2019

HANOVER HIGH SCHOOL CLIMATE ACTION PLAN

LAST UPDATED APRIL 2022

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ACRONYMS AND ABBREVIATIONS

B&G	Hanover High Buildings & Grounds Department
BAU	business-as-usual
°C	degrees Celsius
CAFE	Corporate Average Fuel Economy Standards
CAP	Climate Action Plan
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
EPA	U.S. Environmental Protection Agency
EV	electric vehicle
FSC	Forestry Stewardship Council
GDP	gross domestic product
GHG	greenhouse gas
HHS	Hanover High School
LED	light-emitting diode
$MTCO_2e$	metric tons of carbon dioxide equivalent
NHCAP	New Hampshire Climate Action Plan
NHSDP	New Hampshire State Development Plan
ppm	parts per million
REC	Renewable Energy Credit
RGGI	Regional Greenhouse Gas Initiative
RPS	Renewable Portfolio Standard
UNFCCC	United Nations Framework Convention on Climate Change
UNH	University of New Hampshire
W/m^2	watts per meter-squared

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1 INTRODUCTION

Given the overwhelming consensus that anthropogenic or "human-made" greenhouse gas (GHG) emissions are causing global climate change, Hanover High School (HHS) is joining an increasing number of entities and local governments committed to addressing climate change at the local level. HHS recognizes the risk that climate change poses to its constituents and is acting now to reduce the GHG emissions, or "carbon footprint," through the innovative programs laid out in this Climate Action Plan (CAP). Ultimately, individual behavior changes and collective action is needed to reduce HHS's contribution toward the problem of climate change and adapt to its current and future effects. This CAP takes advantage of common-sense approaches and cutting-edge policies that HHS is uniquely positioned to implement. These actions can reduce energy use and waste, conserve water, and reduce fossil fuels used for transportation. This CAP aims to be consistent with the larger plans for the Town of Hanover, New Hampshire and other state and regional plans.

This is the first CAP developed for a high school in the United States. Further, this plan was written by Hanover High School students under the guidance of Hannah Kornfeld (HHS 2010), who served as a volunteer consultant and made substantial contributions to the production and formatting of this report.

1.1 PURPOSE, SCOPE, AND PROCESS

1.1.1 Purpose

By creating a clear course of action so that everyone can have a role in creating and achieving climate and sustainability goals, the CAP drives and coordinates efforts toward a reduction in GHG emissions of 6 percent below 2016-17 school year emission levels by 2025 and 77 percent below 2016-17 school year emission levels by 2050. These targets are discussed further in Section 3.

The CAP is a framework for the development and implementation of actions that reduce HHS's GHG emissions and provides guiding objectives and strategies to realize HHS's GHG reduction goals.

1.1.2 Scope

This CAP covers strategies for reducing GHG emissions resulting from operational activities associated with HHS. It addresses the major sources of emissions from HHS and sets forth objectives and strategies in seven focus areas (i.e., emissions sectors) that both the school and community can implement together to achieve GHG reductions:

- Building Energy
- Employee Commute
- Student Commute
- School Buses
- Solid Waste Generation
- Wastewater Generation
- Water Consumption

1.1.3 Process

The approach used for this CAP was developed by ICLEI and is called the Five Milestones for Climate Mitigation (see Figure 1 below).

Milestone One: Conduct a baseline emissions inventory and forecast.

Milestone Two: Adopt an emissions reduction target for the forecast year.

Milestone Three: Develop a climate action plan.

Milestone Four: Implement the climate action plan.

Milestone Five: Monitor progress and report results.

Figure 1. ICLEI's 5 Milestones for Climate Mitigation

1.2 UPDATES SINCE 2019 PUBLICATION

Since the initial publication of this CAP, the document has been updated. Building energy sources have been split into anthropogenic and biogenic sources. As a result, Table 1 and Figures 2 and 3 now reflect these changes. Section 5 on Climate Change Policy now includes President Biden's "Build Back Better Plan." Nationally, the 2019 U.S. GHG emissions by source are summarized in Section 4 and shown in Figure 7. The section on Corporate Fuel Economy Standards has been updated to include the National Highway Traffic Safety Administration's (NHTSA) proposed new fuel economy standards.

2 HANOVER HIGH SCHOOL'S GREENHOUSE GAS EMISSIONS

Through the completion of a local emissions study, or "greenhouse gas inventory," the Earth Systems and Ecological Design classes of 2017-18 and 2018-19 have determined emissions levels for the school's operations. Emissions include all sources for which HHS exercises direct operational control including building energy, waste generation, water consumption, and school bus fuel consumption. Emissions associated with vehicle trips by employees and students commuting to the school were also included in the inventory.

An important aspect of GHGs is the unit of measurement used to inventory and estimate emissions. While carbon dioxide (CO_2) is the most prevalent and recognized GHG, there are other GHGs such as methane and nitrous oxide. To simplify the discussion and comparison of these emissions collectively, CAPs use a metric known as carbon dioxide equivalent (CO_2e). The CO_2e metric translates each GHG to an equivalent volume of CO_2 by weighing its relative global warming potential. Methane and nitrous oxide are 25 and 310 times more potent, respectively, than CO_2 in their abilities to trap heat in the atmosphere (DES 2009). Converting these GHG emissions into CO_2e using global warming potential values allows us to consider all gases in comparable terms and makes it easier to communicate how various sources and types of GHG emissions contribute to climate change using a standard unit of measurement of the amount of GHG emissions produced and released into the atmosphere.

2.1 2016 GREENHOUSE GAS EMISSIONS

One of the main objectives of this CAP is to identify and reduce HHS's contributions to global GHG emissions. Measuring GHG emissions is a critical first step in developing the CAP for several reasons. First, the GHG inventory identifies major sources and quantities of GHG emissions associated with the activities and choices currently made by HHS, its staff, and its students. Second, the inventory provides the baseline that is used to forecast emission trends and to develop an accurate near-term emissions reduction target consistent with State objectives. Finally, the inventory sets the baseline for HHS to develop, evaluate, and implement measures to achieve its GHG reduction targets.

The GHG emissions inventory focuses on direct activities that occur within the physical boundaries of HHS (e.g., electricity, gas, wood, and water consumption in the building), the surrounding region associated with HHS's operation (e.g., student and staff commute, school bus use), and other off-site activities such as disposal of solid waste or treatment of water or wastewater.

GHG emissions from the 2015-16 school year were prepared for HHS's operations. The 2015-16 school year inventory shows that HHS's operations generated 3,221 metric tons of CO_2e ($MTCO_2e$). HHS's GHG inventory is broken down into the following seven sectors:

- **Building Energy Use:** The building energy sector emissions include GHG emissions generated from electricity consumption, wood burning, and fossil fuel consumption at HHS. The GHG emissions are split into anthropogenic and biogenic sources. Anthropogenic CO_2 comes from human actions in which fossil fuels are burned. This carbon is part of the long-term carbon cycle. When humans burn fossil fuels, the CO_2 concentration in the atmosphere increases which contributes to climate change (J.M.K.C. Donev et al. 2016). The carbon atoms in biogenic CO_2 are in a short-term carbon cycle. Biogenic CO_2 is released by the combustion or decomposition of natural and organic matter (Envirotech 2021). In this CAP, the anthropogenic carbon emissions have been separated from the biogenic carbon emissions that come from burning wood chips for building heating. This breakdown is shown below in Table 1.

- **Employee Commute:** Employee-generated GHG emissions associated with gasoline, diesel, or other fossil fuel consumption from vehicle trips and vehicle miles traveled during employee commute.

- **Student Commute:** Student-generated GHG emissions associated with gasoline, diesel, or other fossil fuel consumption from vehicle trips and vehicle miles traveled during student commute.

- **School Buses:** School bus-generated GHG emissions associated with diesel consumption from school bus routes.

- **Solid Waste Generation:** Solid waste sector emissions include the methane emissions from the decomposition of waste generated by staff and students at the Lebanon Landfill.
- **Wastewater Generation:** Wastewater treatment results in GHG emissions associated with the electricity consumed during treatment, as well as fugitive methane emissions resulting from the treatment process for wastewater.
- **Water Consumption:** Water-related GHG emissions are associated with the energy and fuel used to convey, distribute, and treat water used at HHS.

Table 1 shows the breakdown of HHS's GHG emissions in the 2015-16 school year. Figure 2 shows the breakdown of anthropogenic sources and Figure 3 shows the breakdown between anthropogenic and biogenic sources.

Table 1 Hanover High School Baseline Greenhouse Gas Emissions in 2016

Emissions Sector	$MTCO_2e$	Percent of Total
Anthropogenic	**2,242**	**100%**
Building Energy	489	22%
Employee Commute	537	24%
Student Commute	413	18%
School Buses	766	34%
Solid Waste Generation	12	<1%
Wastewater Generation	16	1%
Water Consumption	9	<1%
Biogenic	**1,100**	**100%**
Building Energy	1,100	100%
Total (Anthropogenic + Biogenic)	**3,342**	**N/A**

Notes: $MTCO_2e$ = metric tons of carbon dioxide equivalent; N/A = not applicable.

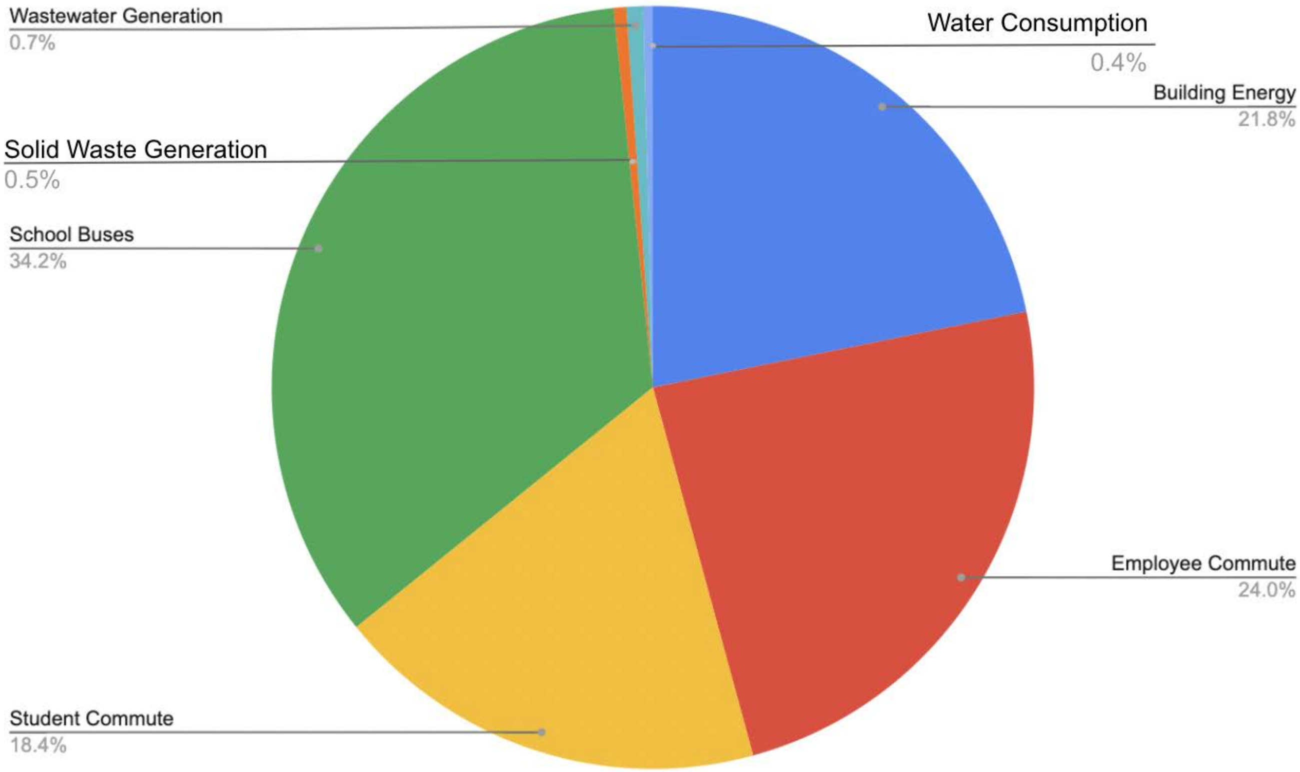


Figure 2. Hanover High School's 2016 Greenhouse Gas Emissions Inventory

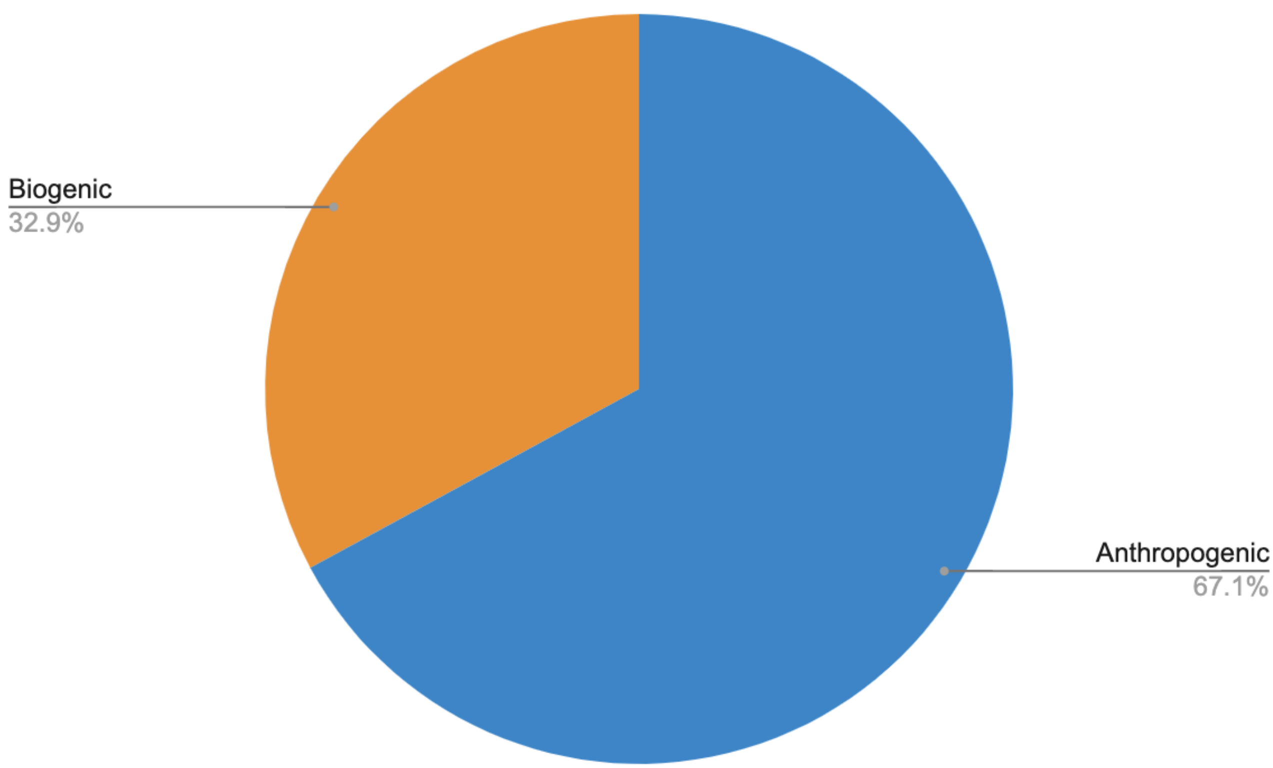


Figure 3. Hanover High School's 2016 Greenhouse Gas Emissions Inventory: Anthropogenic and Biogenic Emissions

2.2 PROJECTED GROWTH IN GREENHOUSE GAS EMISSIONS

GHG emission forecasts provide an estimate of future emission levels based on a continuation of current trends in activity. HHS has completed an emissions forecast based on projections of current data and expected future trends. The emissions forecast is a “Business-As-Usual” forecast, a scenario estimating future emissions levels if no further local action (i.e., measures within this CAP) were to take place. Growth projections in emissions are based on anticipated population growth in the Town of Hanover as provided by the New Hampshire 2016 Subcounty Projections for Hanover through the year 2050 (State of New Hampshire 2016). The forecast indicates that, if HHS does not take action, GHG emissions will continue to increase. Table 2 shows the projected GHG emissions by emissions sector, which are split into anthropogenic and biogenic sources. Figures 4 and 5 display the GHG emissions by anthropogenic and biogenic sources.

For complete information regarding the emissions inventory and forecast, including methodology and supporting data, refer to the Hanover High School Emissions Inventory Report located in Appendix A.

Table 2 Hanover High School Projected Greenhouse Gas Emissions: 2025 and 2050

Emissions Sector	GHG Emissions ($MTCO_2e$)		
	2016	2025	2050
Anthropogenic	**2,242**	**2,260**	**2,341**
Building Energy	489	489	489
Employee Commute	537	547	590
Student Commute	413	420	454
School Buses	766	766	766
Solid Waste Generation	12	12	13
Wastewater Generation	16	17	19
Water Consumption	17	17	18
Biogenic	**1,100**	**1,100**	**1,100**
Building Energy	1,100	1,100	1,100
Total (Anthropogenic + Biogenic)	**3,342**	**3,360**	**3,441**

Notes: $MTCO_2e$ = metric tons of carbon dioxide equivalent.

