Heat Waste and the Dorms:

An analysis of energy consumption of the Macalester dormitories

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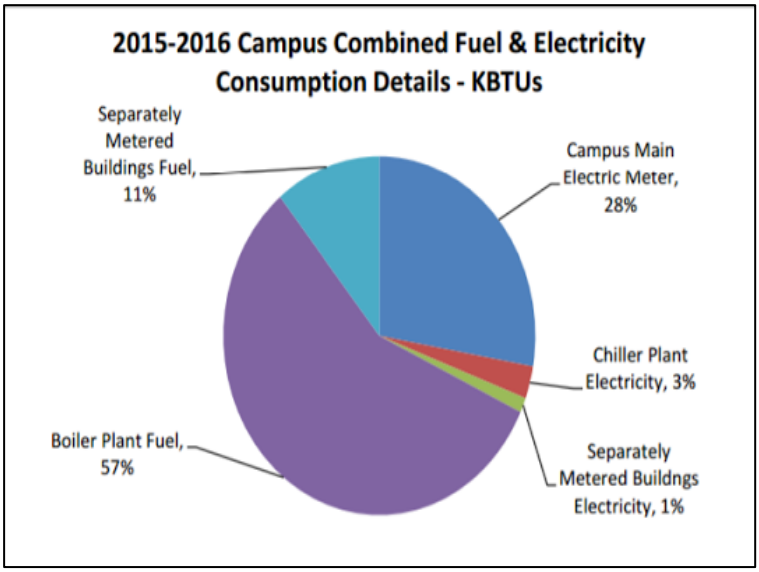
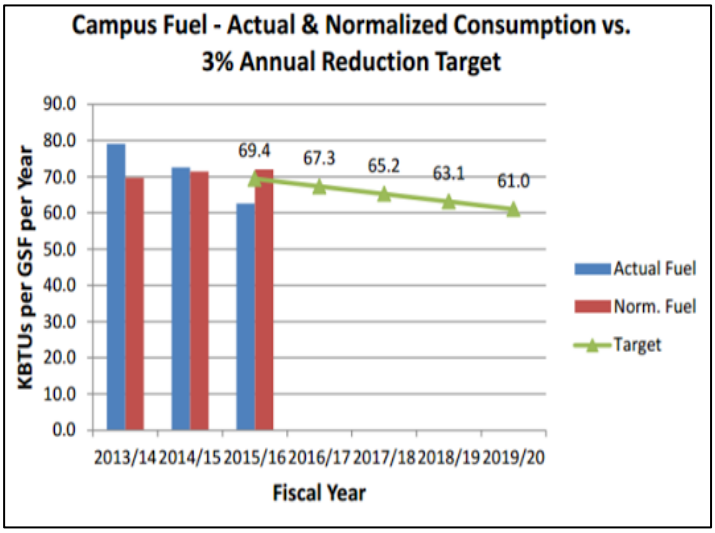
Introduction

Macalester College has committed itself to becoming carbon neutral by 2025. In practice, this is a commitment to lowering its carbon footprint and involves reducing carbon emissions by 52 percent from 2007- 2008 levels. The last 48 percent of the college's emissions would then be offset by off-site renewable practices. A huge part of reducing our carbon footprint is minimizing the natural gas we use to fuel the steam plant and heat all of the buildings on campus. In 2015-2016 the boiler plant was responsible for 57% of the campus' energy consumption for electricity and fuel as demonstrated in the graph below (2015-2016 Campus Annual Energy Use Report). Reducing the fuel consumption of the steam plant by directing action toward reducing heat waste in the dormitories would make a significant impact in helping Macalester reach its Carbon Neutrality goal and its energy conservation goal of reducing use by three percent every year.



