Mission Park heating: can Electricity Still be the Answer?
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Introduction
Mission Park was built in 1971, and last renovated in 2004. It contains four houses – Armstrong, Pratt, Mills, and Dennett – as well as a dining hall. Each room boasts large windows (*figure 1*), and the dining hall has an entire wall made entirely of glass, allowing much natural lighting. Originally built for upperclassmen, the building was recently changed to freshman housing, and houses about 300 freshmen each year in a total of 16 entries.

Each bedroom contains a thermostat so that students can control heat in their rooms. These are labelled with coloured markers that show green, yellow and red settings to encourage energy savings (*figure 2*). The biggest challenge to heating the building is found in the windows, which make up a large portion of the walls in each room and which are currently very poorly insulated. Currently made of only single-pane glass and frames which leave large draft spaces, there is very little to stop the wind or the cold from coming through.

In contrast to most of the campus, which is heated by steam from the steam plant, Mission Park is heated by electricity. The houses have no cooling system, but the dining hall does run coolers during the summer. These uses of electricity, in combination with the normal plug load, cause an extremely high demand for electricity on the campus.

Having lived in Mission for the past year, and coming from a tropical country where I had not been exposed to a heating system at home, I was intrigued by the heating system and its strengths and weaknesses. Being particularly interested in insulation options that would save...
heat, and having heard that the college has at points considered switching Mission off electricity because of the heavy load coming from the heating, I decided to do my project on possibilities for insulation that would decrease heating needs enough to make it feasible to remain on electricity for the long-term. The current high demand puts high stress on the college’s electricity load, to the point where facilities has developed a system for alternating heating between different houses in order to keep the load from becoming too high. Although it might not be first on the college’s priority list at the moment, it is clear that in the future Mission energy will likely have to be adapted to make it more environmentally and economically sustainable. To this end, I conducted my project with two main goals: firstly, to understand Mission heating, with the effects of room thermostats, the differences in heating demands between houses, and other details that had not recently been graphed and analyzed in Mission, and secondly, to evaluate the costs and benefits of either switching Mission to steam or of seriously improving insulation.

There are many different options for retrofitting buildings in terms of insulation, each of which range in cost and difficulty of implementation. I chose to focus on the concept of “Deep Energy Retrofitting,” and in particular the process of changing windows and adding a new “skin” to the outside of the building. To examine this system I referenced the case study of a house belonging to the Environmental engineer John Livermore, who retrofitted his house in Gloucester MA with Deep Energy Retrofitting in 2009¹.

Deep Energy Retrofitting

Deep Energy Retrofitting involves a retrofit of an entire building, including everything from adding sources of renewable energy such as solar panels, to changing water faucets, to re-

¹ (Livermore)
insulating the whole house. I chose to focus on two parts particularly significant to temperature: retrofitting windows to insulate better, and “skinning” the building.

**Skinning**

“Skinning” a building involves putting a whole layer of closed-cell foam, about 6 inches thick, all the way around the building. This can be done directly on the current siding so as to reduce construction waste, and in terms of Mission Park this would likely be particularly easy because the outer shell of the building is smooth concrete. Wood tresses are set against the current siding, as seen in figure 3, and then the closed-cell foam is added on the outside so as not to decrease floor space on the inside (figures 4a and 4b). Finally, another layer of siding is added to the finished product to make it look just as it did before (or in the case of Mission Park, hopefully better). The added diameter to the walls is accompanied by increases in window thickness, so that the whole exterior of the building moves outwards.
**Windows**

Window retrofitting is fairly straight-forward. The frames are extended to fit with the added thickness of the walls (figure 5), and the windows installed are very high-technology, using triple-pane with ThermotechTM, Low-E, argon-filled glass (figure 6).

This would be costly in Mission since the windows are so large, but if the energy savings were enough (calculations for general energy savings are shown later), then it would still be worth it, at least in rooms if not in the floor-to-ceiling windows in the dining hall.

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**Part 1: data collection and investigation of heating patterns**

The project naturally split itself into two parts; first, collecting data about energy consumption, and second, analyzing possible savings from switching to steam or from adding insulation.

