Reducing Middlebury's Carbon Footprint and Energy Consumption: Suggestions for the Energy 2028 Plan

Background

Middlebury College has been at the forefront of climate action among institutions of higher education. Starting in 2007, the College cut much of its carbon emissions on the main campus and reached carbon neutrality in 2016. While this neutrality has come from a host of efficiency measures and a shift to renewable energies, Middlebury College does currently require carbon offsets to meet its goal. In an effort to maintain carbon neutrality and end any reliance on fossil fuels and the need for carbon credits, Middlebury has created the Energy 2028 initiative, striving to power the campus with 100% renewable energy and reduce energy consumption by 25%. The plan was first enacted in 2018, and the college has been taking steps to reduce its energy consumption such as renovating buildings to increase heating efficiency. However, to continue reducing energy use in the future and meet the goals of Energy 2028, more projects involving energy efficiency, community engagement, and, of course, carbon emissions reduction are needed.

This paper is divided into two sections, one focusing on a campus carbon tax that will look at an optimal way to internally raise funds for various initiatives and another that suggests infrastructure changes to improve efficiency across campus and reduce reliance on fossil fuels. The carbon tax section is then split up into sections focusing on what a carbon tax could look like, how the tax should be calculated, and finally how the revenue could then be distributed. The infrastructure section is divided into four core groups, including a suggested replacement for the current biomass plant, a solution to moving away from fossil fuel consumption in houses on campus that are not on the central heating system connected to the biomass plant, a plan for electrifying Middlebury's transportation fleet, and other recommendations for both improving efficiency and encouraging a reduction of energy consumption across the campus. At the conclusion of the paper there is also a drafted Environmental Checklist designed by both groups to suggest considerations when ensuring equity in any actions made within the Energy 2028 initiative.

Carbon Tax in Theory

In theory, an internal carbon tax forces organizations with greenhouse gas emitting actions to incorporate the full cost of their emissions into their decisions[1]. To take a simple example, a government can levy a fixed $0.50 tax on every pack of cigarettes would cause a $4 pack of cigarettes to be priced at $4.50. The additional $0.50 would provide two benefits. Primarily, the tax would be added to a fund to support reducing greenhouse emissions. Secondly, the higher price would discourage consumers from purchasing the cigarette. For Middlebury College, a carbon tax for each metric ton of carbon dioxide and equivalents (MTCDE) emitted would contribute to a "carbon fund" for Middlebury to invest in fundamental infrastructure changes and other community engagement projects. Furthermore, by expanding the scope of the tax to include all energy consumption, the tax would help in the College's 2028 energy reduction goal.

Carbon Pricing at Yale

Internal carbon pricing has been implemented in other educational institutions, most notably Yale University. Recognizing that there is an "economic cost caused by an additional ton of carbon dioxide emissions or its equivalent," Yale put a $40 price on its building-related CO_2 emissions[2]. Yale's buildings have the ability to meter electricity, chilled water, natural gas, and steam consumptions. Each of the

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[1] Keohane, Nathaniel O., and Sheila M. Olmstead. *Markets and the Environment*. Island Press/Center for Resource Economics, 2016.

[2] "Implementation | Yale Carbon Charge." July, 2017. Accessed February 4, 2021. https://carbon.yale.edu/implementation.

participating buildings file a monthly report detailing energy consumption and greenhouse gas emissions and are thus held accountable for their own energy use. The revenue generated is held in their "carbon charge pool". However, Yale does not withhold this carbon charge as a university surplus. Rather, they redistribute and return the average carbon charges back to each department, effectively creating a "revenue-neutral" system[2]. For this reason, each department has two new budget lines called the "charge" (outflow) and "return" (inflow). This means that a building (associated with a specific department) must outperform Yale's average for that building's return to be greater than its charge. Essentially, if aggregate emissions of all participating Yale buildings increase in one year, this creates three scenarios where 1) a building will receive a net return if its increase in emissions is lower than Yale does as a whole on average, 2) a building will receive no net charge if it is equal as Yale and 3) a building will receive a net loss/charge if its emissions increase greater than Yale does as a whole, on average[3]. On the other hand, if aggregate emissions of all participating Yale buildings decrease, a building must decrease by a greater percentage to receive a net return[2]. Yale proved that an efficient implementation of an internal carbon tax can provide financial incentives to encourage significant change in individual and community energy consumption behavior[4]. In addition, the university does not face the risk of a budget shortfall nor questions of how to best utilize that budget[2].

While this system has been proven to be effective, we believe that Middlebury does not necessarily have to imitate their work to reduce emissions by 25%. In fact, with the challenge that no specific building is associated with a specific department or a unit that can be held accountable for emission, we do not think that this approach is suitable for Middlebury. Furthermore, we are confident in the ability to deploy the collected tax revenue in an effective and transparent way and also believe that significant change in emission reduction can only be achieved through fundamental improvements, which requires the need for tax revenue.

Internal Carbon Tax Adjustments

Middlebury's original Internal Carbon Tax Proposal covered four sectors: transportation, campus waste, energy consumption, and new construction. The revenues generated would be transferred to a central fund that would support community engagement, renovations, energy efficiency upgrades, and other projects that reduced carbon emissions. However, while the original internal carbon tax provided bases around which funds could be generated, it was never implemented and now is over two years outdated. The newly proposed tax adjustments outlined below will expand on the original tax proposal in both scope and revenue.

Transportation: Planes and Cars

The transportation section of the carbon tax is the only one targeted to each department on campus. This includes estimated emissions for rental cars, buses, trains and airplanes involved in sending students, faculty or staff to department events. Under the original proposal, transportation emissions from the last five years for each department would be calculated to establish a baseline. This baseline would serve as a cap for emissions and this cap would drop by 2.5% each year. Any emissions that superseded this cap would be internally taxed.

The primary method for collecting travel related expenditures is from inputs on Oracle. These are entered into spreadsheets where calculations are carried out to determine the tax levied. For air travel, current spreadsheets charge 0.5% of the total cost as the carbon charge. There are several flaws with this approach. The first is that 0.5% is an insignificant fraction of the total travel cost. This is not high enough to change the behavior of departments or to even warrant awareness. According to Gabe Desmond '20.5,

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[3] "Frequently Asked Questions | Yale Carbon Charge." July, 2017. Accessed February 2, 2021. https://carbon.yale.edu/about/frequently-asked-questions.

[4] Elder, Luke, and Brenda Meany. 2016. "Yale Carbon Charge Pilot: A Statistical Analysis," 20.

this conversion rate of dollars to the carbon charge was determined by a group of students over five years ago and is out of date. Additionally, price does not serve as an accurate proxy indicator for carbon emissions. Flight prices can vary significantly depending on time of day, week, and popularity of routes. In a spreadsheet populated from Oracle, a flight from Monterey, CA to San Diego, CA was more expensive than a flight from San Diego to Burlington, VT. The first flight would be charged a higher carbon tax than the second, even though a cross country flight would emit significantly more carbon dioxide compared to an in state one. With the Covid-19 pandemic, airline prices have plummeted, which would result in decreased carbon taxes even though the distance flown would be the same. While having a common rate applied to all flights would seem to promote consistency, it could mean that the carbon tax applied to an identical flightpath could vary daily even if emissions are the same.

Estimating carbon emissions from distance flown or miles drive would be a much more accurate indicator. Implementing this change would require obligatory reporting of departure and arrival locations for all travel invoices. Although not easily customizable, if the Oracle system could be adapted to require this information, code could be written to calculate distance between the listed destinations and estimate a carbon charge. This would produce a more accurate charge that bypasses price fluctuations.

