Investing in Environmental Technology: An On-Campus Geothermal Building

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Abstract: *Jesuit Community at Fairfield University is determined to build a new residence with the smallest environmental footprint possible. They settled on a geothermal heat pump to heat and cool the building. A financial analysis of this aspect of the project reveals that the numbers may not be profitable in a business sense but there are other issues to consider.*

INTRODUCTION

In March of 2005, Walter Conlan, rector of the Jesuit Community with a residence located adjacent to the campus of Fairfield University received the news that he was to begin rethinking Jesuit housing options. The community had gone through major demographic changes. From a high of 75 members living in the St. Ignatius residence in 1976, the population had declined to just 28. Twelve would take up residence in a new building if one were to be constructed. The Jesuit order owned the current residence, St. Ignatius, and the surrounding land which abutted the university property at an extreme southern corner of the campus. Fairfield University was founded by the Jesuits in 1942 with ownership of the residence property retained by the order.

After considering multiple possible locations on and off the campus the community settled on a spot just down the hill from Bellarmine Hall with a southern exposure and a view of Long Island sound five miles in the distance. Bellarmine Hall was the main house of the estate that comprised the university. Constructed in the 19th century, the house had its own version of geothermal; underground tunnels that were used to cool the building in summer. The new location of the residence would be more central to the campus than St. Ignatius furthering the goal of better incorporation into the university community. The university was willing to finance construction of the new building and provide a 30 year lease at $1 per year in exchange for the land and the 36,500 square foot existing St. Ignatius structure. The budget for the entire project was set at $9.6 million.

Fr. Gilbert Sunghera, S.J., assistant professor of architecture at the University of Detroit Mercy helped to initiate the design and bring it to a stage ready to communicate to prospective architects. Great care was taken to design a residence that minimized the impact of the new structure on the environment. This included the careful design of the building's footprint to minimize loss of trees, a floor plan that captured breezes and provided natural sunlight to corridors, and the overall optimal solar orientation of the building. The design of the residence in some cases incorporated more expensive decisions that were more representative of Jesuit values.

Many architectural firms were screened in an attempt to find one that clearly embraced the Jesuit environmental and spiritual goals for the building. The design was to serve as a hallmark for programs in spiritual direction and formation of lay colleagues, some retreat options, as well as spaces for faculty and staff development and programming. Building materials from sustainable sources harvested responsibly was a major concern as was minimizing the use of energy. Six architectural firms from a long initial list made the final invitation to spend time with the Jesuits in August 2006. Gray Organschi, a New Haven design firm made up of two Yale architectural professors was selected as most compatible with the Jesuits' goals.

Energy Efficiency

The campus was already invested in energy efficiency having recently built a new natural gas cogeneration electricity plant. The Associate Vice President and Director of Facilities Management, Rick Taylor was committed to reducing energy use on campus. Reducing energy use had been of interest to the university for many years. There was a solar demonstration project on the roof of a student townhouse that had successfully supplied electricity for some time. The Jesuits considered solar but even with advances in solar technology over the years, New England weather made the economics prohibitive. A secondary factor was the need to provide continuous campus demand for electricity at a sufficient level for the new cogeneration plant to run efficiently. In early 2007 Gray Organschi (GO) suggested geothermal heating and cooling as an option. GO had experience building private residences with geothermal and could engage engineering firms knowledgeable about larger installations.

The principles behind the use of geothermal heat pumps (GHP) are the same as those for more common air heat pumps. Where air heat pumps take advantage of the temperature differential between ambient air and the interior of buildings, GHP utilizes the more stable subsurface ground temperature which is typically about fifty degrees. In an open loop system groundwater is used much the same way as ambient air in heat pumps. In summer, cooler groundwater is circulated throughout the building absorbing interior heat. In open loop systems the water is pumped out of the building to a holding pond. In the winter GHP brings subsurface water warmer than the ambient air into the mechanical room where it gets a conventional heat source temperature boost before circulating throughout the building. In both winter and summer the differential between the groundwater and desired internal temperature is narrower than it would be for ambient air reducing the expense of cooling and heating. Equipment beyond the mechanical room is the same as in a conventional heating/cooling system. Geothermal is most effective for heating in colder climates.