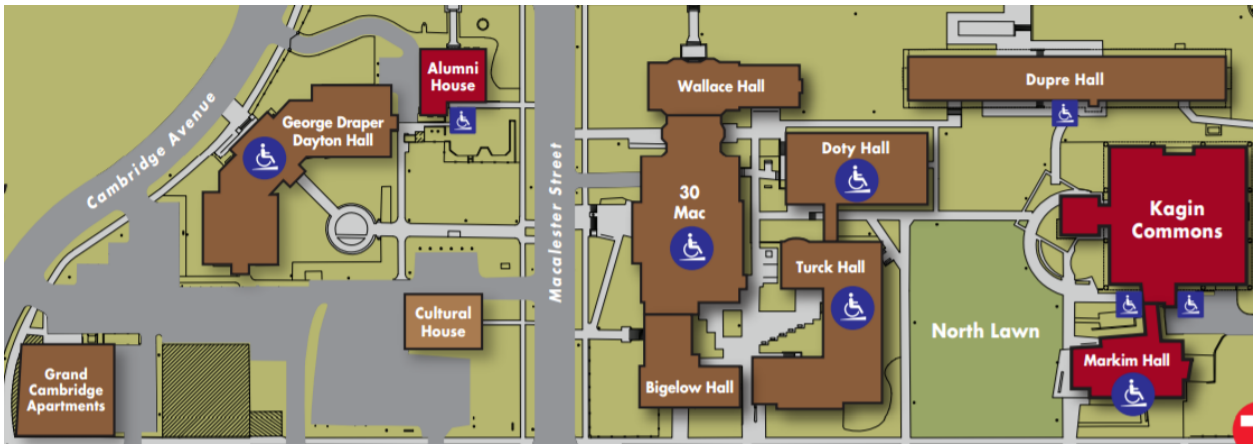
Reducing Macalester's carbon emissions by targeting the dormitories as a major contributor to heat waste could be especially beneficial as there has been difficulty in the reducing the campus fuel usage in the past few years. The graph above demonstrates the total campus' fuel emissions for the past three fiscal years. While the actual amount of fuel used over the past couple years has been declining, this representation is misleading because it doesn't account for fluctuations in winter weather. The better representation of fuel use for year to year is through weather normalized values. For example, 2015-2016 was a particularly mild winter, so less fuel needed to be spent to warm the buildings. The relative amount of fuel used when the winter temperatures are taken into account and corrected for, however, shows that there has actually been an increase in campus fuel

dependency. When one considers the targeted levels for the upcoming years, it is obvious that there is a need for fuel emission reductions (2015-2016 Campus Annual Energy Use Report).



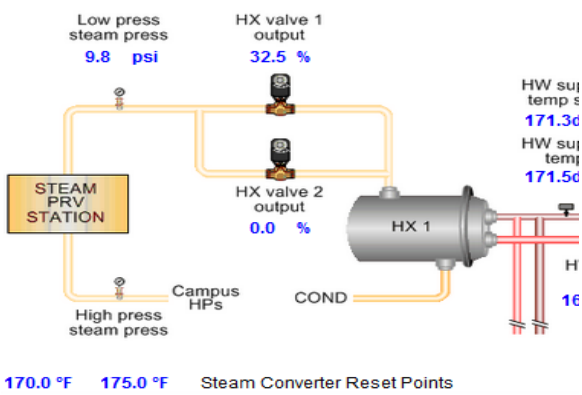
Part of the process of reduction is understanding how heat is primarily lost during the winter in order to optimize the efficiency of the heat that is produced. One obvious way that heat is lost is from students opening windows in the dorms during the winter. We became aware of this issue primarily through our own experiences at Macalester during the winter. We noticed that many students complained the rooms were too hot and they opened the windows to regulate the temperature. We quickly realized this was a trend among students, with three dorms constituting the primary culprits: Doty Hall, Dupre Hall, and the 30BigWall dorm complex. In order to suggest future solutions to this problem, we explore how the problem dormitories are heated, why there are issues with over-heated dormitories, and possible methods for reducing heat loss as well as general ways to save money by conserving heat.