The 2.5% annual decrease of the transportation emissions cap for departments was intended to begin in 2018 and result in a 25% decrease in time for the 2028 benchmark. However, since implementation has been delayed several years, the annual decrease could be adjusted to end with 25% by 2028. Should this be implemented in 2021, the decrease would need to be approximately 3.5% and if it begins in 2022, it would need to be 4.2%. Given the significant drop in travel due to the pandemic, and the development of virtual participation in events, meetings and conferences, a larger annual reduction in transportation is less daunting than before the pandemic.

Campus Waste: Inorganic waste

Under the original internal carbon tax, the waste sector only accounted for greenhouse gas emissions from organic waste. The tax revenue generated from this sector was $5,800, but will soon be negligible as Middlebury is implementing a digester capable of harnessing the methane gas released from decomposing organic matter. Thus, an adjustment would instead target inorganic waste, both recyclables and nonrecyclables. Although the College has a healthy recycling lifestyle with over 60%[5] of its waste being recycled or composted, recycling still produces greenhouse gases. As a brief example, the California Environmental Protection Agency estimated that manufacturing processes using HDPE and PET recycled plastics produced an average of 0.27 $MTCO_2E$ per ton[6]. Different paper products had higher emissions that ranged from 1.0 $MTCO_2E$ per ton for corrugated cardboard to 2.2 $MTCO_2E$ per ton for magazines and 3rd class mail[6]. Middlebury College's Recycling and Waste Management Department already organizes and weighs its waste and recycling. While it would be better to ask the companies that recycle Middlebury College's waste for more accurate carbon emission rates, simply multiplying the recycling emissions by the tons of recycled waste would yield an emissions estimate. For example, given that Middlebury College recycled 379,660 lbs (189.83 tons) of plastics in 2018, so a tentative emissions would be around 51.25 $MTCO_2E$[7]. Using the $40 per MTCDE standard determined in the original tax proposal, recycling emissions of plastics would have been taxed at $2050. This is not to say that recycling does not reduce the production of greenhouse gases, but by taxing the recycling emissions, Middlebury College could raise additional funds to replace the decrease in revenue from taxing organic waste.

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[5] Middlebury College. *Recycling and Waste Management at Middlebury.* http://www.middlebury.edu/offices/business/recycle. Retrieved 6 Feb 2021.

[6] California Environmental Protection Agency. *Method for Estimating Green House Gas Emission Reductions from Recycling.* https://ww3.arb.ca.gov/cc/protocols/localgov/pubs/recycling_method.pdf. Published 14 Nov 2011. Retrieved 6 Feb 2021.

[7] Middlebury College. *Middlebury College Recycling, Composting, and Waste Data 1993 to 2018.* Retrieved 6 Feb 2021.

Nonrecyclable waste that could produce greenhouse gas emissions goes to landfills. The EPA estimates that 50% of the gas released from landfill decomposition is carbon dioxide while the other 50% is methane[8]. While the exact rates of decomposition vary depending on the material, The Research Triangle Institute (RTI) proposed two formulas to estimate methane and carbon dioxide generation from landfills[9]. The formulas are complicated, requiring multiple variables, but are able to estimate mass per year of methane and carbon dioxide generation around which Middlebury could calculate the internal carbon tax for nonrecyclables. For example, Middlebury College generated an average of 898722 lbs (407.7 tonnes) of nonrecyclable waste between 1993 and 2018[7]. Using the CH_4 generation formula presented by RTI and Middlebury's waste data, under moderate weather conditions, 17 tonnes of methane would be generated each year from 1993 to 2018. Furthermore, this would mean that Middlebury also generated 51 $MTCO_2E$. Assuming that the tax on methane emissions is also $40 per tonne of methane, then the total tax each year would be $2720[*].

Energy Consumption: Building Insulation and Energy Efficiency

Middlebury College relies on fossil fuels like propane to heat some older buildings during the winter. New renovations have decreased Middlebury College's reliance on these greenhouse gas emitting energy sources, so a carbon tax on the college's nonrenewable energy use would provide ever decreasing revenue for the central fund. Thus, the new internal carbon tax would tax campus energy use as well. By targeting both renewable and nonrenewable energy use, the tax would generate more funds that could be used to help Middlebury College fulfil its Energy 2028 plan by discouraging excessive energy use. Thus, in addition to the original proposed carbon tax of $40 per MTCDE emitted, Middlebury College would tax the renewable energy consumed in excess of the 2.5% decrease per year of the 25% reduction plan. Adjusted for starting in 2022, there would need to be a 4.3% decrease to reach the 2028 25% energy reduction deadline. The tax on excess energy would match the price of 3rd party purchased energy or an agreed upon price by the committee proposed by the original tax proposal.

New Construction: Buildings and Renovations

New construction projects will follow the original method of 0.5% flat tax. Major renovations to existing buildings will always integrate more efficient heating, energy consumption, and insulation. Currently, renovation priorities take into account the building's insulation. Thus, buildings such as Stewart Hall and Warner Hall will eventually have better insulation to reduce energy consumption, and the potential for indirect greenhouse gas emissions would decrease. Additionally, newer renovations and buildings could include modern electric heating systems, further reducing the use of greenhouse gas emitting fuel sources.

It is possible to begin estimating the carbon emissions of new construction projects. Overall energy consumption could be measured. Other nonrenewable electricity sources could also be monitored, such as gasoline and propane. Furthermore, waste generated from the building process could be weighed and greenhouse gas emissions estimated similar to the waste management tax process outlined previously. While this would not be comprehensive, it would provide a good starting point to determine whether the 0.5% tax is justified.

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[8] Environmental Protection Agency. *Basic Information about Landfill Gas.* https://www.epa.gov/lmop/basic-information-about-landfill-gas. Retrieved 7 Feb 2021.

[9] RTI International. *GHG Emissions Estimation Methodology for Selected Biogenic Source Categories.* https://www3.epa.gov/ttnchie1/efpac/ghg/GHG_Biogenic_Report_draft_Dec1410.pdf. Retrieved 7 Feb 2021.

*Note: These calculations were based off of *GHG Emissions Estimation Methodology* Equations 2.1.1 and 2.1.2. These calculations should be done each year to ensure the most accurate estimation.

Sector	Original Carbon Tax Revenue	New Carbon Tax Revenue
Transportation	$0 to $35,000 from 2018 to 2028	Greater than $35,000 per year
New Construction	0.5% of cost specific to each building	0.5% of cost specific to each building
Campus Waste (organic waste only)	$5,800 per year	$2720 for nonrecyclables $2050 minimum for recycling
Energy Consumption	$400,000 per year	Need more data for an estimate

Table 1: A summary of Middlebury College's original Internal Carbon Tax Plan for Energy 2028 compared to the new plan.

Managing the Carbon Fund

One of the benefits of the internal carbon tax is the generated capital. The revenue can be invested in furthering Middlebury's Energy2028 objectives. While the establishment of the carbon fund and the oversight committee described in the original document are necessary, the current proposal could benefit from the following specifications and adjustments.

With the tax adjustments outlined above, we anticipate the revenue from the carbon tax to be greater than $400,000. We further propose that the revenue be distributed as follows: 75% to the College's capital fund; 15% for education and outreach; 5% for achievement grants; and 5% to external organizations. In the long term, we foresee designating a larger proportion of the generated revenue to support external organizations, but aim to keep the revenue primarily internal in the inaugural years of the carbon tax. In the following section, we elaborate on productive uses of the revenue within each allocation.