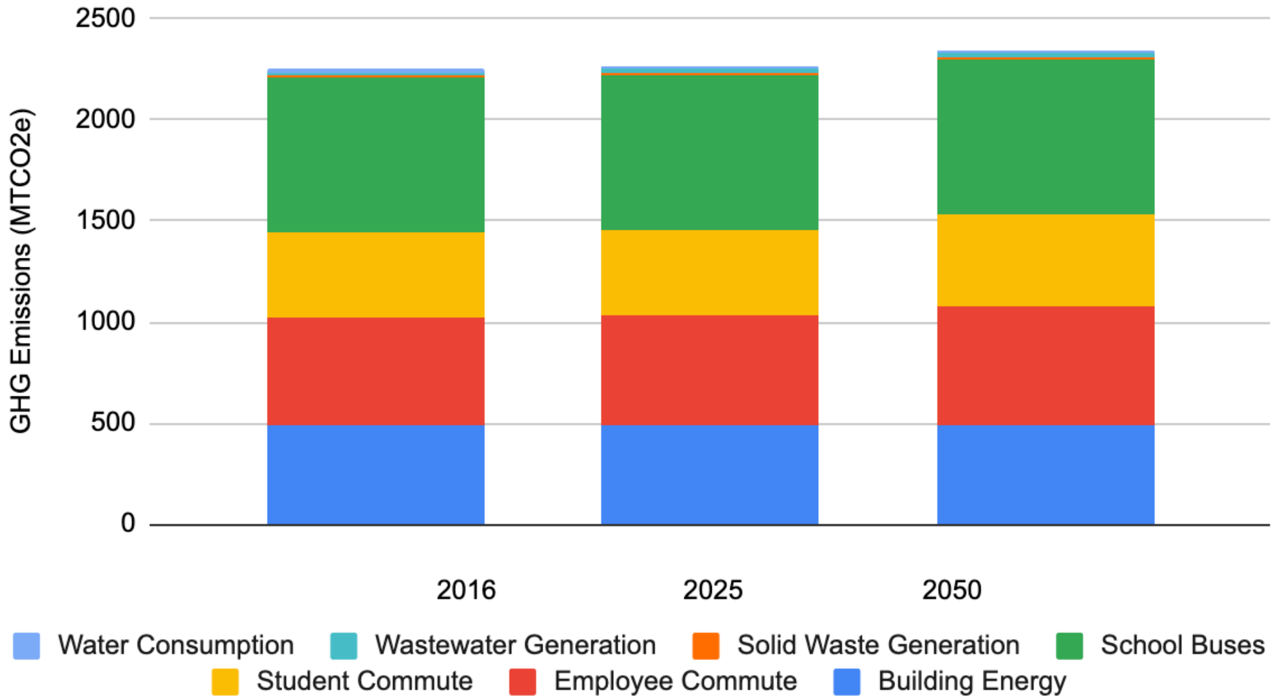


Figure 4. Hanover High School's Greenhouse Gas Emissions Forecasts: 2025 and 2050

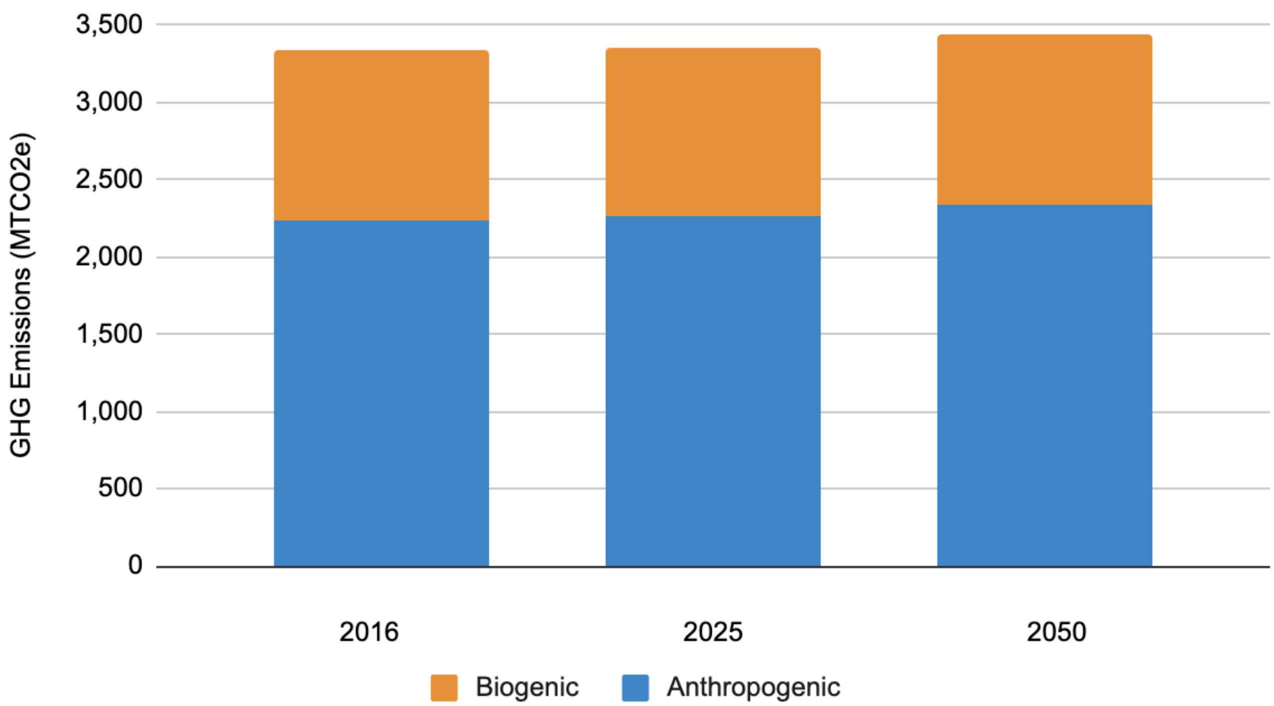


Figure 5. Hanover High School's Greenhouse Gas Emissions Inventory and Forecasts: Biogenic and Anthropogenic Sources

3 GREENHOUSE GAS REDUCTION TARGETS

The State of New Hampshire aims to reduce its GHG emissions by 20 percent from 1990 levels by 2025 and 80 percent below 1990 levels by 2050 (DES 2009:24-25). Almost all scientific sources recommend a reduction of 80 percent by 2050, which is the amount of GHG reduction deemed necessary by the United Nations' Intergovernmental Panel on Climate Change to keep temperatures from exceeding a 2-degree Celsius (°C) increase. The HHS CAP aims to align with these recommendations, as described in the following section.

3.1.1 Emissions Reduction Target

Because HHS's 1990 GHG emission levels were not estimated, proportional targets for this CAP were calculated based on statewide changes in GHG emissions over time since 1990. To determine the proportional reductions needed from 2016 levels that would be equivalent to the State's targeted reductions from 1990 levels, the State's GHG inventories for 1990 and 2016 were compared. According to the inventories available in the New Hampshire CAP, statewide emissions were approximately 15.8 million $MTCO_2e$ in 1990 and 13.4 million $MTCO_2e$ in 2016 (DES 2009). Based on these statewide changes in emissions from 1990 to 2016, and in consideration of established statewide reduction targets for 2025 and 2050, applying proportional reductions to HHS's 2016 emissions levels would mean reductions of at least 6 percent by 2025 and 77 percent by 2050.

The combination of measures that are presented in this CAP are designed to achieve the 2025 goal and make substantial progress towards the longer-term 2050 goal. Table 3 shows HHS's GHG reduction targets for 2025 and 2050, which require a 6 and 77 percent reduction, respectively, from the baseline 2016 conditions. This level of reduction corresponds to an annual emissions limit of 2,125 $MTCO_2e$ in 2025 and 538 $MTCO_2e$ in 2050. This is the maximum amount of annual GHG emissions allowable while achieving the reduction targets. Figure 6 shows the trajectory of HHS's GHG emissions without additional action in comparison to the GHG reduction targets established.

Table 3 Hanover High School Greenhouse Gas Reduction Targets

	2016	2025	2050
BAU Emissions ($MTCO_2e$)	2,242	2,260	2,341
Percent Reduction below 2016 Levels	N/A	-6%	-77%
Annual Emissions Allowable ($MTCO_2e$)	N/A	2,125	538
Emission Reductions Needed to Meet Target ($MTCO_2e$)	N/A	136	1,802

Notes: $MTCO_2e$ = metric tons of carbon dioxide equivalent; N/A = not applicable.

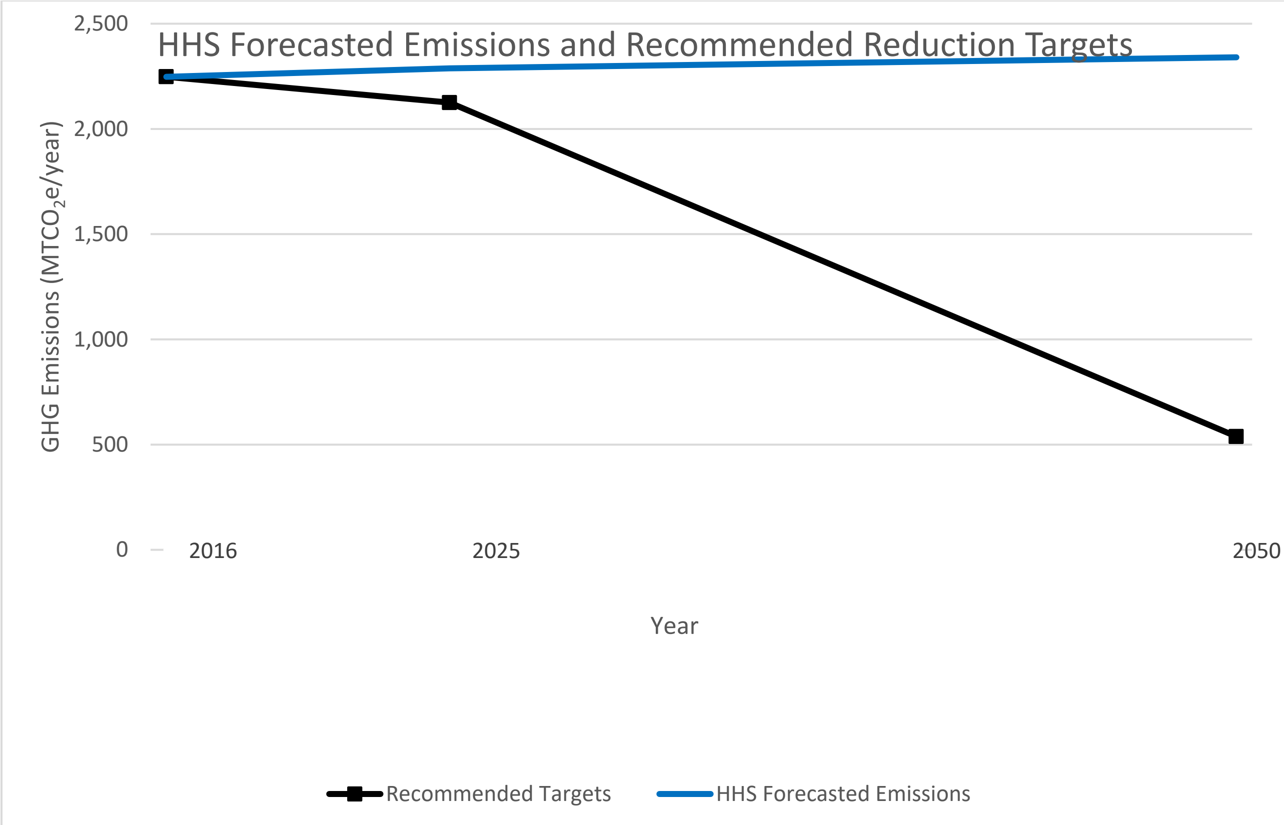


Figure 6. Hanover High School's Greenhouse Gas Reduction Targets: 2025 and 2050

3.2 SUMMARY OF CLIMATE ACTION PLAN

The summary table below identifies the emission sectors within the HHS CAP, the GHG-reducing measures within each emissions sector, and a comparison to HHS's GHG reduction targets for 2025 and 2050. Each GHG reduction measure has a detailed section within this document where specific actions are described.

School policies and practices can dramatically reduce GHG emissions from a range of sources and help prepare HHS for the anticipated impacts of climate change. As shown in Table 4 below, the GHG reduction measures identified would exceed HHS's 2025 GHG reduction target and make significant progress towards achieving the 2050 longer-term GHG reduction goal.

It is important to note that only GHG reduction measures that have enough available data and methodology were quantified to show the anticipated GHG emissions reductions. While all of the measures included in the CAP would result in some GHG emissions, due to lack of available data or unknown methods, only those that can be quantified count towards HHS meeting its GHG reduction target for 2025. Although many GHG reduction measures are not quantified, they are still important particularly because of the co-benefits described below.

Table 4 Hanover High School Climate Action Plan Summary

GHG Reduction Measure Number	Measure Description	Anticipated GHG Reduction ($MTCO_2e$ by 2025)	Anticipated GHG Reduction ($MTCO_2e$ by 2050)
BE-1	Purchase certified sustainable wood chips	1,200	1,200
BE-2	Upgrade heaters	N/A	N/A
BE-3	Improved building insulation	N/A	N/A
BE-4	EnergyStar®-rated appliances	N/A	N/A
BE-5	Energy audit of building	N/A	N/A
BE-6	Install energy-efficient lighting	N/A	N/A
BE-7	On-site renewable energy generation	109	109
BE-8	Net metering	N/A	N/A
SW-1	Compost used paper towels	N/A	N/A
SW-2	Increase recycling and composting education	3	3
WA-1	Install dual-flush toilets	N/A	N/A
TR-1	Electric vehicle charging stations	11	14
TR-2	Carpool incentives for students	N/A	N/A
TR-3	Bike shelter	N/A	N/A
SB-1	Efficient school bus system	N/A	N/A
SB-2	Renewable diesel in school buses	766	766
SB-3	Replace diesel-fueled school buses with electric versions	N/A	N/A
SB-4	Bike and ski racks on school buses	N/A	N/A
C-1	Buy local food	N/A	N/A
C-2	Transition to reusable/compostable cutlery and dishes	N/A	N/A
M-1	Create CAP team with Environmental Club	N/A	N/A
M-2	Revise HHS Mission Statement to reflect climate goals	N/A	N/A
Total – Anthropogenic		889	892
Total – Biogenic		1,200	1,200
Emissions Reduction Needed (Anthropogenic)		136	1,802
Target Met?		Yes	No

Notes: GHG = greenhouse gas; $MTCO_2e$ = metric tons of carbon dioxide equivalent; N/A = not applicable; CAP = Climate Action Plan.

3.3 CO-BENEFITS

While the measures included in the CAP are generally geared towards reducing GHG emissions, many will also result in environmental or economic “co-benefits.” Environmental co-benefits include improved air quality, water supplies, biological resources, public health outcomes, and beneficial outcomes for other resources. For example, a significant co-benefit of implementing CAP measures related to fossil fuel combustion will result in fewer toxic air contaminants, leading to better air quality and improved health. Through working within HHS and with other communities, the HHS community can do its part towards achieving a stable climate and can receive co-benefits from reducing its carbon footprint. Even more importantly, these efforts can positively impact other communities. Other measures focus on improving energy and water efficiency, lowering overall operating costs at HHS.

A more detailed discussion of reduction measures, along with their co-benefits, can be found in Section 6, “Emissions Reduction Measures.”

4 CLIMATE CHANGE SCIENCE

4.1 CLIMATE CHANGE SCIENCE

Although climate change is the center of many political debates, the warming of Earth's climate system is a widely accepted fact in the scientific world. Ninety-seven percent of "actively publishing climate scientists" agree that Earth's climate is changing as a result of human activities (NASA 2018). The atmosphere's current CO_2 levels (as of March 2019) are 410 parts per million (ppm), which is the highest measurement in the past 800,000 years (NASA 2018). Before the industrial revolution, Earth's CO_2 levels fluctuated between roughly 180 ppm during ice age periods and 280 ppm during interglacial periods (NASA 2018). These rising and falling levels are considered within the normal spectrum of the Earth's temperature cycles, which has a frequency of about 100,000 years. In a glacial cycle, temperatures and CO_2 levels fluctuate up and down, and about every 15,000 years the temperatures spike, and then rapidly fall soon after. In comparison, the current level of over 410 ppm represents uncharted territory. Because of the unprecedented levels of CO_2, scientists do not know exactly how these high CO_2 levels will affect humanity and other life that lives on this planet. However, scientists do know that throughout climate history, temperature is directly correlated with atmospheric CO_2 levels (NOAA 2008). When graphed, temperature and carbon dioxide follow each other closely.

CO_2 is just one of the GHGs in Earth's atmosphere that contributes to warming Earth. GHGs have a warming effect due to their ability to trap heat in the atmosphere. GHGs in Earth's atmosphere absorb infrared radiation emitted from Earth's surface and also re-emit infrared radiation, commonly known as heat. The greenhouse effect refers to the natural process of infrared radiation being absorbed by GHG molecules, and then re-emitted in all directions, some of which is directed back towards Earth. "Without naturally occurring greenhouse gases, Earth's average temperature would be near 0°F (or -18°C) instead of the much warmer 59°F (15°C)" (NASA 1998).

However, since the Industrial Revolution, the burning of fossil fuels and other human activities has led to a dramatic increase in the concentration of GHGs in the atmosphere. GHGs that have high global warming potentials have a long residence time in the atmosphere, absorb effectively in the infrared part of the electromagnetic spectrum, and have a relatively high concentration in the troposphere (lowest layer of the atmosphere). Once GHG molecules absorb infrared radiation, they collide with and transfer kinetic energy to other molecules in the atmosphere such as nitrogen and oxygen, which increases the temperature of the atmosphere. As the concentration of GHG molecules in the atmosphere increases, more energy is trapped. In this way, GHGs act as a "blanket" and prevent heat energy from escaping back out to space.

Scientific research published in peer-reviewed journals shows that the current CO_2 levels in Earth's atmosphere have been rising since the industrial revolution (Scripps Institution of Oceanography UC San Diego 2017). Human activity is also responsible for the release of methane, nitrous oxide, and other potent GHGs (Keeling 1997). Humans are already experiencing the effects of a warmer climate through more extreme weather events, increases in pests and disease, devastation to wildlife habitat, and perhaps most directly relevant to HHS, increased costs (Keeling 1997).

Arguably, the most concerning part of global climate change is that it is extremely difficult to reverse. Now that there is momentum in warming Earth, the extent of sea ice is diminishing, sea levels are rising, oceans are warming, and glaciers around the world are melting. Further, these events lead to positive feedback loops that amplify warming. Due to climate momentum, it will take hundreds of years for GHG concentrations in the atmosphere to return to preindustrial concentrations. For these reasons, we need to take responsibility for emissions coming from the HHS community and implement this CAP immediately.

4.2 GREENHOUSE GAS EMISSIONS SOURCES

In 2019, the United States generated 6,558 million $MTCO_2e$. Figure 7 below shows the sources of GHG emissions in the U.S. and their respective percentages of total GHG emissions. The transportation, electricity, and industry sectors produced the majority of GHGs due to the burning of fossil fuels (EPA 2022). The transportation sector produced more GHG emissions than any other sector, and petroleum-based fuels accounted for 90 percent of the fuels used in this sector (EPA 2022). Electricity production is the second-largest share of GHGs in the U.S., with coal and natural gas accounting for 62 percent of the fuels in this sector. The industry sector primarily produced GHGs emissions through the consumption of energy to produce materials from raw goods. Commercial and residential use of fossil fuels and agriculture made up the rest of the GHG emissions inventory. Land use and forestry accounted for 11 percent of U.S. emissions.

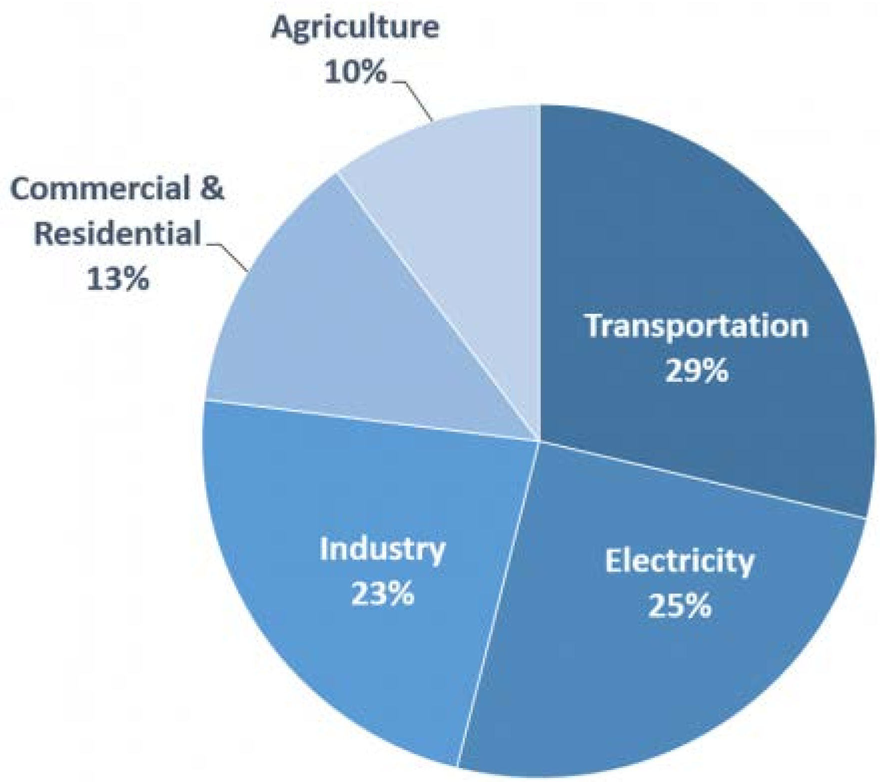


Figure 7 U.S. Greenhouse Gas Emissions by Source in 2019
Source: EPA 2022

Overall, greenhouse gas emissions have increased by 2 percent annually since 1990, with small dips and shifts due to the state of the economy, gas prices, and other related factors (EPA 2022). In 2019, GHG emissions decreased compared to 2018; this decrease can be attributed to less overall energy use as well as a widespread shift towards renewable energy sources (EPA 2022). Figure 8, below, shows this trend.

