

# Green Heating: Reducing Overheating and Pollution on Campus

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## **Problem Statement**

The University uses a campus-wide Energy Management System (EMS) to monitor and optimize climate control and energy use. Each of the campus building spaces use temperature settings based on conditions such as room occupancy and function. Therefore, it is critical that the EMS is reliable for the University to operate the spaces in an energy efficient manner. In several campus buildings, students, faculty, and staff have expressed dissatisfaction with the space conditions due to uncomfortably high temperatures during winter. Given the large size of the university, one building was chosen as a case study for this project. This test building was identified with having the most complaints related to overheating on campus.

As a University standard, occupied spaces should be kept at 68 °F during the heating season. This coincides with industry standards for thermal comfort of occupants, and is designed for optimal energy use. However, many rooms are well above this set point. Such temperature excursions lead to occupant discomfort, while also increasing the energy used for heating.

The University uses natural gas fired boilers to generate steam, which is used in a closed loop to provide heat for the buildings on campus, along with other applications. The over-heating in buildings reflect a higher steam use, and a correspondingly higher fossil fuel use to produce steam, which results in higher air pollution and a higher environmental burden. Therefore, tracking and precisely managing thermal conditioning of the buildings lowers the cost of heating (through lower fuel use), as well as prevent higher emission releases from the boilers.

## **Project Summary/Background**

The goal of the project is to develop a methodology to reduce the energy usage of the building, concurrently decreasing heating costs, realizing corresponding reduction in air pollutants and green-house gas emissions, while increasing occupant comfort. By tracking and

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managing the buildings space temperatures and set points under this project, there was an opportunity for corresponding reduction in steam produced and natural gas burned. Lowering the natural gas consumption will reduce the University's emissions, thus decreasing the campus environmental footprint.

At the beginning of this project, the Energy Management System (EMS) group did not have data showing how much the spaces were being over-heated. They knew that buildings on campus are over-conditioned, but were unable to identify and remedy the problem due to lack of data and resources. This project approach is innovative since this type of data collection and analysis has not been conducted previously in the University buildings. By combining the data obtained from the EMS and other external data collection, this project was able to identify problem areas and proposed solutions to the over-heating issue. Maintenance staff at the University confirmed that they do not have a standard procedure to address over-heating complaints on campus. Also, the maintenance staff did not have access to the data collecting equipment that is needed to perform this diagnostic analysis. Therefore, the Sustainability Division at the University noted that this study, conducted by a team of students, would create a significant benefit to the study building and to the campus.

In addition, this project was identified as having the most positive outcome when evaluating environmental tradeoffs, since it is environmentally, economically, and socially beneficial. There are no environmental or social tradeoffs associated with this project, since the project decreases resource consumption and reduces harmful emission, while increasing occupant comfort and productivity. The only potential negative tradeoffs to the project are implementation costs. These economical tradeoffs are minimal in comparison to the energy cost savings.

When developing an approach to analyze the problem, the team first needed to identify how

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steam was distributed to the building. Heat is distributed by both air-handling units and steam radiators. Therefore, we needed to develop distinct approaches to analyze each of these two systems. For the air-handling units, the team had obtained temperature data logged by the Energy Management System. Therefore, the approach chosen by the team was to use external data loggers and equipment to verify or contradict the EMS data, enabling the team to detect potential problems in the steam coils and/or air-handling units. For the steam radiators, a literature search was performed to identify how these systems are currently inspected in industry. A combination of ultra-sound and thermal inspection was recognized as a current industry approach used to detect problems in steam radiator systems<sup>1</sup>. This approach was used by the project team.

### **Relationship to Sustainability**

The project encompasses all three components towards sustainable development at the University: environmental, economical, and social sustainability. By eliminating the excess heating, the total energy consumption at the University will decrease, therefore, diminishing its demand for fossil fuels. This is an environmentally sustainable practice since it will both conserve natural gas as one of the earth's scarce resources, and reduce harmful combustion emissions, such as carbon dioxide associated with climate change, and other pollutants. The project is economically sustainable, as it will decrease the University's annual energy costs, providing financial security since energy prices are escalating. Maintaining appropriate temperatures in academic buildings will provide thermal comfort to its occupants. This is socially sustainable, as it will provide a more habitable and comfortable educational environment, uniting the campus community and increasing productivity.