In Europe, GHP is used almost exclusively for heating (Rybach and Sanner 2000). Twenty-five percent of new one and two family construction in Switzerland uses GHP. Even so, only 1% of all Swiss residential heating is GHP. Ninety-five percent of heat pumps are geothermal saving 335,000 metric tons of CO_2 emissions annually over oil heat. China is the world leader in GHP installations with the US a close second. The 600,000 GHP installations in the US represent a barely measurable percentage of heating/cooling capacity (Mehnert 2004). A major hurdle to more widespread use is the initial cost of installation. The high cost differential in installation is largely due to the expense of drilling multiple wells. Recouping investment is dependent on subsequent savings which directly correlate with energy prices. GHP installation lasts many years, typically beyond the number of years any initial buyer will live in a GHP house. If the cost were to be incorporated into a thirty year mortgage, sticker shock would be reduced. In commercial buildings, contractors may be more concerned with holding down construction costs since in many cases these are considered separately from operational costs. Often the builder/owner of the building is not the tenant. Charging higher rents while reducing operating costs might not be a viable marketing option in the real estate market. Besides the lack of knowledge about geothermal energy, there is also a shortage of reliable installers. A botched job can end up running up higher utility bills than a conventional alternative.

GHP technology has been around for many years. The first use of geothermal heat pumps was in Lardrello, Italy in 1904 (Dickson, Fanelli 2004). They have been viable commercially in the US since the 1950s when they were originally used for cooling in Florida, pumping water from and back into canals. The largest GHP installation site in the world is Fort Polk, LA. Four thousand homes housing 12,000 people were retrofitted for GHP resulting in a 26 million kWh reduction in electricity use, and 260,000 therms of natural gas savings. The installation eliminated 22,400 tons of CO_2 emissions at a cost of just under \$19 million. At 17,000 ton capacity, Galt House East Hotel and Waterfront in Louisville, Kentucky is the largest commercial GHP system in the world. Galt House estimates its annual savings over a conventional installation amount to over \$270,000 per year and they cut CO_2 emissions by over 1.8 million pounds. By using a 140,000 gallon reservoir under the mechanical room as a heat sink with a closed loop system they even saved \$2 million on installation costs.

Retrofitting buildings for geothermal can be expensive but the annual savings over conventional heating/cooling can amount to 15-25% on non-residential building and as much as 40% for residential buildings (FEMP 2004). Richard Stockton College in Pomona, New Jersey retrofitted their entire campus with GHP in the mid-1990s with estimated present value cost savings of as much as \$5 million over thirty years (Stiles et al 2009). GHPs also reduce peak load. Peak load power is the most expensive and most polluting electricity on the grid. Electric companies have to build and maintain enough power plants to serve peak power demand. That means keeping some plants idle just for those peak days. Most often these plants are older coal fired plants with minimal pollution reduction equipment installed. Reducing peak load throughout a demand system effectively allows shutting down out of date facilities reducing CO_2 emissions to an even greater extent than simply reducing normal demand.

GREEN ENERGY ON CAMPUS

The vast majority of US installations are closed loop systems employing high density polyethylene (HDPE) pipe buried in the earth circulating water with propylene glycol antifreeze additive. Open loop is less expensive to install but viability is dependent on geology, aquifer yield and a suitable location to dump groundwater. Drilling is less costly for open loop systems because fewer wells are drilled and casing installation in the shaft is not required. The initial engineering plan in late winter of 2007 at Fairfield called for three standing column wells with 1500 foot boreholes for an open loop system. The installation cost differential between an open loop system and conventional heating/cooling using an efficient gas boiler was estimated to be \$88,000 at the time. According to the first engineering report, an alternative closed loop system would require thirty-five 300-450 foot wells with steel casing spaced fifty feet apart at an additional cost of 20% for the drilling and ultimately 25% lower operating efficiency than the open loop system. A test well had not been drilled adding to the uncertainty. A closed loop installation would include well casing eliminating any danger of a cave in. Recently a GHP open loop project in nearby Bridgeport had experienced a well cave in leaving $20,000 of drilling equipment in the well. The problem geologically in Bridgeport's Golden Hill neighborhood was that the subsurface rock was schist, a medium grade formation subject to flaking resulting in the cave in. Construction of a Choate School dormitory's geothermal open loop system had to switch to closed loop when well drilling encountered similarly unstable subsurface geology. The estimated average daily water discharge from the Fairfield aquifer was 535 gallons with major discharges mainly on cold, dry winter days when temperatures dipped below 15F. Discharge was an estimate with considerable uncertainty since no test well had been drilled to determine the productivity of the aquifer.