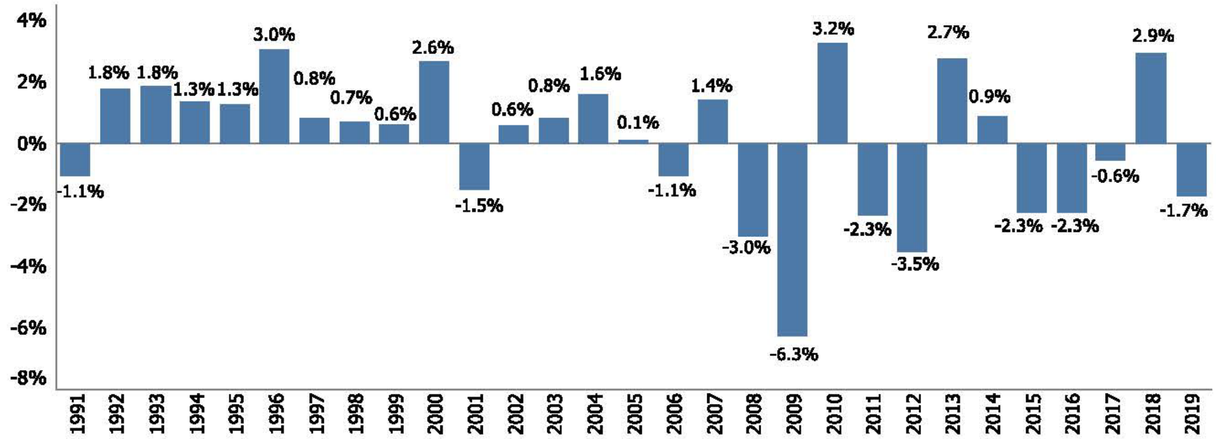


Figure 8. Annual Percent Change in Gross U.S. Greenhouse Gas Emissions Relative to the Previous Year
Source: EPA 2022

4.3 EFFECTS OF CLIMATE CHANGE ON THE ENVIRONMENT

There are almost 200 worldwide scientific organizations that believe climate change is caused by human action (OPR 2019). This is creating an imbalance in Earth's energy budget. Before the Industrial Revolution, Earth was in radiative balance, with 240 watts per meter-squared (W/m^2) hitting the surface of Earth, and 240 W/m^2 escaping from Earth's atmosphere. However, it has been estimated that currently there is approximately 0.8 W/m^2 less energy escaping back into space as a result of human activity (NASA 2009). Despite this being a seemingly small difference, the 0.8 W/m^2 change is increasing the temperature of Earth's atmosphere.

As Earth's atmosphere warms, glacial ice melts, exposing the dark surface of Earth which reduces the albedo, or reflectivity of Earth's surface. With less reflective material covering Earth, less light gets reflected back into space, and more gets absorbed by Earth's surface, contributing further to warming. This amplification of warming is known as a positive feedback loop. Rising temperatures are also causing the melting of permafrost, the frozen soil sublayer in the poles. As permafrost melts, bacteria decompose organic matter anaerobically. This produces methane, an even more potent GHG than CO_2. The release of methane increases the concentration of GHGs in the atmosphere and therefore contributes to Earth's warming temperatures which melts more permafrost, another example of positive feedback. "Global sea level has risen by about 8 inches since reliable record keeping began in 1880. It is projected to rise another 1 to 4 feet by 2100. This is the result of added water from melting land ice and the expansion of seawater as it warms" (NASA 2019b). Warmer water takes up more space than cooler water, causing sea levels to rise. Rising sea levels lead to destruction of land through erosion and flooding. Furthermore, as ocean levels increase, humans are forced to evacuate their communities. These displaced people have come to be known as climate refugees. In addition, as sea levels rise, ocean water is pushed inland against the fresh water of rivers. This phenomenon, known as salt water intrusion, contaminates drinking water sources of coastal areas, and changes the salinity of estuaries which impacts the structure and function of estuarine ecosystems.

Climate disasters are increasing in number and gravity and are impacting economies around the world. "In 2019 (as of April 9), there have been two weather and climate disaster events with losses exceeding $1 billion each across the United States" (NOAA 2019). The rise in temperature has caused plants to migrate from their original habitats to places that are within their preferred temperature range. Climate change is having profound impacts on Earth's ecosystems, leaving them less resilient and less able to provide the ecosystem services upon which humanity depends. As the effects of climate change continue, the scarcity of resources will increase conflicts among countries and people around the world.

Regionally, the northeastern U.S. will experience more heat waves, heavy downpours and sea level rise. "Infrastructure, agriculture, fisheries and ecosystems will be increasingly compromised" (NASA 2019b). As a result, many states and cities are beginning to incorporate climate change into their planning.

5 CLIMATE CHANGE POLICY

5.1 INTERNATIONAL

5.1.1 Paris Agreement

The Paris Agreement of 2015 was enacted at the Paris Climate Conference in December 2015 by the parties to the United Nations Framework Convention on Climate Change (UNFCCC). The Agreement is a formation of many articles, the most essential of which states that all parties seek to keep the global temperature rise this century to below 2°C above pre-industrial levels and to additionally pursue efforts to limit the temperature increase even further to 1.5°C. To achieve these goals, the Agreement emphasizes that the parties should aim to start reducing GHG emissions as soon as possible. The Agreement also requires that all parties report regularly on their emissions and on their implementation efforts. This refers specifically to the Nationally Determined Contributions which countries must prepare, work towards, and then report on every five years. According to the UNFCCC, developed countries should continue to take the lead by undertaking economy-wide reduction targets, while developing countries should continue enhancing their mitigation and adaptation efforts. Developing countries are also encouraged to move toward economy-wide targets over time (UNFCCC n.d.).

It is difficult to measure progress from the Agreement since it was only enacted recently, but there are some measures that indicate it has helped push the world towards sustainability. One of these measures is the number of non-state actors that have pledged their support of the Paris Agreement as well as the member parties. In the U.S. alone, more than 2,500 mayors, governors, businesses leaders, and investors have pledged their support to the Paris Agreement (Hobert 2017), including multiple New Hampshire towns: Hanover, Lebanon, Keene, Portsmouth, and Nashua (Greene 2017).

Another measure of progress is the global investment in renewable energy. As a result of the Paris Agreement, wind power is now less expensive than other forms of energy in many locations. In addition, new renewable energy capacity installed worldwide in 2016 reached 161 gigawatts, which is a 10 percent increase from 2015 (Hobert 2017). However, there have been setbacks as well, including the U.S.'s announcement to pull out of the Paris Agreement. Ultimately, progress will be determined in 2023 when the first "global stocktake" occurs in which the Conference of the Parties serving as the meeting of the parties to the Paris Agreement take stock of the implementation of the Paris Agreement and assess collective progress towards achieving the purpose of the Agreement and its long-term goals. This progress will continue to be measured every five years after 2023 (UNFCCC n.d.).

5.1.2 Under 2 Memorandum of Understanding

The Under 2 Memorandum of Understanding (The Climate Change Group 2018) was founded by 12 initial members in 2015. Now known as the Under 2 Coalition, the memorandum represents a legal agreement in which parties involved do not form a legal commitment. The founding members include: Acre, Baden-Württemberg, Baja California, British Columbia, California, Catalonia, Jalisco, Ontario, Oregon, Vermont, Wales, and Washington. By committing to the Under 2 Coalition, parties agree to conceive and implement a plan to help limit global warming to 2°C. The goal of the Coalition is to reduce GHG emissions to 80-95 percent of 1990 levels, which translates to limiting emissions to 2 $MTCO_2e$ per capita per year by 2050.

The plan has grown to over 200 members on six continents and 43 different countries in the three years since its founding. These members constitute 1.3 billion people and $30 trillion in gross domestic product (GDP), which constitutes 43 percent of the global economy (The Climate Change Group 2018). The reason that the Under 2 Coalition has so many members is that it allows local governments who want to do something about climate change to join, instead of having to wait for their federal government to join a formal agreement like the Paris Agreement. Because this coalition is relatively young, it is challenging to determine its effectiveness at this point, but its climb in membership bodes well for future success.

5.2 FEDERAL

5.2.1 Build Back Better Plan

In 2021, the Biden Administration proposed the "Build Back Better Plan" legislation aimed at rebuilding the middle class in the United States, which includes provisions outlining climate goals and the goal of cutting GHG pollution by well over one billion metric tons (15 percent of total emissions) by 2030. The Build Back Better Plan passed the House of Representatives on November 19, 2021 but has failed to be approved by the Senate as of April 2022. The Biden Administration instead aims to split the bill up into smaller sections and pass them in chunks instead of all at once.

The Build Back Better Plan includes sections intended to combat climate change while benefiting middle class Americans. There are four main points that this plan focuses on. One section plans to provide rebates and tax credits to middle class families shifting to clean or renewable energy in an effort to reduce costs and encourage Americans to switch their energy sources. The legislation also aims to grow domestic supply chains for "solar, wind, and other critical industries" with the intention of creating more jobs and bolstering the economy in addition to creating renewable energy technology such as solar panels, wind turbines, and electric cars. Another segment targets environmental justice and provides funding for projects such as port electrification and the deployment of cleaner transit. The last climate-oriented section of the plan will provide resources to farmers, ranchers, and forestland owners to support their continuing efforts to reduce emissions.

5.2.2 Infrastructure Bill

On November 15, 2021 the Biden Administration signed an infrastructure bill into law, which contains many climate-oriented goals relating to infrastructure. This bill focuses on improving and rebuilding our country's infrastructure, from rebuilding roads and bridges to reworking public transportation. One main effort aims to incorporate transportation drawing on clean and zero-emission vehicles as the infrastructure is replaced, with a specific focus on electric buses. This legislation also approves $7.5 billion to build a network of electric vehicle chargers across the country and $65 billion to upgrade the power infrastructure in the U.S. in order to "facilitate the expansion of renewables and clean energy, while lowering costs." Lastly, the bill allocates $21 billion to clean up "Superfund and brownfield sites, reclaim abandoned mine land and cap orphaned oil and gas wells," which will address legacy pollution issues.

5.2.3 Corporate Average Fuel Economy Standards

Corporate Average Fuel Economy Standards, commonly known as CAFE standards, were enacted in 1975 by Congress. These standards "reduce America's consumption of oil, save consumers money at the gas pump, and protect public health and the environment by curbing global warming pollution. They also help spur investments in new automotive technology, creating jobs and helping sustain the recovery of the American auto industry" (Union of Concerned Scientists 2017). CAFE standards are updated regularly based upon a five-year projection of automobile fuel efficiency. The standards are based on the average efficiency value of a fleet of cars per manufacturers. Efficiency in automobiles in the United States is measured in miles per gallon. For example, the 2017-2021 CAFE standards require manufacturers to have a fleet wide average of 40.3-41.0 miles per gallon for passenger cars and light trucks. When the 2017-2021 standards expire, a revised set of CAFE standards will be created for 2022-2025.

In August 2021, the National Highway Traffic Safety Administration (NHTSA) announced that it would propose new fuel economy standards, a reconsideration of the fuel economy standards set in 2020. The new standards would increase fuel efficiency 8 percent annually for model years 2024-2026 and increase the estimated fleetwide average by 12 miles by gallon. These changes would reduce GHG emissions by 1.8 billion tons over the next three decades.

5.2.4 EPA's SmartWay Transportation Partnership

The SmartWay Transportation Partnership is a voluntary public-private program started by the EPA in 2004 that helps companies advance supply chain sustainability by measuring, benchmarking, and improving freight transportation efficiency. The program was developed in response to the scale and growth of emissions from heavy-duty diesel trucks in the U.S. This program provides a system for tracking fuel use and freight emissions across supply chains, helps companies identify efficient freight carriers to improve supply chain sustainability, and reduces GHG emissions from the movement of goods (EPA 2017).

SmartWay also works to improve the relationship between the EPA and the transportation sector. Since its start, SmartWay has grown from 50 partners to currently more than 3,700 partners and affiliates. It has helped its partners save 215.4 million barrels of oil and has eliminated 103 million tons of air pollution (EPA 2018b). In addition to having a positive environmental impact, SmartWay has led to significant economic savings. SmartWay has helped U.S. trucking companies save $29.7 billion in fuel costs, and trucking is an industry that represents 8 percent of U.S. GDP. (EPA 2018b).

5.2.5 25 x '25 Initiative

"25x'25" is a movement by the United Nations, Rockefeller Brothers Fund, and the Energy Foundation which calls for more renewable energy in the U.S. Specifically, it sets a goal that by 2025, the U.S. will be producing 25 percent of its energy from renewable sources such as wind, solar, and biofuels. The 25x'25 goal has been endorsed by nearly 1,000 partners, 35 current and former governors, 15 state legislatures, and Congress through the Energy Independence and Security Act of 2007. Since the launch of the 25x'25 vision, the U.S. has increased renewable energy production by almost half. In 2013, 11.2 percent of energy consumed in the U.S. came from renewable energy sources. To achieve the 25x'25 plan, the U.S. needs to reform certain practices. These include increasing production of renewable energy, working on its efficiency and productivity, and delivering and expanding to markets.

If the U.S. is able to achieve these goals, between 4 and 5 million new jobs will be created. Additionally, the U.S. will have cleaner air through reduced urban smog and pollution in the atmosphere. This plan will also bring new technologies to the market and help to save consumer expenditures while reducing dependency on oil from Middle East such as Saudi Arabia. These changes will produce $700 billion in new economic activity annually and reduce CO_2 emissions by 1 billion tons. So far, the U.S. is on track to procure 24 percent of its energy from renewable sources by 2025 (25x'25 Initiative 2018).

5.3 REGIONAL

5.3.1 Regional Greenhouse Gas Initiative

The Regional Greenhouse Gas Initiative (RGGI) implemented in 2009, is the first mandatory market-based program in the United States to reduce GHG emissions from power plants. It is a cooperative effort among Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, Vermont, and New Jersey (RGGI 2018).

The program limits how much CO_2 power plants can legally produce and requires them to pay a fee which is proportional to the amount of CO_2 they produce. Furthermore, RGGI requires that states use the money to invest in the most feasible renewable energy and energy efficiency projects in their states. This usually includes customer rebates and efficiency projects. The system provides incentives for power plants to become more efficient while simultaneously creating jobs and infrastructure for renewable energy production.

To craft a viable plan, RGGI had to ensure that the economic damage of lost power plant revenue (caused by limiting CO_2 production and charging fees) was offset by the stimulation of the economy in the form of new energy-efficient projects (RGGI 2018). There has been $3 billion worth of economic growth due to RGGI since it officially began in 2009 and because of RGGI, public health concerns have been alleviated (especially in low income communities). Further, the price of electricity has fallen, and nearly 30,000 job-years have been created. These results incentivize states to remain in the agreement (Ropeik 2018).

The RGGI cap represents a budget for CO_2 emissions from the power sector among the participating states. In short, the states gave themselves until 2014 to reach a cap of 91 million short tons of CO_2 released into the atmosphere. The plan then was from 2015 to 2020 the cap was to decline by 2.5 percent every year (RGGI 2013).

RGGI's goal in 2005 was to reduce power plant CO_2 production by 10 percent by 2018. As of January 2018, member states had cut CO_2 production by 40 percent (Ho 2017). Due to the program's success, RGGI standards are becoming more demanding. The RGGI plans to lower the CO_2 cap and increase the price of CO_2 allowances, also known as Carbon Certificates, which are tradable coupons that are redeemed for the right to generate CO_2, by the ton. Member states expect to see a collective $3.95 billion dollars in economic growth and 34,000 job-years (Ho 2017).

5.4 NEW HAMPSHIRE

5.4.1 New Hampshire State Development Plan

The New Hampshire State Development Plan, *"New Hampshire in the New Economy: A Vision for Expanded Prosperity,"* (NHSDP) was proposed in 2000 and describes changes that New Hampshire must make in order to keep its economy successful. This plan focuses on providing a better-quality workspace for its workers. To achieve these goals, it is imperative that New Hampshire work towards having a cleaner and safer environment.

According to the NHSDP, the State of New Hampshire must lay out a need for "a commitment to investing in education, worker training, health care, environmental protection and modernization of state government" (State of New Hampshire 2000:4). With this commitment in mind, New Hampshire aspires to "ensure a prosperous future; one in which all its residents are afforded the opportunity to succeed" (State of New

Hampshire 2000:4). New Hampshire recognizes the various aspects of this plan, including controlling the environmental needs and impacts of agriculture, business, and transportation.

The NHSDP features energy conservation as a key sector to ensure continued economic prosperity. A relevant goal is that the state aims "to assist schools in becoming more energy efficient and to educate students about renewable energy" (State of New Hampshire 2000:40).

5.4.2 Renewable Portfolio Standard

New Hampshire's Renewable Portfolio Standard (RPS) was created in 2007 after an economic analysis by the University of New Hampshire (UNH). The UNH study looked at the success of other states in the region after enacting RPS legislation and concluded that establishing an RPS for New Hampshire could be beneficial for its economy and environment. The RPS was submitted to the New Hampshire Department of Environmental Services and Public Utilities Commission. The purposes of New Hampshire's RPS are to provide fuel diversity to New Hampshire and the larger New England region, to lower the local dependence on fossil fuels, and to stabilize and lower energy costs. The RPS also encourages investment in renewable or low emission technologies to stimulate the local economy. This investment will help combat climate change and raise emission standards by ensuring that a larger share of the electricity consumed by residents of the state is produced using renewable methods.

The RPS achieves these goals by requiring that all electric service providers in the state purchase or generate Renewable Energy Credits (RECs). One REC is equivalent to the generation of one megawatt-hour of renewable electric power generation. Power companies can buy RECs from a company or individual who is producing electricity using renewable energy. RECs allow companies to support renewable energy efforts without having to generate the energy themselves. Power companies may also choose to get RECs by building their own renewable power generation. The target for renewable energy generation started at 4 percent in 2008 and has gradually risen each year.

The U.S. Energy Information Administration (EIA) estimated the total renewable energy production in New Hampshire to be at 55,989 British thermal units (BTUs) and the total renewable energy consumption to be 69,075 BTUs by 2019 (EIA, n.d). New Hampshire is ranked 13th in the U.S for renewable energy as a share of statewide energy. New Hampshire's Renewable energy accounted for 19.5 percent of New Hampshire's electricity portfolio in 2019 (NHPUC, n.d.). New Hampshire's RPS target of 25.2 percent renewable power generation will be reached by 2025.

5.4.3 New Hampshire Climate Action Plan

The New Hampshire Climate Action Plan (NHCAP) was enacted in March 2009 by the New Hampshire Climate Change Policy Task Force.

The goal of the NHCAP is twofold: to lower current GHG emissions to 80 percent below the 1990 GHG emission levels by 2050, and to stimulate the state's economy. In order to do this, NHCAP has identified energy efficiency, renewable energy, and lowering car dependence as the most effective ways to reach their goal. The State also says that maintaining its forests is critical to preserving carbon storage and tourist attractions. New Hampshire plans to implement education and outreach programs (DES 2009).

