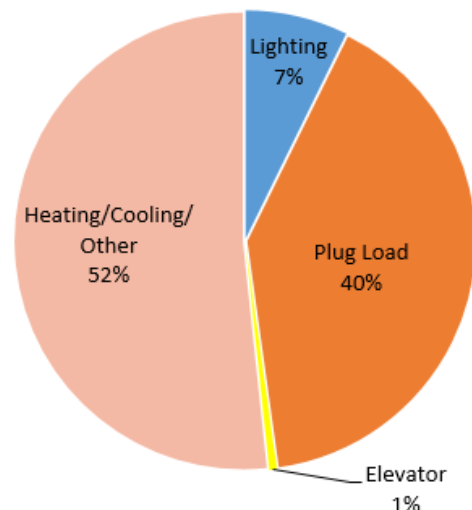


Figure 35. Pilkey Center disaggregated electricity consumption in FY17.

The laboratory spaces included a variety of equipment, much like the Bookhout Laboratory. Consequently, the plug load in FY17 accounting for 40% of the total load. Most notably, the ultra-low temperature freezers in the 203A – Freezer Room were estimated to consume 18 to 22 kWh per day. In comparison, a typical laptop consumes 37 kWh annually.

### Library / Auditorium

The Library is the third-highest electricity consumer at the DUML accounting for 16% of the total DUML electricity consumption and the highest EUI of 278 kBtu/ft<sup>2</sup>. The total emissions in FY17 were 230 MTCO<sub>2</sub>eq or equivalent to 49 passenger vehicles driven for a year. The historical trend showed a 14% increase since FY15 and peak loads occurring over the summer months (**Figure 36**).

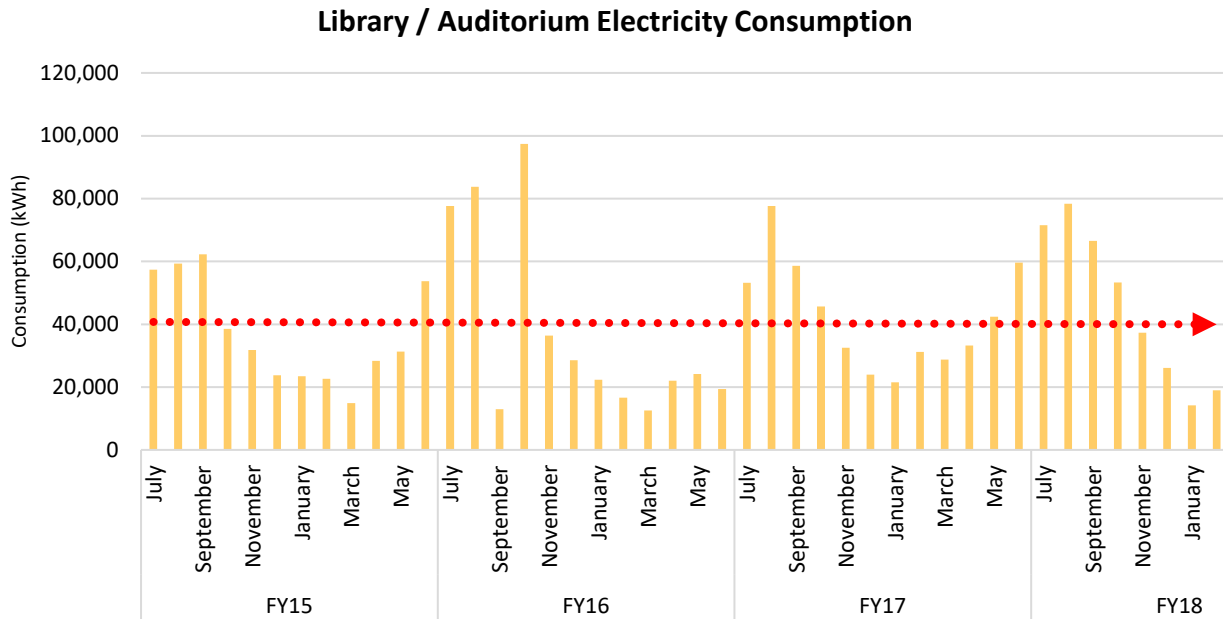


Figure 36. Historical consumption trend displays seasonality with peak load during the winter months. This figure only contains the electricity load and the heating load from propane is not included.

The building survey revealed that plug load is minimal accounting for only 1% of the total energy use (**Figure 37**). The Library/Auditorium only contains common appliances including computers, printers, screens, and networking equipment that consume minimal plug load compared to laboratory buildings. The driver behind the high cooling load may be stemming from the shared chiller unit with Bookhout Laboratory. Consequently, the Library may be negatively impacted from this shared unit since the Bookhout has a higher cooling load. Considering this fact, the cooling load represented in this analysis may not reflect the buildings true consumption. Moreover, the lack of basic weatherization such as double pane windows and insulations in the building materials as well as the large space volume of the auditorium may be contributing to the high heating load.

The lighting fixtures comprised of fluorescent bulbs (F34T8 and F32T8) and the total bulb count was 656.

### Library / Auditorium Breakdown (FY17)

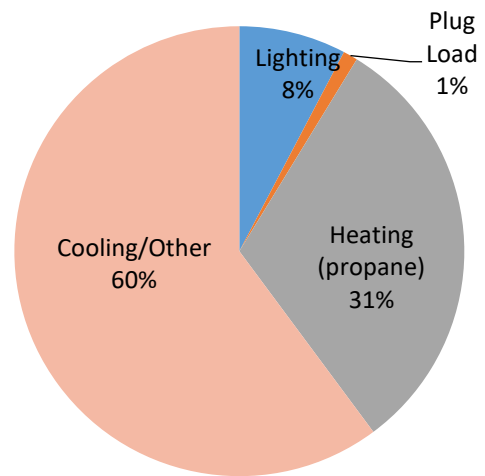


Figure 37. Library / Auditorium breakdown in FY17 showed a significant cooling load followed by heating, lighting, and plug load.

*Repass Center*

In FY17, the Repass Center used 4% of the total electricity at the DUML with an EUI of 80 kBtu/ft<sup>2</sup>. The total emissions were 44 MTCO<sub>2</sub>eq which is equivalent to 9 passenger vehicles driven for a year. The total electricity consumption has been increasing since FY15, totaling an 8% increase. This may be a result of increased cooling and heating load, increased number of laboratory equipment, or a combination of the two. The historical trend indicated seasonality with peak loads during the summer months (**Figure 38**).

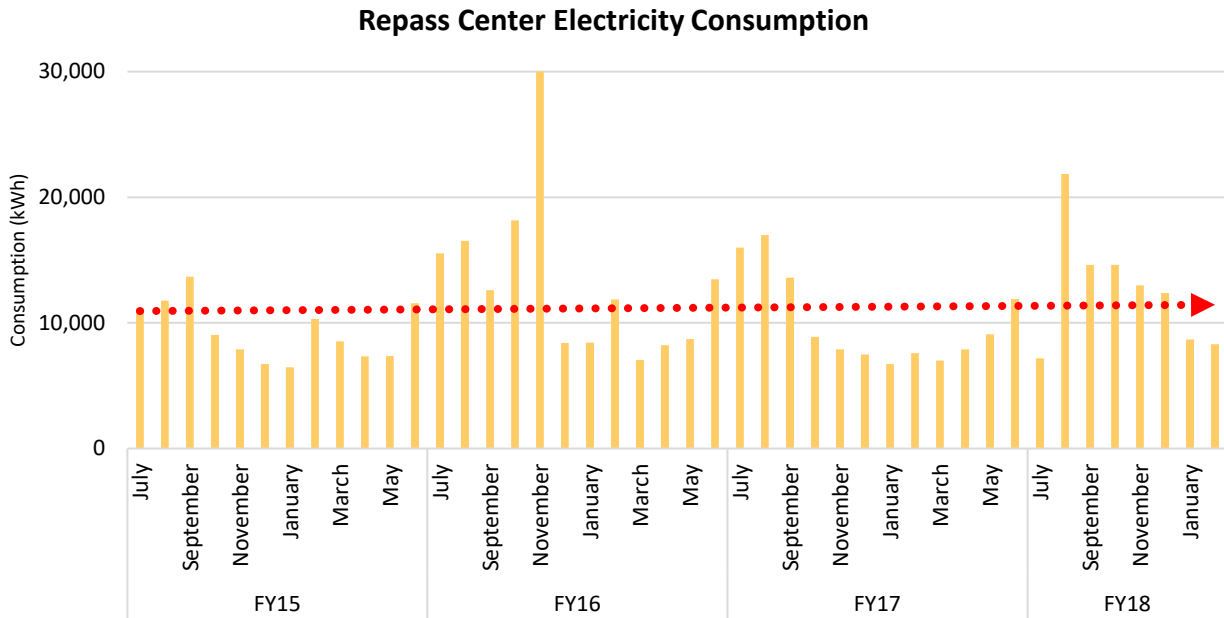


Figure 38. The historical electricity consumption shows seasonality with peak load during summer months. The total annual consumption has increased by 8% since FY15.