1. <u>The Dormitories:</u>

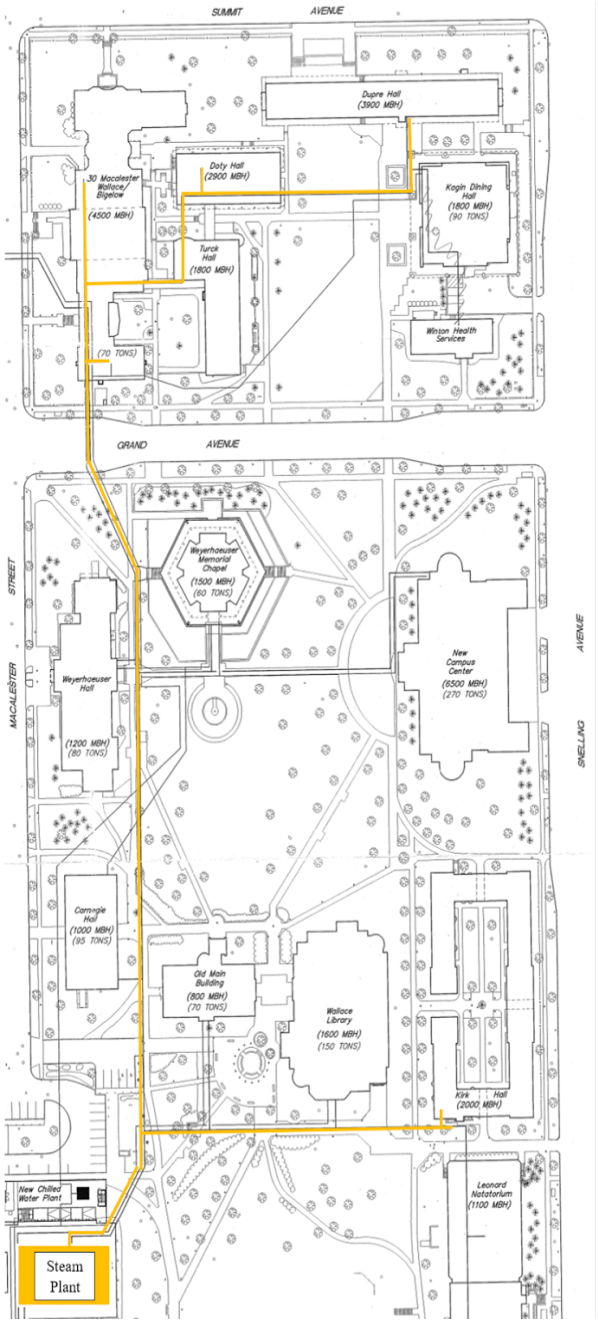


Macalester College requires that students (with the exception of second year transfer students) live in the dormitories for the first two years. With a school attendance of approximately 2,100 undergraduate students, this means that every year there are at least 1,000 students living in the dorms. Within the housing complex there are three main dormitory buildings that house first year students: Turck, Doty, and Dupre. Sophomores and upperclassmen have a greater variety of campus provided housing options which include: The Veggie Co Op, the language houses, the cottages, the Cultural House, the Summit House, the Grand Cambridge Apartments, the Eco House, and the main dormitory buildings: Kirk, Bigelow, 30 Mac, Wallace, and George Draper Dayton (GDD) Hall. For the purposes of this paper we will be focusing only on the primary dormitory buildings and will later highlight and emphasize the buildings which use the most energy.

All of the main dorm buildings, including Doty and Dupre, are heated by the on campus steam plant underneath the Janet Wallace Fine Arts Center and Gallery. The steam plant produces steam, which is sent to buildings through a complex system of underground pipes. The steam then travels through the heat exchanger located in the individual buildings where the heat is transferred to hot water which can circulates through radiators in individual dorm rooms. Hot water, heated by steam, comes into the radiator and heats up the steel plates, which then produce heat which is released into the room. Back in the heat exchanger, the steam has spent its energy to heat the water and has condenses into water. This water travels back to the steam plant via underground pipes and is referred to as condensate. On the left is a diagram of the heat exchanger from the Leonard Center, a more complex system than the dorms perhaps, but with the same overall mechanism courtesy of Mike Pumroy. Provided on the next page is a diagram of the steam