To increase energy efficiency, the NHCAP aims to improve efficiency in existing buildings, and change building energy codes to reduce environmental impact. In an effort to increase the use of renewable energy, New Hampshire plans to promote the generation of electric and non-CO_2-emitting energy, and to produce energy through the use of biogenic waste sources such as wastewater, food waste, and animal manure. As the State attempts to cut down on car usage, which will decrease GHG emissions, New Hampshire plans to improve bus and train services on local and regional levels, build more infrastructure for bikes and pedestrians, and implement more park-and-rides (DES 2009).

The NHCAP includes actions specifically designed to reduce GHG emissions associated with schools throughout the state. The actions recommended in the NHCAP that address schools include GLA 2.6, which reads “Promote Public School Siting and Building Aid to Reduce Energy Use” and RCI 4.1, which reads “Include Energy Efficiency and Conservation in School Curriculum” (DES 2009:23-24).

5.5 TOWN OF HANOVER

5.5.1 Sustainable Hanover

The Sustainable Hanover committee has launched a multi-year initiative that demonstrates ways to minimize environmental impacts with home landscaping and maintenance practices that mimic natural ecosystems. By applying principles of permaculture, it hopes to reduce water runoff, and air and noise pollution, to improve biodiversity, create natural habitats for wildlife and to require less maintenance.

Weatherize Hanover, launched in 2019, is a key component of Hanover’s goal to reach 100 percent renewable energy by 2030. Weatherizing homes involves making physical home improvements such as insulation and air sealing to reduce energy costs, improve comforts, and resolve issues such as ice dams, moisture, mold, cold spots and drafts. Weatherize Hanover provides resources on weatherizing and provides cost estimates by qualified contractors to weatherize homes.

The Hanover community is currently developing a sustainability master plan in accordance with New Hampshire’s statutes relating to master plans. The sustainability master plan will guide the town to a more sustainable future.

5.5.2 Renewable Energy Commitment

In May 2017, the Town of Hanover, New Hampshire voted on a community goal to transition to 100 percent renewable energy. The goal currently states that Hanover will have 100 percent renewable electric energy by 2030, and 100 percent renewable heating and transportation energy by 2050 (Levy 2017). Hanover is the first town in New Hampshire to commit to the Sierra Club’s “Ready for 100” goal, a national movement led by the environmental organization working to help cities convert to running on 100 percent renewable energy. The 69 cities who have already committed to the “Ready for 100” goal, range from smaller towns such as Blackburn, Virginia, to large metropolises such as San Diego, California and Orlando, Florida (Sierra Club 2018).

Members of the Hanover community made the decision to commit to the Sierra Club’s campaign during a vote at a town meeting, making Hanover the first municipality in the United States to have a renewable energy goal both voted on and approved by community residents (Town of Hanover 2017). The Sustainable Hanover Town Committee, which endorses the transition to clean and renewable energy, proposed the idea for committing to the Sierra Club’s campaign. The Town plans to spend $50,000 per year on energy-efficient improvements (Sears 2018). Hanover has been working with the Concord Energy Committee and plans to find more opportunities for solar power in the area.

6 EMISSIONS REDUCTION MEASURES

The following GHG emission reduction measures will help HHS meet its 2025 GHG reduction target and make significant progress towards meeting its longer-term 2050 goal. The GHG reduction measures are divided into eight sectors. Measures were developed by the 2017-18 and 2018-19 Earth Systems and Ecological Design classes, in collaboration with the Buildings and Grounds Department (B&G). Each measure includes a description of how it would result in GHG emission reductions, the co-benefits associated with the measure, and anticipated GHG reductions, as applicable.

6.1 BUILDING ENERGY

Energy consumed in the school building accounted for 48 percent of HHS's total GHG emissions in the 2015-16 school year. Improving the efficiency of the building will contribute significantly to achieving HHS's greenhouse gas reduction target. This section focuses on opportunities to retrofit and upgrade the building and to ensure that future activities in the building are compatible with our community's climate protection goals.

6.1.1 BE-1: Purchase Forestry Stewardship Council or Third Party Certified Sustainable Woodchips

The majority of HHS's building energy is associated with burning woodchips to provide area and water heating. Currently, woodchips that are purchased by HHS are not certified sustainable, meaning the woodchips are not sourced from a forest that has been certified to be well-managed. If woodchips purchased by HHS were certified sustainable, all GHG emissions associated with the school's burner would be effectively eliminated. The Forest Stewardship Council (FSC) is an example of an independent, non-profit organization that accredits wood suppliers as certified sustainable. FSC's goal is to protect forests for future generations.

HHS has a signed contract with a woodchip provider that expires July 1, 2019. HHS should renegotiate a contract with a woodchip provider that offers FSC-certified sustainable woodchips.

<u>Co-Benefits</u>
By using FSC-certified sustainable woodchips, HHS can support healthy forest management that conserves biological diversity, water resources, soils, unique ecosystems, and landscapes.

<u>Anticipated GHG Reduction (biogenic sources)</u>
2025: 1,100 MTCO_2e/year
2050: 1,100 MTCO_2e/year

6.1.2 BE-2: Upgrade Heaters

An air-to-air heat pump can provide both heating and cooling, is significantly more efficient than our heating system, and does not require combustion. About half of the GHG emissions that are produced at HHS come from burning woodchips for heat. Reducing combustion of woodchips by using heat pumps will reduce our GHG emissions. In addition, these units are extremely energy efficient and could be powered by on-site solar panels.

Co-Benefits
Many of the heating units at HHS need to be replaced (either now or in the near future). This investment will reduce HHS's electric bill. Furthermore, this will help stabilize the temperature in the building, which will increase comfort for both staff and students.

6.1.3 BE-3: Improved Building Insulation

Improved insulation in the building would reduce the amount of energy needed to heat the interior of the building. Energy conservation would mean less GHGs emitted from the heating system. Insulated windows reduce the amount of energy needed to heat a building.

Co-Benefits
Improved insulation would bring economic co-benefits because (after installation) the heat would remain inside, thus lowering the need for continuous heating and energy. Insulated windows can reduce exterior noise from reaching the inside of buildings. While providing noise reduction, insulated windows will also lower the amount of money the school spends on heating and cooling the building. Since less wood will be burned in the HHS heating plant, the school will consume and require less wood to be transported to HHS, thus decreasing the school's carbon footprint.

6.1.4 BE-4: EnergyStar®-Rated Appliances

There are currently many old refrigerators located in classrooms and offices throughout the school. Purchasing EnergyStar®-rated appliances will reduce GHG emissions because they reduce power plant emissions. Major home appliances account for about one-fifth of the energy-related GHG emissions in the U.S. Most EnergyStar®-rated appliances use about half the energy of conventional appliances.

Co-Benefits
Buying an energy efficient appliance reduces the tax associated with purchasing the appliance. Although these EnergyStar®-rated items may be slightly more expensive when you purchase them, it will lower the electricity bill because it uses less energy.

6.1.5 BE-5: Perform Energy Audit of Building

HHS should hire an energy services company to perform a building energy audit and to identify potential energy savings through efficiency measures.

Co-Benefits
Building energy efficiency savings through measures identified in the audit would reduce costs associated with building operation and maintenance.

6.1.6 BE-6: Install Energy-Efficient Lighting

Replacing fluorescent bulbs with light-emitting diode (LED) lights would decrease GHG emissions, because LEDs are 40 to 50 percent efficient, whereas the fluorescent light bulbs currently installed are about 20 percent efficient (DIAL 2016). LED bulbs typically last 15 to 25 years whereas fluorescent bulbs typically last about 10 years (NRDC n.d.).

Co-Benefits
Fluorescent bulbs contain mercury and a phosphor coating, both of which are considered hazardous waste. Fluorescent lights age significantly if they are frequently switched on and off (Stouch Lighting 2019). The light produced by LEDs has been shown to improve concentration, motivation, and mood.

6.1.7 BE-7: On-Site Renewable Energy Generation

Generating renewable electricity on-site would reduce and maybe even eliminate HHS's reliance on fossil fuels. If a solar photovoltaic system of 625 kilowatts (approximately 42,000 square feet or one acre) was installed to provide electricity to HHS, all GHG emissions associated with electricity generation would effectively be eliminated. In the 2020/2021 fiscal budget, HHS budgeted $115,000 for electricity

Co-Benefits
Economic co-benefits because we wouldn't need to pay for utility power.

Anticipated GHG Reduction
2025: 109 $MTCO_2e$/year
2050: 109 $MTCO_2e$/year

6.1.8 BE-8: Net Metering

With net metering, the school would have solar panels that could produce surplus energy during the day, but the school would also be able to pull energy from the power grid at night when the solar panels were not producing energy. This means that the school could benefit from the power grid but would not need to rely on the grid completely. The school would consume less electricity and would be more self-sufficient, thus lowering the emission of GHGs.

Co-Benefits
Because the school would be producing more of its own energy, the electricity bill would be less expensive. If the school was able to produce surplus energy, the energy could be sold back to the power company or donated to low income residents who cannot afford to pay for electricity.

6.2 SOLID WASTE GENERATION

HHS’s solid waste is disposed of, primarily, at the Lebanon Landfill. Emissions from decaying putrescible material directly contribute approximately 1 percent of HHS’s total GHG emissions. However, this does not include the emissions associated with hauling of waste to the Lebanon Landfill. This section focuses on opportunities to reduce waste, reuse materials, and recycle what cannot be reused.

6.2.1 SW-1: Compost Used Paper Towels

Currently, the majority of our paper towels are sent to the landfill, and landfills are a source of GHG emissions. Composting paper towels will not only recycle carbon into bioavailable forms; it will also reduce the amount of waste, thus decreasing the amount of GHGs produced.

Co-Benefits
Composting paper towels could provide a source of fertilizer for future food growth, as well as reduce the weight of HHS waste, and therefore the cost, of hauling trash to the landfill.

6.2.2 SW-2: Increase Recycling and Compost Education

Waste in the landfill releases GHG as they decompose anaerobically. HHS has recycling and compost to reduce this effect. Without education for staff and students, these systems become underutilized, and trash ends up in the recycling or compost receptacles.

Co-Benefits
Working as a school to compost and recycle brings the school community together. By reducing the school's trash, the school may save money depending on the specific costs of recycling, composting, and trash disposal at the time.

Anticipated GHG Reduction
2025: 3 $MTCO_2e$/year
2050: 3 $MTCO_2e$/year

6.3 WASTEWATER GENERATION

Wastewater generation accounted for approximately 1 percent of HHS's total GHG emissions in the 2015-16 school year. There are currently no feasible reduction measures associated with this emissions sector.

6.4 WATER CONSUMPTION

Water-related GHG emissions accounted for less than 1 percent of HHS's total GHG emissions in the 2015-16 school year. This section focuses on opportunities to reduce water consumption and its associated energy demand.

6.4.1 WA-1: Choice Flushing

Choice flushing on a toilet would decrease our water consumption. By using less water, the amount of energy and money that is spent on unnecessary water would also decrease. A toilet's water use is about 1.28 to 1.6 gallons per flush. However, the "liquid flush" option allows for a half flush because less water is necessary.

Co-Benefits
By using choice flushing, HHS can lower its water bill and use less energy. This change will also reduce HHS's exports to wastewater treatment plants, thus lowing GHG emissions.

6.5 EMPLOYEE AND STUDENT COMMUTE

GHG emissions associated with staff commute accounted for 24 percent of HHS's anthropogenic GHG emissions in the 2015-16 school year. GHG emissions associated with student commute accounted for 18 percent of HHS's anthropogenic GHG emissions in the 2015-16 school year. This section focuses on opportunities to reduce emissions associated with commuting and incentivizing carpooling and emerging technologies such as electric vehicles.

6.5.1 T-1: Electric Vehicle Charging Stations

Electric vehicles (EVs) reduce reliance on fossil fuels by using electricity to power the vehicle. Reducing fossil fuel consumption improves energy independence and energy security. Electricity can be generated from renewable sources such as solar photovoltaics or wind turbines. If electricity is sourced entirely from renewables, there are effectively no GHG emissions associated with driving EVs.

Co-Benefits

There are economic co-benefits because renewable energy is free (after installation of the infrastructure). There are also air quality and public health benefits to driving EVs because there is no tailpipe releasing emissions of pollutants.

6.5.2 T-2: Carpool Incentives for Students

Carpooling reduces the number of vehicles used on a daily basis. Each vehicle releases an amount of GHGs, starting from the construction of the vehicle, to when it is being operated on the road ways. The less vehicles being driven, the less GHGs emitted. Having an incentive for students to carpool will not only help lower GHG emissions by the school, but also create sustainable methods that can be passed on to future generations. An incentive to carpool could be to offer a free parking pass to those who carpool with a total of three students.

By carpooling to school, HHS can cut down the amount of GHG being released into the atmosphere. As shown in Figure 5, 28.5 percent of the U.S.'s GHG emissions comes from transportation, resulting in approximately 200 million $MTCO_2e$ in 2016. If half the number of cars were driven to HHS every day but students or staff, that would have a significant impact on the rate at which GHGs are being emitted.

Co-Benefits

A co-benefit of carpooling is an economic gain. Since driving requires gas and gas requires money, people who carpool will save a significant amount of money by not paying for gas. This would provide improved air quality, reduced traffic congestion, and reduced commute times. The cost of road repairs and gas money spent would be reduced. Also, the amount of money that is spent on a car or parking passes could be shared among students, which would result in more parking spaces available. Through this action, we would also create a more cohesive community.

6.5.3 T-3: Bike Shelter

Encouraging students and staff to bike to school would decrease reliance on cars and buses which emit GHGs. A bike shelter could also include a solar-powered charging station for electric bikes.

Co-Benefits

Encouraging biking for students and staff would encourage exercising which is a health benefit. By reducing use of vehicles on the way to and from school, the morning traffic would be reduced, thereby decreasing emissions from idling cars and reduce traffic congestion.

6.6 SCHOOL BUSES

GHG emissions associated with school buses accounted for 34 percent of HHS's anthropogenic GHG emissions in the 2015-16 school year. This section focuses on opportunities to reduce GHG emissions associated with the use of diesel-fueled school buses.

6.6.1 SB-1: Efficient School Bus System

A school bus system that is efficient and accessible will decrease the number of vehicles driven to school. This will reduce the number of cars commuting into Hanover. Having an efficient school bus system means having the fewest number of school buses possible to pick up students.

Co-Benefits

The price of fossil fuels will continue rising so the sooner we can reduce our reliance on them the more money and GHG emissions we can save. A more efficient school bus system will also benefit the social environment of the school because there will be an increase in the number of students that ride school buses, and therefore they will have a time to bond and make new friends. It will also cut down on traffic for commuters.

6.6.2 SB-2: Renewable Biodiesel in School Buses

School buses relying on biodiesel (or other renewable diesels) will reduce GHG emissions because they are not a fossil carbon-based fuel. School buses running on biodiesel would also allow for soaps, oils, beauty products, and alcohols to be repurposed instead of wasted.

Co-Benefits

There are economic, social, and environmental co-benefits to using biodiesel fuel in school buses. In terms of economic benefits, once a streamlined system is established to create and pump the biodiesel, the ingredients of the biodiesel are much cheaper than the cost of diesel. Also, using biofuel would begin to reduce the U.S.'s reliance on fossil fuels. Less tax money would be allocated to protecting our oil supplies overseas. This money could instead be diverted to develop local biofuel initiatives. Environmentally, soap, beauty products, and cooking oil can be easily acquired through partnerships with hotel or restaurant industries who are looking to repurpose/recycle some of their waste. Also, making biodiesel is significantly less energy-intensive than refining gasoline and diesel. Socially, there are air quality and public health benefits that result from using biodiesel instead of fossil fuels.

Anticipated GHG Reduction

2025: 766 $MTCO_2e$/year
2050: 766 $MTCO_2e$/year

6.6.3 SB-3: Electric School Buses

Electric school buses would significantly decrease fossil fuel emissions by switching energy from diesel fuel to electricity. The buses could be charged at solar-powered charging stations to eliminate GHG emissions associated with school buses.

Co-Benefits

Electric buses require less maintenance as there are fewer parts than an internal combustion engine. They are quieter, and do not release harmful gases and particulates into the atmosphere. Also, it protects the community from the risk of global oil price hikes.

6.6.4 SB-4: Bike and Ski Racks on School Buses

Bike and ski racks on school buses would encourage more students to ride the bus, instead of using their own cars. Some students may drive themselves to school because they cannot take their equipment on the bus. Bike racks could also encourage students to bike to their bus stop, instead of driving to their bus stop. More students riding the buses would reduce GHG emissions and fossil fuel consumption because they would not be driving their own fuel-consuming vehicles.

Co-Benefits

More students riding the bus could result in more available parking spaces, which could be used for EV charging stations. Students could bring their bike to school in the morning on the bus when it is cool, but bike home in the afternoon when it is warmer.

6.7 CAFETERIA

6.7.1 C-1: Buy Local Food

Use of locally grown food from small farms in lieu of food produced on large scale industrial farms will decrease the amount of GHGs associated with production and transport of food to the school. For example, synthesis of chemical fertilizers used in conventional agriculture requires significant amounts of fossil fuels. It will also decrease the fuel needed to transport food to the school.

Co-Benefits

Conventional agriculture uses chemical pesticides which can harm pollinators, and the health of many other organisms, including humans. Chemical fertilizers can runoff into local waterways causing eutrophication. By offering locally produced food in the cafeteria, HHS can support farmers that employ sustainable farming practices. Buying locally grown food can also help grow the local economy by supporting small-scale farms.

6.7.2 C-2: Transition to reusable or compostable cutlery and dishes

Currently, compostable cutlery and dishes are used in the Cafe, but unfortunately is not accepted by the compost company employed by HHS and is therefore sent to the landfill. Using a dishwasher to wash reusable dishes and utensils would reduce the waste HHS is sending to the landfill and therefore reduce GHG emissions. An alternative to purchasing reusable cutlery would be to find a compost company that takes compostable cutlery.

Co-Benefits

A co-benefit of using reusable dishes/cutlery is financial savings from a decreased purchasing demand. Additionally, there will be less waste in the landfills. Reusable materials in the Cafe are more pleasant to eat with and will encourage students to set aside time for lunch, thus building community. The sales from the Cafe will increase as well when students feel morally better about supporting their business.

6.8 MISCELLANEOUS

6.8.1 M-1: Create CAP Team with Environmental Club

Creating a CAP team of students committed to this project within the Environmental Club that can work with B&G, the school's administration, and the Dresden School Board to implement the CAP for HHS is critical. Monthly meetings with a representative from each of these groups will help ensure effective communication, provide an opportunity to discuss effective strategies for implementing the CAP, and will also build community.

Co-Benefits

The co-benefits of the creation of this team include raising awareness of the urgency of addressing climate change in our own community. Further, students will learn that they can reduce their own carbon footprint by making small changes in their own behavior and thereby contribute to the success of the CAP.

6.8.2 M-2: Revise HHS Mission Statement to Reflect Climate Goals

Include the word "action" in HHS mission statement such that it reads: "action to reduce HHS GHG emissions and mitigate the impacts of climate change."

Incorporating "action" in the HHS mission statement will highlight the importance of implementing this CAP. Similar to the emphasis on minds, heart, and voices, this would reinforce the school's commitment to addressing climate change.

Co-Benefits

Students will be more motivated to lead and participate in GHG reduction measures.

6.9 SUMMARY

As noted in Table 4 above, the GHG reduction measures identified in this CAP would reduce HHS's GHG emissions to well below the 2025 reduction target and make significant progress toward the longer-term 2050 reduction goal. Figure 9 below demonstrates how the reduction measures achieve the identified target.