I started by gathering data on electrical demands and graphing these to find patterns and anomalies in heating and plug load electricity demands in each of the four houses. Because the dining hall has such different and specific demands of its own, I have excluded it wherever possible (although certain data, such as data from School Dude, reads only the energy of the whole building, thus including the dining hall).
Looking at these graphs, a number of important anomalies came up. In terms of heating electricity, the biggest anomaly was the high use of heating energy in Mills during the summer (figure 7). Meeting with Ken Jensen, the Supervisor of Mechanical Maintenance at Williams, revealed that the dining hall’s cooling system runs on the same meter as the heat, and this is used during the month of July².

In terms of plug load electricity demand, it was striking at first to see the difference between loads in the two outer houses – Armstrong and Dennett – and the two inside houses,

² (Jensen)
Pratt and Mills, as shown on figures 8 and 9:

Further investigation into these anomalies showed that the meters in Armstrong and Dennett were reading more than the house’s demand: Armstrong was also reading Thompson
House’s plug load demand, and Dennett’s meter reads the outdoor lighting for Cole Field, the Tennis Courts, and much of Dodd Neighbourhood. Although I did not do the calculations for these reductions, it is safe to assume that the data for Armstrong and Dennett would come out to be fairly similar to the other two houses. As for the difference between Pratt and Mills, interviews with Facilities did not reveal any particular reason for the difference; it is a small enough difference that it could be attributed to differences in behaviour within the two houses.

In terms of behaviour, although this project could not address behaviour significantly, I did use data loggers in several different rooms in Mission over a week to observe patterns of thermostat use. I then graphed these data here alongside average outside temperatures to show the effect of heating use in certain rooms. The rooms shown here I chose because they are on the same side of the building (facing North), but in one, the occupants had their thermostat turned completely off, and in the other the heat was used in the yellow or red zone of the thermostat for most of the week. The first two figures (10 and 11) show the raw data, showing the clear difference in variation between a room using the thermostat and a room relatively following the trend of air temperatures\(^3\). The following three graphs show the average daily outside temperature (as measured in Albany, NY, data provided by the University of Dayton\(^4\)) and the average daily temperature in each of the two rooms.

\(^3\)Important note: data on these graphs is only applicable to the study before May 9th; the data after this has been blocked out because it was collected after the study ended.
\(^4\) (University of Dayton)
Clearly, use of the thermostat can be very easily detected, both in times of large heating differences (such as the increase to 85 degrees on April 30th), and in the times when the thermostat was set to a specific temperature over a longer period of time. It is clear exactly where the thermostat is set in those periods, as seen in the period of May 4th through 7th, where it remained consistently around 76 degrees F (already in the “red zone” of the thermostat range) and on May 7th and 8th, where it appears to have been set at about 80 degrees F. This data opens a whole possibility for behavioural study across a dorm, and would have likely been even more striking during the coldest winter months.
Average Daily Temperatures
Albany, NY

Figure 12: temperature range 40 – 70

Average Room Temperature:
Dennett 201

Figure 13: temperature range 69 – 76

Average Room Temperature:
Pratt 209

Figure 14: temperature range 70 – 82
Clearly, there is a significant difference between the outside temperature and each of the rooms, even the one where the heater was rarely used. But the room with heat used is clearly much hotter. However, there is still a clear difference between the room that used heat and the one that didn’t, with the heated room showing an overall average of about 75 degrees F, and the less-heated room averaging about 72 degrees F. However, I believe this would have been a more significant difference if the room with no thermostat heat had been in Pratt instead of Dennett, because there is also a separate trend that I did not have the chance to investigate, whereby it seems that Dennett is warmer than the other houses in general. Both the stairwells and hallways in Dennett are particularly hot, so this heat often gets into the rooms even when the thermostats are completely turned down. Talking to Ken Jensen, I found that facilities was not aware of this phenomenon; it would be another interesting project to look at these differences and how these could hopefully be solved by looking at hallway and stairwell thermostats, and finding whether Dennett’s orientation makes it more prone to heat up. However, for the purposes of my project I have included the room-by-room data simply to illustrate the fact that different habits can have a significant effect on energy consumption and that a successful approach to energy savings in Mission would need to address both structural changes and behavioural incentives.

