Investigating Ground Source Geothermal Heating for Garfield House

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Introduction

Tucked away in the southwest corner of the Wood Neighborhood, the James A. Garfield house is a sort of mixed bag when it comes to enumerating its merits and drawbacks amongst the variety of student housing found at Williams. On the one hand, there is a fair amount of historical significance associated with Garfield, as it dates back to 1885, serving as a fraternity house for several decades, and is a quaint example of the Tudor architectural style (EDM, 2008). However, positive feelings towards the dorm are not shared by all of its student residents, nor by those who can't help but shake their heads in disbelief while looking at the associated figures on the building's rampant energy consumption. Through verbal communication and previous write-ups by staff members and students, it becomes fairly obvious that Garfield faces a number of issues, including poor insulation, cramped living quarters, and an accessibility nightmare that will have to be addressed before any major renovation can get underway (Knight, 2008). While it is difficult to pin down just how long the status quo will be left alone with regard to Garfield, a planning committee will in all likelihood be formed in the foreseeable future; with this in mind, it is important to brainstorm ideas, even if only to help weed out plans that won't make the cut. In doing so, this committee will not become bogged down with doing all the legwork to create a list of options, instead they get to examine and choose from a set of complete yet concise analyses with relevant data and a firm suggestion for or against a given course of action. In keeping with this theme, this paper will examine the feasibility of incorporating ground source geothermal into Garfield as either a compliment to or a standalone renovation project.

Setting

Garfield House is situated along the western edge of campus at an elevation of approximately 715 ft above sea level. It is accessed from South St., with the rotary about 150 yd to the north, and the Clark Art Institute almost a 1/3 of a mile to the south. It is abutted directly to the south by a sizeable grass field, with thin woods and the CDE to the west and north, respectively. Being located in Williamstown, MA, the subsurface temperature of the local soils is thought to be in the range of 45-50˚F year round, according to personal correspondence with Geosciences Department faculty members.

Methods

In order to make some sort of comparison between the current energy costs to heat Garfield and the possible reduction seen with the installation of ground source geothermal, most work was done within Microsoft Excel for data entry and manipulation. The primary data set used was monthly heating oil consumption from January 2004 through December 2009, or 72 monthly values. Formulas were set up to assign the number of days for each month, which were then used to calculate a mean monthly consumption rate of energy in BTUs/hr. These figures were compared with one given by a 2008 preliminary geothermal study done by Haley & Aldrich, Inc. for a horizontal closed-loop system to see how often all of Garfield's heating needs would be met by such a system. Months in which this was not the case were looked at further by calculating a new fuel consumption rate if a geothermal system were put in place. The original and revised consumption rates were then assigned a conservative cost estimate based on retail price data from the

Massachusetts Department of Energy Resources. Similar methods were used to generate figures from other dorms of comparable size to Garfield in order to contrast the different levels of energy use and costs associated with heating Garfield.

An experimental method for trying to model heat loss was done by creating a simple 3D model of Garfield in Google SkecthUp using measurements taken with a Laser Technology TruPulse laser rangefinder. These numbers were then plugged into a thermal conduction equation in Excel to get a rough idea of heat loss with and without insulation present.

Data

Using 60% of the retail price for heating oil to represent monthly wholesale prices, Williams is seen to have spent $92,340 from 2004 through 2009 on heating Garfield house alone, which works out to a mean annual fuel cost of $15,390. 2009 comes the closest to this value, with an annual fuel cost of $14,760 based on mean monthly consumption rates and prices.