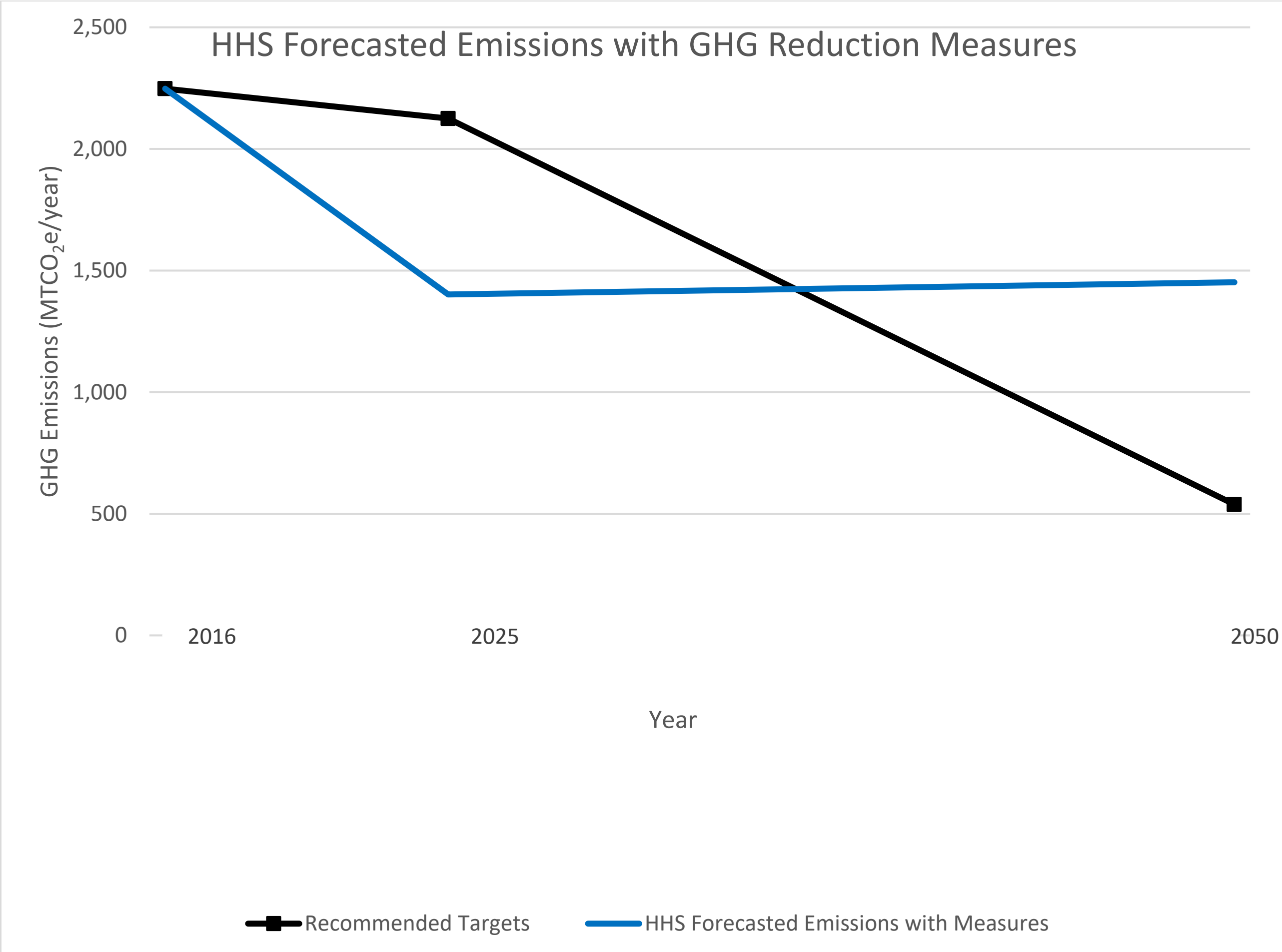


Figure 9. Hanover High School's Forecasted Emissions with Implementation of Greenhouse Gas Reduction Measures

7 IMPLEMENTATION

Implementing each GHG reduction measure under the HHS CAP requires identifying the groups within the school that would be responsible for implementation, determining priority, anticipated cost, and timeframe required to complete the action. Priority and cost are categorized as low, medium, and high ($, $$, $$$ for cost) based on an analysis performed by the 2018-19 Earth Systems class. Timeframes are categorized as near-term (1 to 2 years), mid-term (3 to 6 years), and long term (more than 6 years). Table 5 below shows the implementation requirements of each GHG reduction measure.

Table 5 Implementation Matrix

Measure Number	Measure Description	Implementing Body	Priority	Cost	Timing
BE-1	Purchase certified sustainable wood chips	Building Administration	High	$	Near-term
BE-2	Upgrade heaters	Building Administration	Medium	$$$	Long-term
BE-3	Improved building insulation	Building Administration	High	$$$	Long-term
BE-4	EnergyStar®-rated appliances	Building Administration	High	$$	Long-term
BE-5	Energy audit of building	Building Administration	High	$$	Mid-term
BE-6	Install energy-efficient lighting	Building Administration	Low	$	Mid-term

BE-7	On-site renewable energy generation	Building Administration	Medium	$$$	Long-term
BE-8	Net metering	Building Administration	Medium	$	Long-term
SW-1	Compost used paper towels	Building Administration	Medium	$	Near-term
SW-2	Increase recycling and composting education	Environmental Club	High	$	Near-term
WA-1	Install dual-flush toilets	Building Administration	Low	$$	Long-term
TR-1	Electric vehicle charging stations	Building Administration	Medium	$$	Mid-term
TR-2	Carpool incentives for students	Building Administration Environmental Club / personally	Medium	$	Mid-term
TR-3	Bike shelter	Building Administration and Bike Club	High	$	Near-term
SB-1	Efficient school bus system	Building Administration	High	$	Near-term
SB-2	Renewable diesel in school buses	Building Administration	High	$$$	Mid-term
SB-3	Replace diesel-fueled school buses with electric versions	Building Administration	High	$$$	Long-term
SB-4	Bike and ski racks on school buses	Building Administration	Medium	$$	Mid-term
C-1	Buy local food	Building Administration and Environmental Club and Cafe Services	Medium	$$	Mid-term
C-2	Transition to reusable/compostable cutlery and dishes	Cafeteria	Medium	$	Mid-term
M-1	Create CAP team with Environmental Club	Environmental Club	High	$	Near-term
M-2	Revise HHS Mission Statement to reflect climate goals	HHS Council	Low	$	Mid-term

Notes: GHG = greenhouse gas; $MTCO_2e$ = metric tons of carbon dioxide equivalent; N/A = not applicable; CAP = Climate Action Plan.

7.1 IMPLEMENTATION PROGRESS

Since the CAP was adopted, significant progress has been made on implementing the goals. Below are summaries of the progress made as of April 2022.

- Measure BE-1: A group of students in the 2020/2021 school year wrote a request for proposals (RFP) to identify a source of sustainably harvested wood chips within a 50-mile radius of HHS. This RFP was written to fulfill Measure BE-1 and can be viewed in the appendix of this document.

  Two companies responded to the RFP and the school chose to go with Cousineau Forest Products from Henniker, NH. Documentation from Cousineau that provides information on meeting the requirements laid out in the RFP is a challenge because Cousineau sources its wood chips from several logging companies across New Hampshire.

- Measures SB-2 and SB-3: Based on current information provided by the school bus energy industry, the option of replacing fossil fuel-based diesel with renewable diesel, seems unlikely due to the rapid progress in developing electric school buses. At this time, implementation of Measures SB-2 and SB-3 are on hold until the school bus company makes further progress obtaining electric school buses.

- Measure BE-5: In December 2019, Resilient Buildings Group from Concord, NH performed an Energy Assessment of the Hanover High School building shell, lighting, and building systems. This report can be found in Appendix 2. Liberty Utilities provided funding for the Energy Audit through the NHSaves energy efficiency incentive initiative.

- Measure BE-6: During the 21/22 school year, students used maps of the lighting units throughout the school to determine the number of light bulbs and fixtures that need to be replaced with energy-efficient LEDs. Lighting will be replaced with LEDs during the 22/23 school year.

- Measure M-1: A Climate Action Plan Implementation Team (CAPIT) was formed during the 2018-2019 school year and was composed of HHS students, teachers, administrators, and community members. We also worked with a consultant from the biomass heating industry. This group met twice to discuss implementation strategies. Since that time, the CAPIT has become a sub-committee of the high school's student-run Environmental Club.

8 ACKNOWLEDGEMENTS

The students and teacher of HHS's Earth Systems and Ecological Design class would like to thank Hannah Kornfeld for providing guidance throughout this project, and for her significant contributions to helping write and edit this report. The Earth Systems class would also like to thank Educating for Sustainability consultant Scott Stokoe, Director of Facilities Anthony Daigle, and Principal Justin Campbell for their feedback and support.

9 REFERENCES

25x25 initiative. N.d. About 25x'25. Available: http://www.25x25.org/index.php?option=com_content&task=view&id=12&Itemid=41. Accessed June 7, 2018.

The Climate Change Group. 2017 (December). The Under2 Coalition. Available: https://www.theclimategroup.org/project/under2-coalition. Accessed May 30, 2018.

DES. *See* New Hampshire Department of Environmental Services.

EIA. *See* U.S. Energy Information Administration.

EPA. *See* U.S. Environmental Protection Agency.

Green Energy Times. 2017 (May 15). Hanover becomes first New Hampshire town to commit to 100 percent renewable energy. Available: http://www.greenenergytimes.org/2017/05/10/hanover-becomes-first-new-hampshire-town-to-commit-to-100-percent-renewable-energy/. Accessed April 28, 2019.

Greene, B. 2017 (August 3). Lebanon is Latest N.H. City to Sign on to Paris Climate Goals. Available: http://nhpr.org/ post/lebanon-latest-nh-city-sign-paris-climate-goals#stream/0. Accessed June 7, 2018.

Harrold, K. 2016 (August 19). New Hampshire Renewable Portfolio Standard. Available: http://www.puc.state.nh.us/sustainable energy/RPS/NH RPS Retrospective 2007-2015 Report - FINAL.pdf. Accessed June 7, 2018.

Ho, B. 2017 (December 19). RGGI States Set a New Standard for Climate Action in 2017. Available: https://www.nrdc.org/experts/bruce-ho/rggi-states-set-new-standard-climate-action-2017. Accessed June 7, 2018.

IPCC. *See* Intergovernmental Panel on Climate Change.

Intergovernmental Panel on Climate Change. 2013. Climate change 2013: The physical science basis. Working Group I contribution to the IPCC Fifth Assessment Report. Cambridge, United Kingdom: Cambridge University Press. Available: www.ipcc.ch/report/ar5/wg1. Accessed April 28, 2019.

Keeling, C. D. 1997 (August 5). Climate change and carbon dioxide: An introduction. Retrieved from http://www.pnas.org/content/94/16/8273. Accessed April 28, 2019.

Levy, S. 2017 (May 10). Hanover becomes first New Hampshire town to commit to 100 percent renewable energy. Available: https://content.sierraclub.org/press-releases/2017/05/hanover-becomes-first-new-hampshire-town-commit-100-percent-renewable-energy. Accessed April 28, 2019.

Lindsey, R. 2017 (October 17). Climate Change: Atmospheric Carbon Dioxide. Available: https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide. Accessed April 28, 2019.

Mitchell, C. 1997. Greenhouse and the Science of Uncertainty. Retrieved from http://www.abc.net.au/science/earth/climate/uncertain.htm. Accessed February 8, 2018.

NASA. *See* National Aeronautics and Space Administration.

National Aeronautics and Space Administration. Scientific consensus: Earth's climate is warming. Available: https://climate.nasa.gov/scientific-consensus/. Accessed April 28, 2019.

______. 2019 (April 25). Climate change evidence: How do we know? Available: https://climate.nasa.gov/evidence/. Accessed April 28, 2019.

National Oceanic and Atmospheric Administration. 2008. Temperature Change and Carbon Dioxide Change. Available: https://www.ncdc.noaa.gov/global-warming/temperature-change. Accessed April 28, 2019.

National Highway Traffic and Safety Administration. 2017 (August 27). Corporate Average Fuel Economy. Available: https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy. Accessed June 1, 2018.

Natural Resources Defense Council. 2017 (September 29). What Is the Clean Power Plan? Available: https://www.nrdc.org/stories/how-clean-power-plan-works-and-why-it-matters. Accessed January 9, 2018.

New Hampshire Department of Environmental Services. 2009 (March). The New Hampshire Climate Action Plan. Available: https://www.des.nh.gov/organization/divisions/air/tsb/tps/climate/action_plan/documents/nhcap_final.pdf. Accessed November 12, 2018.

New Hampshire Public Utilities Commission. N.d. Electric Renewable Portfolio Standard (RPS). Available: https://www.puc.nh.gov/Sustainable%20Energy/Renewable_Portfolio_Standard_Program.htm. Accessed March 20, 2022.

New Jersey Department of Environmental Protection, Air Quality, Energy and Sustainability. 2019 (January 31). Regional Greenhouse Gas Initiative. Available: http://www.state.nj.us/dep/aqes/rggi.htm. Accessed April 28, 2019.

NHPUC. *See* New Hampshire Public Utilities Commission.

NOAA. *See* National Oceanic and Atmospheric Administration.

NRCD. *See* Natural Resources Defense Council.

Osterberg, D. E. N.d. *Latest Research on Climate Change in the Upper Valley* [PowerPoint Presentation]. Available: http://uvaw.uvlsrpc.org/files/4215/1084/1224/Osterberg_presentation.pdf. Accessed April 28, 2019.

Peng, S., Huang, J., Sheehy, J. E., Laza, R. C., Visperas, R. M., Zhong, X., Centeno, G. S., Khush, G. S., and K. G. Cassman. 2004 (July 6). Rice yields decline with higher night temperature from global warming. Proceedings of the National Academy of Sciences of the United States of America. 101(27) 9971-9975. Available: https://www.pnas.org/content/101/27/9971. Accessed August 15, 2021.

Philip, A., Sims, E., Houston, J., and R. Konieczny. 2017 (August 14). 63 million Americans exposed to unsafe drinking water. Available: https://www.usatoday.com/story/news/2017/08/14/63-million-americans-exposed-unsafe-drinking-water/564278001/. Accessed August 15, 2021.

Plymouth State University. 2018. Climate Action Plan Chapter 1: Introduction. Available: https://campus.plymouth.edu/climate-action-plan/introduction/. Accessed April 28, 2019.

Public Health Council of the Upper Valley and Upper Valley Lake Sunapee Regional Planning Commission. 2015 (November). *Climate+Health: Climate and Health Adaptation Plan for the Public Health Network of the Upper Valley*. Available: https://uvpublichealth.org/wp-content/uploads/2015/12/UVClimate-Health-Adaptation-Plan-_-Nov2015.pdf. Accessed April 28, 2019.

RGGI. *See* The Regional Greenhouse Gas Initiative.

Ropeik, A. 2018 (April 17). Regional Greenhouse Gas Initiative Still Boosting Northeast Economies, Study Says. Available: http://www.wbur.org/bostonomix/2018/04/17/regional-greenhouse-gas-initiative-economic-impact. Accessed April 28, 2019.

The Regional Greenhouse Gas Initiative. 2018 (June). Elements of RIGGI. Available: https://www.rggi.org/. Accessed June 4, 2018.

Scripps Institution of Oceanography UC San Diego. 2017. History & Legacy: Keeling Curve Lessons. Available: http://scrippsco2.ucsd.edu/history_legacy/keeling_curve_lessons. Accessed April 29, 2019.

Sears, A. 2018 (January 12). Hanover Leading NH to 100-Percent Renewable Energy. Available: https://www.publicnewsservice.org/2018-01-12/energy-policy/hanover-leading-nh-to-100-percent-renewable-energy/a61010-1. Accessed April 28, 2019.

Sierra Club. 2018 (May 10). 100% Commitments in Cities, Counties, & States. Available: https://www.sierraclub.org/ready-for-100/commitments. Accessed April 28, 2019.

State of New Hampshire. 2016 (September). County Population Projections, By Municipality. Available: https://www.nh.gov/osi/data-center/documents/2016-subcounty-projections-final-report.pdf. Accessed November 12, 2018.

______. 2000. New Hampshire in the New Economy: A Vision for Expanded Prosperity. Available: https://www.nh.gov/osi/planning/resources/documents/state-development-plan.pdf. Accessed April 28, 2019.

Town of Hanover. 2017 (May 10). Getting to 100% Renewable energy in Hanover NH. Available: https://www.hanovernh.org/sites/hanovernh/files/uploads/renewable_energy_information.pdf. Accessed April 28, 2019.

UNFCCC. *See* United Nations Framework Convention on Climate Change.

UNICEF. 2021 (March 18). Water and the global climate crisis: 10 things you should know. Available: https://www.usda.gov/oce/energy-and-environment/food-security. Accessed August 15, 2021.

Union of Concerned Scientists. 2018 (November 1). The Clean Power Plan: A Climate Game Changer. Available: https://www.ucsusa.org/our-work/global-warming/reduce-emissions/what-is-the-clean-power-plan#.WxknRkgvzrd. Accessed April 28, 2019.

United Nations Framework Convention on Climate Change. N.d. Summary of the Paris Agreement. Available: http://bigpicture.unfccc.int/#content-the-paris-agreement. Accessed May 30, 2018.

USDA. *See* U.S. Department of Agriculture.

U.S. Department of Agriculture. No date. Climate Change, Food Security, and the U.S. Food System. Available: https://www.usda.gov/oce/energy-and-environment/food-security. Accessed August 15, 2021.

U.S. Energy Information Administration. N.d. New Hampshire Renewables Data Map. Available: https://www.eia.gov/beta/states/states/nh/data/dashboard/renewables. Accessed March 20, 2022.

U.S. Environmental Protection Agency. 2018 (April 11). Sources of Greenhouse Gas Emissions. Available: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions. Accessed June 5, 2018.

______. 2016. Inventory of U.S. greenhouse gas emissions and sinks: 1990–2014. Available: https://19january2017snapshot.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2014_.html. Accessed April 28, 2019.

______. 2017 (December 19). Learn About SmartWay. Available: https://www.epa.gov/smartway/learn-about-smartway. Accessed May 31, 2018.

______. 2018 (May 22). SmartWay Program Successes. Available: https://www.epa.gov/smartway/smartway-program-successes. Accessed May 31, 2018.

______. 2017 (May 3). SmartWay Sustainability Accounting and Reporting. Available: https://www.epa.gov/smartway/smartway-sustainability-accounting-and-reporting. Accessed June 5, 2018.

______. 2014 (April). SmartWay Transport Partnership Program: Recommendations and Findings. Available: https://www.epa.gov/sites/production/files/2014-09/documents/smartway-wkgrp-report-042014.pdf. Accessed May 31, 2018.

______. 2022. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020. Available: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks. Accessed April 26, 2022.

World Bank. 2007 (October). What Are the Links between Agricultural Production and Food Security? Available. https://elibrary.worldbank.org/doi/10.1596/978-0-8213-6807-7_FocusC. Accessed August 15, 2021.