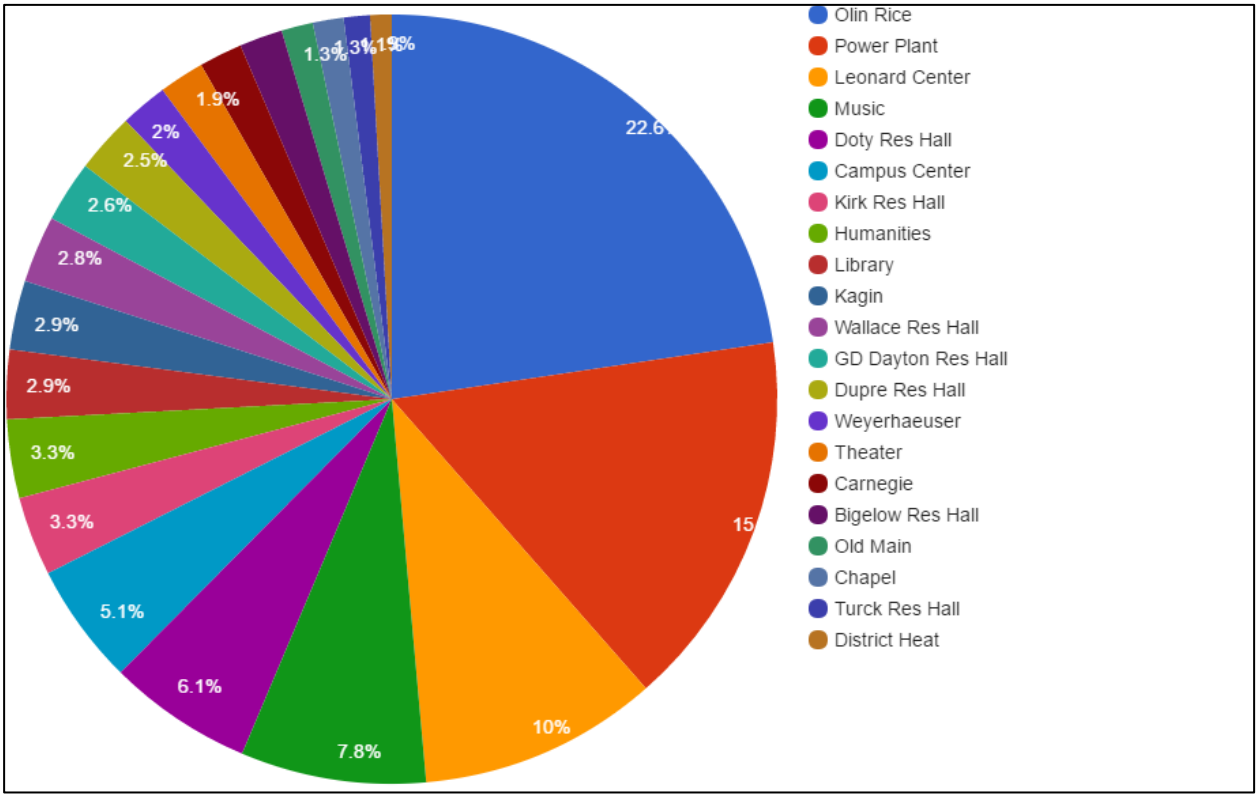
plant's underground distribution system with the pathways leading to the dorms highlighted ("Campus Steam and Chilled Water Distribution System").



The Facilities Services Department recently hired Energy Manager Mike Pumroy who works to reduce campus energy use. He maintains data from the steam plant in the hopes of being able to optimize the campus heating system. Staff record the condensate recovered from each building — measured in Gallons per day — which can be considered an equivalent to energy usage. This is because each gallon of water that is returning has previously been heated and sent to the buildings as steam to activate their radiators. Energy was originally put into the steam in the form of burning fossil fuel, usually natural gas . That energy is released in the form of heat through our radiators and vents. So for every gallon of condensate that returns to the steam plants, were releasing greenhouse gas emissions into the atmosphere.

The chart above shows the amount of condensate each building on campus reported in 2015. On the right, the buildings are listed in order of decreasing amount of condensate used ("Facilities Services Aggregated Condensate Report"). It should be noted that Doty and Kirk Res Halls were reported 5th and 7th respectively, with Dupre and the 30BigWall dorms following not far behind. Combined, these four heat users constitute a total of 16.6% of the campus' heat usage. This makes the dorms the second biggest heat user on campus and a good area