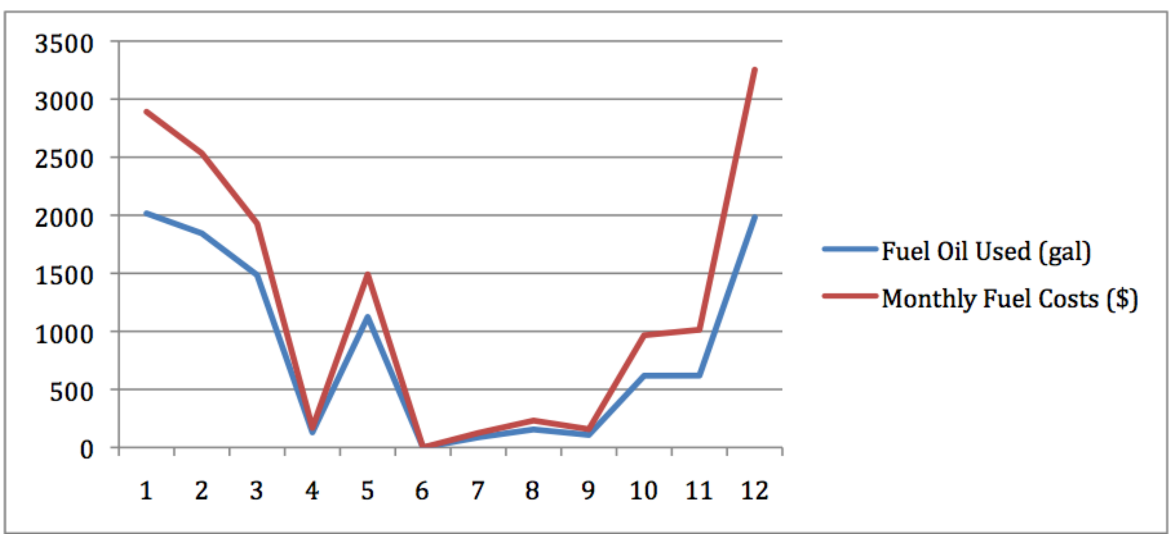

Fig. 1 2009 Garfield oil consumption & costs for oil purchases.

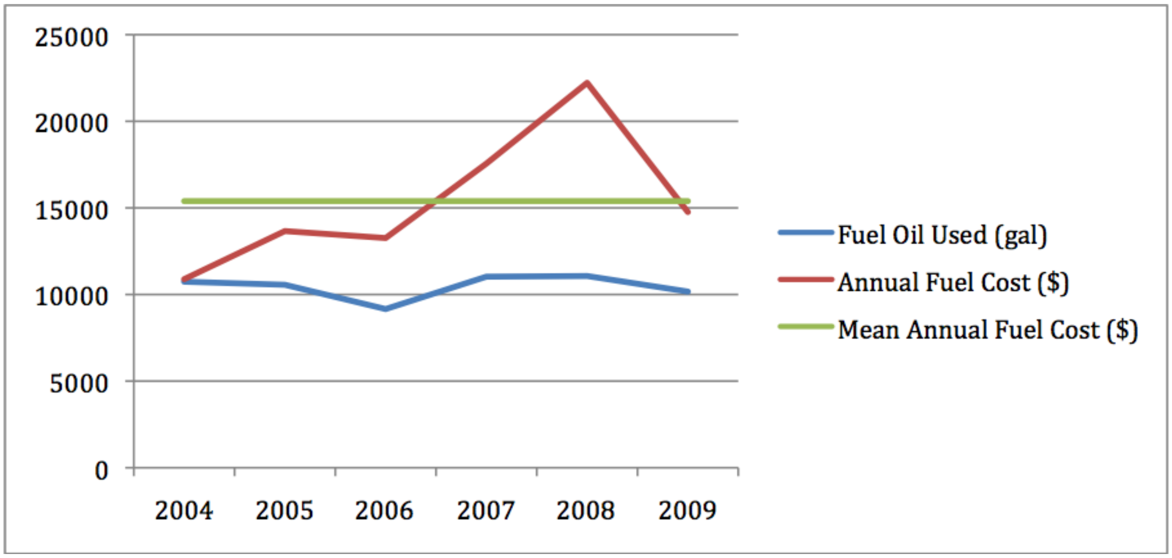

Fig. 2 2004-09 Garfield oil consumption & costs for oil purchases (mean included)

