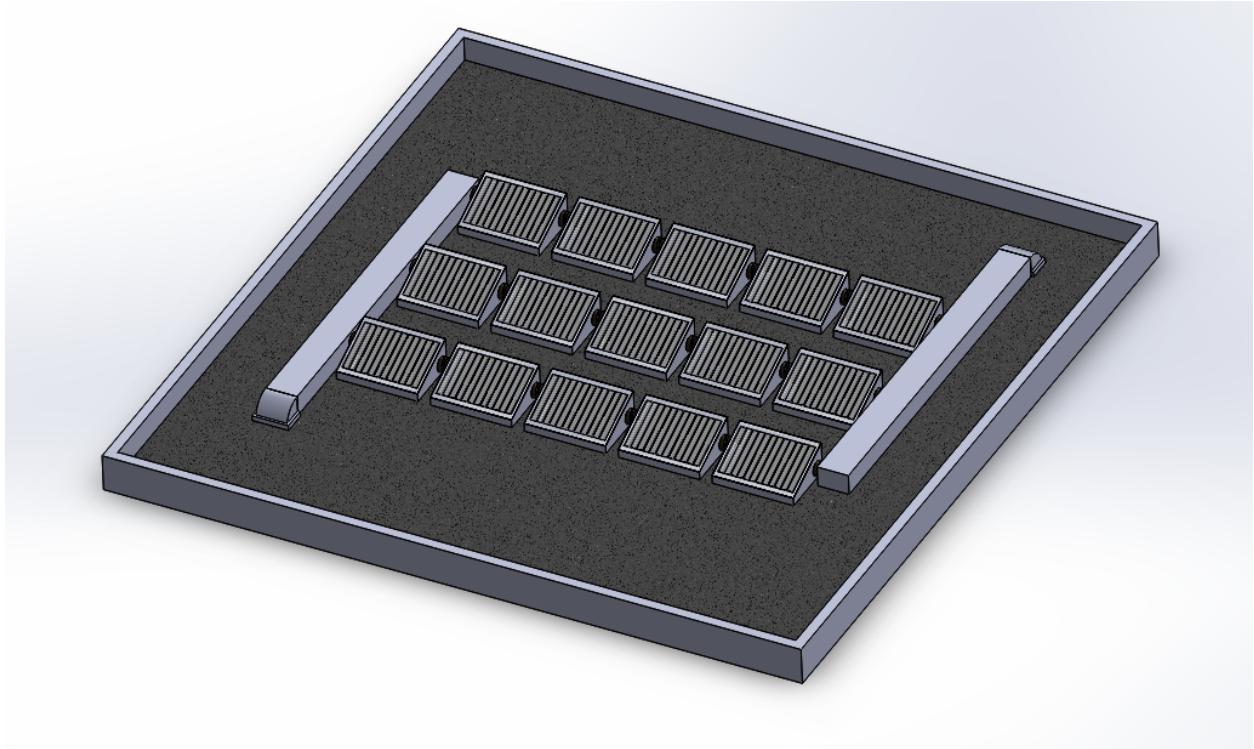


Sustainability Through Aluminum: Implementation of Aluminum Heat Absorbers to Reduce Fuel Demand



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Abstract

Through the course of our project, our team determined that Penn State has a large energy crisis with the current boiler heating system that provides heat and electricity to the West side of Campus. As a way to help improve that, we designed an alternative heating system that requires no fossil fuel input and is entirely self-sufficient. We intend for this product to produce a significant amount of heat per month so that it will cut the heating costs of buildings on campus, and also save mass amounts of greenhouse gas byproducts from being released into the environment. The following report contains information on how we journeyed through the design process, finalized our design, and concluded that our design would be a beneficial addition to the Penn State campus.