The disaggregated energy use breakdown in FY17 is shown in **Figure 39**. The largest load came from cooling and heating (52%) followed by plug load (37%), and lighting (11%). The main type of lighting fixtures were fluorescent bulbs (F32T5 and F28T5) and the total bulb count was 158.

The majority of plug load came from the AC unit in Room 111 which contains network equipment including servers and switches. These equipment constantly generate heat in this isolated room requiring additional cooling. Therefore, the AC unit is set to cool at 70 degrees fahrenheit throughout the year to compensate for the additional heat sources.

The building has a number of performance issues with the installed environmental features and the FMD is currently investigating potential solutions. One problem is the geothermal circulation system that utilizes the high temperature heat in the groundwater below the building. However, the actual temperature of the heat was well above

**Repass Center Breakdown (FY17)**

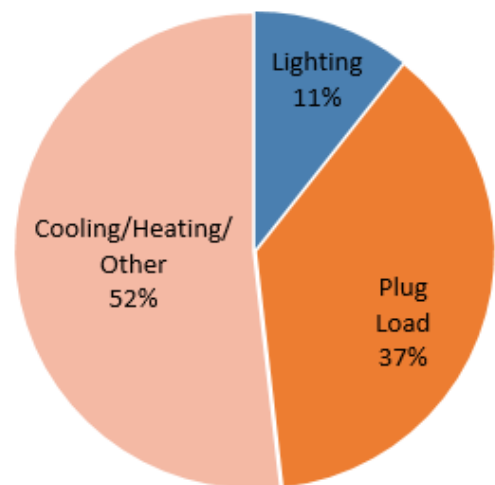


Figure 39. The Repass Center total electricity consumption in FY17.

the designed temperature (S. Palumbo, personal interview, December, 2017) and required additional cooling to compensate. The green roof and the cistern system have begun to deteriorate, leaking rainwater below into the electrical room. The insulation materials for piping have also deteriorated.

### Dining Hall

The Dining Hall’s total electricity consumption in FY17 was equivalent to 36 MTCO<sub>2</sub>eq or 8 passenger vehicles driven for a year. The consumption trend showed a 2.9% increase from FY15 to FY17 with peak loads occurring during the summer months (**Figure 40**). This seasonality suggests the cooling load is greater than the heating load. The propane usage was discussed in scope 1 emissions and is only used for cooking purposes.

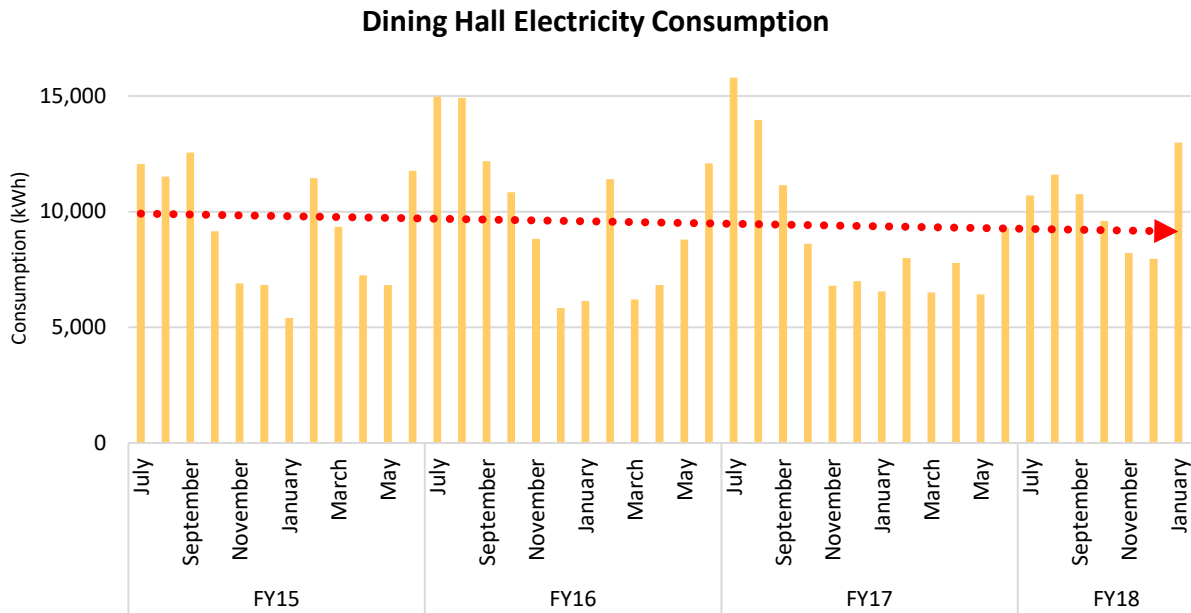


Figure 40. Dining Hall electricity consumption patterns indicate seasonality, peaking during the summer months.

The disaggregated breakdown (**Figure 41**) showed the propane usage for cooking made up more than half of the total energy use. Although the building has commercial-grade kitchen appliances including freezers, refrigerators, beverage machines, dish washers and cold storage rooms, most cooking equipment are propane-powered, lowering the electricity use. Nevertheless, the building contains a few high-electricity consuming appliances such as soda fountains, hot food base, and commercial-grade coffee machines.

The main type of light bulb was fluorescent bulbs (F32T8) and the total bulb count was 138.

### Dining Hall Breakdown (FY17)

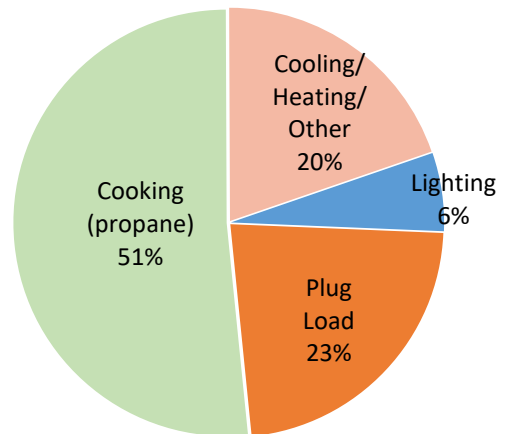


Figure 41. Dining hall breakdown shows that propane for cooking is the main energy consumption.

### Scope 3

Scope 3 emissions include the other indirect emissions from activities but occur from sources not owned or controlled by the institution. For this analysis, this includes air travel and employee commuting.

The total Scope 3 emissions at the NSOE in FY17 was 1,273 MTCO<sub>2</sub>eq or 273 passenger vehicles driven for a year. The breakdown shows that 23% of emissions were from commuting and 77% of emission were a result of air travel (**Figure 42**).