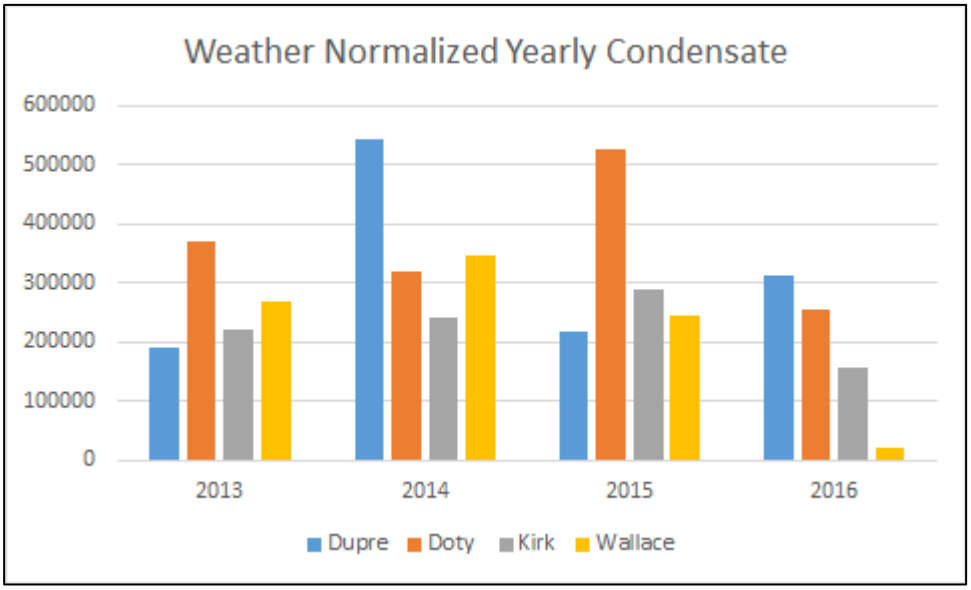
for reduction of carbon emissions.



Students can control the amount of hot water sent to their radiator through a hand valve. The hand valve, which looks like a lever, simply can be adjusted from varying degrees between “hot” and “cold”. Although Mike Pumroy states that this is the “most primitive form of temperature control” this lever is the only control students have over the temperature within their room. The only other way a student can change the temperature of their room is by opening the window.

Despite the uniform method of heating the dorms, they use significantly different amount of energy. Variations between each building such as design, size, number of occupants, etc. contribute the large discrepancy in energy cost. The following portion of the report is dedicated to examining the top four dormitory buildings that have been using the most energy over the past several years. Each section will present the statistical data detailing each individual dorm’s energy expenditure as well as structural components, location, and any information that may contribute to the energy usage of said building. The graph below demonstrates the reported condensate from these highlighted dorms since 2013. This data

has been weather normalized from year to year



It should be noted that for 2016 that data has only been reported for the months January through May.

Doty Hall

Built in 1964, Doty Hall is located in the middle of the north block of campus and just west of Kagin Lawn. Doty is a freshman dormitory with the first floor designated as all-gender housing and the second through fifth floors consisting of single gender floors— in 2015 and 2016 there have been three all female floors and one all male floor likely due to the the greater attendance by female students at Macalester (Res Life). The housing situation consists of primarily doubles with three singles each located on the second through fifth floors.

Based on the Facilities Aggregated Condensate Report provided by Mike Pumroy, we were able to acquire data detailing the energy required by the steam plant to heat each building. Since 2013, Doty has recorded some of the highest numbers in the condensate report and almost always appearing in the top five energy users. While the larger non dormitory buildings Olin-Rice and the Leonard Center are the two biggest users of heat, the impact of the dorms is significant.

In 2015, Doty Hall was the fifth biggest user of steam of all buildings on campus. According to the Aggregated Condensate Report, Doty accumulated 445,940 gallons of condensate in 2015 alone. This was close to a quarter of Olin-Rice (1,662,300 gallons) and over *half* of the Leonard Center (736,999 gallons). This is to heat a building that is significantly smaller and utilized by a much smaller proportion of the student body. As you may recall from Figure 5, Doty Hall (the purple slice) takes up 6.1% of the total campus energy usage in terms of heat (7,344,107 gallons) while not serving many students. Housing 159 residents, Doty blows the other dorms out of the water in terms of per resident energy expenditure. In 2015, this hall required 2,805 gallons of condensate per resident to heat the building for the year. The next biggest user per resident is Wallace at only 1,756 gallons per resident.