List of Acronyms

- Btu – British Thermal Unit, equal to approximately 1055 joules
- kBtu – thousands of Btu
- OPP – Penn State's Office of Physical Plant
- SRCC - Solar Rating & Certification Corporation
- CO₂ - Chemical formula for Carbon Dioxide, a major greenhouse gas

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Introduction

The goal of this project is to install an array of aluminum solar air heaters onto the roof of the Kern Graduate Building. These absorbers will collect thermal energy from the sun, use that energy to heat air, and pump that warmed air into the building during the colder months of the year. This system will reduce both the cost to heat the building and the Carbon Dioxide (CO₂) emissions that result from the combustion of the coal needed to heat the building. The air heater array will be linked into the existing HVAC system of the building to ensure that the heated air will be dispersed evenly throughout the whole of the building, and will also allow the fans to be controlled via the existing thermostat, so that hot air is not being put into the building during warmer months by the absorbers

Project Research Overview

The Pennsylvania State University's own Office of Physical Plant (OPP) provided the majority of the data used in this report. The age of the boilers that are in the West Campus Combined Heat and Power Plant, the amount of fuel that is consumed over the course of each year and the total cost of that fuel was provided by Paul E Moser's 2010 "Steam Services Fact Sheet" that is linked in the references section. The amount of heat that the Kern Graduate Building used for the month of January 2012 and the cost of that heat was also provided by OPP, in their January 2012 Building Energy Report, which is also linked to in the references section. The final piece of building data, the square footage of the Kern Building's roof, was calculated using Daft Logic Google Map Area Calculator, which is linked in the references section

Data pertaining to the solar air collectors themselves was gathered from three separate sources. The cost of each absorber was determined by the list price given on Alibaba.com That cost was multiplied by total number of collectors in order to calculate total cost. The efficiency of the collectors was determined by checking that specific collector's rating on the Solar Rating & Certification Corporation (SRCC), a group responsible for rating all types of solar devices, and inputting those numbers into Build-it –Solar's efficiency calculator, which is also linked in the reference section.

Design Process

The Problem

As we started to look into Penn State's vast amount of heat usage, we quickly realized that the whole system is very inefficient. Besides using two different fuel types, natural gas and coal, at the different steam plants, it turned out that Penn State actually has a split heating system, in that the source of heat for the west half of campus comes from a different location than the source of heat for the east half. This turned out to be a very wasteful system, especially when we discovered that the boiler systems were described as "vintage" in reports found online. Penn State also uses a vast amount of heat through a large portion of the year, so it was clear that this was a big problem.

Figure 1 – West Steam Plant Data

Steam Services – Fact Sheet		July 2010
<u>Home Page:</u>	www.opp.psu.edu/about/divisions/operations/us/steam.cfm	
<u>Plant Locations:</u>	WCSP Corner of West College Avenue and Burrowes Road ECSP Porter Road between Park Avenue and College Avenue	
<u>Fast Facts:</u>	2009/10 Data Buildings Served by the Steam Distribution System260 Heating Area.....14.1 million sq. ft. Steam Generated1,241,217,669 pounds Peak Steam Generated373,000 pph [Jan. 29, 2010] Peak Daily Coal Consumed.....373 tons Coal Consumed.....69,031 tons Natural Gas Consumed29,445 mcf Bottom Ash Generated.....6,889 tons Fly Ash Generated.....1,600 tons	

Gathering Information

The West Campus Steam Plant, which provides electricity for and heats the Kern Building, as well as 260 other buildings on the West Side of Penn State's campus, relies heavily on the combustion of coal to provide that electricity and heat. In 2010, 69,000 tons of coal was used to provide for the energy demand of the buildings of West Campus. This corresponds to almost two hundred thousand tons of CO₂, a major greenhouse gas, being released into the atmosphere. The use of aluminum heat absorbers can help alleviate the need to combust so much coal.

Figure 2: Kern Building Data

Building Energy Report		
Utility Month: Jan-12		
Kern Grad Bldg		
Energy Units and Costs		
Utility	Jan-12 Units	Cost
Electricity	103,981.00 kWh	\$9,530.45
Steam	481.13 klb	\$9,785.87
Total:		\$19,316.32

In January 2012, the month with the heaviest heat demand that year, the Kern Building consumed the heat equivalent of combusting approximately 20 tons of coal, and the cost to heat the building was \$9700. As calculated by the “Daft Logic Google Map Area Calculator”, the Kern Building has a roof area of x square feet. Utilizing 6’ by 4’ panels, it is reasonable to build an array of about 411 collector panels on half the roof. Preliminary calculations determined that with 411 panels, and a calculated average of 125 BTUs/sqft per hour of sunlight, it was determined that almost one third of heat demand could be met.