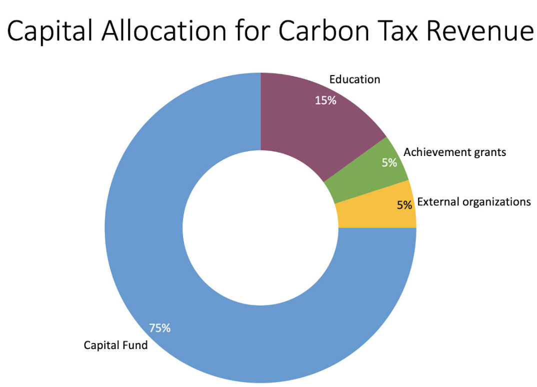

Figure 1: Breakdown of capital allocation for carbon fund assets from carbon tax revenue.

Education and raising awareness in the overall student body

The energy reduction, divestment, and renewable initiatives of Energy2028 are necessary and fundamental to the College's goal of environmental responsibility. However, the fourth and final pillar of Energy2028 bears great importance in broadening the impact and ingraining the principles behind these objectives. For this reason, 15% of the revenue generated from the carbon tax will be used towards sustainability education. Training and developmental programs should be available to students who are willing to take classes, intern, or volunteer on sustainability programs. These educational opportunities could be integrated into the school's usual curriculum schedule as classes during the school year or could also be run separately from classes. Allowing students to take part in these tasks through forms of classes and/or J-term workshops will effectively raise more awareness and increase knowledge of the sustainability issues our small community and the greater global community are trying to address. Furthermore, the classes can be catered more specifically for different majors while at the same time addressing these important sustainability issues. For example, carbon accounting and carbonomics classes can be cross registered under economics and environmental studies majors while sociology and history majors can take a class where they research the college's historic approach to sustainability. A specific example where a university has successfully approached its education component in tackling its internal sustainability issues is the University of Sonora's certified sustainability management system.[10] A sustainability management system (SMS) provides the framework for creating a greener campus and it strives to also enhance its engineering majors on practical sustainability education through practical apprenticeships. Specific areas of focus were efficient use of water and energy, laboratory safety and hazardous waste management, along with the reusal, reduction, recycling of non-hazardous materials such as paper and plastic on its campus.

An easily implementable educational tool Middlebury College could immediately create would be to establish Energy2028 Day, dedicated to amplifying the Energy2028 plan. While most current students hold knowledge of the extensive plan that was endorsed by the Middlebury board of trustees in January of 2019, it is paramount that future students also learn about the college's sustainability plan to keep the student body engaged. By creating Energy2028 Day, the college can make time for a range of events aimed at engaging and educating students. No-waste dinner, film screenings, special lectures, and shows are examples of events other colleges host on Earth Day that easily can be implemented on "Energy2028 day". Because the plan officially was put in place on January 29th, "Energy2028 day" could be a reoccurring event this date every school year.

An additional aspect of raising awareness involves publicizing the existence of the internal carbon pricing fund and welcoming applications for projects. All students, faculty, staff and community members should be encouraged to submit proposals before the seven member management committee. It has been suggested that proposals have a detailed budget that outlines expenses, feasibility and long run cost savings. Applicants should have access to assistance in putting together proposals and preparing for presentations. Welcoming applicants would allow for more diverse projects and can find opportunities that would have otherwise gone unnoticed.

Recognizing and rewarding progress

It is also crucial that the College recognizes and rewards progress of any form of environmentally-sustainable actions, and a 5% portion of the carbon tax revenues will be directed towards this. The process of recognizing and rewarding will highlight the efforts of people taking steps to decrease carbon emissions and can also serve to incentivize further action. While the college itself has undertaken numerous projects such as achieving the LEED (Leadership in Energy and Environmental Design) platinum status, the highest designation given by the US Green Building Council for the Franklin Environmental Center at Hillcrest, it is also important that individual students take action whether that be by goodwill or incentives, so that the carbon emissions can be further decreased. A potential example of this is rewarding students an increased declining balance based on their dorm's electrical output. At the end of semester, the facilities department at Middlebury College can aggregate all of the electrical usage for each dorm building and the dorm building with the least amount of electrical usage for that semester will win its inhabitants an increased declining balance. While this is a relatively simplistic effort in recognizing and rewarding student and faculty efforts in decreasing carbon emission output, it will lead to a greater population within our campus to be more aware of the sustainability efforts the school is undertaking. This greater awareness coupled with an increased educational component as mentioned

[10] Dave, Malay, et al. "Transforming Universities into Green and Sustainable Campuses: A Toolkit for Implementers." *Green Universities Toolkit 2.0*, 2014.

above will create a cycle where more students will go from just awareness to acting upon projects and participating in more sustainability educational sessions.

External organizations

Another option of recognizing the college's efforts in sustainability is to direct 5% of the funds from the internal carbon price towards external programs such as HOPE (Helping Overcome Poverty's Effects) and Habitat for Humanity, both of which have locations in Addison County. Funds for HOPE Addison County can be used to help the program identify and help individuals secure resources and necessities such as food, medical care, and financial assistance. Moreover, Habitat for Humanity works to build energy efficient housing for local low income families. By donating to housing projects within Habitat for Humanity Addison County, the college will be able to help fund simple, yet energy efficient housing in our local community. The carbon committee should retain responsibility for identifying appropriate organizations and allocating the funds.

The aforementioned projects cumulatively represent 25% of the annual carbon tax revenue. The remaining 75% will be directed towards the College's capital fund, which supports large-scale sustainability projects like the ones proposed below.

Emission and Energy Reduction Group

Background to Geothermal:

Geothermal heat pumps represent a promising source of environmentally friendly climate control that could supply much of Middlebury College's campus. Geothermal Pumps are made up of three components:

1. Pipes that run underground
2. A heat pump inside of the house
3. A distribution method such as forced air

Geothermal Pumps regulate internal temperature by utilizing heat stored in the earth. Underground has a constant temperature of 55 F - 85 F depending on location, environment, and other factors.[11] Pipes carrying water underground exchange heat with the earth. The heat collected underground is brought up to the heat pump which then distributes it throughout the building. Geothermal Pumps can also cool buildings by collecting hot air from indoors and pushing it through the pipes where it remains underground. This system can be a closed loop or an open loop when water is plentiful. The system is made of 100-400 ft vertical loops in environments where space is limited and horizontal loops dug 4 - 6 ft when space is not limited.

Environmental Advantages of Geothermal Heat Pumps

Geothermal does not burn fossil fuels to heat or cool a building, but instead uses electricity to run the pumps. Thus, if using renewable electricity, there are no emissions from heating or cooling.

Geothermal also reduces the amount of energy it takes to run the system itself. The EPA considers geothermal the most energy efficient space conditioning system and estimates a 72% reduction in energy consumption when compared to the running of other systems.[12] This means Middlebury will use less energy than other heating methods.

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[11] Earth River Geothermal, Inc. "How Much Does a Geothermal Heat Pump System Cost?" Earth River Geothermal, Inc., December 16, 2019. https://earthrivergeothermal.com/how-much-does-a-geothermal-heat-pump-system-cost/.

[12] "Geothermal Heating and Cooling Technologies," Renewable Heating and Cooling Technologies, United States Environmental Protection Agency, February 4, 2021.
https://www.epa.gov/rhc/geothermal-heating-and-cooling-technologies

Finally, geothermal systems have long lifespans which reduces the impact from construction, material acquisition, delivery, and installation when compared to other methods of climate control.