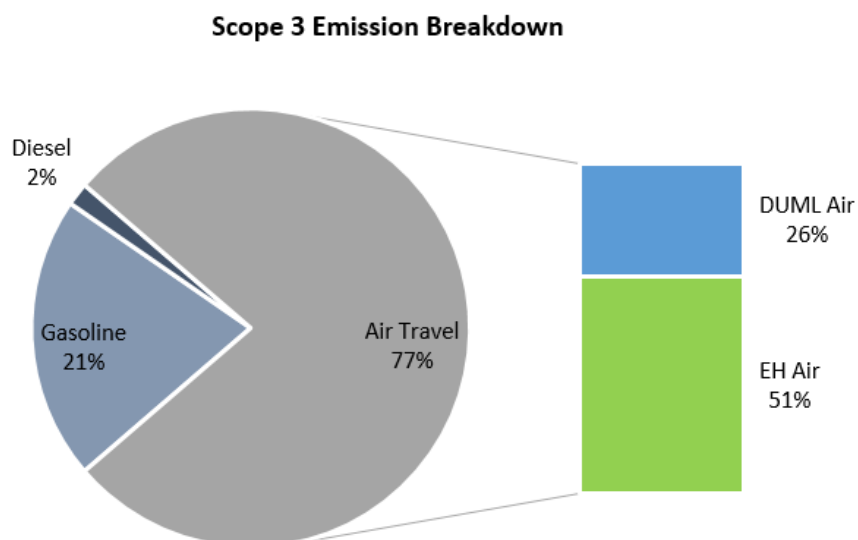


Figure 42. The total emissions from Scope 3 for Durham-based NSEO faculty and staff, and the Duke Marine Lab makes up 1,273 MTCO<sub>2</sub>eq. 77% of the emissions are a result of air travel by faculty and staff.

### Commuting

In the 2007 GHG inventory for Duke at large, transportation accounted for approximately 23% of the total GHG emissions with 52% of those emissions from commuters (Duke University, 2009).

#### Durham

The average miles per trip calculated via the annual Duke faculty and staff survey data is 11.39 miles one-way. **Figure 43** details the various modes of transportation used by faculty and staff based in Durham. To remain consistent with the Duke University GHG emissions inventory, the percentages in this analysis mirror the percentages used in the calculation for Durham-based employees. From here one can see the largest percentage of people drive alone to campus daily.

Using the average fuel efficiency data from the U.S. Department of Transportation, the average fuel efficiency of cars is around 23 miles per gallon (Sustainable Duke, n.d.). These data are consistent with the latest GHG emissions update for the university. Using these data for the 45 faculty and 95 staff members based in Durham, the total fuel consumption for FY17 is 25,376 gallons of gasoline and 2,140 gallons of diesel. This equates to about 250 MTCO<sub>2</sub>eq for the most recent fiscal year.

### Modes of Commuting for Durham-Based Employees

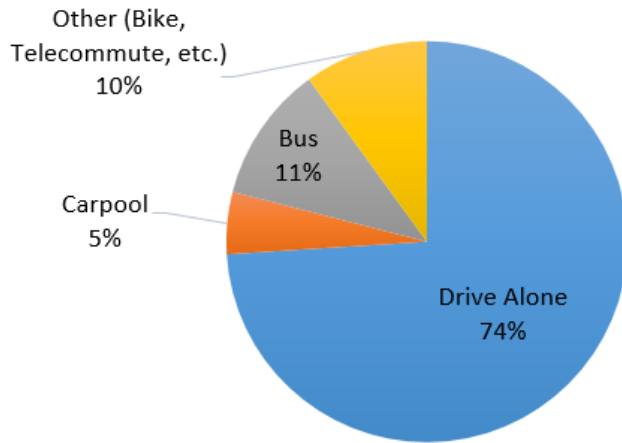


Figure 43. Modes of transportation for Durham-based faculty and Staff. These percentages are used in the Duke University GHG emissions inventory.

### Marine Lab

Figure 44 shows where DUML faculty and staff live in relation to Pivers Island. The average miles per trip calculated via a straight-line GIS analysis was 4.95 miles one-way.

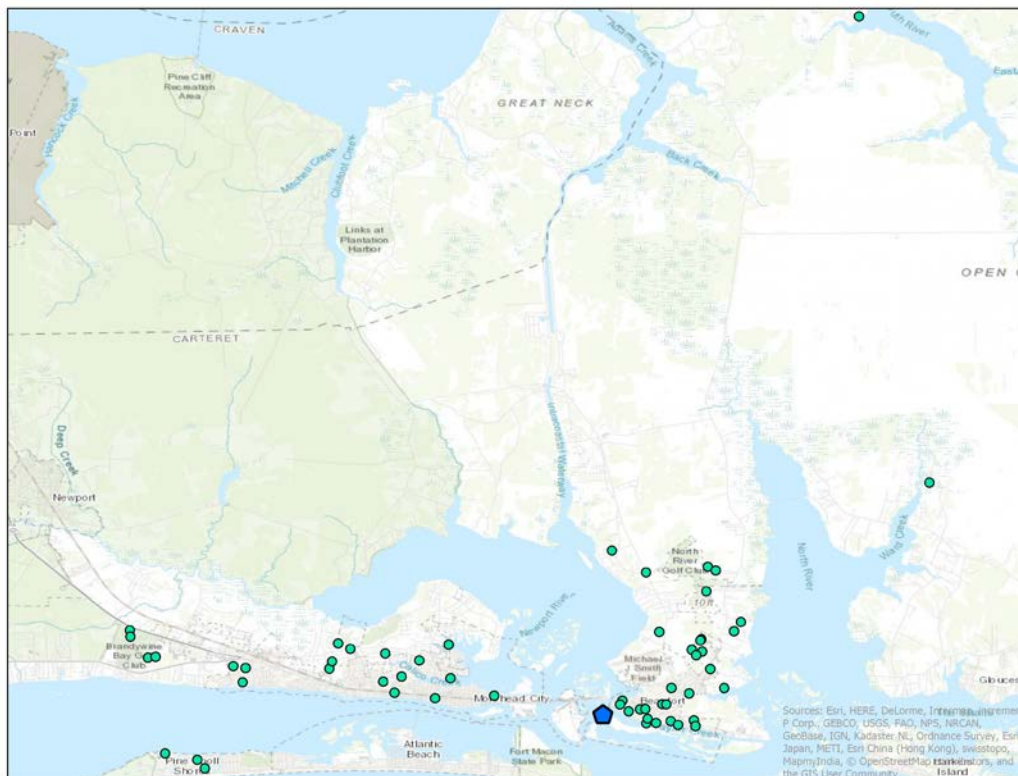


Figure 44. GIS analysis of commuting distance between faculty and staff residences and the DUML. Green circles represent residences and the blue pentagon represents the DUML.

The transportation survey distributed in December 2017 to the DUML community received 110 responses, which is representative of most of the DUML community. The questions in this survey are in the **Appendix**. Data from this survey yielded the various modes of transportation used by faculty and staff (**Figure 45**), and the modes of transportation use by employees. Values for the 25 faculty and 25 staff were used to calculate commuting emissions for the DUML. This resulted in a total fuel consumption for FY17 as 4,456 gallons of gasoline. This equates to around 40 MTCO<sub>2</sub>eq for the most recent fiscal year.

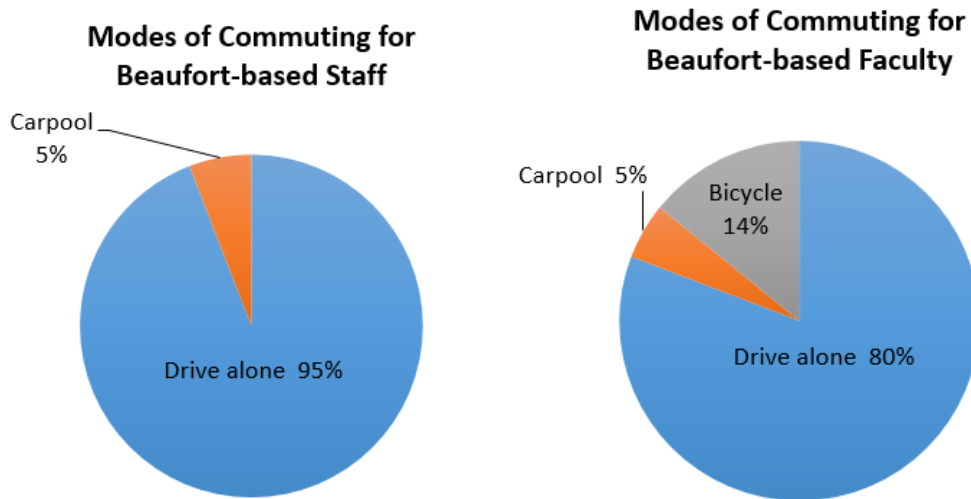


Figure 45. Modes of transportation for staff and faculty members at the DUML. The majority drive alone to and from campus.