Solutions Generated

The first issue we encountered when we considered implementing our design was whether to use our system to heat a building’s water, air, or both. Our original idea was to heat just the water because hot water is essentially used all year round and we assumed that this would be an easier design. We designed a system where our panels heat some sort of thermodynamic fluid, that is being pumped through a system. This fluid would then be run through piping, which coils through the water tank for a building. The heat from the fluid would then disperse out of the coil, thus heating the water tank. This was a good idea until we encountered a few obstacles. The first was that it would be very costly to create an entire new system for our thermodynamic fluid to be pumped through a building. The second was that we found out that not every building had its own water heater, so our system would effectively be obsolete on certain buildings. The next idea we had was to heat both the air and water for a select amount of buildings that use high amounts of both, and have their own water heaters. We decided to go with something such as the dorms, which perfectly fit our needs. We continued on with this idea for a while until we came upon another issue. We realized that to heat water for a building at all, you generally want to be able to produce steam. This means that you need to achieve temperatures high enough to boil water, which we knew our system could not possibly do on its own. We decided to scrap the entire idea of heating a building’s water, and to only heat the air.

Analysis and Selection of Solution

After deciding to only a building’s air, our concept became much more clear and feasible. The first choice we made was how many panels we should use, and we decided to use the majority of the roof due to the fact that it was mostly wasted space anyways. So, we line the roofs with our aluminum panels, which then transfer the heat to a thermodynamic fluid and copper plate behind the panel, which then transfer the heat to an air cavity. After figuring out how our panels functioned, as described above, we had to decide how to disperse the heat to the building. We decided to build our system into the current heating vents, which would allow us to save a great deal of money, and make our system much easier to implement. So the air is heated by the panels and is then pumped out, via the additional vents and fans put on the roof. The air then circulates through the building, heating it up, and then eventually gets pulled back into our system, where it can be heated continuously throughout the day. The whole system is controlled by the same

thermostat that all buildings already use, so our system will be shutdown and restarted, just as all systems work now.

Economics of the Solution

Fiscal Economics and Efficiency

Our heating system turned out to be quite economically and efficiently sound. Based on the statistics we found on the Kern Building, we were able to formulate a possible implementation plan and explain how our aluminum heat absorbers would function. We found that the Kern Building has a total roof square footage of 31,853 square feet. Realistically, we decided that we would only be able to use about half of that square footage for the implementation of our aluminum panels. This amounted to a square footage of 12,329 square feet (with air transferring pipe square footage deducted). Each panel takes up a square footage of 29.95 square feet; each with an absorbing square footage of 24 square feet. With this factored in; it amounts to 411 panels on the roof of the Kern building. Each panel costs an average of \$300, which amounts to \$123,300 total. Our panels are significantly efficient, generating approximately 125 Btu per square foot of absorbing panel. This means that our panels are absorbing the sun's rays efficiently enough to produce a significant amount of heat. With about 4 hours of daylight on average for State College, Pa, the panels would generate a cumulative of 153,134 kBtu per month. Kern's average heating cost for the winter months is \$9785, which amounts to 553,491 kBtu of heat. The amount of heat produced by the array amounts to approximately $\frac{1}{3}$ of the total heat required by Kern for its winter months. This means that we would be saving Kern \$3,261 per month on heating costs. By saving this much money on heat every month, the panels would eventually pay for themselves in just under 4 years. Not only are we saving the university large sums of money, we are also saving approximately 6.67 tons of coal combustion per month which equals 5,720 pounds of carbon dioxide saved from being released into the environment.