**Energy Savings: Results and analysis**

The second half of the project, once I had collected the data and looked at general patterns of heat use across Mission, involved analyzing different possibilities for energy savings. First, I looked at the difference in cost and carbon emissions between the same amount of energy
in steam and in electricity, and then looking at the potential savings from Deep Energy Retrofitting. The data used comes from the Williams Sustainability website\textsuperscript{5}.

| Total heating electricity consumption in 1 year | 921000 kWh |
| Total Cost (at $0.135 per kWh) | $124,335.00 |
| Total electricity into MMbtus: | 921000 kWh $\times 0.003412 = 3143.37$ MMbtus |
| Cost of heating with steam (at $13.66 per MMbtu of steam) | $42,938.48 |
| Total saved by switching to steam: | $81,396.52 |

\textit{Table 1: Savings switching to steam}

Of course, this comparison is not perfect because the differences in steam heating would make it so that the amount of energy used would not be exactly the same as electricity, but as a rough comparison it is clear that steam is much cheaper than electricity. Another important factor to consider is the reduction in carbon emissions, which are shown in \textit{table 2}:

| Carbon Emissions per mmmbtu of electricity | 131 kg\textsuperscript{6} |
| Carbon emissions for current amount of electricity used in heating | $3143.4 \times 131$ kg $= 411,785.4$ kg |
| Carbon Emissions per MMbtu of steam | 53 kg |
| Carbon emissions at predicted amount of steam usage in a year | $3143.4 \times 53 = 166,600.2$ kg |
| Emissions saved per year | 245,185.2 kg |

\textit{Table 2: Savings in Carbon Emissions}

Clearly, there would be many environmental benefits of switching to steam. However, in terms of cost a judgment couldn’t be made without calculating total cost of the project and finding the payback time (ie, the time it would take for the savings to equal the amount spent on the renovations). Switching the whole of Mission Park to steam would be very complicated,

\textsuperscript{5} (Zilkha Center for Environmental Initiatives)
\textsuperscript{6} Emissions levels received from Todd Holland, Energy Efficiency Engineer
because new piping would need to be laid, as well as retrofitting the rooms with baseboard radiation, valence panels, radiant ceiling panels, or convectors.

The square footage of Mission Park (4 houses and dining hall) is 96 000 sq feet. Using a very general estimate of $40 per square foot, the cost would come out to be $3.84 million. At this estimate, the payback time would be approximately 47.2 years. Clearly, this wouldn’t be an economically viable option.

The alternative way to save energy and reduce emissions would be to decrease the need for heat energy by increasing insulation, as described above in the Deep Energy Retrofit section. To calculate possible savings from this alternative, I took the numbers for the case study in Gloucester to find the ratio of savings, and applied it to Mission electricity data.

From the Livermore project, the predictions for savings amounted to at least 60%, as shown in table 3.

<table>
<thead>
<tr>
<th>Pre-project</th>
<th>Predicted outcome</th>
<th>Percentage savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Heat Loss (kW)</td>
<td>11.5</td>
<td>4.6</td>
</tr>
<tr>
<td>Heating (MMbtu/year)</td>
<td>63.7</td>
<td>21.4</td>
</tr>
</tbody>
</table>

**Table 3: Livermore Project savings**

I then applied these values to Mission, using data from the Sustainability website (table 4).

<table>
<thead>
<tr>
<th>Total Cost of heating with electricity (as above)</th>
<th>$124 335.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cost after predicted savings (60% reduction)</td>
<td>$48 734</td>
</tr>
<tr>
<td>Total cost saved</td>
<td>$74 601</td>
</tr>
</tbody>
</table>

**Table 4: Savings, Sustainability data**
In order to compare this project and find the payback time, I estimated the total cost of the project based on the estimated costs from the Livermore case study. The approximate cost for the insulation and windows part of the project (including labour and materials), was $40 000 for a house of about 2480 square feet, which comes to a cost of $16.1 per square foot. Translating this to Mission Park, we get an approximate cost of $1,548,387.10, or $1.55 million.

If this estimate is correct, then applying the data above would give us a payback time of 20.7 years at an optimistic level of 60% reductions in energy use.

However, using data from the School Dude website, which includes Mission Dining and would include all electricity consumption in the building, the results much more favourable (table 5).

<table>
<thead>
<tr>
<th>Total electricity consumption (kWh)</th>
<th>1 831 779</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cost at $.135 per kWh</td>
<td>$247,290.20</td>
</tr>
<tr>
<td>Cost after 60% reduction</td>
<td>$98,916.07</td>
</tr>
<tr>
<td>Savings after 60% reduction</td>
<td>$148,374.10</td>
</tr>
<tr>
<td>Cost after 50% reduction</td>
<td>$123,645.10</td>
</tr>
<tr>
<td>Savings after 50% reduction</td>
<td>$123,645.10</td>
</tr>
</tbody>
</table>

**Table 5: projected savings with School Dude data**

Using the same estimate of total cost of $1.55million, these data would have a payback time of 10.4 years at 60% reductions, and 12.5 years at 50% reductions.