The Haley & Aldrich, Inc. study puts forth three possible geothermal systems that could be installed on campus, with each having an assigned capacity for heating and cooling. A horizontal closed loop system is typically the simplest to install due to the shallow depth of excavation and installation, and so this was the geothermal

Fig. 3 Garfield next to proposed excavation site (Aerial Photo Credit: Google Earth)

variant used for the following calculations. This hypothetical system is capable of producing 120,000 BTU/hr, requiring 50,000 ft^2 of open space for trench excavation and pipe installation. This large space requirement is usually difficult to meet, but the field immediately south of Garfield is of adequate size and distance from the structure it is intended to heat. Using the 120,000 BTU/hr rate, Garfield's heating needs would have been met with only a geothermal system for 32 of 72 months, not including 4 months of zero fuel consumption. If geothermal were expected to only provide 50% of Garfield's heating needs, then this would have been the case for 46 months, again excluding those 4 months of zero fuel consumption.

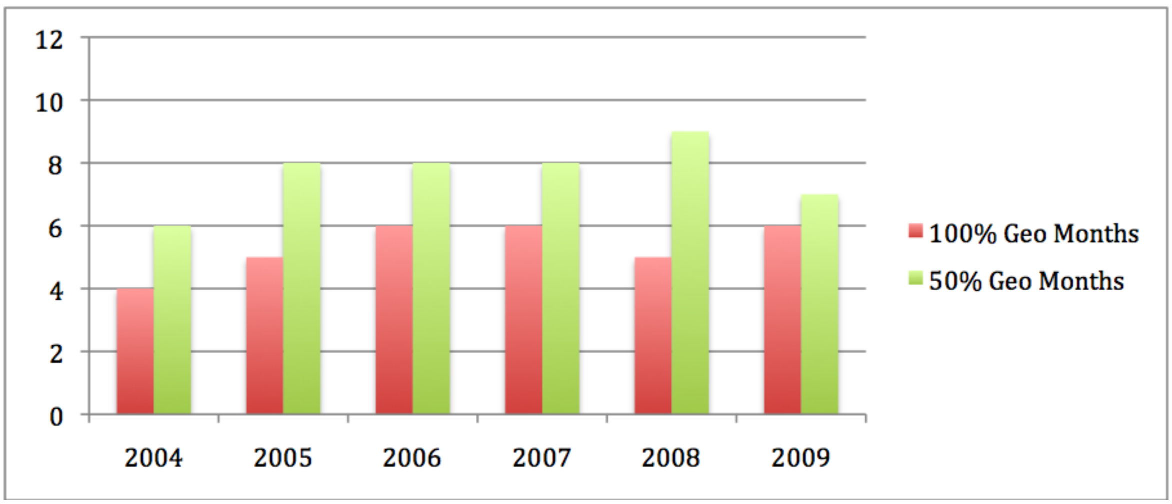

Fig. 4 Number of months per year 100% & 50% covered by geothermal heating.

A simple extrapolation of fuel cost savings can be made from this data. Assuming either the 2004-09 data is representative of the next 6 years, or that a horizontal closed loop geothermal system of today existed and could have been installed in 2004, then the difference between actual fuel consumption and the gallons of heating oil equivalent to 120,000 BTU/hr for 6 years will represent a revised fuel consumption and fuel cost. In this case, the presence of a geothermal system to augment the current oil-burning boiler would amount to 50.49% savings on fuel consumption and 51.20% savings on fuel costs. This works out to an average annual savings of $7,879 on fuel costs.