The transportation survey also asked about the impact and perceptions of the new Gallants Channel Bridge scheduled to open in the spring of 2018. In response to the question of if the new bridge would affect the means by which the respondents travel to and from the DUML, 37% of responded yes, while 63% were unsure and/or did not believe the bridge would have an effect. Some respondents believed the bridge would have a positive effect on their commute by shortening the amount of time spent per day. Others commented that the bridge would change their ability to bike, walk, or would lengthen their commute distance. From this survey, it does not seem the new bridge will dramatically change modes of transportation as the majority drive alone.

It is important to note that the GHG analysis did not include trips that faculty and staff members make to and from main campus, only their daily commute, to stay consistent with Duke's overall GHG calculation. However, it interesting to examine how many round-trips Beaufort-based employees take each year. The results from the transportation survey showed that on average each person visits Durham nine times per year. With Durham being about 180 miles away from Beaufort, these visits can potentially have a 12.5% increase on the commuting emissions if this was formally added into the GHG emission inventory. In addition to taking nine trips a year, carpooling is infrequent when traveling between the DUML and Durham. **Figure 46** details the frequency of carpooling and shows that 58% of people do not carpool frequently.

### Frequency of Carpooling to Durham from DUML

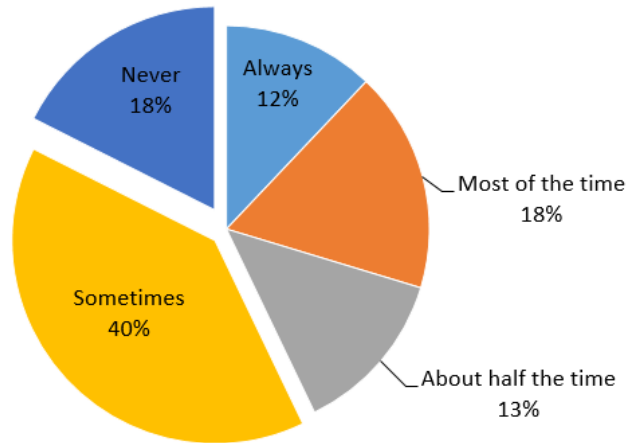


Figure 46. Frequency of carpooling to Durham from the DUML. While not formally included in the GHG emissions inventory, it is important to note that 58% of do not carpool frequently when taking this trip.

### Air Travel

Overall, emission from air travel took up about 40% of total emission of the NSOE for the FY included in this analysis. For FY17 air travel accounted for 985 MTCO<sub>2</sub>eq or 211 passenger vehicles driven for a year. Emissions have decreased by 20% in FY17 compared to FY15. However, this is mainly as a result of the reduction in air travel expenses rather than a decrease in the number of trips taken, as the university calculates miles flown from a dollar amount. **Table 7** details the number of trips taken for the NSOE for the years of analysis and the emissions that can be attributed to these trips. Air travel emission for employees based in Durham campus decreased, while emission by employees of DUML increased. However, because only trips paid for and logged in the university travel system are included in the inventory, not all travel by faculty and staff is included in this inventory and is most likely an underestimate of total emissions.

	<i>FY15</i>	<i>FY16</i>	<i>FY17</i>
<i>Total Trips</i>	1,325	1,418	1,326
<i>EH Trips</i>	1,040	1,014	837
<i>DUML Trips</i>	285	404	489
<b><i>Total Emission (MTCO<sub>2</sub>eq)</i></b>	<b>1,226</b>	<b>1,237</b>	<b>985</b>

Table 7. Number of trips taken by the NSOE and the total emissions attributed to these trips.

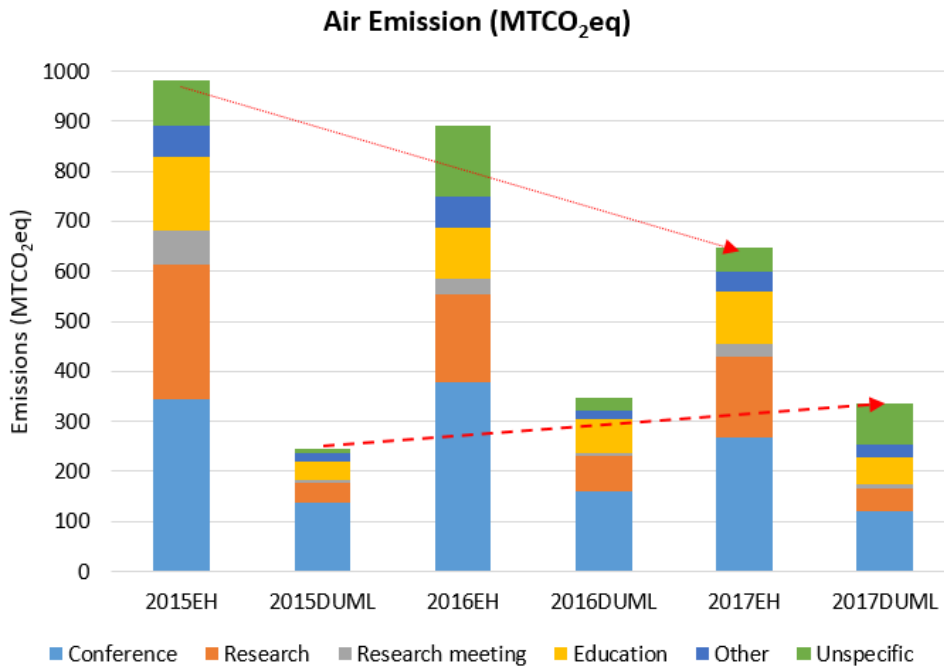


Figure 47. Air emission of EH and DUML categorized by the reason for travel.

The main reasons for air travels are conferences and research (**Figure 47**). Around 40% of air emissions are caused by faculty and staff members attending and flying to conferences. Travel for research contributes 25% of air emission by Durham-based employees and 13% of air emission by DUML-based employees. Education activities, are 16% of air emission, including invited speakers, travel classes, and advanced courses. In addition, there are some unspecific trips which accounted for 25% of trips for DUML in FY17. However, only trips paid by the School are included in the inventory. Since some travel classes and field trips involved air traveling were not paid by Duke, our calculation excluding those trips might under-estimate the actual air emission for the whole school.

## Recommendations

As mentioned in the objective section, the results of this analysis produced possible avenues for climate action, education, and energy efficiency at the NSOE. The student team on this project also presented their findings to various stakeholders at the NSOE to share the results of this analysis. This section will detail the recommendations identified by the team.

### Climate Action Plan Feasibility

The first step of developing a CAP is the GHG inventory which was initiated in this analysis. Although this study did not set reduction targets or create a formal pathway towards climate action, it was able to set the baseline for the NSOE. If the NSOE and DUML administration wish to set formal targets or form a CAP, this report, the student team, and Sustainable Duke will be able to support this mission. As the School of the Environment at Duke, it is important to set a formal commitment to climate action via a CAP.

However, there may be barriers to the development of specific CAPs at Duke. Although the creation of a CAP may be relatively easier at the NSOE due to support from administration, this idea may not garner sufficient support in all areas of campus. In addition, many schools share buildings and their footprint is difficult to clearly define or separate which makes an initial GHG analysis difficult. For example, in this analysis the team chose to not include the LSRC building even though this building houses a large subset of the NSOE. However, this building is quite large and is shared by over 20 different departments at the university. This makes it difficult to divide out emissions and impacts. Lastly, the time it took to create the baseline GHG emissions for the NSOE took an entire academic year and a collaborative team. If this idea was to be replicated in other parts of the university a proportional amount of time and effort would be required for a complete analysis.