Rick Taylor left the university in mid-2007 and Joseph Crouse took over as the interim Assistant VP while a search was conducted for a new Assistant VP. The pace of the project slowed. Official groundbreaking did proceed on April 22, 2008; Earth Day as well as the Feast of Our Lady, Mother of the Society of Jesus. Fr. Conlan was optimistic but also realistic. The original June/July 2008 occupancy was certainly impossible but several of the environmental goals were intact. The sod roof was included in the current design plans as was the use of sustainable materials such as bamboo flooring. Open loop geothermal still had the green light but there was more visible concern from the university administration about the additional cost of the installation at construction meetings. Crouse saw eliminating geothermal as the quickest way to reduce construction costs. In the spring of 2008 Fr. Conlan wrote to the Jesuit Order in Rome to defend the project and request further funding. The environmental statement the building would make convinced Rome and they approved an additional $375,000 to pursue the sod roof and the geothermal heating/cooling. The additional funds placated Crouse's concerns about the added expense particularly since the money would only be available if the project included both the sod roof and the geothermal system. To keep within budget Fr. Conlan accepted a smaller building footprint and the use of less expensive finish materials, e.g. polished concrete floors instead of hardwood or marble. The most important environmental values would be preserved and communicated.

In April of 2008, Fairfield University's President Jeffrey von Arx S.J. joined with 460 university and college presidents in signing the American College and University President's Climate Commitment, pledging to measure and reduce greenhouse gas emissions (GHGs) on campuses. The Jesuit Residence would be an excellent example of honoring this commitment.

New VP and another Look at the Plans

In May of 2008, David Frassinelli took over from Crouse as the new Assistant VP and a review of geothermal began in earnest. He wanted an independent assessment. Haley & Aldrich, an engineering firm based in Boston with considerable experience with GHP was called in to evaluate the situation. Paul Ormond of H&A alerted David Frassinelli that the water discharge would need to be further from sewer lines than originally planned because of a newly revised Connecticut regulation. Moving the discharge a greater distance would require laying additional pipe, possibly into the university pond. A further concern was water quality. The mineral content of the water could change over time making dumping it anywhere problematical since it would eventually end up in the aquifer that the Town of Fairfield used for drinking water. Finally, the quantity of discharge was uncertain. While the building heating/cooling requirements might entail 535 gallons average daily discharge, it was possible that one or more of the wells could hit high discharge groundwater that would mean considerably more water being produced than the building would need for heating/cooling increasing drainage problems. David felt the apparent cost advantage of the open loop system was more uncertain since there was no way of estimating the risk of excess water or the danger of deteriorating water quality.

The Fairfield Inland Wetlands Commission had initially approved the project with no knowledge of its geothermal aspect. A closed loop system would not need any additional approval since it has no impact on wetlands or water quality. Meeting new rules on discharge for an open loop system would mean going back to the commission for a new approval for a much wider dispersal of the discharge, probably into the pond. This might not follow as easily. A New York Seminary geothermal project provides a cautionary tale (Dwyer 2008). The Seminary had to educate successive New York City agencies on the efficacy of geothermal. Approval was delayed for four years causing costs to mushroom by 50%. The university would also have to go back to the same commission for approval of construction of a new dormitory in the not too distant future. If the Jesuit Residence project was back on the table it could endanger or delay the new dormitory.