In order to facilitate comparisons to Garfield, energy use was calculated out into units of BTU per square foot per heating degree day (degreedays.net, 2010). Unfortunately it is difficult to peg down a particular figure for national or state-level averages, but a clear picture emerges from a simple head to head comparison with other buildings around campus, such as those that are also similar in size and

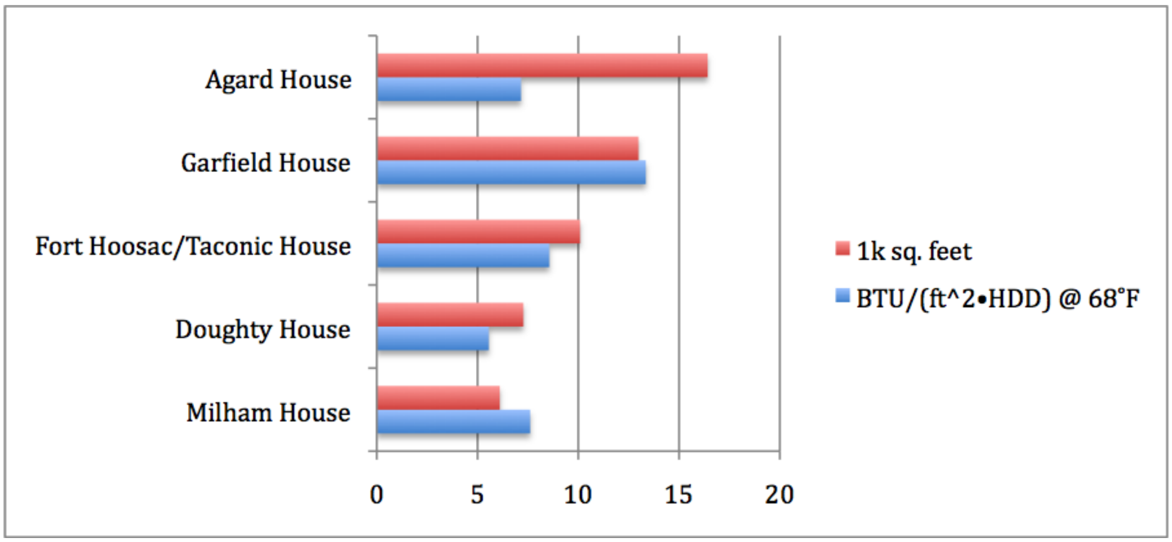

Fig. 5 2009 data for top 5 heating oil users

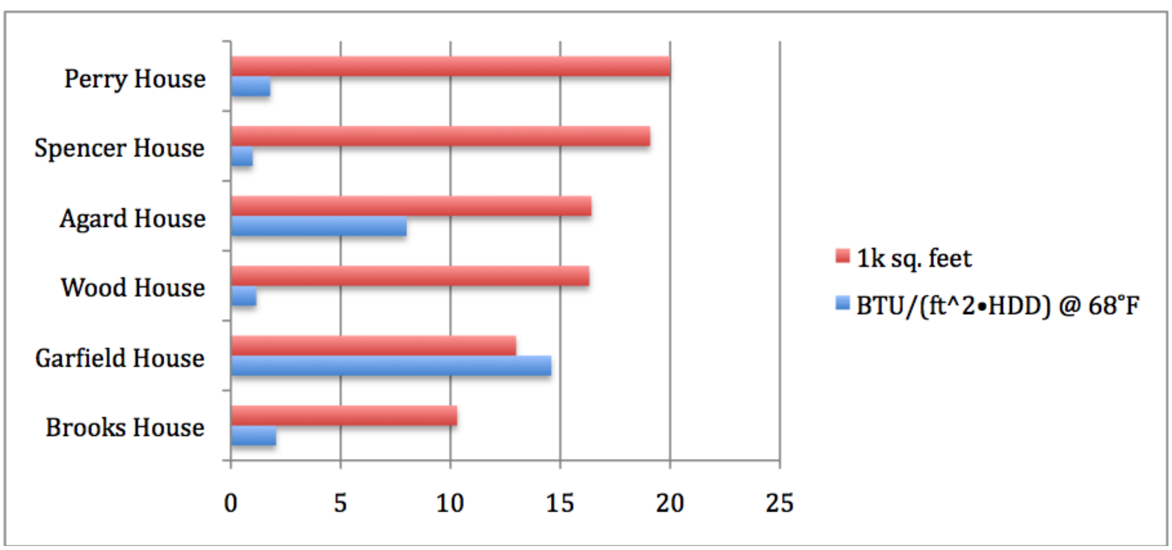

Fig. 6 January-March 2010 data for row houses

heated by oil, as well as the other row houses. In both sets of comparisons, Garfield house is shown to be the highest energy consumer, in some cases by an order of magnitude.