### Overall Recommendations

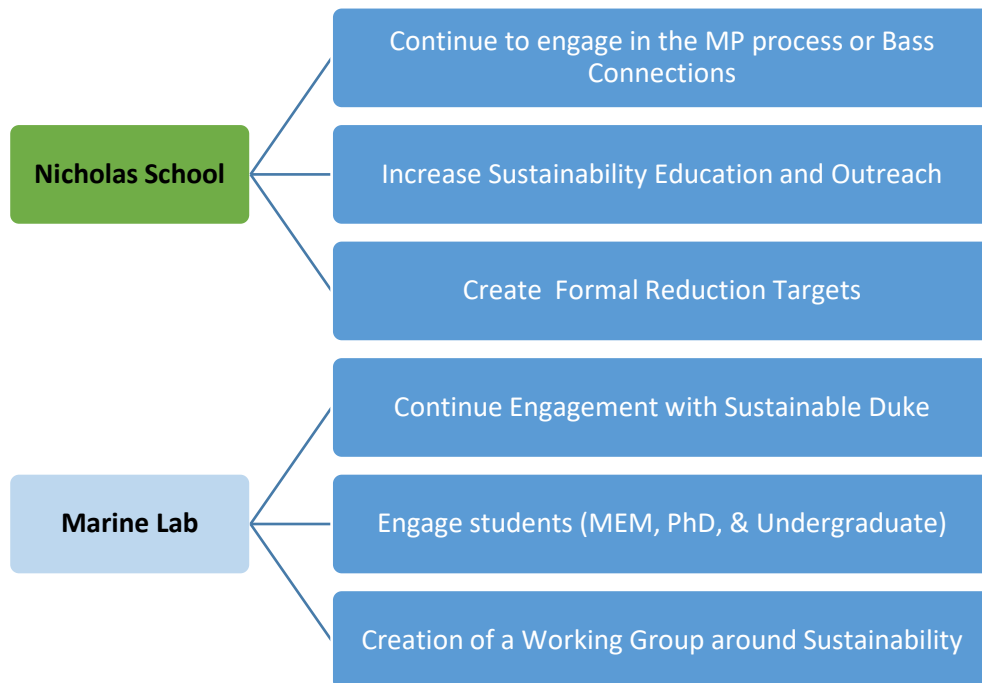


Figure 48. Overall recommendations for the Nicholas School.

Overall recommendations for the Nicholas School and the Duke Marine Lab are summarized in **Figure 48**. The school should continue to actively engage on climate action initiatives at various levels. Continued engagement in the Master’s Project or Bass Connections Project space would allow for continued engagement throughout the school year from students, faculty, and staff of all disciplines on this topic. In addition, as a school of the environment, there must be continued sustainability education and outreach on climate action. If the school administration feels strongly about creating a formal pathway to climate neutrality, then the creation of formal reduction targets could be established with the input of students and other campus stakeholders.

Specifically, for the DUML it will be important to create a formal working group around sustainability to ensure on-going progress. Due to the community atmosphere that is built at the DUML, the student team believes it is important to have active engagement with students, faculty, and staff of all levels on the island. The establishment of the working group can include stakeholders of various affiliations, all with the common goal of increasing the sustainability efforts of the lab. In addition, through the

duration of this project the DUML administration has been actively involved with Sustainable Duke, a relationship that will continue to have benefits in the long-term as both entities strive towards climate neutrality.

It is also important to note that this analysis provides a baseline of emissions and would allow for goal setting and implementation of reduction targets in some major areas. However, this analysis is not complete for the NSOE. The analysis does not include LSRC, another major space where the NSOE is located. Additionally, while the analysis attempted to systemically follow the Duke GHG emissions calculations, there were some categories that were omitted due to size and lack of data. If the NSOE wants to continue tracking these metrics it will be important to create a more complete GHG inventory after filling in missing the data gaps. With continued engagement via a sustainability working group, collaboration with Sustainable Duke, and student participation via a future MP or Bass Connections project, a more complete pathway towards climate neutrality is feasible for the NSOE.

### Scope 1

Recommendations for Scope 1, direct emissions, are summarized in **Figure 49**. These recommendations are broken down into two categories: Environment Hall and Marine Lab.

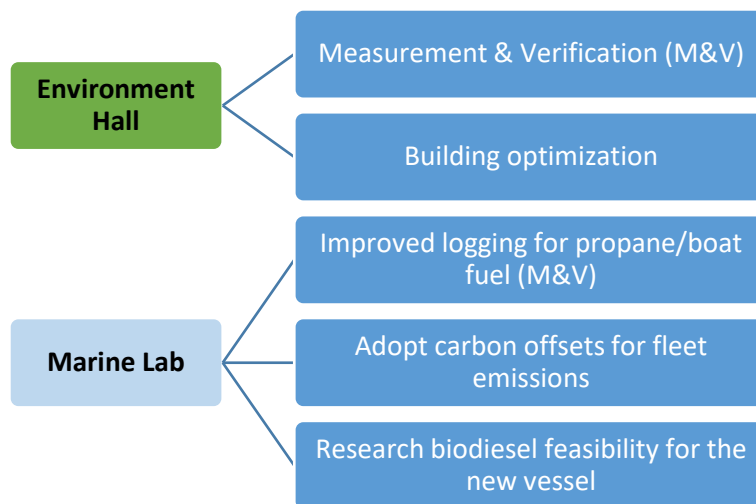


Figure 49. Recommendations for Scope 1 emissions.

#### Environment Hall

The only source of emissions from Scope 1 at EH is the natural gas consumed to provide heating. This use has been reduced significantly since FY15, due to the FMD’s effort to optimize the building and ensure its LEED performance. Further optimization of building operation may help reduce consumption of natural gas and emissions in the future. However, accurate monitoring of the building is essential to improve the building performance. A continuous measurement and verification process will help identify any other malfunctioning systems.

#### Marine Lab

In this analysis, propane consumption for previous years was estimated based on weather conditions and fuel consumption for boats was estimated based on a trip record. Data for propane and boat fuel usage at the DUML was limited and not recorded in a systematic way. To calculate an accurate measurement of emissions, it is essential that the DUML creates a system to log and track this data.

In addition, the team found that the new vessel will become one of the biggest contributors to all emissions, projected to be 58% of FY17 emissions for the DUML (973 MTCO<sub>2</sub>eq). Alternative fuels, like biodiesel, are considered a cleaner substitute for traditional petroleum diesel. The team suggests conducting a feasibility study for adopting biodiesel for new vessel, as well as looking into this possibility for the older vessels. If biodiesel options are available, a simple cost benefit analysis would help determine if the feasibility.

Lastly, the use of carbon offsets is another option to achieve carbon neutrality. According to the ACUPCC, a carbon offset is the reduction or removal of a MTCO<sub>2</sub>eq that is used to counterbalance or compensate for (“offset”) emissions from other activities. Carbon Offset can work in a few different ways, however, the DUML could work with Sustainable Duke and the Duke Carbon Offsets Initiative to work on developing projects around offsets in Beaufort or exploring other opportunities to reduce their emissions.

## Scope 2

Recommendations for Scope 2, emissions from purchased electricity, are summarized in **Figure 50**. These recommendations are broken down into four categories: Measurement & Verification (M&V), Behavioral, Energy Efficiency, and Microgrid.

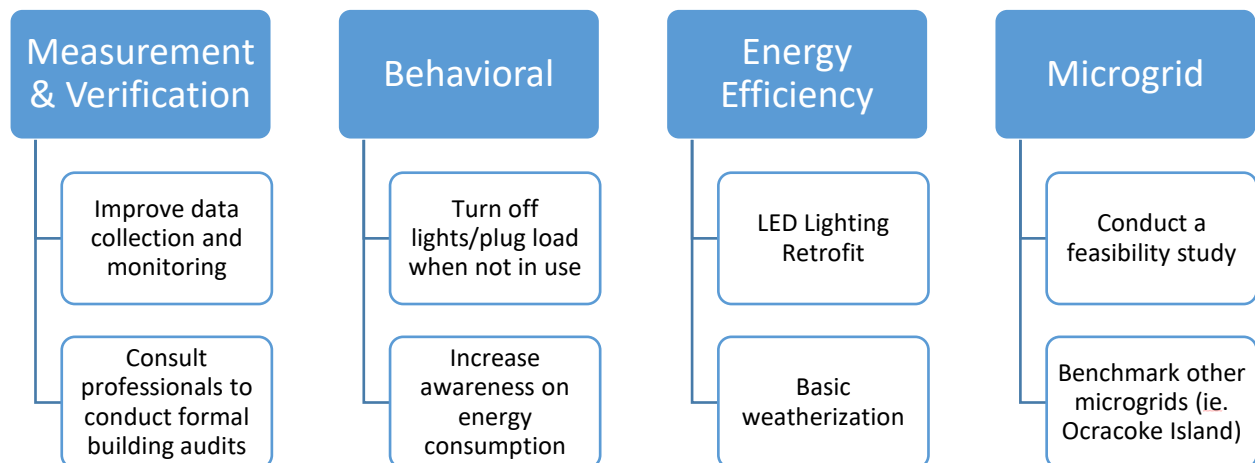


Figure 50. Recommendations summary for Scope 2 emissions.