Economic Advantages of Geothermal Heat Pumps

Geothermal does have a high upfront cost. Specific prices are difficult to come by since projects are unique to a building and where it is located. Industrial sized geothermal heating units would require individual estimates. The cost of individual geothermal heat pump units is covered in a later section.

The long term savings from geothermal makeup for the high initial cost. Geothermal pumps can collect \$3-\$4 of heat for every \$1 of electricity. Gas furnaces produce \$0.65-\$0.95 of heat for every \$1 of electricity.[13] The U.S. Department of Energy projects that most geothermal projects can recoup their installation cost through energy savings in 5-10 years.[14]

Durability of Geothermal Heat Pumps

Geothermal systems have long lifespans, reducing maintenance and expenditures to replace critical components.The pipes used in geothermal systems are highly durable and can last up to 50 years before needing to be replaced. The heat pump system used in geothermal can last up to 25 years.[15]

Feasibility of Geothermal Heat Pumps

Geology and hydrology of the geothermal site are important to consider. Geothermal projects can be completed in adverse terrain, it is simply more difficult and costly. Middlebury would need to get its land assessed to determine how feasible geothermal would be; however, geothermal is successfully used across New England. Thus, it is worth considering.

Replacing Biomass:

While the biomass plant at Middlebury has served the campus well, the system has its limitations and is approaching the end of its projected 25 year lifespan.[16] Currently, the biomass plant supplies campus buildings connected to the central heating system, which does not include 40 buildings which will be discussed later. In order to meet demand, the plant uses roughly 25,000 tons of wood chips annually that are sourced in Vermont and New York.[17] While the process is considered carbon neutral, since the wood chips come from trees that had sequestered carbon and the supply only represents 1% of growth within regional forests, the biomass plant emitted 20,928 metric tons of carbon dioxide per year on average between fiscal year 2017 and fiscal year 2019.[18]

One potential replacement for the biomass plant is a geothermal system. A new geothermal system would be indisputably renewable because it uses naturally abundant heat from the ground and electricity generated from sustainable sources to run the pumps.[19] From an environmental perspective, geothermal would provide a long-term low-carbon solution that does not require above ground land.[20] As

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[13] "How Geothermal Heat Pumps Work," Earth River Geothermal, February 5, 2021, https://earthrivergeothermal.com/geothermal-heat-pumps-work/

[14] U.S. Department of Energy, "Energy Efficiency & Renewable Energy," U.S. Department of Energy, February 2011, https://www.energy.gov/sites/prod/files/guide_to_geothermal_heat_pumps.pdf

[15] U.S. Department of Energy, "Energy Efficiency & Renewable Energy," U.S. Department of Energy, February 2011, https://www.energy.gov/sites/prod/files/guide_to_geothermal_heat_pumps.pdf

[16] "Middlebury Energy 2026." Middlebury College Office of Sustainability Integration. June 2018-Draft.

[17] "Biomass Gasification." Middlebury. Accessed February 8, 2021. http://www.middlebury.edu/sustainability/operations-and-action/biomass-gasification.

[18] "Biomass Gasification." Middlebury. Accessed February 8, 2021. http://www.middlebury.edu/sustainability/operations-and-action/biomass-gasification.

[19] Tepfer, Fred, John Treston, Rick Waligora, John Webster, Douglas Wells, and Kevin Williams. "Going Underground on Campus," n.d., 74.

[20] "Design Blitz Group Slides." Middlebury College J Term Sustainable Solutions Lab Internship. Accessed February 6, 2021.

explained above, geothermal systems are costly upfront, but they require little maintenance, can last 50 years, and offer significant savings and reductions in energy consumption.

In order to sustainably operate a geothermal system on campus it would be important to consider what electricity would be used to operate the pumps. One option would be to purchase electricity from Green Mountain Power who is striving to generate 100% of its electricity from renewables by 2030.[21] Another option would be to build a hydroelectric plant using the Otter Creek waterfall. It is projected that a hydroelectric plant could produce around 8.5 GWh/yr of electricity for the campus, which is equivalent to about 1/3rd of Middlebury's total electricity consumption.[22]

Case Studies:

Because of geological factors it is difficult to estimate what a geothermal system would cost to implement on Middlebury's campus, but it is possible to look at other colleges who have utilized geothermal.

Skidmore College in Saratoga Springs, New York built three innovative district fields across campus with 670 boreholes for their geothermal system that now heats and cools roughly 35% of the campus.[23] They aim to heat and cool 50% of their campus in the near future.[24] Unlike other geothermal systems, Skidmore chose to use several large district fields to supply the entire campus. Rather than setting up individual systems for each building, they were able to reduce their overall cost by utilizing a connected system.[25] The system cost Skidmore only $1.4 million after grants and other incentives.[26] Skidmore's geothermal success offers suggestions for the viability of such a project at Middlebury. Skidmore is of comparable size and in the same geographical region.[27] A thorough analysis of Middlebury's underground potential will be needed to assess the feasibility of district fields, but this could be a viable approach to reduce the number of boreholes needed to heat the campus.

Ball State in Muncie, Indiana has around 15,000 students, significantly more than Middlebury College, and recently built a geothermal system on campus consisting of 3,400 boreholes.[28] The whole process took 5 years to complete and cost $83 million. However, after state aid and other grants it cost the college only around $5 million out of pocket.[29]

Moving forward, a full assessment needs to be conducted about the geothermal potential at Middlebury, as well as potential grants that could go towards the project.

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[21] "GMP Launches Vision to Have 100% Renewable Energy by 2030." Green Mountain Power, August 5, 2020. https://greenmountainpower.com/gmp-launches-vision-to-have-100-renewable-energy-by-2030/.

[22] "Middlebury Energy 2026." Middlebury College Office of Sustainability Integration. June 2018-Draft.

[23] "Geothermal Energy." Skidmore College. Accessed February 8, 2021. https://www.skidmore.edu/sustainability/renewable-energy/geothermal.php.

[24] Coleman, Lee. "College Looks Underground to Heat, Cool Its Buildings." The Daily Gazette. Accessed February 8, 2021. https://dailygazette.com/2012/12/29/college-looks-underground-heat-cool-its-buildings/.

[25] "Geothermal Energy." Skidmore College. Accessed February 8, 2021. https://www.skidmore.edu/sustainability/renewable-energy/geothermal.php.

[26] Braulick, et al. "Comparing Geothermal Systems Between Colleges." Accessed February 5, 2021. https://apps.carleton.edu/geothermal/assets/Comparing_geothermal_systems_between_colleges.pdf

[27] Skidmore College. Accessed February 8, 2021. https://www.skidmore.edu/.

[28] "Ball State University Geothermal." Environmental Resilience Institute Part of the Prepared for Environmental Change Grand Challenge. Accessed February 8, 2021. https://eri.iu.edu/erit/case-studies/ball-state-university-geothermal.html#:~:text=The%20geothermal%20project%20cost%20%2483,of%20the%20geothermal%20system%20installation.

[29] "Ball State University Geothermal." Environmental Resilience Institute Part of the Prepared for Environmental Change Grand Challenge. Accessed February 8, 2021. https://eri.iu.edu/erit/case-studies/ball-state-university-geothermal.html#:~:text=The%20geothermal%20project%20cost%20%2483,of%20the%20geothermal%20system%20installation.