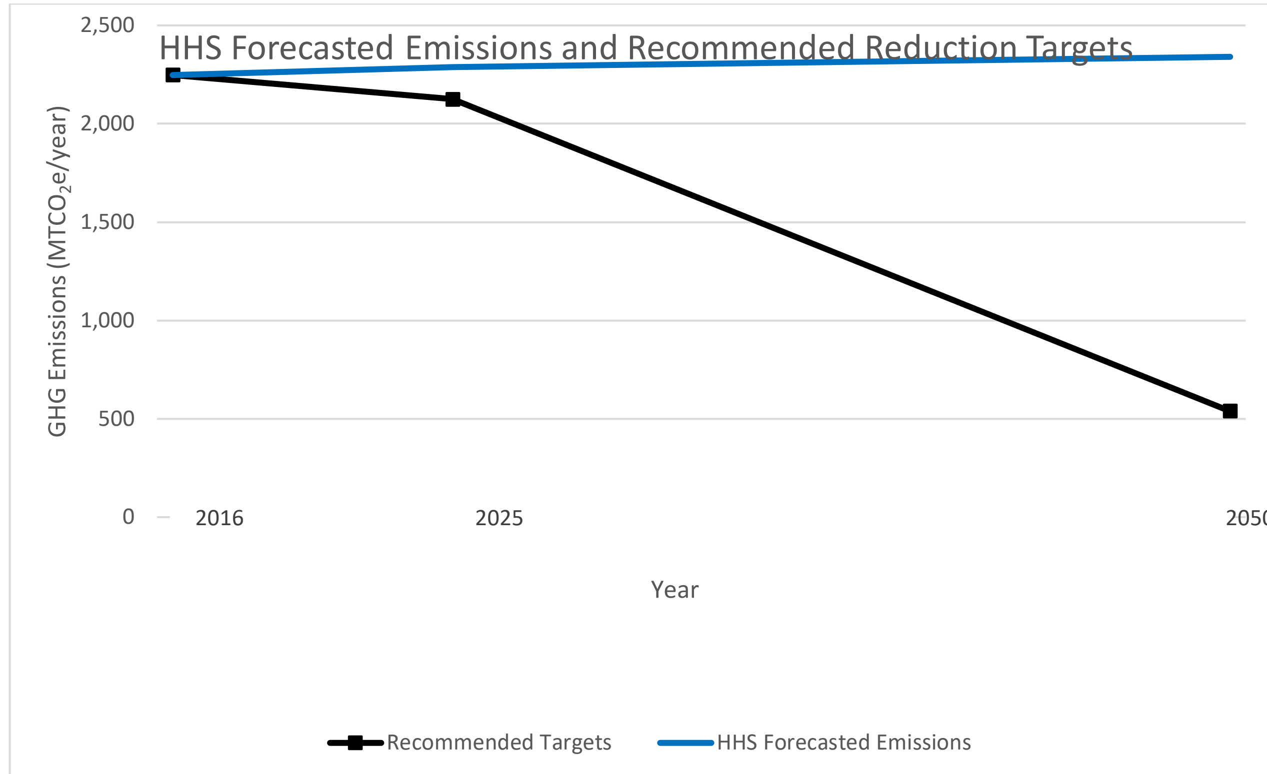
Appendix A

Supporting Calculations and Documentation

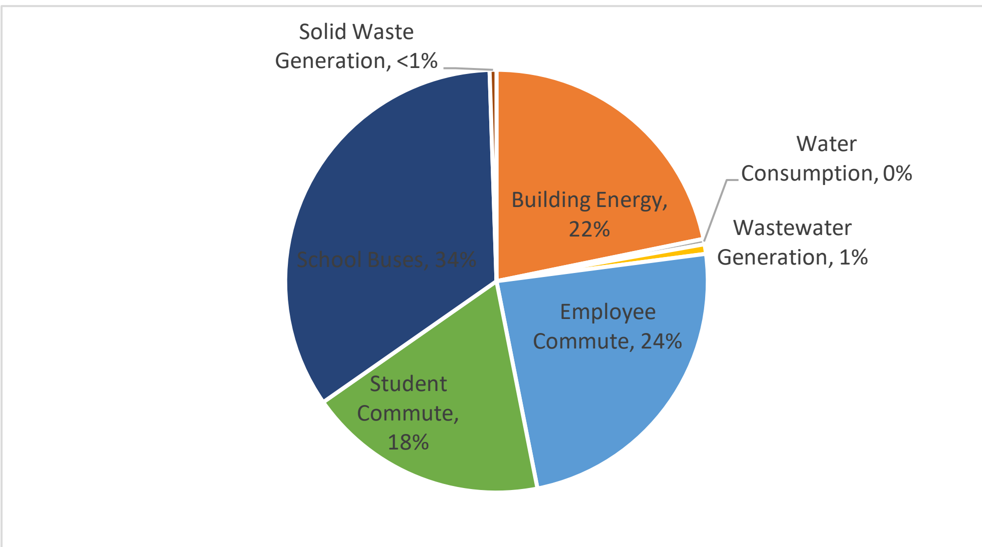
HHS GHG Emissions Inventory and Forecast

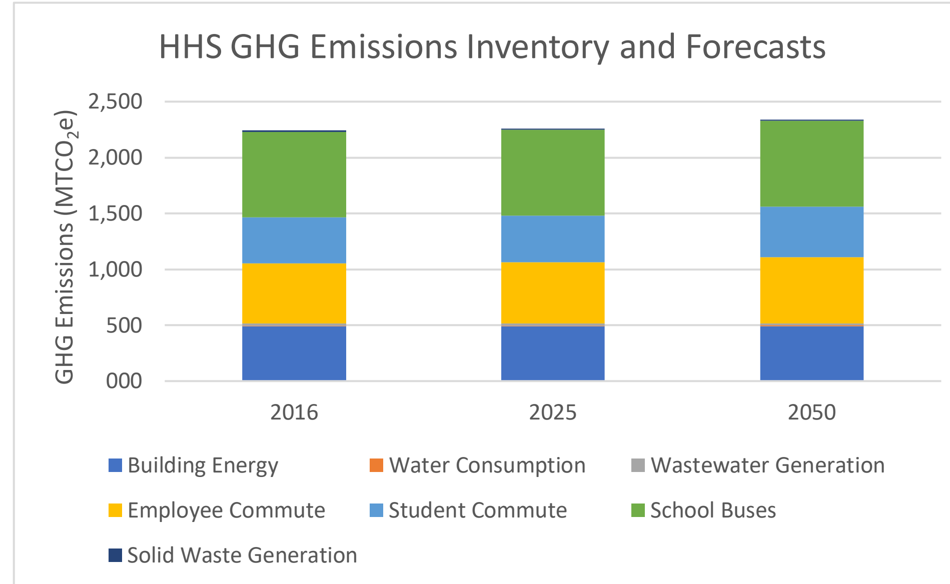
		2016			2025			2050		
Sector	Subsector	Activity Data	Units	Emissions	Activity Data	Units	Emissions	Activity Data	Units	Emissions
Building Energy	Electricity	756,000	kWh/yr	108.64	756,000	kWh/yr	108.64	756,000	kWh/yr	108.64
Building Energy	Wood Chips - Biogenic	732	tons/yr	1100.00	732	tons/yr	1,100.00	732	tons/yr	1,100.00
Building Energy	Wood Chips - Anthropo	732	tons/yr	311.08	732	tons/yr	311.08	732	tons/yr	311.08
Building Energy	Propane	1,348	GGE/yr	7.63	1,348	GGE/yr	7.63	1,348	GGE/yr	7.63
Building Energy	#2 Fuel Oil	5,910	gallons/yr	61.17	5,910	gallons/yr	61.17	5,910	gallons/yr	61.17
Subtotal - Anthropogenic				488.52			488.52			488.52
Subtotal - Biogenic				1100.00			1,100.00			1,100.00
Water Consumption	Surface Water	0.0918	MG	9.34	0.093463658	MG	9.513654	0.100978989	MG	10.27864
Wastewater	Stationary CH4			10.44			10.77			12.30
	Stationary N2O			0.03			0.03			0.03
	Process N2O			2.40			2.479957			2.588485
	Fugitive N2O			3.47			3.587613			3.744613
Subtotal				25.68			26.38			28.94
Vehicles	Employee Commute	total gallons	gallons gasoline	505.90	total gallons	gallons gasoline	514.94	total gallons	gallons gasoline	555.82
	Employee Commute	54,671	gallons diesel	31.33	55,649	gallons diesel	31.89	60,066	gallons diesel	34.42
	Student Commute	3,066	gallons gasoline	388.66	3,121	gallons gasoline	395.71	3,369	gallons gasoline	427.53
	Student Commute	42,002	gallons diesel	24.07	42,763	gallons diesel	24.50	46,202	gallons diesel	26.47
	School Buses	2,356	gallons diesel	766.28	2,398	gallons diesel	766.28	2,591	gallons diesel	766.28
Subtotal				1,716.23			1733.319			1810.514
Solid Waste	Landfilled Waste	35.56	tons/yr	11.74	36.98	tons/yr	12.21	38.88	tons/yr	12.84
Subtotal				11.74			12.21			12.84
Total - Anthropogenic				**2,242**			**2,260**			**2,341**
Total				**3,342**			**3,360**			**3,441**

	2016	2025	2050
Building Energy	489	489	489
Water Consumption	17	17	18
Wastewater Generation	16	17	18
Employee Commute	536	558	586
Student Commute	412	429	450
School Buses	766	766	766
Solid Waste Generation	11.74	12	13
HHS Forecasted Emissions	2,248	2,287	2,340
Axis			
Recommended Targets	2,248	2,125	538



Sector	Percent of Total	2016	2025	2050
Building Energy	22%	489	489	489
Water Consumption	0%	9	10	10
Wastewater Generation	1%	16	17	19
Employee Commute	24%	537	547	590
Student Commute	18%	413	420	454
School Buses	34%	766	766	766
Solid Waste Generation	1%	12	12	13
HHS Forecast Emissions		2242	2260	2341
HHS Target Emissions		2242	2125	538





Scaling Factors

	2016	2020	2025	2050
Town of Hanover	11,367	11,470	11,573	12,730
Growth Rate		1%	2%	10%
Student Population	753	760	767	828
Year Round Staff Population	250	252	255	275
Teacher Population	183	185	186	201

Notes
Town of Hanover baseline population estimate is 2015 data

Source: Hanover Projections https://www.nh.gov/osi/data-center/documents/2016-subcounty-projections-final-report.pdf

GHG Inventory and Forecast Calculations

Building Energy	2016			2020			2025			2050		
Source	Amount	Units	MTCO2e	Amount	Units	MTCO2e	Amount	Units	MTCO2e	Amount	Units	MTCO2e
Electricity	756,000	kWh/yr	109	756,000	kWh/yr	109	756,000	kWh/yr	109	756,000	kWh/yr	109
Wood Chips - Biogenic	731.69	tons/yr	1,100	732	tons/yr	1,100.00	732	tons/yr	1,100	732	tons/yr	1,100
Wood Chips - Anthropogenic	731.69	tons/yr	311	732	tons/yr	311	732	tons/yr	311	732	tons/yr	311
Propane	1,348	GGE/yr	8	1,348	GGE/yr	8	1,348	GGE/yr	8	1,348	GGE/yr	8
#2 Fuel Oil	5,910	gallons/yr	61	5,910	gallons/yr	61	5,910	gallons/yr	61	5,910	gallons/yr	61
Total - Anthropogenic			177			177			177			177
Total			1589			1589			1589			1589

Water Consumption												
	Amount	Units	MTCO2e	Amount	Units	MTCO2e	Amount	Units	MTCO2e	Amount	Units	MTCO2e
Surface Water	0.092	MG	9.3	0.09	MG	9.4	0.09	MG	9.5	0.10	MG	10.3

Wastewater Consumption											
Source	Amount	Units	Source	Amount	Units	Source	Amount	Units	Source	Amount	Units
Teachers	1,976,400	gal/yr	Teachers	1,994,309	gal/yr	Teachers	2,012,218	gal/yr	Teachers	2,174,018	gal/yr
Yr Round Staff	247,500	gal/yr	Yr Round Staff	249,743	gal/yr	Yr Round Staff	251,985	gal/yr	Yr Round Staff	272,247	gal/yr
Students	12,198,600	gal/yr	Students	12,309,135	gal/yr	Students	12,419,671	gal/yr	Students	13,418,326	gal/yr
Total	14,422,500	gal/yr	Total	14,553,187	gal/yr	Total	14,683,874	gal/yr	Total	15,864,591	gal/yr

Stationary Emissions		Units	Stationary Emissions		Units	Stationary Emissions		Units	Stationary Emissions		Units
P	884	people	P	890.82	people	P	897.646345	people	P	959.2917099	people
Digester gas	884	std ft3/person/day	Digester gas	890.82	std ft3/person/day	Digester gas	897.646345	std ft3/person/day	Digester gas	959.2917099	std ft3/person/day
Annual CH4 emissions	10.44	MTCO2e	Annual CH4 emissions	10.61	MTCO2e	Annual CH4 emissions	10.77	MTCO2e	Annual CH4 emissions	12.30	MTCO2e
Annual N2O emissions	0.03	MTCO2e	Annual N2O emissions	0.03	MTCO2e		0.03			0.03	

Process Emissions			Process Emissions			Process Emissions			Process Emissions		
Annual N2O emissions	2.40	MTCO2e	Annual N2O emissions	2.42	MTCO2e	Annual N2O emissions	2.48	MTCO2e	Annual N2O emissions	2.59	MTCO2e

Fugitive Emissions		MTCO2e	Fugitive Emissions		MTCO2e	Fugitive Emissions		MTCO2e	Fugitive Emissions		MTCO2e
Annual N2O Emissions	3.47			3.50			3.59			3.74	

Solid Waste			2020	2025	2050
	32	lb/cubic yard			
Mixed recycling	520	cubic yards	524.71	529.42	571.99
	8.32	tons	8.40	8.47	9.15
Mixed Paper	1.16	tons	1.17	1.18	1.28
Mixed MSW	33.72	tons	34.03	34.33	37.09
Fly Ash	1.84	tons	1.86	1.87	2.02

Box WW.2.(alt) Example Calculation of N_2OEmissions from Combustion when only Population Served by System is Known

A centralized wastewater facility serves a city with a population of 100,000 people. No other data is available. Based on this scenario the N_2O emissions from the combustion of digester biogas can be calculated as follows

Description		Value
N_2O emissions	= Total N_2O emitted by combustion ($mtCO_2e$)	Result
P	= Population served by anaerobic digester	100,000
Digester gas	= Measured standard cubic feet of digester gas produced per person per day (std ft^3/person/day)	1.0
fCH_4	= Fraction of CH_4 in biogas	0.65
BTU_{CH4}	= Default BTU content of CH_4, higher heating value (BTU/ft^3)	1028
10^{-6}	= Conversion from BTU to 1 MMBTU	10^{-6}
EF_{N2O}	= N_2O emission factor (kg N_2O/MMBTU)	6.3×10^{-4} kg N_2O per MMBTU
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{N_2O}	= Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP^{11}

Sample Calculation:

$$\text{Annual } N_2O \text{ emissions} = (100{,}000 \times 1 \times 0.65 \times 1028 \times 10^{-6} \times (6.3 \times 10^{-4}) \times 365.25 \times 10^{-3}) \times 310 = 4.8\ mtCO_2e$$

4.766492777

***Equation WW.1. (alt)* Emissions from Devices Designed to Combust Anaerobic Digester Gas**

$$\text{Annual } CH_4 \text{ emissions} = (P \times \text{Digester Gas} \times fCH_4 \times BTU_{CH4} \times 10^{-6} \times EF_{CH4} \times 365.25 \times 10^{-3}) \times GWP$$

Where:

Description		Value
Annual CH_4 emissions	= Total annual CH_4 emitted by devices designed to combust digester gas ($mtCO_2e$)	Result
P	= Population served by the WWTP with anaerobic digesters	User input
Digester gas	= Standard cubic feet of digester gas produced per person per day (std ft^3/person/day)	1.0
fCH_4	= Fraction of CH_4 in gas	0.65
BTU_{CH4}	= Default BTU content of CH4, higher heating value (BTU/ft^3)	1028
10^{-6}	= Conversion from BTU to 1 MMBTU	10^{-6}
EF_{CH4}	= CH_4 emission factor (kg CH_4/MMBTU)	3.2×10^{-3} kg CH_4 per MMBTU
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{CH_4}	= Global Warming Potential; conversion from mt of CH_4 into mt of CO_2 equivalents	GWP^7

Source: As listed in LGO Equation 10.2 from EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007, Chapter 8, 8-7 (2009) and 40 CFR Part 98, Mandatory Reporting of Greenhouse Gases; Final Rule, Table C-2, page 79154 of the Federal Register / Vol. 75, No. 242 / Friday, December 17, 2010 / Rules and Regulations, is referenced an emission factor for digester gas combustion: 3.2×10^{-3} kg CH_4 per million BTU. See: http://edocket.access.gpo.gov/2010/pdf/2010-30286.pdf

***Equation WW.7* N_2O Process Emission from Wastewater Treatment Plants (or aeration basin) that Uses Nitrification or Denitrification**

$$\text{Annual } N_2O \text{ emissions} = ((P \times F_{ind\text{-}com}) \times EF \times 10^{-6}) \times GWP$$

Where:

Description		Value
Annual N_2O emissions	= Total annual N_2O emitted by WWTP processes ($mtCO_2e$)	Result
P	= Population served by the WWTP adjusted for industrial discharge (if applicable)	User input
$F_{ind\text{-}com}$	= Factor for high nitrogen loading of industrial or commercial discharge	1.25
$F_{ind\text{-}com}$	= Factor for insignificant industrial or commercial discharge	1
EFnit/denit	= Emission factor for a WWTP with nitrification or denitrification (g N_2O/ person equivalent/year)	7
		10^{-6}
10^{-6}	= Conversion from g to mt (mt/g)	
GWP_{N_2O}	= Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP^{21}

Source: *As listed in LGO protocol Equation 10.7 from EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1890-2007, Chapter 8, 8-13 (2009)*

***Equation WW.12.(alt)* N_2O Emission from Effluent Conversion when only Population Served by Wastewater Treatment Plant is Known**

$$\text{Annual } N_2O \text{ emissions} = ((P \times F_{ind\text{-}com}) \times (\text{Total N load} - \text{N uptake} \times \text{BOD5 load}) \times \text{EF effluent} \times 44/28 \times (1 - \text{Fplant nit/denite}) \times 365.25 \times 10^{-3}) \times GWP$$

Where:

Description		Value
N_2O emissions	= Total annual N_2O emitted by effluent (mtCO2e)	Result
P	= Population	User input
$F_{ind\text{-}com}$	= Factor for industrial or commercial discharge	1.25 (if applicable)
Total N-Load	= Average total nitrogen per day (kg N/person/day)	0.026^{34}
N uptake	= Nitrogen uptake for cell growth in *aerobic* systems (kg N/kg BOD_5)	0.05
OR		
N uptake	= Nitrogen uptake for cell growth in *anaerobic or lagoon* systems(kg N/kg BOD_5)	0.005
BOD_5	= Amount of BOD_5 produced per person per day (kg BOD_5/person/day)	0.090
EF	= Emission factor (kg N_2O-N/kg sewage-N discharged)	0.005 for river or stream discharge, 0.0025 for direct ocean discharge[35]
44/28	= Molecular weight ratio of N_2O to N_2	1.57
F*plant nit/denit*	= Fraction of nitrogen removed from the WWTP with nitrification/denitrification	0.7
OR		
F*plant*	= Fraction of nitrogen removed from the WWTP without nitrification/denitrification	0.0
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP	= Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP^{36}

Source: *As listed in LGO protocol Equation 10.10 from EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007, Chapter 8, 8-13 (2009); except Grady, C.P. L., Jr., G. T. Daigger, and H. C. Lim, Biological Wastewater Treatment p. 108-109, 644 2nd Edition (1999)*

GHG Reduction Targets

Milestone Year	Statewide Existing and Target Emissions (MMTCO2e)	Target Percent Reduction - HHS	
1990	15.79		Source: NH CAP 2009
2016	13.44		
2020	13.08	-3%	
2025	12.632	-6%	
2030	10.737	-20%	
2040	6.948	-48%	
2050	3.158	-77%	

	2020	2025	2050
BAU Emissions	2,251	2,260	2,341
Target Emissions	2,184	2,125	538
Remaining emissions to reduce		136	1,802

Emission Factors				
Electricity	316.8	lb CO2e/MWh	Source: eGRID 2016	NH State Output Rate
#2 Fuel Oil	10.35	kg CO2/gallon	Source: eGRID 2016	
Propane	5.66	kg CO2/gallon	Source: eGRID 2016	
Wood	1639.62	kg CO2/ton	Source: eGRID 2016	
Water Conveyance	88	kWh/MG	Source: US Community Protocol 2012	Low values used because local water supply
Water Treatment	620	kWh/MG	Source: US Community Protocol 2012	Assume treatment capacity is less than 1 MGD
Water Distribution	360	kWh/MG	Source: US Community Protocol 2012	

Conversions	
MT/lb	0.000453592
MT/ton	0.907185

biogenic kg CO2/ton
biogenic kg CH4/ton
biogenic kg N2O/ton

Appendix B

Implementation Progress Documentation

Introduction
Hanover High School (HHS) values sustainability and understands the impact the school has on the planet. The school strives to reduce fossil fuel consumption in an effort to mitigate climate change. Thus, it is important to the school district that forestry practices used to generate the wood chips purchased for our heating system are consistent with sustainable forestry as much as possible. Through this, the district seeks to achieve the district climate goals and the ancillary benefit of supporting good forestry in the Upper Valley region. Sustainable forestry is caring for, managing, and protecting the forest ecosystems from which wood products are harvested. It is a dynamic and evolving concept that satisfies consumer needs while maintaining the long-term health of the forest and surrounding ecosystems.