### Improved Measurement & Verification

Measurement and Verification (M&V) is a process to quantify and determine the energy savings from a conservation measure (Federal Energy Management Program, 2015). It is particularly helpful when attempting to implement energy efficiency programs, conservation measures, or certifications such as LEED (Richardson, 2017). Key activities include meter installation, data collection, data verification, monitoring, quality assurance, and systematic management (Efficiency Valuation Organization, n.d.). In other words, the first step towards achieving energy efficiency is systematic data collection, as it is difficult to implement any programs without baseline data.

Improved M&V is not limited to Scope 2 as it applies to all aspects of this project. However, the biggest benefit of M&V may be seen in this category. Lack of data was the main challenge and a significant amount of time was invested in data collection. Therefore, we recommend improving the M&V process

to ensure sufficient data is systematically collected, managed, and verified. Specific attention should be given to EH as there was a large discrepancy between the estimated building performance and its observed performance. Although FMD has corrected various issues, continuous measurement and, more importantly, verification is required to ensure the building performs as designed in the future. Therefore, we strongly recommend improving the M&V process at both EH and DUML.

Additionally, it is recommended that a formal building audit is completed by contracting a third-party, with the assistance of FMD. An in-depth formal audit on key buildings will allow for a better understanding of the buildings energy use. Although this team established a baseline disaggregated energy use in six major buildings, none of the team members are certified energy engineers or energy managers. It will be important to consult certified professionals to improve data accuracy and derive a detailed assessment of energy use.

### *Behavioral Change*

While the LEED certified buildings at DUML, EH, and several other buildings have a motion-sensor activated lighting system, most buildings lack this feature. During building walkthroughs, the team often observed lights turned on when not in use. There is an opportunity to increase awareness on energy use and engage occupants to become active participants in energy conservation measures. Because individual occupants are not responsible for the utility bills, it is easy to observe a diffusion of responsibility which results in lack of active participation on energy conservation. Therefore, it is critical to increase awareness and give ownership to occupants through several strategies. Reductions in energy use will in turn effect future Scope 2 emissions.

As an example, installing stickers and signs next to light switches can inform occupants about the energy use and encourage them to turn the lights off when not in use. The DUML can mimic some of the features found in EH like an interactive screen on the lobby floor that displays information related to energy use and stickers near all light switches and elevators. The team encourages the NSOE to collaborate further with Sustainable Duke to find creative ways to engage occupants on building energy use and behavior.

### *Energy Efficiency*

The FMD has plans to conduct a lighting retrofit for the entire Duke University campus and will conduct a lighting audit at DUML in coming months. A preliminary LED lighting retrofit estimation for EH, Bookhout, Library, Pilkey, Repass, Dining Hall, and the Recreational Facility showed an estimated annual savings of 63 MTCO<sub>2</sub>eq and \$12,452 in utility cost (**Table 8**).<sup>7</sup> The total payback period is approximately 2 years.

<b>LED Lighting Retrofit Estimation</b>	
Total Annual Energy Savings (kWh)	400,694
Total Annual GHG Savings (MTCO <sub>2</sub> eq)	144.6
Total Annual Energy Savings (\$)	\$28,730
Total Energy Savings (10 Years)	\$351,391
Payback (years)	1.97

*Table 8. Estimated LED lighting retrofit results.*

<sup>7</sup> This assumed changing F34T8, F32T8, F28T8, and F25T8 to a 13W LED bulb, F14T8 to a 9.5W LED bulb, and downlights to 10W LED bulb. All bulbs were assumed to run 8 hours per day with supplied electricity price of \$0.0717 per kWh and a 2.1% inflation rate for 10 years. The estimated labor cost was set at \$5.99 per bulb and the bulb cost was \$7 each.

For lab spaces, considering freezers and refrigerators are placed in the hallway in both Bookhout and Pilkey, there is an opportunity to reduce energy use by consolidating equipment and reducing the number of individual units. Moreover, several of freezers are old, presenting an opportunity to upgrade to newer energy efficient models.

For EH, the team recommends considering turning off the lights above the window by the thermal corridors during the daytime (**Figure 51**). There are an estimated forty-four 28W fluorescent light bulbs installed in this manner and at least half are running continuously. Because the thermal corridor already receives an abundant amount of natural light, these bulbs provide minimal illumination. Additionally, the team identified several exterior lightings that were turned on continuously that could be switched off during the daytime.



*Figure 51. Environment Hall thermal corridor windows have lighting fixtures above that could be turned off during the day (Payette, n.d.)*

#### *A Microgrid Feasibility Study*

Scope 2 is the largest GHG emissions contributor to the total NSOE emissions and at the DUML. Considering that purchased electricity is dependent on the energy provider's generation fleet, it is difficult to directly influence their operations and anticipate rapid transition to emissions-free generation fleet. Therefore, establishing partial or full energy independence from the electric grid is an alternative to achieving significant emissions reduction. The main value propositions of a renewable microgrid coupled with sufficient storage include: 1) improved efficiency from reduced energy intensity and distribution system loss, 2) improved reliability from near 100% uptime for peak loads, 3) environmental sustainability from renewable generation, 4) improved cyber and physical security, and 5) better electrical quality by providing a more stable power (Dohn, 2011). Furthermore, the electricity expenditure could be eliminated which was approximately \$204,000 in FY17.

One example is the microgrid at the Ocracoke Island, North Carolina. This isolated tourist island completed a microgrid system in 2017 to address the power outages and high electricity rates (Walton, 2017) (**Figure 52**). This microgrid included a 15 kW solar PV system, a 500 kW battery storage, a 3 MW diesel backup generator, and demand response resources (Wi-Fi connected smart thermostats and water heaters).

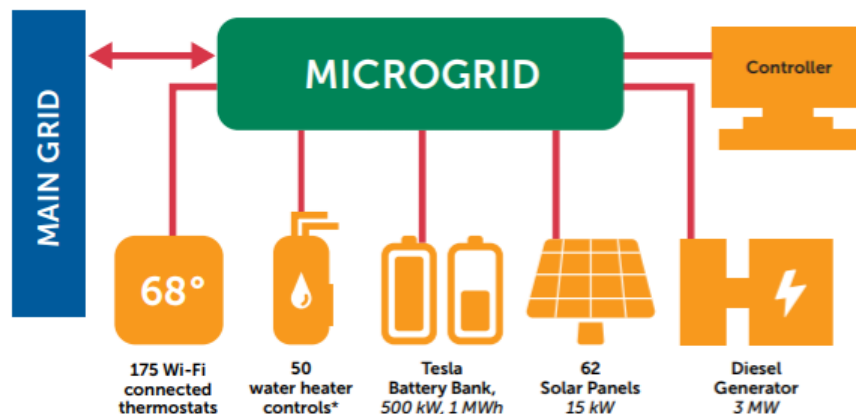


Figure 52. Ocracoke Island's microgrid system overview (Walton, 2017).

One of the biggest challenges is the cost. Because each microgrid project is unique, the generalized costs or metrics tend to vary greatly. The typical cost range and potential generation assets are shown in **Table 9**. Every project is different, and the capital cost will depend on the size of the microgrid, asset selection, existing assets, load sensitivity, load control potentials, distribution configurations, and many other factors (Dulaney, Adams, Musilek, & Meagher, 2017).