Using R-values and estimates of insulation thickness given by Michael Briggs from Facilities, as well as measured surface area derived from the SketchUp model, Garfield in 2009 might only have faced a mean annual heat loss of 36 MBTU/hr.

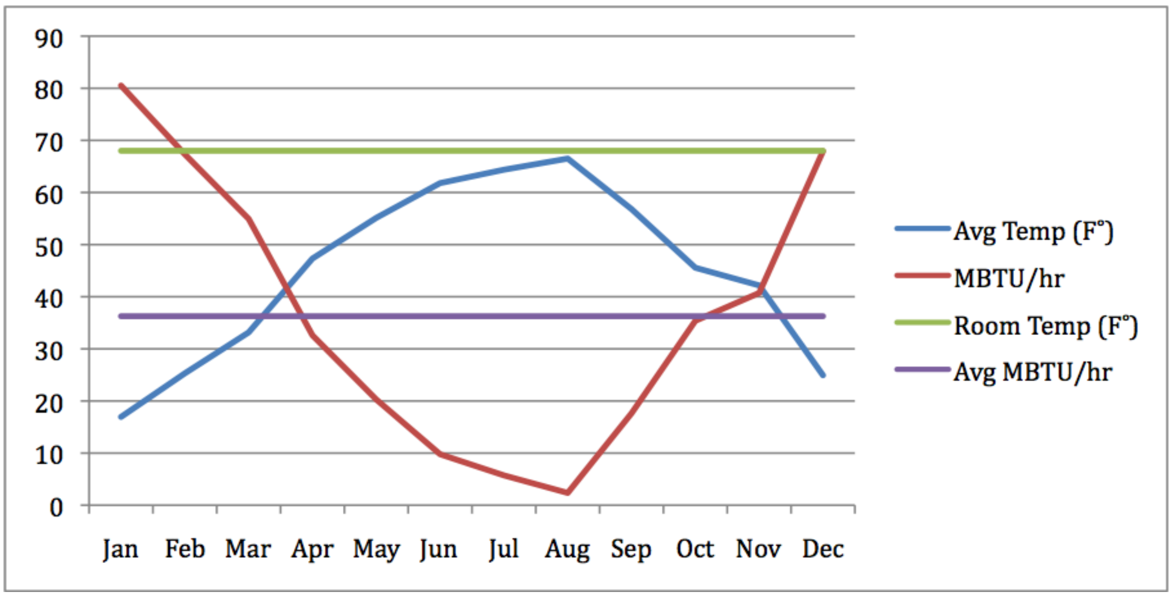

Fig. 7 2009 heat loss plotted against average monthly temperatures

Currently Garfield is thought to lack any proper insulation other than the existing structural materials, making it difficult to assign an R-value to the exterior walls and roof, as both will alternate between solid wood and air pockets bounded by wood in cross section. For the sake of comparison, R-values of 5 and 6 for the walls and roof, respectively, results in a heat loss of 151 MBTU/hr, approaching the 162 MBTU/hr mean annual energy consumption for Garfield in 2009 (Strait, 2010). Note that both of these estimates ignore the presence of glass windows as part of the surface area with their own R-values, as time and simple measurement techniques were prioritized.