Dupre Hall

Dupre is the largest dormitory on the Macalester campus both in size and student occupation, housing over 260 first-year and sophomore students on four co-ed floors. Dupre consists of about 60% double rooms and 40% single rooms; in addition, there are two triples and one quad on each floor (Res Life). The building, located on the northeast corner of campus, at the corner of Summit and Snelling Ave, was built in 1962 and renovated in 1994. Mike Pumroy contends that Dupre is an inefficiently designed building for maintaining heat during the winter in Minnesota. He asserts that since the first floor primarily consists of open space with pillars holding up the rest of the building, cold air flows under the building and forces the heating system to consume more energy to heat the building.

The Facilities Services Aggregate Condensation Report also contains information about the amount of energy Dupre consumes to heat. From 2013 through 2016, Dupre reported 5.25 percent of the total Macalester condensate, meaning it essentially, on average, used 5.25 percent of the total heat put out by the steam plant. This varies year to year fluctuating based on the severity of the winter. For example, in 2015 Dupre consumed 3 percent of the total (184,170 gallons). Meanwhile in 2016, in which data has only been reported for the months January through May, Dupre has already reported 313,614 gallons of

condensate, almost double the reporting for the entirety of 2015 (184,170 gallons). In regards to weather normalization, this consumption rate makes Dupre one of the biggest dormitory users of heat energy on campus. Being one of the most populated dorms, condensate reported per resident was on average 1,231 gallons. Which, compared to the other dorms, is slightly lower.

Kirk Hall

Unlike Doty and Dupre, Kirk Hall houses everyone but first year students. The building consists of nine different sections which house 151 students, most of whom are juniors and seniors of either gender depending on the floor and section. Built in 1926 and renovated in 1993, Kirk is Macalester's second oldest dormitory and is located along Snelling Avenue. Kirk contains 49 singles, 28 doubles, and 6 triples and hosts both the Interfaith House and the Gender Free Living Community.

Looking at the Facilities Services Aggregated Condensate Report, Kirk reports, on average, 3.25 percent of the total Macalester total condensate. That comes out to on average 225,195 gallons of condensate a year and puts Kirk third on the list for dormitories consuming the most energy. Although not as high as the others in terms of energy consumption, Kirk is also the smallest of the three dormitory buildings. Housing the fewest numbers of students, the average condensate per student was 1,645 gallons. This makes Kirk the second highest dorm for heat-energy consumption per resident.

30Mac, Bigelow, and Wallace Halls (30BigWall)

Initially constructed in 1907, Wallace Hall is the oldest dormitory on campus, however renovations in 2002 added suites to the fourth floor. It is located on the corner of Summit Avenue and Macalester Street and houses 165 sophomores. The dorm is co-ed by floor but single gender by room. Wallace is connected to Bigelow, another primarily sophomore dorm by the small, healthy-living sophomore dorm known as 30 Mac. Built in 1997 in the small space between Wallace and Bigelow, 30 Mac only houses about 35 students, and its contribution to heat waste is insignificant compared to the

other dorms. Bigelow hall, on the other hand, houses enough students for it to be considered for possible energy use optimization.

Bigelow hall was built in 1947 and remodeled in 1992. It connects to Turck — a freshman hall — on the South-East side as well as 30 Mac on the North-West side. With four floors, Bigelow has housing for over 110 students including sophomores, first years, and upperclassmen. Bigelow and Wallace share a laundry room in the basement located under 30 Mac. The 30BigWall dorm complex also contains WMCN and the MAC Weekly.

Heat in Wallace Hall and Bigelow halls is regulated per room by the same antiquated lever system present in Dupre, Doty, and Kirk. Rooms are also equipped with double paned windows which are the only other source of student temperature control. In 2015, Wallace reported a return of 206,890 gallons of condensate. This accounts for approximately 2.8% of all energy used to heat the buildings on campus. Bigelow, which houses about 50 fewer students, managed to use just a bit over half of Wallace's heat energy. This meant that in 2015 it used 132,830 gallons (1.8%). In the past the amount of steam Bigelow has used has fluctuated based on the severity of the winter, but has not gone below its 2013 level in which only 122,650 gallons of condensate were reported. On the other hand Wallace, while still being a significantly larger user of heat, has been making greater progress in reducing the amount of heat it requires. In 2013 and 2014 it used 1.5 and 1.7 times respectively as much heat. It is also currently on track to use even less in 2016 than its 2015 amount.