When analyzing different measures to improve sustainability, one must note the importance of energy abatement. Reducing energy services is one of the quickest and easiest sustainability

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solutions since it typically involves minimal investment and a short payback period. However, these energy-reducing projects also typically have a smaller environmental impact than renewable energy measures that can eliminate emissions completely. Thus, reducing energy services is often referred to in the industry as a “low-hanging fruit” of sustainability improvement measures. Therefore, reducing energy services should be the first step towards energy sustainability. Decreasing energy usage lowers the energy usage cost. These utility cost savings can be invested into higher cost renewable energy measures moving forward. Reducing the energy usage will also reduce the energy demand of the renewable energy technology, decreasing the implementation costs of a renewable energy project. Potentially, the cost savings from reducing the Universities energy usage can be utilized to implement more renewable energy projects on campus in the future.

This project specifically impacts the local environment of the campus and its surrounding areas. The University steam station is located in a neighborhood adjoining the campus, therefore, emissions associated with burning the natural gas directly affects the environment of the campus and the surrounding local environment. Therefore, any reduction in boiler fuel use, will directly improve the air quality on the campus and its surroundings.

### **Materials and Methods**

To begin this research project the team first met with the campus Energy Management Systems (EMS) group to gather existing data. The EMS group shared the last three months of data that included temperatures of various rooms and the air temperatures associated with the air-handling units. Despite an effective data collection system, time does not permit EMS employees to perform a full analysis on all of the data. During this time the research team also visited the steam station where the steam boilers for the campus are located.

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The team visited the building to be assessed in order to analyze and measure data associated with the over-heating of the building. During the first visit of the building, the team placed HOBO data loggers inside the air-handling units to record the temperature data in each of the units. An infrared thermometer was also used to collect the temperatures of the coils when the air conditioning system was running and when it was off.

Next, the team looked at radiators in the building. To analyze the radiators the team used two pieces of equipment: a thermal-imaging camera and an ultrasonic leak detector. The thermal camera was used to look at the temperature profile of the radiators. The ultrasonic leak detector was used to listen for clicking noises at the outlet of the radiator, which would indicate that the steam trap was working and the steam was not passing through the steam trap.

When analyzing the radiators, each radiator was categorized into one of four types: failed open, failed closed, blocked, or working. Failed open occurs when both pipes on either side of the steam trap have steam in them, indicating that the orifice cannot close which allows steam to pass through the trap. The second category is failed closed. This occurs when the orifice in the trap cannot open, resulting in condensate build up in the radiator. This creates a radiator that will not heat effectively. The third type of problem in radiators is blockage, which occurs when any pipe in the system is blocked. The fourth and final category is working, which is seen when the pipe on one side of the steam trap has steam in it and the opposite side has condensate.

Each team member contributed to the project. Members worked together to identify, prepare for and complete the tasks. Weekly meetings were held to help organize the project, data and timeline for each task. Each student on the team had a leadership role within the project.

These roles included project manager, technical advisor, data collection advisor, and artistic advisor. Accordingly, each team member focused primary attention on their leading role, while

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also assisting with other project tasks. In addition, the campus West Zone Advisor provided assistance in accessing the mechanical room, steam pipes and air-handling units for the building.

### Results, Evaluation and Demonstration

The data obtained from the campus EMS staff revealed unusual trends in building temperature, which are shown in Figure 1. The set point temperature fluctuated between 60 °F, during unoccupied periods (nights and during the weekends), and 68 °F during occupied periods (daytime). However, the actual room temperatures rarely fell below 70 °F. In fact, the average temperature for room 004 was 70.9 °F while the average temperature for room 117 was 74.4 °F. The mixed air data in the air handling unit was particularly unusual because the temperatures ranged from 120 – 150 °F during the night and weekends when the air handler was off.