Discussion & Conclusions

At first glance, it is surprising to see just how much oil Garfield consumes, although this has been known by Facilities and visitors to the Williams Sustainability website for some time now. Putting a price on that consumption also serves to illustrate what a burden Garfield is in its current state. While the $7,879 figure is a rough estimate, it is by no means a small number in terms of savings, especially when taking into consideration that figure is based on solely the geothermal upgrade (i.e. no insulation added). Granted, there are large capital costs involved, as well as the electrical demand of the heat pump itself. Using $2,500 per ton of capacity (120,000 BTU/hr = 10 tons), plus $15,000 for excavation, then $25,000 to cover unforeseen costs (retrofits, etc) and annual electricity costs of $1000/yr, based on the heat pump having a COP of 3.5 (gshp.org.uk, 2010) and the $0.13/kWh price paid by the college for outside electricity (Sustainability at Williams, 2008), generates a generous price tag of $65,000 with $6,800/yr to pay it off in less than 10 years. This payback period would probably be even shorter if extra work was done on Garfield, such as installing insulation in the ceilings and exterior walls, work which is already to be expected if and when Garfield undergoes renovation.

While the comparison of Garfield against other row houses stands out the most in terms of energy consumption, it is hard to reconcile the discrepancies as most of the other row houses are heated with steam from the highly efficient steam plant, benefitting from economies of scale with a shared heat source, whereas Garfield and Agard are both individually heated by oil. Nevertheless, Garfield is only the second smallest row house by square footage, yet it consumes between 5-10 times as much as the row houses on the central steam system, and almost twice as much as Agard on a per square foot per heating degree day basis. These numbers alone call into question the viability of arguing for the preservation of Garfield from an operational standpoint. Obviously proponents of saving Garfield will point to the history of the house, which shouldn't be ignored; however, given the direction Williams is headed with regard to making the campus more sustainable, the fact that Garfield's unique architectural style isn't on its own a compelling reason (unless there is some underlying significance to its design), and that any further efforts to overhaul the building will alter its appearance in a negative way—the fire escape stairwells, for example—it is hard to see how Garfield will remain a part of campus in the long term. Nevertheless, Garfield will still be here in the near future, as it is unlikely that any new student housing will be built with low occupancy in mind, and so the only short-term measures that can be taken will be those that involve upgrading the existing infrastructure of Garfield.

The numbers generated from the insulation calculations are rough at best, given the previous disclaimer about ignoring the effects of having windows incorporated into the exterior walls of Garfield, as well as approaching the modeling problem as if Garfield consists of its outer shell and one large empty interior space. This is an idealized version of the actual Garfield, which is split into 3 floors plus a basement, with enclosed rooms and winding hallways that restrict airflow (and therefore convection of heated air), as well as adding surface area that absorbs and emits radiant heat, and more walls of different thicknesses and materials with their own thermal conductivity. In summary, the SketchUp model results are not very precise nor terribly accurate; however, they still illustrate the difference between—and therefore the potential gains to be realized—having no insulation and a well-insulated outer shell. Michael Briggs of Facilities has expressed his preference for spray-in foam and cellulose insulation for the walls and ceilings of Garfield, respectively, due to their ease of installation and cost based on their R-values. While no known cost estimates have been made for a project involving Garfield, adding insulation is known to be a cost-effective option for lowering a structure's energy consumption.

There is no definitive solution to the wasteful energy consumption of Garfield; if there was, chances are such a solution would probably be known by now if not already implemented. Installing a ground source geothermal heating system one of several options, ranging from passive inaction to razing and starting from scratch with a new building. It does have distinct advantages, such as being a well-developed technology, being cost-effective in the Northeast when factoring in fuel savings and operational costs, and it is a green way to supply heating, especially if its small power demand can be met with renewable energy sources. The main drawback of high capital costs may hamper its implementation, especially given the College's fixation on short payback periods. True, throwing money at a problem will not make it solve itself, but most worthwhile projects take solid investment of time and money. A great place to start would be to set up a more formal study on using geothermal to heat Garfield, which is needed before such a system can be seriously considered. Even if the resulting professional opinion is negative, the reasons given for not moving forward can be used to evaluate other projects around campus that are not subject to these obstacles. The efficiencies achieved by the College's cogeneration plant are hard to match, but steam lines can only be extended so far before current and new structures on the edge of campus are better off relying on another source for heating. Geothermal systems could very well fill that niche when the time comes for significant renovations or expansion, and Garfield could serve as a testing bed before more significant investments are made for future reliance on ground source geothermal heating.

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