In October 2008 H&A came up with a design for a closed loop system with only fifteen wells. Switching from open to closed loop meant installing a dry cooler and other equipment in the mechanical room. The changeover added $231,972 to the project. Operational costs would also be somewhat higher than for open loop. The wells would use HDPE pipe and they would be lined with an insulating grout casing eliminating any danger of collapse. There would be no water discharge. The propylene glycol antifreeze employed would be of food grade quality minimizing risk if leakage occurred. The closed loop system was more expensive but it was very low risk while maintaining the environmental integrity of the project.

Fr. Conlan estimates the useful life of the building will be at least 75 years. He believes this should be taken into consideration in any financial analysis. The building could also qualify as a LEED green building which was the original intent. The three gradations of a LEED building designation are silver, gold and platinum. An early OG consultant, Altieri 10, thought that the building as initially designed could qualify for the highest certification. Having the inspection and certification done by LEED would cost upwards of $100,000. Given the current cost constraints, David had rejected spending $100,000 but was considering applying for certification from a lesser known group. He thought the building could now meet the gold standard.
An environmental issue that arises with GHP is the reintroduction of warmer water than the water extracted. In open or closed loop systems the subsurface temperature could rise. David was familiar with this issue having encountered it under somewhat different circumstances at Cornell. Cold deep lake water was used to cool a building with the discharge sent back into the lake. The result was a changed aquatic environment. That project did proceed. H&A proposed to address this issue by rotating the use of the 15 wells in such a way as to minimize subsurface temperature changes preserving the temperature gradient indefinitely.

Installation cost issues were somewhat muted by the dramatic increase in oil prices over the summer of 2008. Though this signaled at the time a likely very expensive fossil fuel future, the university was already locked into a natural gas contract that would enable it to provide campus electricity at a cost of $0.11/kWh, a much more favorable rate than the $0.22/kWh charged by United Illuminating (UI), the local utility. Under the university agreement with UI, the cogeneration plant was limited to producing 4.6 MW of power which was sufficient to serve the university's power demand most of the time. In exchange for this limitation UI agreed to provide standby power.

With the stock market swoon continuing in January 2009, the university was about to announce budget cuts. The operating budget was largely dependent on tuition. Increases in tuition for 2009-2010 would need to be muted to reflect the general economic malaise. The endowment which typically returns 5% tax free had also suffered significant reverses. It was likely that the new dormitory would be postponed leaving the Jesuit Residence as the only ongoing construction project. The additional cost of the closed loop system was a sobering figure. If the project had begun with a closed loop GHP system and conventional system sent out to bid at the same time, the cost differential would likely be much narrower. The question now was if the closed loop system could indeed prove financially beneficial in the longer term and how long that term would need to be to surmount a large investment differential.

The GHP system would use 143,779 kWh per year with 60% of that power coming from the cogeneration plant and the rest from UI. A conventional system would use a mix of electricity, 83,915 kWh and 9,213 therms of natural gas. The conventional mix of electricity would be more heavily tilted to UI, 80% of it, because the greatest demand would coincide with peak demand during the summer. Therms currently cost $1.51/therm. Natural gas inflation is projected to be 5% per year; somewhat more moderate than the expected UI 7.5% inflation for electricity. Since the cogeneration facility uses natural gas, those electric costs would inflate similarly to natural gas prices. CO_2 emissions would be less under the GHP system. UI kWh produced 0.909 lbs of CO_2 per kWh generated while the cogeneration plant emitted only 0.40 lbs per kWh. Emissions per therm are 11.7 lbs. Recently CO_2 trading in the open market in Europe priced emissions at $15.82/ton with expectations of 7% annual increases. Though the closed loop system cost considerably more to install, maintenance costs should be similar to that of a comparable conventional system.

With higher initial costs David wondered if he would be able to defend the geothermal aspect of the project on economic grounds. The $375,000 additional funding seemed to preclude taking geothermal out. Regardless of the added funding, he would like to be able to justify the added expense economically. Could he do so?

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