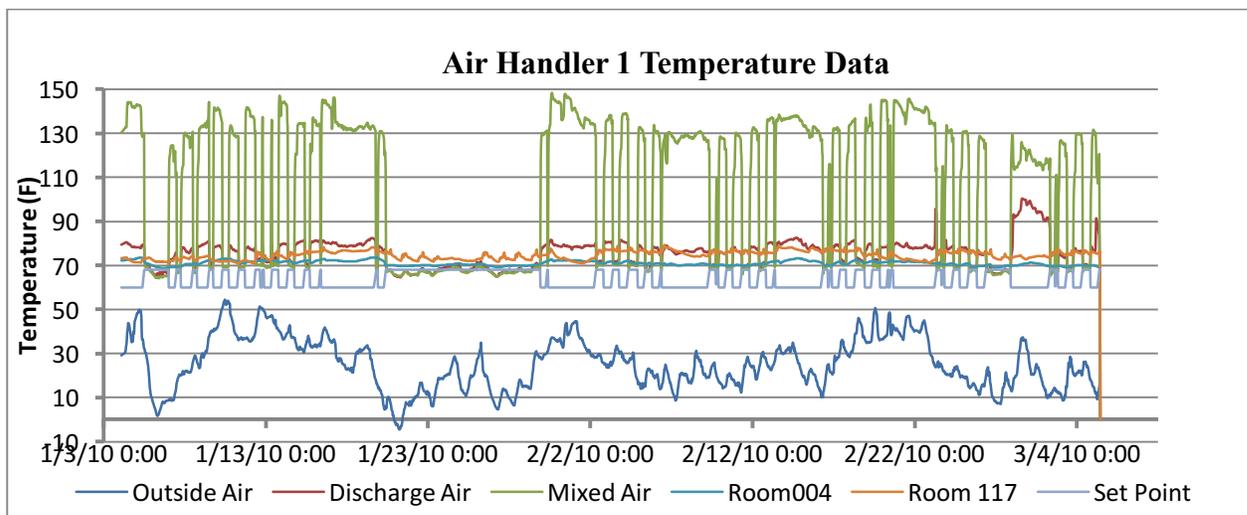


Figure 1: Air Handler 1 Temperature Data

The air handler was inspected when the unit's fan was off. The infrared temperature-gun recorded temperatures near 150 °F on the systems heating coil. A HOBO temperature data logger was placed in the air handler to record temperature data every 30 minutes for the next week. The data obtained from the logger confirmed that the coil was keeping the mixed air chamber between 120 and 150 °F during the night and weekend (see A.1). The valve that should have shut the steam flow off was found to be broken. Maintenance staff confirmed this finding for air

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handlers 1 and 2.

Averaging the data for occupied hours vs. non-occupied hours revealed that the average temperature during non-occupied hours was 0.8 °F above the average occupied hour's air temperature. This result is surprising because the non-occupied set point is 8 °F less than the occupied set point. The reason for higher temperatures during non-occupied time periods is the outside air damper, which closes when the building is unoccupied. With the damper closed, none of the cold outside air could cool the building.

Replacing the valves to the air handler heating coils solves a portion of the over-heating problem. However, the air handler data could not explain why the temperature remained near or above 70 °F, without decreasing, during unoccupied periods. An investigation of the steam radiators (which provide heat for 75% of the building) was performed. After reviewing four of the units, the only element that was common amongst them was that none of them had the same temperature distribution. After reviewing articles about steam radiators, a common problem was uncovered. Steam traps are used at the outlet of two pipe steam radiators to prevent steam from entering the condensate return line. These traps go through thousands of cycles each day and only have an expected life of 4 years<sup>2</sup>.

Despite using the thermal imaging camera in an unusual way, this technique was very effective in determining if the steam traps were operating properly. Figure 2 and Figure 3 show examples of steam radiators reviewed during the analysis. Figure 2 shows an example of a steam trap that has "failed open." The temperature distribution on either side of the steam trap is practically identical and at temperatures high enough to be steam on both sides of the trap. Figure 3 shows an example of a radiator with a trap that has "failed closed." It appears that the radiator is filling with water because of the drastic drop in temperature part way down the

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radiator pipes.