With 30 Mac reporting a negligible amount of condensate, the 30BigWall dorm complex contributes to a total of 339,720 gallons of condensate per year. This volume of returned steam contributes to approximately 5% of the campus' heating costs making it one of the larger fossil fuel users on campus.

In terms of per resident energy expenditure Wallace ranks number two; on average 1,756 gallons of condensate were required per resident to heat their dorms. We have speculated that this phenomenon could be related to the fact that the windows in Wallace are significantly larger than the windows in many of the other dorms. This theory is backed up by the results of a survey we conducted (discussed in the

next section of this report) in which students overwhelmingly reported leaving their windows open with their heat on in the winter. Bigelow Hall reported a smaller amount of condensate per student at 1,471 gallons.

2. The Problem:

Macalester has an issue with heating its dormitories. Almost 70 percent of students surveyed said their rooms were too hot during the winter and 82 percent said they therefore felt the need to open the windows during a time when the temperature could be below zero. This means many students are contributing to the issue of heat loss because their rooms are too hot and that let that excess energy escape when they open their windows.

Each room has an individual heating unit which connects to a water heater fueled by steam from the steam plant. As mentioned earlier, students can control the temperature in their room with a lever which ranges from hot to cold. Although 72 percent of students confirmed that they were aware and used the lever, 82 percent of those students still felt it was hot enough to warrant opening the window, despite the fact that 88 percent had been explicitly told not to open their windows by Residential Life and were aware of the possible consequences.

One of the main contributions to this problem is the fact that the facilities department at Macalester is not aware of the temperature in any of the dorms which require the most heating: Doty, Dupre, or the 30BigWall complex. All three of these buildings, according to Mike Pumroy, have no mechanism for measuring and reporting the temperatures in those buildings at any given time. This means that facilities has little knowledge about the actually temperature of these buildings and therefore cannot effectively control the temperature in these buildings.

Why is this Important?

Fuel costs to run the steam plant constitute a significant portion of the Facilities Services annual budget. During the 2015-16 school year, Macalester spent $383,749 on fuel to heat the campus. During the 2014-2015 school year, that number was significantly higher, at $641,195 because facilities was forced to use a more expensive fuel source due to natural gas shortages during the winter. If facilities overshoots its budget due to weather conditions, rising costs, or students wasting heat by opening their windows, the college, as Mike Pumroy states, "has to pay its bills." The college has to pay utility providers, whether or not it fits into the budget the college set. In this way, overshooting the facilities budget could force the college to take money from second priority areas, like programs and activities. For this reason, conserving energy and cutting down on waste is a top priority for the Facilities Services.

Further, in order to become more sustainable we need to utilize our resources, like the steam plant, in the most efficient ways. The College has a goal of reducing energy usage by 3 percent every year, and conserving heat energy is a key part of that goal. Currently, students are uncomfortable in their rooms and the College is wasting resources running too much steam to buildings which are already too warm, but where students continue to leave their windows open. This is a lose-lose situation which needs to be fixed in order to save resources and create a more sustainable system of heating.

3. Recommendations:

Improved Controls and Feedback Mechanisms

The first solution we propose as a step towards creating a more sustainable heating system would be to place thermostats or heat space monitors to record the temperature in the dorms which currently do not have them. These heat monitors would be placed strategically in hallways and lounges in order to capture the temperature throughout the building, record it over time, and send the information to facilities. Facilities can then analyze the data and cut down on heat loss. In this way, if the monitors recorded that

Dupre and Doty were too warm during certain parts of the day, the monitors would inform facilities and they could rectify the problem by sending less steam, or reducing the temperature of the steam sent to those buildings during those times. Pumroy would ideally like monitors which send data daily or hourly in order to best capture problem times.