Accordingly, all bidders must submit a brief statement in response to the RFP which describes how their business practices meet the expectations of the school district. Bidders must also submit contact information for two to three references who can attest to the care and attention to good harvesting practices in the conduct of the bidders' operations. The successful bidder will be required to document each load delivered. Deliveries from the same job can use the same documentation.

1. **Source of chips: public land, private land. Location – town and state so we can estimate trucking distance**
2. **Purpose of harvest: forest management and/or salvage/forest health treatment and/or habitat improvement and/or land clearing for conversion to agriculture or other non-forest use**
3. **Evidence, if any, that harvest is result of written forest management plan, or from 3rd party audited forestry (Tree Farm, FSC, SFI etc) or coming from lands with NH current use management plan (for documented stewardship) or VT use value assessment approved management and harvest plan**
4. **Name and contact info of Professional forester involved in administration of harvest, if any**
5. **Statement that harvest complied with all applicable local, state and federal laws and best management practices.**

-

Hanover High School

41 Lebanon St
Hanover, NH
03755

Energy Assessment

Prepared by: *Resilient Buildings Group*, Inc.

Liberty Utilities 15 Buttrick Road Londonderry, NH 03053 (603) 327-5905 nhsaves@libertyutilities.com	**Resilient Buildings Group, Inc.** 6 Dixon Ave, Suite 200 Concord, NH 03301 (603) 226-1009 cpennoyer@resilientbuildingsgroup.com	**Hanover SAU** 41 Lebanon St #2 Hanover, NH 03755 (603) 643-6050

Executive Summary

Resilient Buildings Group (RBG) conducted a site visit of the Hanover High School building in Hanover, NH. Liberty Utilities provided funding for the Energy Audit through the NHSaves energy efficiency incentive initiative. During the Audit, RBG examined the building's shell, lighting, and all pertinent building systems.

The assessment shows that the energy performance of the Hanover High School can be further improved. This report will give the School Administration Unit an overview of the building's existing conditions and an initial outline of problem areas and recommendations for cost-effective ways to reduce energy use and costs.

Existing conditions at the Hanover High School

1. Site

- **Total Conditioned SF:** 190,366 ft^2

2. Shell.

- **Year Built:** The building was originally constructed in 1924. Additions were built in 1935 and 1963. In 2007, the building and its mechanical system were renovated and updated
- **Number of Levels:** Three stories above grade and one story below grade.
- **Slab & Insulation:** The building has a slab constructed from 4" of concrete over a poly vapor barrier and crushed stone. The foundation walls are insulated with 2" of R-10 polyisocyanurate insulation that extends 4' below grade.
- **Exterior Wall Construction and Insulation:** The building is constructed from a multiple types of wall assemblies. The most common wall construction consists of Concrete Masonry Units (CMUs) covered with brick on the exterior. Although there are small sections of the original building that are uninsulated, almost all the building's walls are insulated to a minimum of R-19. The newer portions of the building are insulated with 4" of continuous R-22 rigid polyisocyanurate on the exterior side of the walls.
  - Penetrations: Exhaust vents, fuel lines, refrigerant lines, and electrical conduits for exterior lighting.
- **Roof Type and Insulation:** The roof is covered with an EPDM membrane installed in 2008 on top of rigid foam board insulation. RBG estimates an average of $5^{1/2}$" of R-30 rigid insulation tapered for drainage.
  - Penetrations: The roof has penetrations for the kitchen hoods, air handlers, RTUs, gravity vents, and bathroom exhaust vents.
- **Doors and Windows:**
  - **Windows:** The building utilizes a combination of sliding, fixed and double hung style windows. Most of the windows are thermally broken aluminum framed units with double glazing. The windows in the SAU portion of the building are the oldest in the building. These units are single glazed, wood framed, and non-thermally broken. Although some of these windows do not close perfectly, they all have exterior storm windows in good condition.
  - **Exterior Doors:** The majority of the building's doors are insulated aluminum with double paned glazing.

3. Heating, plumbing, ventilation, & air conditioning

- **Heat Generation Equipment:** The building's primary heat source is a wood chip plant. The backup system consists of three oil fired Buderus boilers installed in 2008. Both boilers are atmospherically vented and have a rated AFUE of 87%. These three boilers have a combined output of 11,946 Mbtu/hr.
- **Heating Distribution**: Heat is distributed throughout the building via unit ventilators, fan coil units, and fin tube radiators
- **Domestic Hot Water (DHW):** The building receives DHW from an indirect fired hot water heater that has a well-insulated storage tank.
- **Plumbing Fixtures:** This building has standard efficiency bathroom sinks and toilets.
- **Air Conditioning Equipment:** There is a central chiller that supplies multiple air handling units and unit ventilators with chilled water. There are also multiple roof top units and packaged AC units that serve portions of the building. The packaged AC units rang in size from 3 to 4 tons. Additional spot cooling is provided by ductless heat pumps.

The existing oil-fired boilers

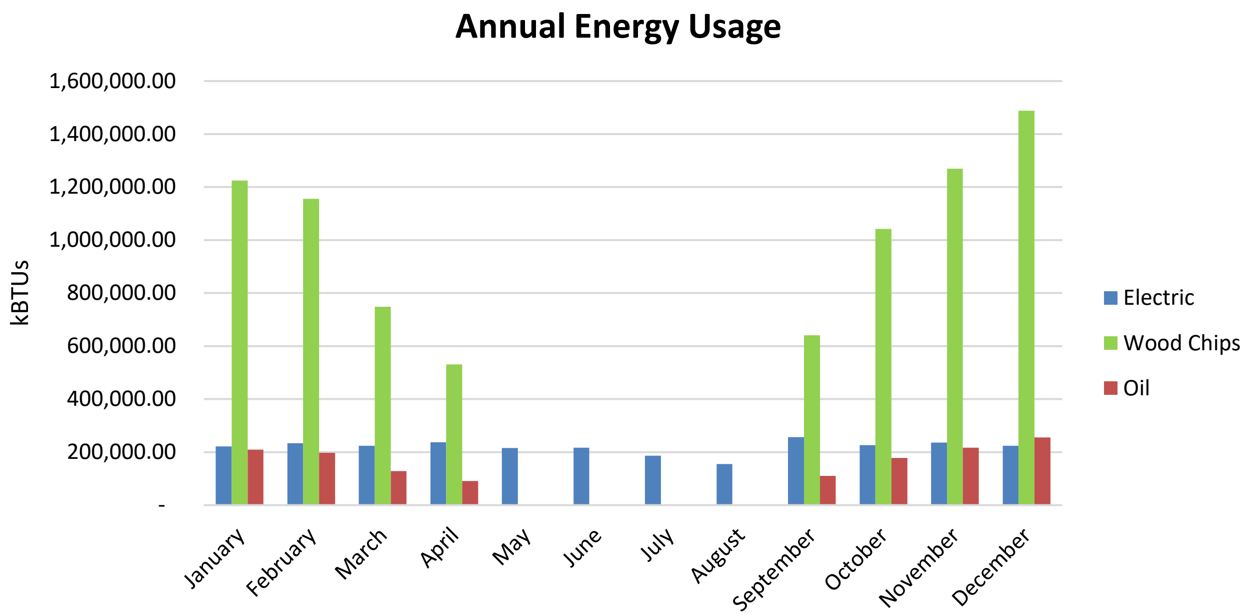
- **Ventilation Equipment:** The buildings mechanical system is balanced, which means that it supplies fresh air and exhausts stale air from the interior spaces. Some portions of the building have gravity vents that open when there is excess static pressure from the fresh air supply.

  The gym is served by two equally sized McQuay energy recovery ventilators that were installed in 2005. If these units pressurize the gym too much, gravity dampers open and exhaust the excess air to the outdoors.
- **Controls:** The building has a working Building Management System that is checked frequently by the building operators.

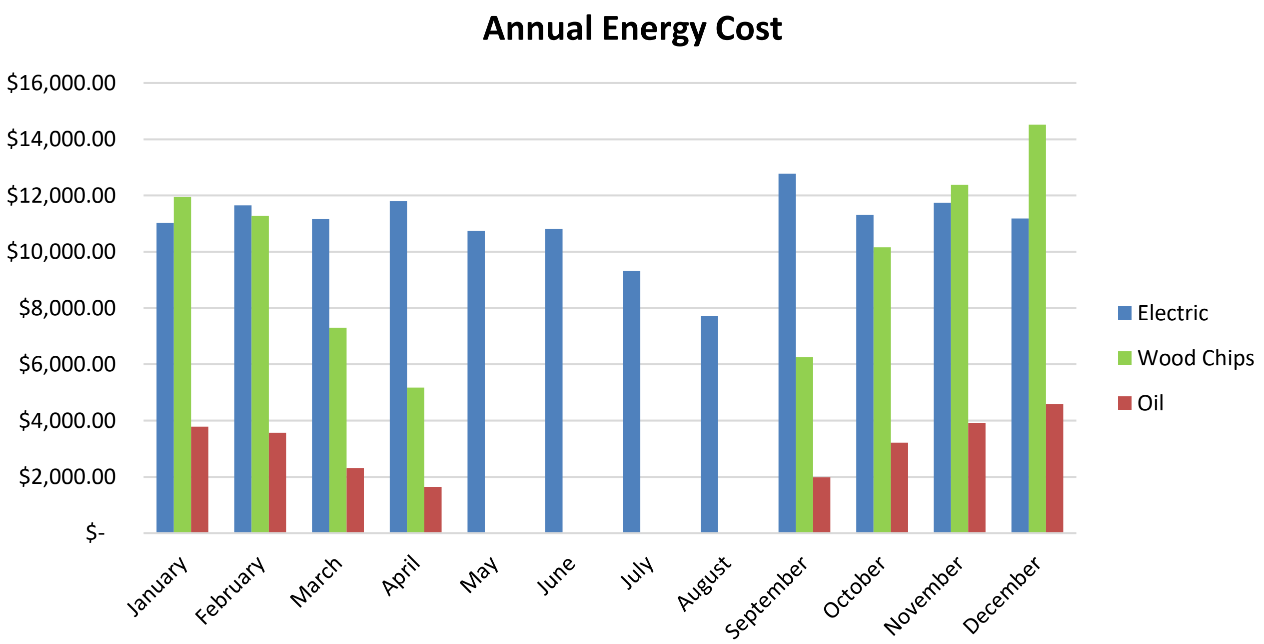
4. Electrical

- **Electric Meters:** The building has a single electric meter.
- **Lighting Type:**
  - The building's interior is lit with a mix of incandescent and fluorescent lamps. The building is planned to undergo LED lamp retrofits in the near future
- **Lighting Controls:** The lighting in the building is controlled by a mix between occupancy sensors and standard toggle switches.

Preliminary Energy & Cost Analysis



Using past utility bills for the building, RBG calculated an average yearly consumption of 10,000 gallons of #2 heating oil, 900 tons of wood chips, and 771,955 kWh of electricity, which translates to a total of 12,120,813.0 kBtu of energy consumed per year on average. *



The building's average annual energy costs are $25,000 for heating oil, $54,000 for wood chips, and $131,232 for electricity, which equates to a combined average of $210,323 per year. *

*Based on three years of oil and two years of electric bills. Analysis includes one building with a total conditioned square footage of 190,366 ft². The oil cost information is based off an assumed price of $2.50 per gallon. The wood chip cost information is based off an assumed price of $60 per ton.

Building Benchmarking

Examining historical energy consumption of a building is known as Building Benchmarking. Building Benchmarking rates a building's performance on two metrics: **Energy Use Intensity (EUI)** and **Cost Use Intensity (CUI).**

EUI is the annual energy use in BTUs (British Thermal Units), usually displayed as kBTUs to signify thousands of BTUs per square foot of conditioned space (kBTU/ ft^2/YR). **Site EUI** only accounts for the energy consumed on the building site. **Source EUI** incorporates both the building's energy consumption and the efficiency losses associated with the generation and distribution of electricity. **CUI** displays the annual energy cost per square foot in the building per year ($/$ft^2$/YR).

- Our calculated **EUI and CUI for the Hanover High School:**
    - **Source EUI:** 91.34 kBtu/ft^2/YR
    - **Site EUI:** 63.67 kBtu/ft^2/YR
    - **CUI:** 1.10 $/$ft^2$/YR

ENERGY STAR® PortfolioManager® Technical Reference

Primary Function	Further Breakdown (where needed)	Source EUI (kBtu/ft^2)	Site EUI (kBtu/ft^2)	Reference Data Source - Peer Group Comparison
School	K-12 School	104.0	48.5	CBECS – Elementary, Middle & High School

For a typical school building, the national average site EUI is 48.5 kBtu/$ft^2$and the average source EUI is 104 kBtu/ft^2. The Hanover High School has a higher site EUI and a lower source EUI compared to the national average. RBG believes that the Hanover High School has a lower source EUI because the building uses less electricity than the average school building.

In the EEM section of this Level I Audit report, RBG presents measures that will significantly improve the building's energy efficiency and lower its operating expenses.

Suggested Energy Efficiency Improvements

Three major areas of activity were examined for energy-saving opportunities: building envelope, mechanical systems, and electrical systems. Many of the proposed energy efficiency recommendations may qualify for the energy efficiency incentives offered by NHSaves.

Infrared Images*

The included infrared images of the High School building were taken during RBG's site visit on November 11, 2019.

These images show temperature movement in the form of light and dark colors. The light colors represent warmer temperatures and the dark colors represent cooler temperatures. These images give an insight to the problem areas of the building's envelope.

Building Envelope Upgrades:

B1: Roof Insulation: The existing roof is insulated with an estimated $5^{1/2}$" of rigid insulation, which has a thermal resistance of R-30. The target R-value for this type of assembly is R-60. When replacing the roof membrane at the end of its lifetime, add an additional $5^{1/2}$" of rigid polyisocyanurate insulation. This additional of rigid insulation will increase the roof's thermal resistance to R-60.

Be sure to carry the rigid insulation over the parapets between each building section. Currently these areas are not well insulated, which leads to excess heat loss from thermal bridging.

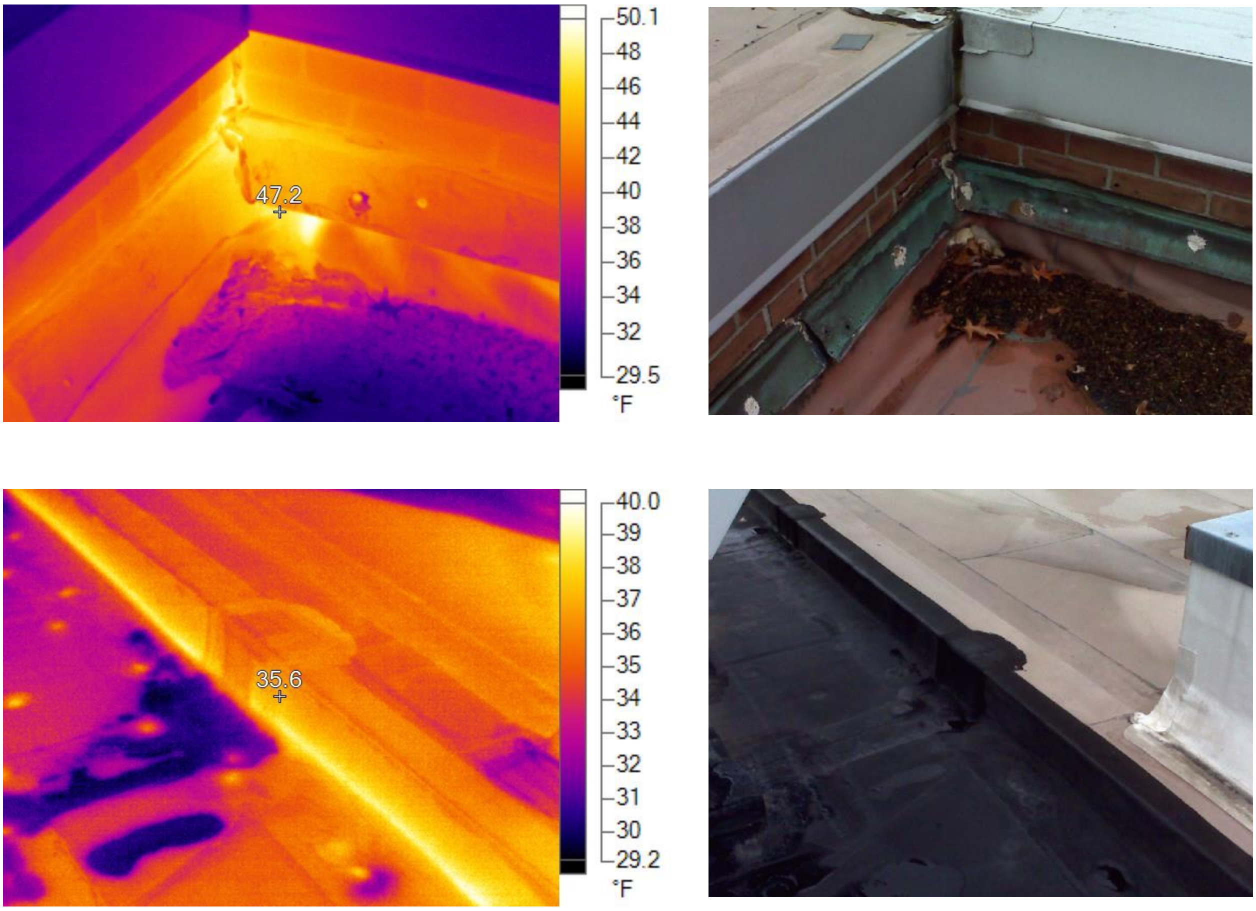


Figure 1: IR images of thermal bridging through the parapets.