<i>Technology</i>	<i>Cost range (\$)</i>	<i>Note</i>
<i>Microturbine</i>	\$1000 – \$1,500	
<i>Combined heat &amp; power (CHP)</i>	Highly variable	Capital cost is subject size and complexity of the project
<i>Wind (\$/kW)</i>	\$2,000 – \$5,000	Smaller turbines usually cost more
<i>Solar (\$/kW)</i>	\$1,600 – \$2,500	Main factor is the size of the panel
<i>Battery storage (\$/kWh)</i>	\$500 – \$1,000	Main factor is the size
<i>Fuel cell (\$/kW)</i>	\$7,000 – \$10,000	
<i>Reciprocating engine (\$/kW)</i>	\$450 – \$700	Natural gas fired engines are often priced higher than diesel engines
<i>Demand response</i>	Opportunity cost	Generally the most cost-effective resource

Table 9. Potential resources for a microgrid and its estimated cost range in 2017 (Source: Dulaney et al., 2017)

The team recommends conducting a microgrid feasibility study to identify the optimal installed capacity of generation, electrical requirements, generation resource portfolio, costs, risks, and policy.

## Scope 3

Recommendations for Scope 3, indirect emissions from transportation, are summarized in **Figure 53**. These recommendations are broken down into two categories: Air Travel and Commuting.

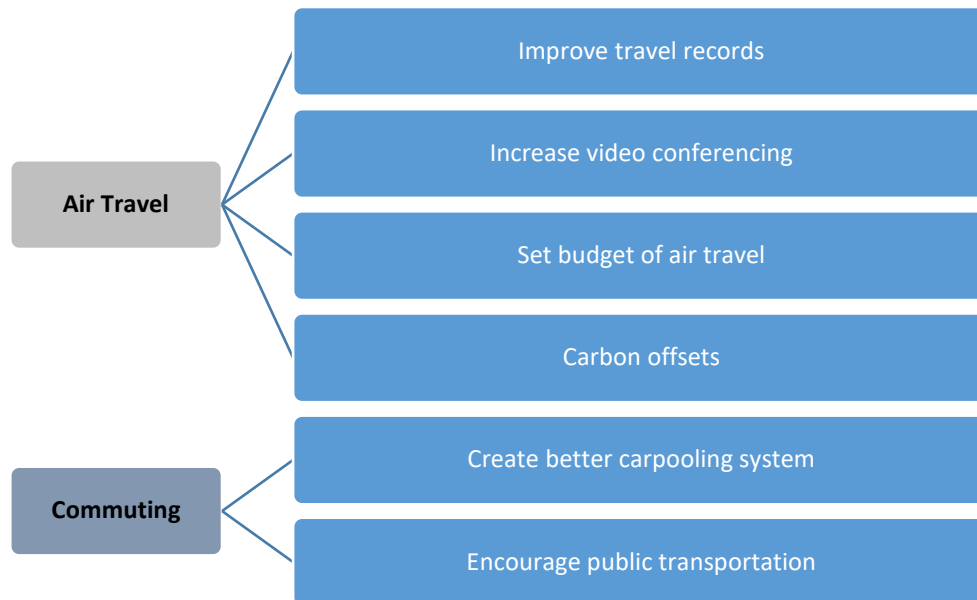


Figure 53. Recommendations for Scope 3 emissions.

### Air Travel

The addition of an air travel management system would help with increased documentation of all trips taken by faculty and staff at the NSOE. The university currently estimates flight miles by ticket price, but there would be greater accuracy if total miles flown was recorded per trip. In addition, this system would increase awareness on the emissions associated with their air travel to the faculty and staff community at the NSOE.

Secondly, a fixed budget should be made for air travel to limit unnecessary flights. For example, the American Geophysical Union (AGU) meeting engages more than 20,000 people from all around the world at one annual conference. However, the organizers are now questioning if this annual meeting is even necessary. This one conference accounts for more than 1,500 MTCO<sub>2</sub>eq emission each year (Parrish, 2017). In light of this fact, the NSOE should set a policy where video conferences are encouraged. However, when air travel is inevitable, faculty and staff must go through an approval process according to this set standard.

Duke is currently working on carbon offsets for air travel, which hopes to be continued in the future. The Duke Carbon Offset Initiative (DCOI) has launched three projects to produce offsets: Swine Waste-to-Energy, Residential Energy Efficiency and Urban Forestry. Earlier this year, Duke and Delta Airlines worked together supporting urban forestry to offset 5,000 carbon credits for Duke travel by planting trees in Durham communities. In addition to collaborative programs like this, Duke or the NSOE could find ways to add the cost of a carbon offset to each flight, and the cost of this offset could be charge to the faculty or staff member taking the flight.

### *Commuting*

For commuting, the implementation of a formalized carpooling system at the DUML will be effective as many faculty and staff live near each other. A carpooling system would reduce the number of cars on the road daily and could have an impact on GHG emissions if widely adopted. Although not directly impacting the calculated GHG emissions, there should be a special attention paid to trips between Beaufort and Durham. There is an opportunity for the DUML to make a difference by either choosing to travel less to Durham or increasing carpooling when a visit is necessary.

In Durham, a carpooling effort may be less accessible due to the varied nature of where faculty and staff live, however the NSOE can promote the use of public transportation and other lower emission ways of travel. Sustainable Duke should engage with Durham-based faculty and staff to create awareness around the impacts of commuting on GHG emissions and share alternative ways to commute.

### **Conclusion**

The total GHG emissions of the NSOE in FY17 was 3,295 MTCO<sub>2</sub>eq which equates to 1.26% of the total Duke University's GHG emissions for the same fiscal year. With knowledge on current GHG emissions and facilities operations, coupled with information on successes and challenges, it is feasible to implement a climate action plan specific to the NSOE. Although this study quantified GHG emissions and provided a deeper understanding of the culture and values of the NSOE, there is still more work to be done before a CAP is implemented. However, as a school of the environment within a university dedicated to sustainability, staying current on climate action is important to the overall mission. The results of this study suggest that the NSOE should continue active engagement on climate action.

To implement a formal CAP, understanding all levels of analysis are important. Throughout the duration of this project, the team collaborated with members, stakeholders, and administration of the NSOE on the work and the results of the analysis. Many have shown an interest in continuation of this work into the future. However, additional research must be completed to determine the most cost-effective GHG emission reduction opportunities. It is the hope that there will be further work at the NSOE to increase sustainability and environmental stewardship.

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## Appendix

### Methods

This section provides detailed discussions that were not covered in the main text.

#### Natural Gas Consumption

Only the Environment Hall consumes natural gas for heating purposes which is delivered by the central steam plants in Durham campus that uses natural gas other fuels to generate steam.

The Energy Witness reports monthly consumption in kilo Btus (kBtu) for units.<sup>8</sup> Because the GHG inventory uses an emission factor of 0.0529 MTCO<sub>2</sub>eq per 1 mmBtu of natural gas, a conversion process was necessary to derive natural gas consumption in mmBtu.<sup>9</sup> A number of conversion factors were used in this process (U.S. Energy Information Administration, 2017; U.S. Environmental Protection Agency, 2015):

- 1 kBtu of steam = 0.83752 pounds of steam
- Duke central steam plants uses 700 Mcf of natural gas to produce 1 pound of steam<sup>10</sup>
  - o 1 pound of steam = 700 Mcf of natural gas
- 1 Mcf of steam = 1.026 mmBtu of steam
- 1 mmBtu of natural gas = 0.0529 MTCO<sub>2</sub>eq

This can be expressed in an equation as follows:

$$\text{Input (kBtu)} \times \frac{0.83752 \text{ Lbs}}{1 \text{ kBtu}} \times \frac{700 \text{ Mcf}}{1 \text{ Lbs}} \times \frac{1.26 \text{ mmBtu}}{1 \text{ Mcf}} \times \frac{0.0529 \text{ MTCO}_2\text{eq}}{\text{mmBtu}}$$

For example, the consumption in February, FY18 was reported as 514,272 kBtu. Using the conversion factors, this would equal to 615 Mcf of natural gas or 631 mmBtu of natural gas. The associated GHG emissions from this consumption is 33.4 MTCO<sub>2</sub>eq and the fugitive emissions is 3.7 MTCO<sub>2</sub>eq. In total, 37 MTCO<sub>2</sub>eq of emissions occurred at EH during February, FY18.