Replacing #2 Fuel Oil Heating Systems with Geothermal Heat Pumps

Middlebury College projects total CO2 emissions from Scope 1 activities to be 6,903 metric tons of CO2 for FY19/20. One of our group's goals is to reduce this amount by 25% (1,725.75 metric tons of CO2).[30]

The college currently uses #2 fuel oil to power 40 houses not connected to the central steam heating system.[31] CO2 emissions from #2 fuel oil are projected to be 1,613 metric tons of CO2 in FY19/20 Eliminating these emissions would result in a 23.4% reduction of CO2 emissions from Scope 1.[32]

Geothermal heat pumps represent a promising alternative to #2 fuel oil. As mentioned above, geothermal does not burn fossil fuels to heat or cool a building. This means Middlebury could eliminate emissions related to heating buildings with #2 fuel oil by switching to geothermal. Additionally, the reduction in energy required to run geothermal heat pumps compared to more traditional furnaces would contribute to Middlebury's goal of reducing energy consumption. It is difficult to determine how much energy is currently used to power the #2 fuel oil heating systems, but geothermal would significantly reduce this amount.

Geothermal projects can be expensive. Specific prices are difficult to come by since projects are unique to a building and where it is located. The average installation cost for a single family home ranges from $10,000 - $30,000. This might sound expensive, but as the scenarios listed below indicate, Middlebury could pay more than three times this range per building and still pay a reasonable price to reduce emissions from heating the campus by 23.4%.[33]

- $30,000 x 40 building using #2 fuel oil = $1,200,000.
- $50,000 x 40 building using #2 fuel oil = $2,000,000.
- $100,000 x 40 buildings using #2 fuel oil - $4,000,000.

These scenarios also do not take into account the potential to recoup the cost of geothermal conversion from geothermal energy savings. The U.S. Department of Energy projects that most geothermal projects can recoup their installation cost through energy savings in 5-10 years.[34] Provided Middlebury can fund the cost of geothermal heat pump installation, it make both environmental and fiscal sense to switch from #2 fuel oil to geothermal.

The process of converting #2 fuel oil heating systems to geothermal would have a significant impact on Middlebury's current emissions. And more can be done. There are 50 buildings on campus heated with natural gas.[35] Replacing these systems is not as urgent because Middlebury is switching to renewable natural gas. However, geothermal might be preferable to natural gas, even if it is renewable. A fossil fuel free campus would be an achievement worth pursuing for a community at the forefront of the environmental movement.

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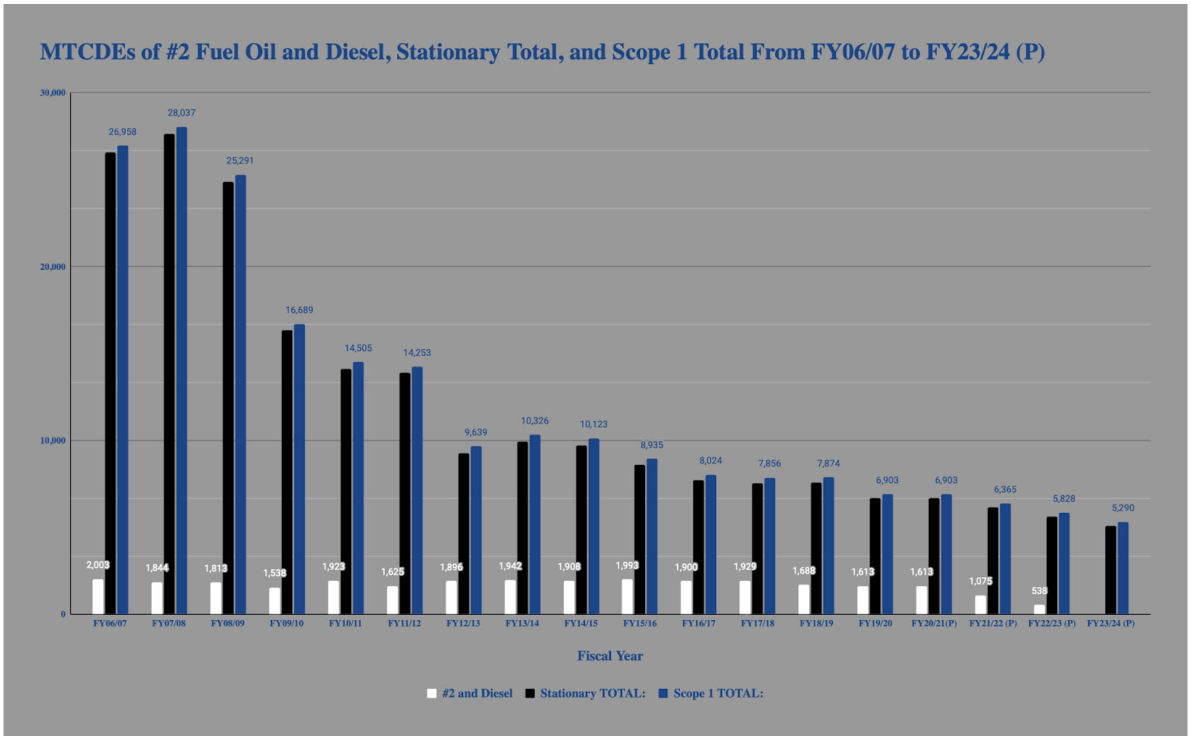
[30] Mike Moser, Carol Quenneville, Susan Personnette, Dean Quellettee, Kristen Anderson, Melissa Beckwith, Steve Olsen, and Alexa Euler, *GHG FY20 In Progress 0121 with Biomass*.
[31] Middlebury College. "Energy 2028: Where Do We Stand?" Presentation.
[32] Middlebury College., *GHG by Source FY08 to FY20 0121 w renewupd.*
[33] Earth River Geothermal, Inc. "How Much Does a Geothermal Heat Pump System Cost?" Earth River Geothermal, Inc., December 16, 2019. https://earthrivergeothermal.com/how-much-does-a-geothermal-heat-pump-system-cost/.
[34] U.S. Department of Energy, "Energy Efficiency & Renewable Energy," U.S. Department of Energy, February 2011, https://www.energy.gov/sites/prod/files/guide_to_geothermal_heat_pumps.pdf
[35] Middlebury College. "Energy 2028: Where Do We Stand?" Presentation.



Historical (FY06/07 - FY19/20) MTCDEs of #2 fuel oil and diesel, stationary total, and Scope 1 total and projected (FY20/21 - FY23/24) MTCDEs, assuming constant MTCDEs except for the conversion of 33% of buildings heated by #2 fuel oil each to geothermal heat pumps each year starting in FY21/22.[36]

Optimization of Energy Efficiency in Dorms and Private Spaces

Upon discussion with Mike Moser, Director of Facilities Services at Middlebury College, many efficiency projects to improve the energy efficiency of private spaces on Middlebury's campus have been proposed, are in the works, or have been completed. These projects include improving insulation within residence halls, improving the efficiency and stopping leakage of heating systems, and plugging spots where heat escapes buildings. The method used to find these inefficiencies is called a blower door test. A large fan is used to blow air into the building being tested while an infrared thermometer is used to see hot spots where air is leaking out of the building. Suggestions of more projects, including controlled lighting and heating in residential spaces, have been discussed, and are feasible, but present a challenge for students because of different living preferences. Another question when asking whether these projects are worth the investment is: To what extent does Middlebury need to monitor and control the individual living situations of its students? Considering these two points, it is not recommended that Middlebury make improvements to living spaces that allow campus facilities to manipulate the temperature and lighting systems in individual living spaces.

Though current efficiency projects are ongoing, students can play a large role in decreasing both electrical and thermal energy consumption. A few actions that students can take include using more natural light instead of artificial light when possible, using blinds in private spaces as an insulator, and moving furniture and objects away from radiators.