These monitors would also indicate if there was a problem with the heating system itself. As it is, facilities does not know when a steam trap (a mechanism which regulates steam temperature) is broken unless a student complains of a room or hallway which is much too hot or much too cold. These monitors would alert facilities to sudden changes in temperature which would be indicative of a broken steam trap and allow them to fix it more quickly, thereby wasting less energy, creating a more efficient system, and making conditions in the dorms more comfortable for students. Monitors in individual dormitory rooms would also alert facilities to students who are opening their windows despite the rule, and allow them to contact students and ask them to close their windows. This could also allow facilities to implement an incentive structure to stop students from opening their windows, like charging students for the wasted heat and money if they constantly refuse to close their windows.

Pumroy also contemplates putting in automated controls in dormitory rooms rather than the hand valve. A system of automated controls would provide more data for facilities and take the control over the temperature out of the hands of students. Although only a small portion of the students surveyed said they were unaware of the hand valve control (11 percent) the automated system could more efficiently maintain the temperature in a given room eliminate the need for students to open their windows because the temperature would be maintained at a steady, most likely agreeable, temperature. The problem with automated controls, and the benefit of the hand valve, is that the hand valves are very low maintenance. Automated controls may prove to be more work for facilities to maintain, but they could also save money by making it unnecessary for students to open their windows during the winter.

Lastly we considered the idea of having students, possibly through Residential Life, provide feedback on the conditions in the dormitories. That way if the majority of the students in a dorm building report that it is too hot facilities can adjust the temperature and amount of steam sent to that building. This

sort of direct feedback is the point of our report, and a mechanism to provide this in the future could help while more systematic infrastructure changes are in the works.

Windows and Insulation

Other renovations the college could implement to conserve heat during the winter would be replacing the windows and renovating the roof with insulated, heat conserving materials. Currently, Pumroy is unaware of the type of windows and roofing the college has in the dormitories. This lack of knowledge is most likely indicative of the fact that they are not energy efficient and conserving. If the college had made an effort to install energy saving renovations, Pumroy would most likely be aware of them. After looking at the Recommissioning Report of 2010, we remain unsure about whether or not the college has taken steps recently to increase energy efficiency in terms of heat loss in the dorms. Given the age of Kirk, Doty and Dupre, as buildings built during the 1960's and for Kirk during the 1920's, the likelihood of the windows being double paned or the roof being the most efficiently insulated is very low. Much of the heat lost in old buildings is through the roof and the windows, even when the windows are not opened. Macalester could replace the windows, weatherstrip the existing windows, or recaulk the frames around the windows. Any and all of these renovations could help save energy by preventing heat from escaping through the cracks between frames and windows (Improving the Energy, 2008).

Education

A common recommendation with this sort of issue is educating students, but we do not feel that will prove a sufficient recommendation in this case. As we have enumerated, 90 percent of students are aware of the hand lever and know how to use it. Combining this knowledge with the fact that 88 percent of students were aware of Res Life's attempts to stop them from opening their windows, and we can conclude that a majority of students are aware of the problem yet continue to open their windows because

comfort trumps school policy when it comes down to it. For this reason, education is not one of our primary recommendations for students.

Conclusion:

Every year Macalester strives to get closer to its goals of carbon neutrality and lessening the energy utilized on campus in order to move towards a more sustainable model. A huge part of reducing energy consumption is being aware of how we waste energy, and as students, since our first winters here, we have known that heat waste is an issue in the dorms. After conducting a survey of students and talking with Mike Pumroy, we have become even more acutely aware of the problem. But with a problem this large comes an opportunity to save a lot of energy and money. By installing monitors, studying the data provided, talking to students directly, and making structural adjustments during renovations and in future projects, we can create a more sustainable campus and more comfortable dormitories, where students will not feel the need to break the rules to be comfortable during the winter.

Sources:

Campus Energy Report: *2015 – 2016 Campus Annual Energy use Report Macalester College*. Facilities Services, 2016. Web. http://www.macalester.edu/facilities/departments/energy/energyreport/2015_2016_Campus_Energy_Rpt.pdf

Macalaester College Campus Map. https://www.macalester.edu/about/maps/pdfs/CampusMapNorth.pdf

Carter, Jen. "Improving the Energy Efficiency of Existing Windows." *Energy.gov*. N.p., 15 Oct. 2008. Web. 15 Dec. 2016.

Facilities Services Aggregated Condensate Spreadsheet. Data from Energy Macalester Energy Manager Mike Pumroy. Via Google Spreadsheet.