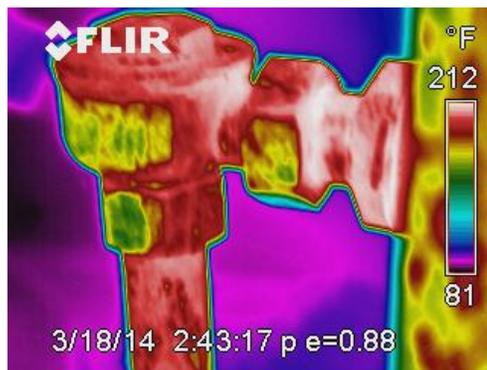


Figure 2: Failed-open steam trap



Figure 3: Failed-closed radiator

Efforts were made to analyze as many of the radiators as possible. The results for the twenty radiators analyzed are as follow: 7 failed open, 7 failed closed, and 6 working properly. In order to calculate the total reduction in steam usage for all 157 radiators in the building, Napier's formula<sup>3</sup> was used to calculate the amount of steam lost to the condensate return line. A table summarizing the calculations can be found in Appendix A.2. Replacing all of the steam traps will reduce the buildings steam usage by 2,200 MMBtu.

There are also significant energy savings that will result from consuming less natural gas to produce steam. Given a boiler efficiency of 84%, there will be a reduction of 2,619 MMBtu's of natural gas used and the associated \$45,982 per year of savings for the University. The reduction in natural gas usage will result in a reduction of pollutants and greenhouse gas emissions from combustion in the boiler. A summary of the emissions reduced from this project is displayed in Table 1. Values for the emission factors of each element in the table were taken from EPA standards<sup>4</sup>. This reduction in emissions is a significant benefit to the environment, which will occur by the same amount every year the radiators are functioning properly and the building set points are being met. The environmental impact has the potential of being much larger if the same analysis is used to replace all of the failed steam traps used in all 20+ buildings on campus.

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Reduction in Pollutants and Greenhouse Gas Emissions (lbs)							
NO <sub>x</sub>	CO	CO <sub>2</sub>	SO <sub>2</sub>	CH <sub>4</sub>	PM	TOC	VOC
359	216	308,118	2	6	20	28	14

Table 1: Reduction in Pollutants and Greenhouse Gas Emissions

The cost savings will more than offset the \$18,070 needed to replace as many as 110 steam traps in the building as well as employ a maintenance worker to complete the work. In addition, the two valves to be replaced in the air handling units cost \$250 each plus \$25 for installation. Replacing the valves and the steam traps will result in a total implementation cost of \$18,595 for the project. Neglecting the minimal cost saving from replacing the valves in the air handling units, the simple payback period for the entire project is 0.4 years. Furthermore, there is also a societal benefit to this study associated with employee and student comfort. Thermal comfort promotes employee satisfaction, health and productivity. Each of these benefits are unquantifiable, but will result if the temperature is maintained at the appropriate range.

### Conclusion

Failed steam traps are causing significant overheating of a campus building as well as pollution. Fixing the steam traps can result in savings as high as \$45,982 and significantly reduce pollution and greenhouse gases emissions. Only 20 of the 157 radiators were tested during this study. More accurate energy savings predictions will result if the same analysis is extended to all of the radiators. The facilities supervisor of the building has expressed their desire to implement the changes as early as this summer so that the problem could be fixed before next winter.

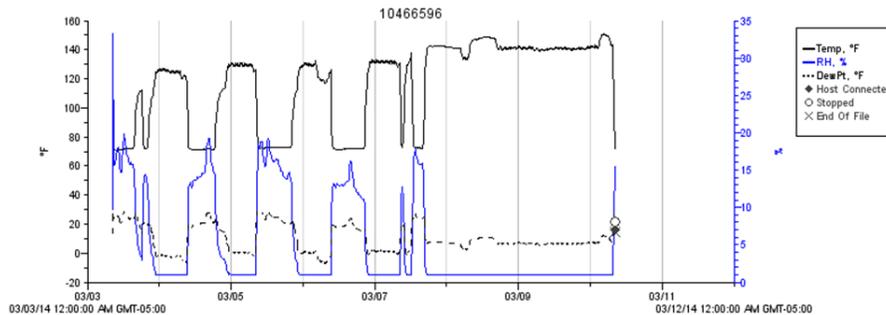
The procedure and results that are obtained in this study are transferable to many different building heating systems. This procedure can be performed on additional campus buildings with similar heating issues. The environmental impact has the potential of being much larger if the same analysis is used in all 20+ buildings on campus. Other industrial, commercial and residential buildings could also be analyzed with essentially the same procedure, resulting in

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similar environmental, social, and economic benefits.