Decreasing Electrical Energy Consumption

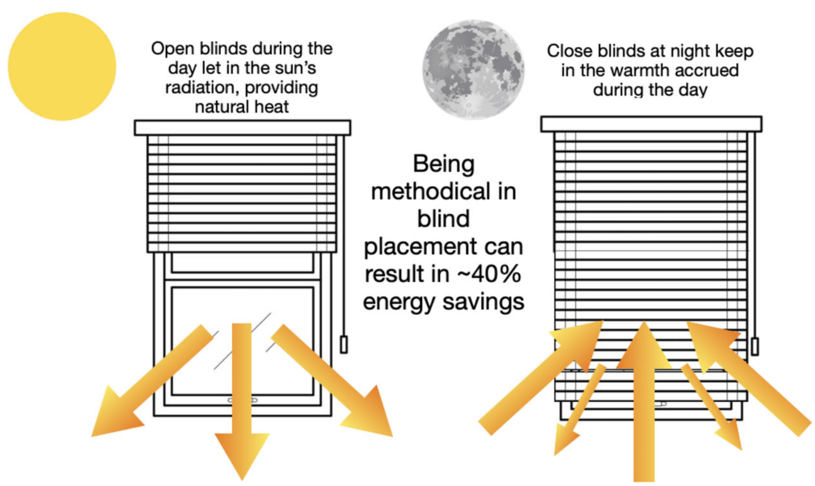
Using natural light when possible and remembering to turn lighting off when not present in private spaces will help decrease the amount of electrical energy used by Middlebury's campus. Ways to

[36] Mike Moser, Carol Quenneville, Susan Personnette, Dean Quellettee, Kristen Anderson, Melissa Beckwith, Steve Olsen, and Alexa Euler, *GHG FY20 In Progress 0121 with Biomass*.

encourage students to turn off their lights more often may include adding visible signage to dorm exits encouraging students to turn off lights and leaving reminders on dorm whiteboards to turn off lights when not present inside dorm rooms.

Decreasing Thermal Energy Consumption

More efficient cellular blinds could also help to warm and cool dorm spaces with more efficiency. Windows are a major heat sink of buildings during the heating season with about 30% of a space's energy being lost through windows. Additionally, during the heating season, windows have the potential to be major warmers of dorm spaces. 76% of solar radiation that hits a standard window is converted into heat inside dorm spaces. In order to cool spaces, close blinds in order to block heating inside spaces.[37] Encouraging students to open their blinds when receiving natural light will help to heat spaces without the use of additional Middlebury-made thermal energy. In order to stave off heat loss when light is not present, students should close their blinds to create an insulating barrier between windows and warmed rooms. A consideration for Middlebury is to make the switch from plastic and vinyl blinds to highly efficient cellular insulating blinds. Cellular insulating blinds have the capability to reduce energy consumption in heating seasons by about 40% which may equate to up to 20% energy savings. During cooling seasons, cellular blinds have the ability to block 80% of sunlight, creating a cooler space and reducing the amount of energy needed to cool a space.[38] Investment into these efficient blinds will most likely lead to improved energy efficiency in dorms even if students do not comply with the aforementioned recommendations on blind use. A majority of students close their blinds at night, so the behaviors of students would not have to change in order to have success with installation of efficient cellular blinds.



Moving items away from radiators and heaters is another way to increase energy efficiency in dorm spaces. Objects placed against radiators absorb heat and do not let the heat radiate through the space. If heat is not efficiently radiating through dorm spaces, more heat and thermal energy must be used to warm spaces therefore decreasing efficiency. Facilities could have a part in moving objects away from radiators by configuring rooms into more energy efficient formats before students arrive. This

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[37] "Energy Efficient Window Attachments." Energy.gov. Accessed February 9, 2021. https://www.energy.gov/energysaver/energy-efficient-window-attachments.

[38] "Energy Efficient Window Attachments." Energy.gov. Accessed February 9, 2021. https://www.energy.gov/energysaver/energy-efficient-window-attachments.

project would involve moving furniture away from radiators and moving furniture in ways to encourage students to not store objects near radiators.

Recommendations Summary

Most of these recommendations require the help of students and the community to make effective. Addition of resources inside dorm spaces with these recommendations will make students more conscious of their energy use and encourage the community to band together and reduce Middlebury's carbon footprint. These resources may include stickers in rooms to remind students to turn off lights, adjust their blinds, and move objects away from radiators. Leaflets could also be provided to students in their dorms to further inform them how they can be proactive in Middlebury's goal to reduce our energy consumption by 25%.

Overview: Smart Monitoring of Energy and Heating

Middlebury's commitment to reducing overall energy use necessitates several projects that comprise many aspects of student and academic life on campus. While the bulk of these projects can, and are effectively encompassed by building renovation, some go above and beyond the standard upgrades. For example, while improved windows and wall insulation provide significant long term cost and energy savings, smart monitoring of energy and heating provides a unique opportunity to further increase energy savings.

Smart Management of Heat in Dorms

Kenyon College instituted a smart temperature regulation system in individual dorms in 2012. This system is quite intricate, including "smart thermostats, occupancy sensors, and window sensors."[39] Unfortunately, Kenyon College has either neglected to publish their data or simply do not have any. That being said the initial reports from multiple sources corroborate that installing the system in 400 rooms saved around $30,000 in just eight months[40]. From this we can extrapolate both fuel savings using historical prices and scale it to Middlebury's campus. Scaling this data is likely inaccurate given the specific building, climate, and heating system differences between Kenyon and Middlebury College. Given the average price of #2 heating oil in 2014 being $2.69 per gallon and at savings of $30,000 we can assume that Kenyon was probably saving around 11,000 gallons of heating oil. It is important to mention that over this 8-month period we are assuming that Kenyon was exclusively using energy to heat rooms. This would account for savings of 27.5 gallons of heating oil per room. While there is very little research done on the subject of academic housing smart heat systems, one study that controlled for a number of different aspects of heating efficiency and came up with a general estimate of heating costs being reduced by 5.8%-7.9%.[41] While this is substantially less than the 10% claim set by the EPA[42] in their assessment of home smart heating, it still would represent a large reduction of overall core campus heating use.

Smart Management of Electricity in Dorms

The initial documentation on Rutgers' key card system is more substantial than Kenyon's project. Rutgers proposal bases most of its assumptions off a report coming from a hotel chain [43]which is substantially different both in occupancy times and in occupancy types. From this data, and internal

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[39] "College Retrofits Dorms With Wireless Energy-Management Technology | HPAC Engineering," accessed February 8, 2021, https://www.hpac.com/building-automation/article/20927931/college-retrofits-dorms-with-wireless-energymanagement-technology.

[40] "College Retrofits Dorms With Wireless Energy-Management Technology | HPAC Engineering,"

[41] Marco Pritoni, Jonathan M. Woolley, and Mark P. Modera, "Do Occupancy-Responsive Learning Thermostats Save Energy? A Field Study in University Residence Halls," *Energy and Buildings* 127 (September 2016): 469–78, https://doi.org/10.1016/j.enbuild.2016.05.024.

[42] "Thermostats," Energy.gov, accessed February 8, 2021, https://www.energy.gov/energysaver/thermostats.

[43] Ajay Menon, Ian Johnston, and Brian Doyle, "Keycard Based Energy Saving Pilot Program," n.d., 10.

documents, Rutgers estimated savings approximately $47 per occupant over the course a of year with an initial investment cost of around $195[44]. As such, this program would theoretically pay back in around 4-5 years. Like Kenyon, Rutgers has not published any reports outlining the actual efficacy of their program which is problematic for the implementation of future systems. This in conjunction with the work that Jerffrey Ou completed in 2018 would lead us to the conclusion that it is not worth the installation.