B2: Art Studio & SAU Office Roof: The art wing and SAU office portion of the building have a hot roof that is insulated with 6" of dense-packed cellulose between the rafter cavities. This type of assembly can be risky hydrothermally because it is not vented, which means that moisture build up is not easily dried from the assembly. The attic space above the SAU has signs of moisture damage on the interior paper board.

RBG recommends removing the existing cellulose insulation and installing 6" of closed cell spray foam between each rafter cavity on the backside of the exterior sheathing. Be sure to include each exposed rafter in the attic space to alleviate thermal bridging. This measure will increase the assembly's R-value from R-21 to R-33. Closed cell spray foam is the ideal insulation material to use because of its high R-value per inch and its ability to withstand repeated moisture loads.

Figure 2: Water damage on the existing paper board in the attic.

B3: Exterior Insulation: The building’s masonry walls are insulated to R-20. RBG recommends installing 3” of rigid insulation directly against the brick and CMU walls. This measure will increase the R-value of the building’s walls from an average of R-20 to R-45. Be sure to carry the insulation 4’ below grade to mitigate the thermal bridging through the foundation footings. RBG understands that this measure may be cost prohibitive and may have a much longer payback than the typical EEM. Most of the cost associated with this EEM is associated with the finish product such as metal sheeting, stucco, or brick façade.

Before implementing this measure, it is recommended that the SAU conduct an engineering study to determine the impact that rigid insulation would have on the older moisture laden brick walls.

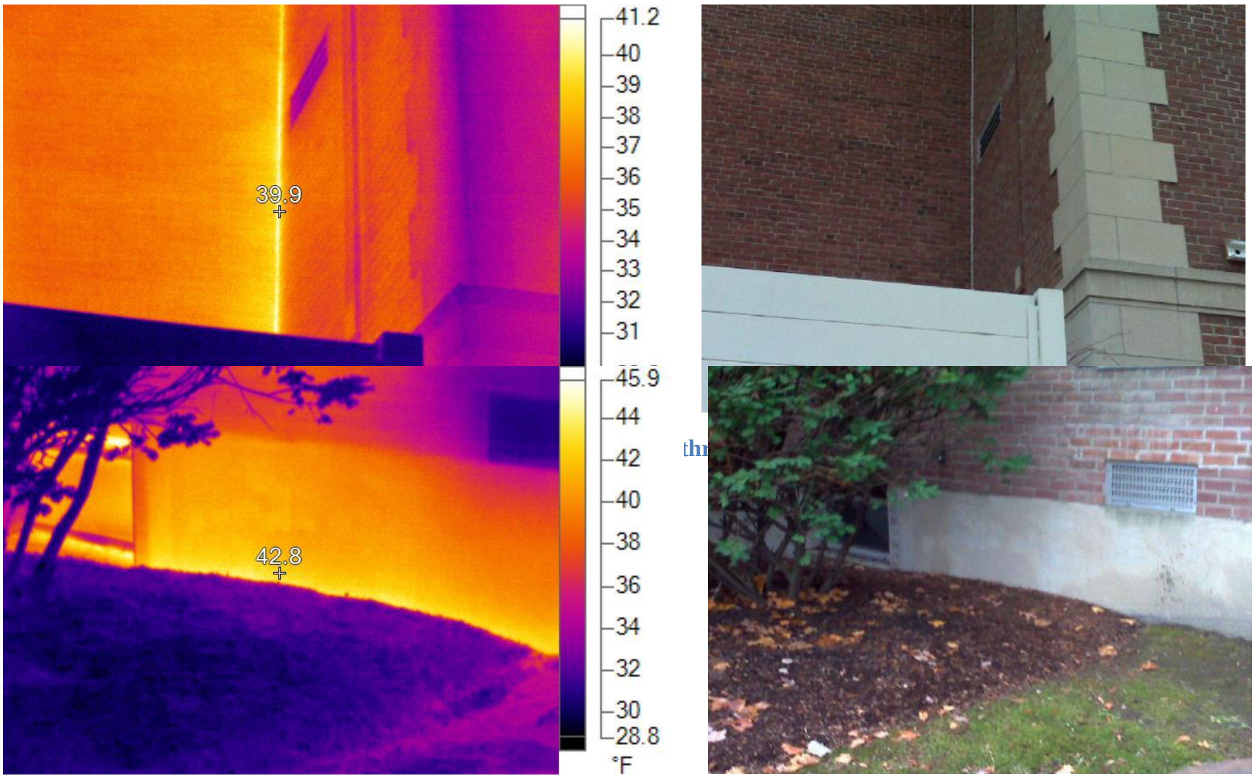


Figure 3:IR image of heat loss through the foundation walls.

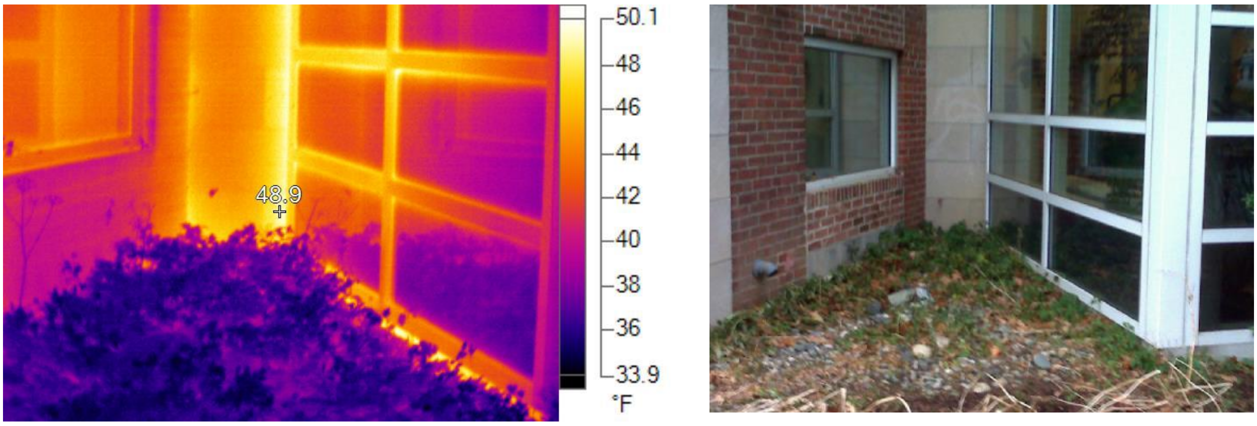


Figure 5: Infrared Image of heat loss through the connection between the new and old sections of the building.

B4: Insulate all Sky Light Curbs: There are many skylights that penetrate the roof. These skylights are double layered acrylic curb mounted units. The building plans for the Highschool show that the skylight curbs are insulated with 2” of rigid polyisocyanurate insulation.

Reduce the heat loss through these skylight curbs by installing 2” more of rigid polyisocyanurate on the interior side.

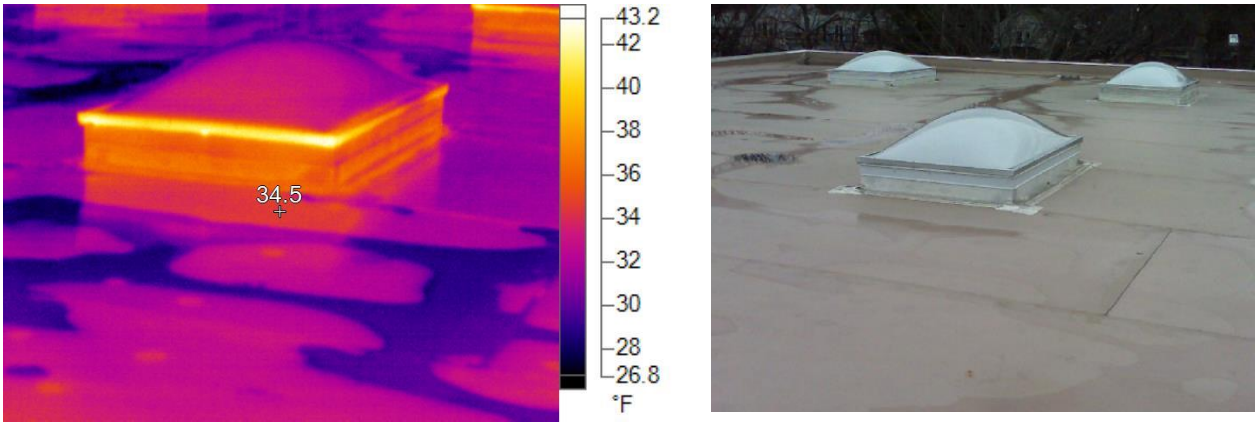


Figure 7: Infrared image of thermal bridging through a typical skylight curb.

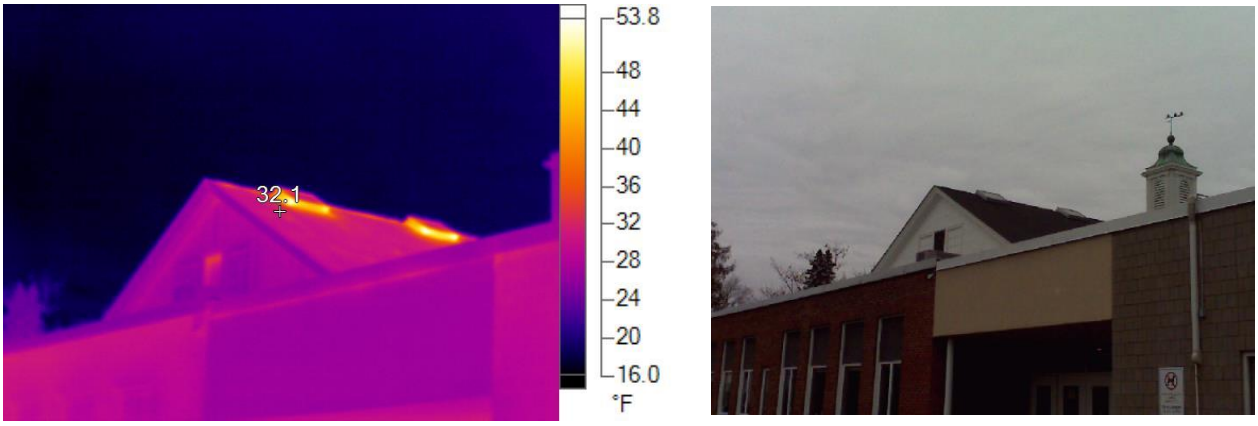


Figure 6: Infrared Image of heat loss through the skylights in the art studio.

B5: Replace the Glass Tile Windows: Although aesthetically pleasing, the existing glass tile windows are thermal weak points in the building's envelope. RBG estimates that the existing tile window has a U-value of 0.50. Compare this to the standard window that has a U-value of 0.27, which is roughly twice as efficient than the existing glass blocks.

RBG recommends removing the glass blocks and replacing them with fixed double-glazed, aluminum framed windows that are thermally broken. The replacement windows should have a minimum U-Value of 0.25.

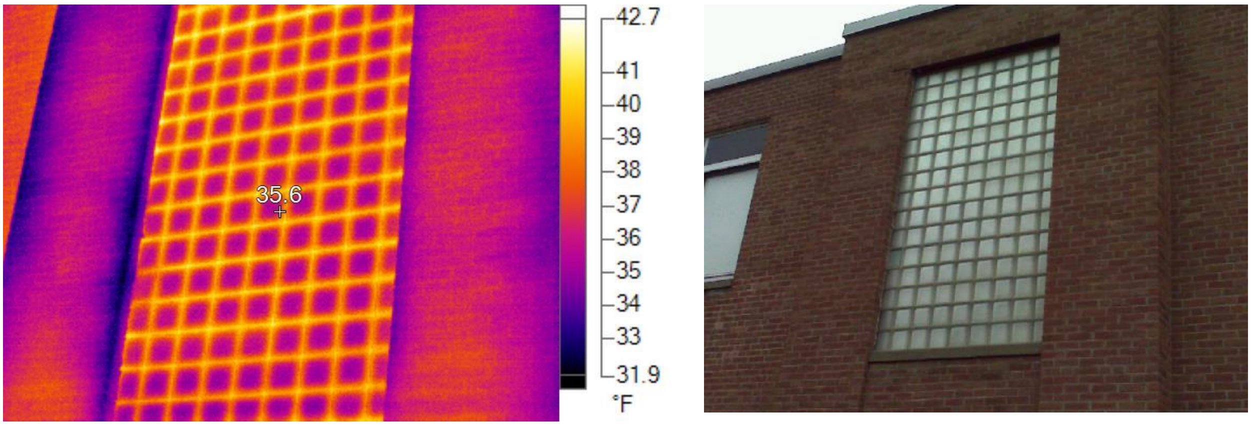


Figure 8: Infrared image of heat loss between each of the glass blocks.

B6: Exterior Shades: During RBG's site visit the building operator, Anthony Daigle, suggested installing exterior shades on the southern facing classrooms. Anthony explained that these classrooms receive excess solar heat gain, causing a major source of discomfort amongst occupants.

There are a variety of exterior shade types that would work for this application. One type to consider is a fixed metal horizontal shade. This type of exterior shade can enhance the building architecturally and has no moving parts. RBG recommends operable exterior shades allowing the occupants to adjust the amount of incoming solar heat gain depending on temperature preferences and season.

Figure 9: Example exterior roller shades.

(Insolroll.com, 2019)

Mechanical Upgrades:

M1: Retro-Commissioning: Conduct retro-commissioning to ensure that the existing heating, ventilation and any other related systems are running properly. Aside from health and comfort benefits, retro-commissioning can significantly improve a building's energy efficiency. According to the DOE, retro-commissioning can reduce annual energy usage by up to 15% in a typical commercial building.

RBG believes that a thorough retro commissioning of the School could solve issues such as the discomfort in the SAU Offices and the slight inaccuracies in the BMS. RBG has Certified Commissioning Agents on staff and would be happy to provide a quote for the School. The NHSaves program could provide an incentive to help cover the cost of the retro-commissioning work at the Hanover High School.

M2: Replace Chiller & Packaged RTUs: Replace the chiller at the end of its lifetime to an equivalent sized unit that has a minimum EER FL of 10.52 or a minimum EER IPLV of 13.75. If the SAU installs a chiller that meets these efficiency requirements the unit could qualify for an incentive through the NHSaves program.

The existing Carrier terminal AC units should be replaced at the end of their service lifetime as well. These units have a SEER of 13.0, which is still considered efficient even by today's standards. For this reason, we do not recommend removing the existing terminal AC units before the end of their service lifetimes.

Electrical Upgrades:

E1: Lighting: Replace all existing fluorescent light fixtures in the building with new LED fixtures as planned. If the installed fixtures are DLC or Energy Star Certified, the NHSaves utility rebate program may be able offer an incentive that could significantly reduce the net cost of implementation. Consider including the stage lighting in the LED retrofit. Depending on the usage hours, upgrading the stage lighting could yield major electrical savings as well.

E2: Lighting Controls: When installing LED lighting, replace the existing toggle switch lighting controls with occupancy sensors in applicable areas. These controls will not only save energy, but they will also increase the lifetime of the installed LED fixtures. The NHSaves incentive program could also provide rebate money to the School for upgrading the facility's lighting controls.

E3: Vending Misers: Install vending misers on all refrigerated vending machines throughout the school. Vending misers act as occupancy sensors for these machines. These units can cut the energy usage from vending machines in half.

Figure 10: Typical Vending Miser.

(vendingmiserstore.com, 2019)

Renewable Energy Upgrades:

R1: Solar Photovoltaic Array. Install a roof-mounted 100 kW PV array on the High School gym's flat roof. A 100 kW array at this location is projected to generate 117,585 kWh/year assuming the installation of high-efficiency panels. The School consumes an average of 771,995 kWhs per year, which means the array would supply 15% the building's current annual electric consumption and costs.

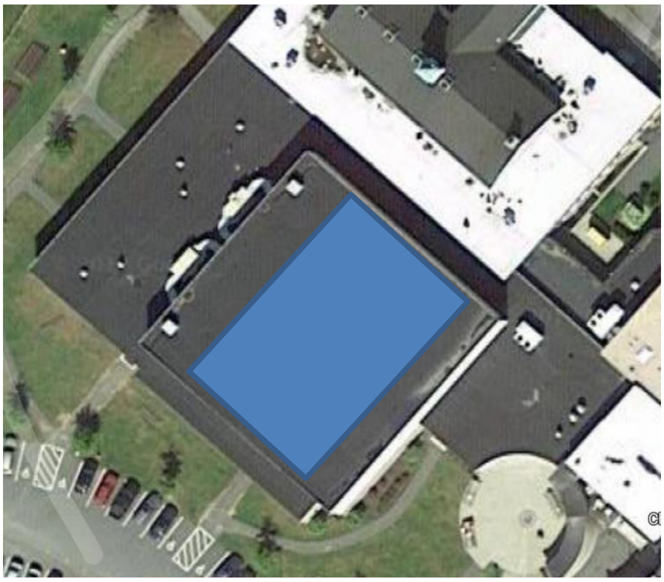


Figure 11: Proposed PV Array

Next Steps

With the completion of this Level I Energy Assessment, the School Administration Unit should consider potential next steps to take advantage of the recommended energy saving and comfort improving opportunities.

To minimize implementation cost and maximize energy savings, pay careful attention to the proper design and installation of the selected EEMs. RBG recommends that the Hanover High School undergoes a Level II Energy Audit to analyze to the cost and energy savings of each presented EEM. The building's mechanical system should also by more thoroughly examined to determine how it's energy efficiency can be improved.

No Cost/Low Cost Energy Saving Opportunities

There are Energy Efficiency Measures (EEMs) that will cost little or no money to implement at the School building. It is important to encourage employees, and students (if possible), to slightly change their behavior. This is not easy, but such efforts will produce energy savings without any other investment. For this reason, RBG provides these initiatives as part of this analysis. By encouraging the building's occupants to alter routines, energy can be saved regardless of energy saving investments. These No-Cost /Low-Cost Initiatives are:

❶ **Weather Stripping:** We recommend continued weather-stripping maintenance to all exterior doors and windows, along with other shell penetrations to prevent infiltration. This should be recognized as an annual maintenance task, as continual maintenance of weather stripping is especially necessary on high-use doors.

❷ **Thermostat Setback (3°F+/-):** To reduce demands on the heating source, thermostat settings can be cut back by 3°F when outside temperature allows. Studies have shown that when the average outside temperature is above 38°F, a slight adjustment down of interior temperature settings does not influence comfort. Over an eight-hour workday this practice can produce a noticeable energy use reduction. It is suggested that the maintenance staff perform a test to see if comfort levels are affected. Resource: https://www.energystar.gov/products/heating_cooling/programmable_thermostats

❸ **Task Lighting:** To reduce electrical demands from lighting, task lighting should be encouraged, where appropriate. A task lighting initiative would encourage building occupants to shut-off the ceiling mounted lighting and utilize task lighting (portable desk lamps, workstation under-shelf lighting, etc.) to provide the illumination they need, whenever possible. Providing task lighting devices for spaces appropriate to their use may entail a small expense if task lights do not presently exist. Furthermore, we recommend replacing existing single bulb incandescent fixtures (such as the task lighting mentioned above, or ceiling mounted lighting) with appropriate LEDs.

❹ **Computer Settings:** An easy way to reduce plug load and electricity use is to turn off all computers at night and when not in use for extended periods of time. Ensure that the staff's computer towers and monitors are shut off when not in use and at the end of each day. This can also be applied to any computers in the School.

For information on power management or procurement specs, a good web resource is: https://www.energystar.gov/products/low_carbon_it_campaign/power_management_computer