Talking with Todd Holland, it appears that this estimate for total cost may be low, with his estimate for total cost being nearer $2.7 million. If this is the case, the project would have a payback time of 36 years according to the other data in table 5 from the Sustainability website,
and about 18.2 years at 60% reduction by School Dude data. At 50% reduction of heat the payback would be 21.8 years by School Dude data.

**Comparing to Energy Star Dorm Standards**

I also decided to compare Mission heating usage to Energy Star standards for college dorms, which estimate about 68 MMbtus per square foot in an average dorm. I calculated total use of electricity, including heat and plug load. As before, the most accurate of the four results are Mills and Pratt, because of the extra load on the meters in Dennett and Armstrong. However, even with the extra load all of the houses appear to be well within the range for an Energy Star dorm, with Mills reading at approximately half of the 68 MMbtus allowed. This is almost suspiciously low, suggesting the possibility of a problem with the multiplier set for the meter in Mills. However, as an overall trend the calculations show up favourably for the dorm as a whole.

<table>
<thead>
<tr>
<th>House</th>
<th>Armstrong</th>
<th>Pratt</th>
<th>Mills</th>
<th>Dennett</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total electricity in kWh</strong></td>
<td>407 783.33</td>
<td>330 736.49</td>
<td>236 955.70</td>
<td>408 988.41</td>
</tr>
<tr>
<td><strong>Total electricity in kbtus</strong></td>
<td>1391356.723</td>
<td>1128803.667</td>
<td>808492.8511</td>
<td>1395468.466</td>
</tr>
<tr>
<td><strong>Square footage of house</strong></td>
<td>20 382</td>
<td>22668</td>
<td>22580</td>
<td>21763</td>
</tr>
<tr>
<td><strong>MMbtus/square foot</strong></td>
<td>68.26399385</td>
<td>49.79723255</td>
<td>35.80570642</td>
<td>64.12114442</td>
</tr>
</tbody>
</table>

*Table 6: MMbtus per square foot by house*

**Conclusion**

Mission Park is clearly a fairly complicated case, not only because it is so unique in its heating system and has so many large and poorly-insulated windows, but also because it houses so many people and would be very costly to retrofit. The calculations done in this project are only the beginning of what would need to be done in order to propose a viable plan for retrofitting, but it is clear that the best
possibility to pursue, both cost-wise and environmentally, will be to stay on electric heat and increase insulation rather than to switch to steam.

In furthering this project, many more cost details and logistical details will need to be investigated. In terms of cost, the details of changing the windows would need to be looked at in much more depth, because there is more difference between windows in a house like Livermore’s and the massive windows in Mission than was accounted for in this analysis. In terms of logistical challenges, the biggest challenge will be the time frame in which to carry out the project. Mission is occupied for at least 9 months of the year, and often even more than that when it is used for summer programs. A solution suggested by Ken Jensen\(^8\) was to perhaps vacate one house in Mission for a semester and relocate students to a different location while intense renovation went on there, and then rotate out another Mission house when that was complete, until the whole of Mission Park was retrofitted. Needless to say, this would be extremely complicated and difficult to get approved, especially since Mission is freshman housing and it would be difficult to find a new place to put a whole house of freshman for a semester or a year.

However, at some point the costs and benefits will reach a point where this inconvenience will be well worth the investment. As far as I can tell this is not likely to happen very soon, partly because of the high cost of the switch and the long payback time (a minimum of 10 years and a maximum of 36 years according to the calculations in this study), and partly because there are so many other renovations and construction initiatives happening or being planned now. However, as with all environmental building initiatives, planning is the key and the more information we can gather now, the more successful we will be when the time comes to renovate Mission. Not only will these investigations help prepare us for future challenges during the renovation process, but they will also reveal simple changes we can make in the meantime. Already my discussions with facilities for this project brought

\(^8\) (Jensen)
issues to their attention that usually go unmentioned by students, such as the pattern of overheated stairwells and hallways in Dennett. Similarly, data on behaviour and thermostat use can also lead to ideas for informational campaigns that will help students understand their energy use and hopefully collectively reduce our use of heating. While these changes will have nowhere near the impact of a large-scale Deep Energy Retrofit, they are important steps in our quest for a green and sustainable campus.

**Works Cited**