Smart Management in Small Campus Houses

Middlebury's campus has vast buildings with 2.4 million square feet just on the core campus. [45] Of that approximately 83% is connected to the central steam plant. [46] Given that we are still accounting for roughly 408,000 square feet of non-centrally controlled heating there exists an excellent opportunity to improve and standardize heating systems[47] . In non-dormitory space, it would make sense to install smart heating systems that are already found sporadically across Middlebury's heating infrastructure. The Nest system claims to be able to reduce heating costs by 10-12% in consumer homes.[48] Given this, slowly phasing these systems into use in smaller non-centrally linked campus houses, regardless of heating method, could provide significant heating efficiency benefits. Two brief notes on this proposal. First, these thermostats are challenging to use for a student who has never interacted with one before, as such there must be literature available in the near vicinity of the thermostat. The location of information seems necessary to make their use effective. Secondly it would make sense for facilities to set them up when they are programmed to a "normal" housing temperature to ensure that these units are working well. Given the cost of $150 per unit and the maximum estimate of 83 non-central buildings (an overestimate, because many are dormitories where this system would not work) the investment cost would be minimal at only $12,450 (omitting installation and setup costs). As such, in houses that are occupied in ways similar to a traditional American house it would be beneficial to install these systems.

Conclusion and Recommendations

Given the limited data regarding smart heating in dorm rooms hesitancy to install these systems is understandable. As such there are two main paths forward. The first involved installing both the key card system and heat monitoring systems when buildings undergo significant renovation. However, there must be enhanced monitoring of a variety of factors including but not limited to: room occupancy rates, room temperature, and energy use. This will allow the Middlebury campus to better monitor the effect of these systems on a small scale before wider implementation. By most metrics and estimates this would produce significant results as were outlined above. This would, of course, require collaboration with an individual with significant statistics knowledge to ascertain the effectiveness of these systems. The second proposal is much simpler and may be more to the liking of facilities. This would simply be to install a wall mounted analogue thermometer with an infographic in each room. Given the cost of roughly $10 per thermometer and the cost of $.56 per a 3"x10" sticker this would represent a much smaller investment of only $27,250 for the whole campus. (this number includes significant amounts of double counting and is based solely off the number of students enrolled, not actual rooms) By providing students with real time information about the actual temperature of their rooms and giving them the information, they need to enact energy savings that may produce favorable results at a fraction of the cost.

Changes and Improvements to Middlebury's Transportation Fleet

Another way Middlebury can better work towards achieving the goal of a 25% emission reduction by 2028 is by looking at possible changes and improvements to its vast transportation fleet. On

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44 Menon, Johnston, and Doyle.
45 E2028 Update 7-15-20 v1
46 E2028 Update 7-15-20 v1
47 E2028 Update 7-15-20 v1
48 "Thermostats."

the main campus, Middlebury utilizes 131 vehicles, ranging from tractors and dump trucks to snowmobiles and snowcats. As of now, there are only two electric vehicles being used on Middlebury's main campus, one being a golf cart and the other a utility vehicle. That means only 1.5% of Middlebury's transportation fleet is electrified. According to a recent study, *Working Paper Sustainability and Innovation*, researchers Martin Wietschel, Matthias Kühnbach, and David Rüdiger found that electric vehicles have up to 43% lower emissions than their diesel counterparts[49]. Electric vehicles as a means of slicing carbon emissions by nearly half should be enough motivation for Middlebury to expand the electrification of its vehicles.

Of course, it is not pragmatic nor realistic to expect a complete 180º shift away from the use of gas in Middlebury's transportation fleet, but there is definitely room for improvement. For example, out of the 12 golf carts used at Middlebury, only one is electric. Made by Yamaha, the G22E G-Max costs around $8,000[50]. Thus, to electrify the entire fleet of golf carts would cost Middlebury roughly $100,000. While this is a substantial sum, it is also one of the simpler ways Middlebury can take action to directly reduce carbon emissions. Similarly, out of the 18 John Deere utility vehicles, only one is electric. While the electric utility vehicles do cost a little more than the electric golf carts ($12,000), they are often seen around campus by students, faculty, and Middlebury residents in general[51]. Not only would the electric utility vehicles make campus a little quieter and contribute to the serenity that is so cherished, they would also explicitly show everyone, from the prospective students touring our campus to the local residents, that Middlebury is actively trying to be more sustainable and eco-friendly.

Unfortunately, as of now, the only electric utility vehicle that John Deere manufactures has a 4x2 foot cargo space, and while Middlebury does use these (eight of them including the electric one), the more commonly used utility vehicle is the one with a 6x4 foot cargo space. Thus, in order to be as realistic as possible, the cost of electrifying the utility vehicles was only calculated with the thought of replacing the eight pre existing 4x2 vehicles. For $12,000 each, it would cost the college nearly $100,000 to electrify eight utility vehicles. In all, if Middlebury's main campus has a total transportation fleet of 131 vehicles and 20 are converted to electric vehicles, there will be 15% fewer gas powered vehicles on campus. This relatively simple and "cheap" fix can contribute greatly to Middlebury's 25% emission reduction by 2028.

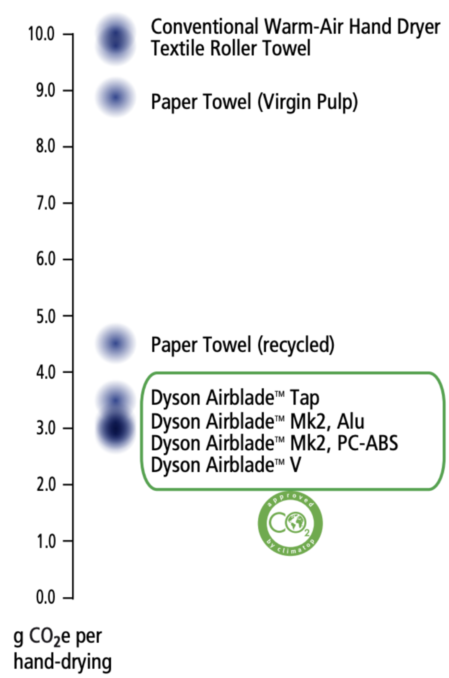


Fig.1: Greenhouse gas emissions per one-hand drying calculated with the European electricity mix.

Steering away from the transportation fleet, another possible way for Middlebury to reduce its carbon footprint lies within the bathroom. Currently, most if not all bathrooms at Middlebury use paper towels as a hand-drying method. However, more eco-friendly alternatives, such as cool-air hand dryers, exist[52]. The Dyson Airblade™ hand dryer emits an average of three grams of CO2 per single use, while its paper towel counterpart emits triple that, a shocking nine grams of CO2[53]. While it is true that recycled paper towels emit less

[49] Matthias Kühnbach, David Rüdiger, Martin Wietschel, "Die aktuelle Treibhausgasemissionsbilanz von Elektrofahrzeugen in Deutschland" Working Paper Sustainability and Innovation, February 2019.

[50] Yamahagolfcar.com, accessed February 7th, 2021

[51] Deere.com/TE 4X2 Electric (2021), accessed February 7th, 2021

[52] Jeremy Gregory, Randolph E. Kirchain, Trisha Mae Montalbo, "Analyzing uncertainty in a comparative life cycle assessment of hand drying systems" *International Journal of Life Cycle Assessment*, June 2016

[53] Myclimate.org, Climatop® Dyson Airblade Factsheet, accessed February 9th, 2021

CO_2, at roughly 4.5 grams per use, the switch to cool-air hand dryers would have benefits aside from the clear reduction in carbon emissions. Firstly, hand dryers are cheaper for the college in the long run, as hundreds upon thousands of rolls of paper towels would no longer be needed to be purchased annually. Additionally, less waste will not only be beneficial for the maintenance workers of Middlebury, but just like the electric vehicles, cool-air, high efficiency hand-dryers will illustrate the social responsibility Middlebury has taken to combat climate change, whilst also improving the overall aesthetics of the school by creating less trash.