#### Estimating Building Load Profile

In establishing the building load profile, active lighting hours were assumed uniformly across different buildings based on the area type: office, classroom, laboratory, common areas, bathrooms, exterior, storage, and kitchen (**Table 10**). For instance, lighting fixtures in Repass Center's classroom was estimated to be used 8 hours per day during a weekday and 2 hours per day during the weekend. The weekday was based on the standard 8-hour work hours and the 2 hours on weekends was estimated based on 20% of weekday usage which equals to 2,290 hours per year. This assumes the lights are turned off when not in use, however, the occupancy during the weekend may fluctuate depending on the time of the year. We anticipate the differences in actual usage will be averaged out throughout the year. Weekdays were assumed to be 260 days per year not accounting for any federal holidays.

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<sup>8</sup> The British thermal unit (Btu) is a measurement of heat and 1 Btu is the amount of heat needed to raise one pound of water by one-degree Fahrenheit. One Btu is approximately 1,055 joules (J).

<sup>9</sup> mmBtu refers to 1 million Btu or 1,000,000 Btu.

<sup>10</sup> Mcf refers to one thousand cubic feet and is used to measure natural gas quantity.

	<i>Weekday (hours/day)</i>	<i>Weekend (hours/day)</i>	<i>Total (hours/year)</i>
<i>Common area</i>	10	10	3,650
<i>Classrooms</i>	8	2	2,290
<i>Offices</i>	8	2	2,290
<i>Laboratory</i>	8	2	2,290
<i>Bathroom</i>	4	1	1,145
<i>Storage</i>	0.1	0	26
<i>Conference rooms</i>	8	2	2,290
<i>Exterior</i>	12	12	4,380
<i>Server rooms</i>	0.5	0	130

*Table 10. Estimated lighting hours for different area types used for establishing load profiles.*

## Assumptions and Limitations

### Rated Power vs. Actual Consumption

There is a large discrepancy between the rated power rating and the actual electricity consumption for appliances. This was only accounted for computer equipment because there is well-documented information for computers. According to Mills & Mills, the disparity between rated power and measured consumption is 49% during gaming mode and 64% during CPU stress test (Mills & Mills, 2016). In other words, the first set was 201W measured out of a 560W system (36%); and 414W measured out of an 810W system (51%). The article concluded that the using the nameplate power rating overestimates the actual electricity consumption, though there exists no standardized metrics to accurately capture the actual consumption for computers. Therefore, we used the average percentage of aggregated data which was equivalent to 39% of the rated power for peak load and 6% of the rated power for idle load (The University of Pennsylvania, n.d.)

### Bookhout Laboratory

Not all rooms were manually surveyed due to security reasons or simply to avoid invading private space. For office rooms that were not surveyed, a model was constructed. There are mainly three types of office rooms by size: large, medium, and small. For example, room 101 is large office houses four researchers, room 104 is a medium size that can house one to two researchers, and room 107 is a small one that houses one researcher. For a large office, plug load included a desktop computer, a monitor, a telephone multiplied by the number of occupants. For large rooms, a standard refrigerator (4.5 cubic feet) was added.

### Elevators

Electricity consumption for elevators in Environment Hall, Bookhout Laboratory, and Pilkey Laboratory was estimated using the Thyssenkrupp’s Energy Calculator (thyssenkrupp Elevator Corporation, n.d.). Since the exact specifications were unavailable, the annual consumption was averaged from different operational speed measured in feet per minute (fpm).

The parameters used in the model and results are as following:

	<i>Environment Hall</i>	<i>Bookhout Laboratory</i>	<i>Pilkey Laboratory</i>
<i>Building type</i>	Office	School	School
<i>Floors served</i>	7	3	2
<i>Application</i>	Hydraulic	Geared	Hydraulic
<i>Drive type</i>	Hydraulic – Wet	Motor generator	Hydraulic – Dry
<i>Capacity (lbs)</i>	4,500	1,500	4,500
<i>Speed (fpm)</i>	50	50	Used average between 50 – 200
<i>Cab lighting</i>	LED	Incandescent	LED
<i>Auto light shut-off</i>	On	Off	On
<i>Auto exhaust fan shut-off</i>	On	Off	On
<i>Total consumption (kWh/year)</i>	7,341	7,384	3,250

Table 11. Elevator input parameters and results using the Thyssenkrupp Energy Calculator.

## Transportation Survey

Thank you for agreeing to be a part of this survey. We are a team of three Nicholas School of the Environment MEM students working to collect data on behalf of the Duke Marine Lab and the Office of Sustainability to inform operational and educational practice around sustainability. The results of this survey will also be used in our Master Project in an effort to develop a climate action plan for the Nicholas School and the Duke Marine Lab.

This survey will ask a few brief questions about your personal transportation to and from the Duke University Marine Lab. The survey should take you around 3-5 minutes to complete. None of your individual responses will be linked back to you and no identifiable data will be collected in this survey. If you have questions about this study, feel free to contact Taylor Price at [taylor.price@duke.edu](mailto:taylor.price@duke.edu) or faculty adviser Jim Hench at [jim.hench@duke.edu](mailto:jim.hench@duke.edu)

Q1 What is your primary affiliation with the Duke Marine Lab?

- Staff member (housekeeping, food services, police, security, deans, directors, department managers, electricians, mechanics, plumbers, human resource, staff assistants, administrative, clerical, librarian, etc.)
- Faculty or researchers (full professors, associate professors, assistant professors, lecturers, instructors, researchers, etc.)
- Student (Undergraduate)
- Student (Masters, CEM, etc.)
- Student (Ph.D.) Or Post-Doc
- Not affiliated with Duke University

Q3 On average, how often do you travel to the Marine Lab from Home?

0 1 2 3 4 5 6 7

Days per week

Q2 What is your primary mode of transportation for commutes from home to campus ?

- Drive alone (in a car, van, SUV, or truck)
- Motorcycle moped/scooter
- Dropped off on campus (including uber, taxi)
- Carpool (2-6 people, 16 years or older)
- Vanpool (7 or more people)

- Public Transportation
- Ride a bicycle (includes electric bike and/or tricycle - e.g. ELF)
- Walk or run
- Telecommute
- Do not commute to campus
- Other \_\_\_\_\_

Q4 How many miles do you currently travel from your home to the Marine Lab, ONE-WAY?

\_\_\_\_\_

Q5 Please estimate the number of times you have traveled round-trip from the Marine Lab to Duke's Main Campus (Durham) in the calendar year 2017?

\_\_\_\_\_

Q17 What are your modes of transportation between Marine lab and Duke's Main Campus ?

- Drive (in a car, van, SUV, or truck)
- Motorcycle moped/scooter
- Dropped off on campus (including uber, taxi)
- Carpool (2-6 people, 16 years or older)
- Vanpool (7 or more people)
- Public Transportation (Buses, trains)
- Flight
- Other \_\_\_\_\_

Q6 When you travel to the Duke's Main Campus (Durham), how often do you carpool (with at least one other person)?

- Always
- Most of the time

About half the time

Sometimes

Never

The 65-foot high-rise Gallant's Channel Bridge is expected to be completed in the next few months. After the opening of the new bridge, the existing drawbridge will be closed and repurposed, and motorists and cyclists will access the bridge on the Beaufort side either from Turner Street or Highway 101

Q8 Will the opening of the new bridge affect the means in which you travel to the Marine Lab?

Yes

Maybe

No

Q9 How will the new bridge affect your travel?

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Q10 How many miles will your commute be ONE-WAY once the new bridge opens?

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Q11 Is there anything else we should know about transportation at the Marine Lab or in Beaufort?

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**Thank you for your participation – your response will help develop a climate action plan for the Nicholas School and the Marine Lab. Again, if you have questions about this study, feel free to contact Taylor Price at [taylor.price@duke.edu](mailto:taylor.price@duke.edu) or faculty adviser Jim Hench at [jim.hench@duke.edu](mailto:jim.hench@duke.edu)**