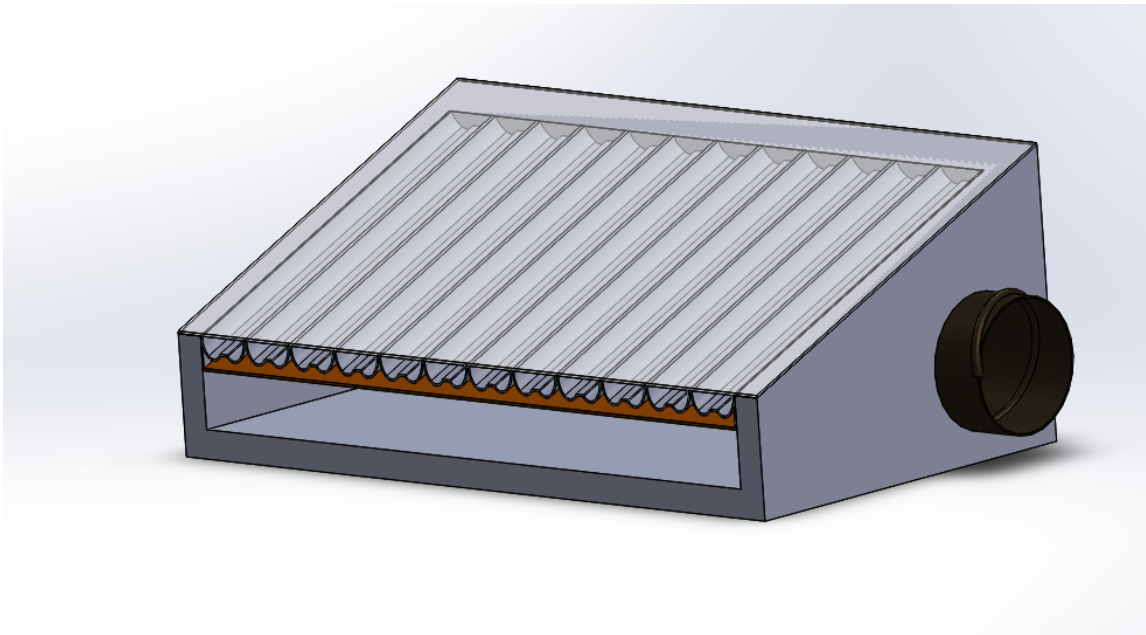
Sustainability of Solution

The main goal of this project was to produce a sustainable product that could be used to better something on Penn State's campus. We as a team decided that our definition of sustainability was *create an efficient system, which sufficiently meets the needs of a requirement while also being environmentally safe and affordable*. I believe that we exceeded our definition of sustainability in our project. We were able to produce a cost effective product that sufficiently contributes to heating buildings on campus and which pays for itself in a short time period. Our aluminum heat absorbers are made out of aluminum alloy 1100. We found that this alloy in particular is the most corrosive resistant aluminum there is which means it is the most sustainable aluminum for our purpose. We also designed our absorbers with glass/Plexiglas sheets on top to prevent any weather damage; extending the lifetime of our product even more.

Conclusion

In conclusion, our team determined that Penn State's heating facilities are very inefficient and need serious improvement. By installing an array of heat absorbers on the roof of the Kern Building, we can save the university just over \$3,000 in heating costs per month and produce an amount of heat equivalent to burning 6.67 tons of coal. By doing this, we are saving thousands of pounds of carbon dioxide gas from being released into the environment and also thousands of dollars for which the university can better spend it.

Figure 3 – Detailed View of the Absorber



Appendix A: List of Figures

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- **Figure 2: Kern Building Data – Page 2**
- **Figure 3: Detailed View of Absorber – Page 5**

References

- EIA. "Carbon Dioxide Emission Factors for Coal." *Carbon Dioxide Emission Factors for Coal*. EIA, Feb. 2010. Web. 10 Dec. 2013.
<http://www.eia.gov/coal/production/quarterly/co2_article/co2.html>.
- Moser, Paul E. *Steam Services Report*. Rep. N.p.: n.p., 2010. Print.
- OPP. *Building Energy Reports Jan 2012*. Rep. University Park: OPP, 2012. Print.
- "UP Solar Solutions Michigan." *UP Solar Solutions Michigan*. N.p., n.d. Web. 6 Dec. 2013.
- "Solar Collector Efficiency Calculator." *Solar Collector Efficiency Calculator*. N.p., n.d. Web. 6 Dec. 2013.
- "Carbon Dioxide Emission Factors for Coal." *Carbon Dioxide Emission Factors for Coal*. N.p., n.d. Web. 6 Dec. 2013.