In all, Middlebury has a long way to go to reach the 25% reduction goal, but with the changes to the transportation fleet, hygienic resources, as well as all the other incredible ideas presented here, Energy2028 can and will come to fruition.

Recommendations:

Managing the Carbon Fund

- Breakdown of capital allocation in the following quantities: 75% capital fund, 15% education, 5% external, 5% achievement grants.
- Publicize the existence of the fund and encourage applications from all members of the Middlebury community. Provide technical assistance with the proposals.
- Implementation of Energy2028 Day, dedicated to educating Middlebury College students and the community about the College's environmental responsibility goals. To take place on January 29, the anniversary of the initiative's approval by the board of trustees.

Internal Carbon Tax Adjustments

- **Transportation**
    - Update Oracle so that there are entry fields for departure and arrival locations for flights. Work with a CS class or student employee to write a code that can calculate distances between listed airports and estimate carbon emissions accordingly. Base the carbon charge on a $40 per ton of estimated emissions.
    - Update the 2.5% annual cap reduction to 4.2%, assuming a carbon price is implemented in 2022, in order to reach a 25% reduction by 2028.
- **Campus Waste**
    - Tax inorganic recyclables based off of recycling company carbon emissions rate per material in addition to organic waste.
    - Tax nonrecyclable waste based off of landfill carbon emission formulas provided by either Research Triangle Institute (RTI) or another company
- **Energy Consumption in Buildings**
    - Tax renewable energy use to reduce campus wide energy consumption
    - Continue to tax carbon emissions from nonrenewable fuel sources
- **New Construction**
    - Continue taxing construction projects at 0.5% their cost.
    - Estimate energy use (both renewable and nonrenewable) and tax it to determine if 0.5% tax is justified.

Automation for heating and energy efficiency

- Begin implementation of automation in the next renovation project. This would ideally include monitoring and control of individual dorm rooms. Once the system is in place analysis of efficacy should be conducted.

- If the installation of automation is not desired, it would still be pertinent to install thermostats in dorm rooms with the infographic located below in the report.
- Installation of smart thermostats in small campus houses should be done gradually over the next year. It is also recommended that there should be a manual located near the units.

Replacing Biomass:

- Conduct an in depth land survey to assess Middlebury's geothermal potential. Assuming a geothermal system could work given the geography, research needs to be done looking into the cost of the project and the scale of support that the college could receive in grants from the state and other incentives.
- In order to protect the sustainability of the project, renewable energy can either be bought from Green Mountain Power or further renewable energy generation projects should be explored, including the development of a hydroelectric plant in Otter Creek.

Optimizing energy efficiency in small spaces:

- Install cellular insulated blinds in all dorm rooms to stop heat loss through windows to create 20% energy savings and a 40% reduction in thermal energy.
- Place materials in dorms and small spaces to encourage students, faculty, and staff to save energy by turning off lights, move objects away from radiators, and manage their blinds to increase energy efficiency.

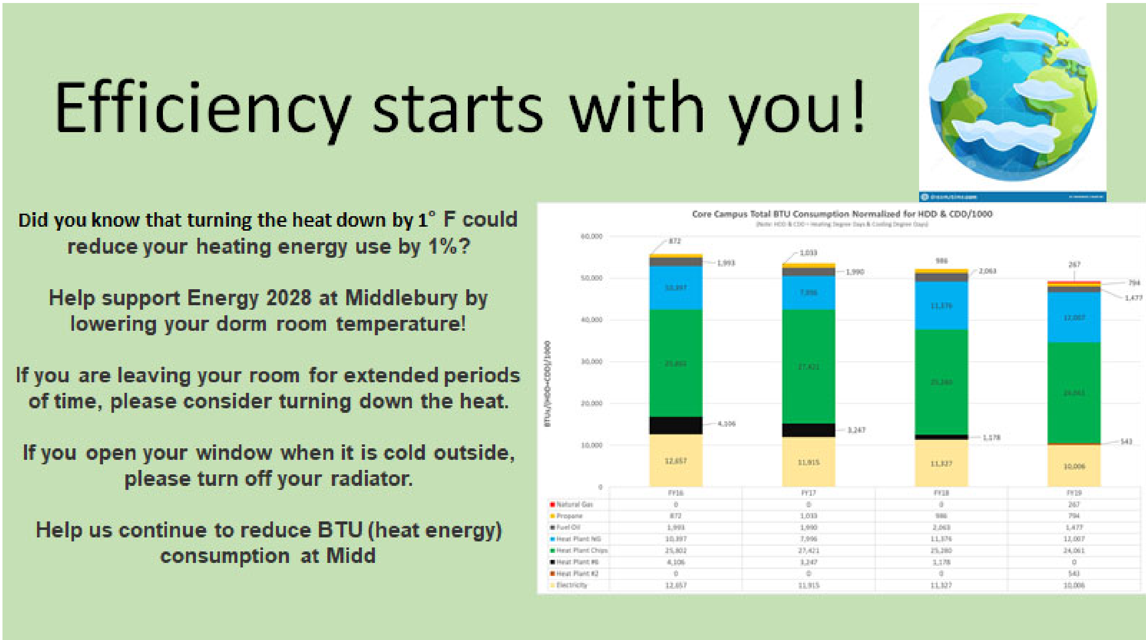
Converting #2 fuel oil heaters to geothermal heat pumps:

- Conduct a survey of geology and hydrology surrounding buildings that are currently heated by #2 fuel oil. Assuming a geothermal system is feasible, spend one year getting estimates for project cost and duration for each building.
- Create a phased approach of 4-7 years (depending on time remaining before the Energy 2028 deadline) for converting #2 fuel oil heated buildings.
- Upon the completion of the project, begin researching the feasibility of converting natural gas heated buildings to geothermal heat pumps.

Transportation Fleet:

- Replace the 12 gas powered golf carts with electric golf carts. At $8,000 each, total replacement cost would be ~ $100,000
- Replace eight 4x2 gas powered utility vehicles with the John Deere TE 4x2 electric model. TE 4x2 costs approximately $12,000, so the total sum to replace the eight pre-existing ones would cost another $100,0000
- Electrification of 12 golf carts and eight utility vehicles equals 15% reduction in gas-powered vehicles on campus
- *Hygiene* - Replace single use paper towels in all bathrooms at Middlebury with more eco-friendly and energy efficient cool-air hand dryers.
    - Dyson Airblade™

Example Energy Infographic for Dorm Rooms:



MIDDLEBURY COLLEGE
Environmental Justice Compliance Checklist

Select one, based on the questions below:
A – This project will not have an effect on human or environmental health
B – This project will have an effect on human or environmental health

a. Step 1: Is the project intended to further Middlebury College's Energy 2028 plan?
b. Step 2: Is the project located off campus in a predominantly minority or low-income neighborhood?
c. Step 3: Would there be adverse environmental impact caused by the proposed action?
d. Step 4: Will the adverse environmental impact of the proposed action disproportionately impact minority and low-income populations relative to the community at large?
e. Step 5: Has mitigation measures been considered and does the mitigation plan include input from public participation of the affected population?