## Appendix:

### A.1 HOBO Logger Data from Air Handler Mixing Chamber



### A.2 Calculations of Total Steam Savings, Energy Cost and Implementation Cost

NYS P2I Project				
<b>Implement Steam Trap Preventative Maintenance System</b>				
<b>Steam Trap Leak Analysis</b>				
				Notes/Source
A	2013 Fiscal Year Campus N.G. Cost	4,761,006 \$		Obtained from EMS
B	2013 Fiscal Year Natural Gas Usage	1,044,623 MMBtu		Obtained from EMS
C	Natural Gas Rate	4.56 \$/MMBtu		A / B
D	Building Steam Usage	3,473 Mlbs		Average Utility Data of 2012-2013 and 2013-2014 seasons.
E	Building Steam Usage	4,154 MMBtu		D x 1.196 (Heat content of 7 psig steam)
F	Steam Cost	86,825 \$		D x G
G	Steam Rate	\$25 /Mlbs		Obtained from EMS
H	Hours of Operations	5,088 hours		Based on Syracuse bin data
<b>Steam Trap</b>				
K	Steam Pressure	7 psig		Obtained from Facilities Supervisor
L	Steam Pressure	21.7 psia		K + 14.696
M	Trap Orifice Diameter	0.100 in		Estimated based on trap size
N	Percent orifice available	75%		Some is consumed by flowing condensate
O	Steam Flow thru orifice	8.8 lbs/hr		$(\pi \times (M / 2)^2) \times L / 70 \times 3,600$ (Napier's Formula)
P	Steam Flow thru Trap	6.6 lbs/hr		N x O
Q	Number of Failed 3/4", IB Traps	55		Estimated based on 157 Radiators w/ approx. 35% failed oper
R	Steam Flowing to Cond. Ret. Sys.	361 lbs/hr		(Q x P)
S	Heat Lost due to vented Steam	361 lbs/hr		R
T	Heat Lost per Year	1,839 Mlbs		S x H /1000
U	Natural Gas Saved	2,619 MMBtu		T x 1.196 / .84 (84% Boiler Efficiency)
V	<b>Wasted Steam Cost</b>	<b>\$ 45,982 /yr</b>		T x G
<b>Steam Trap Repair Analysis</b>				
AC	Man-hours req. per trap	4 hrs		Estimated
AD	Cost per man-hour	\$25 /hr		Obtained from Facilities Supervisor
AE	Repair part cost	\$65 /trap		Obtained from Facilities Supervisor
AF	Cost per trap	\$164.27 /trap		(AC x AD) + AE
AG	Number of trap failures	110		Including traps that failed closed
AH	<b>Cost to repair traps</b>	<b>\$18,070</b>		AG x AF

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## End Notes

1. Thermal Applications: Inspecting Steam Systems. Fluke Corporation. 2005.  
<http://www.testequity.com/documents/pdf/inspecting-steam-systems.pdf>
2. James R. Risko, "Understanding Steam Traps: Steam trap failures can affect process operations and reduce profits. Choosing the right steam traps can improve reliability and reduce cost," *Chemical Engineering Progress*, (February 2011): 23,  
[http://www.tlv.com/global/articles/cep\\_1102\\_understanding-steam-traps.pdf](http://www.tlv.com/global/articles/cep_1102_understanding-steam-traps.pdf)
3. Babcock & Wilcox Co., *Steam, Its Generation and Use* (18 September 2007), 321,  
[http://www.gutenberg.org/files/22657/22657-h/chapters/flow.html#page\\_317](http://www.gutenberg.org/files/22657/22657-h/chapters/flow.html#page_317).
4. U.S. Environmental Protection Agency, Office Of Air Quality Planning and Standards, *Compilation of Air Pollution Emission Factors: Volume 1: Stationary Point And Area Sources*, (North Carolina, 1995), 1.4:5-6.