HISTORIC PRESERVATION BY CREATING A GEOTHERMAL DISTRICT

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When the Radcliffe Institute for Advanced Study embarked on its renovation of the historic Fay House, the project was immediately confronted with an interesting challenge: how to embrace thoughtful historic preservation while still meeting ambitious sustainability and energy efficiency goals.

COULD 1+1=3?

The Radcliffe Institute has long been a leader in thoughtful experimentation and progressive innovations. As an early adaptor in sustainability, Radcliffe had previously constructed two geothermal well systems within the Radcliffe Yard: a 2-well system serving the Gym and a larger 5-well system at Byerly Hall, located immediately adjacent to Fay House. The Byerly Hall system appeared underutilized. Could Fay House be incorporated into the 5-well system at Byerly Hall, creating a geothermal district with two buildings served by a single geothermal system? The opportunity was compelling, accomplishing both energy efficiency goals and historic preservation, while avoiding construction of new, costly systems. As it turns out, when it comes to geothermal, one plus one is sometimes, in fact, three.

Figure 1. Fay House, constructed in 1806 was the first building in what would eventually become the Radcliffe Yard. (Photograph courtesy of Venturi, Scott Brown and Associates, Inc.)

HISTORIC PRESERVATION AND SUSTAINABILITY

Historic preservation and sustainability are a natural fit. In many ways, historic preservation is sustainability. Thoughtful preservation and care of our historic resources should be "priority one" with any plan for sustainability. Gone are the days of so-called "urban renewal" in which buildings and entire blocks were demolished wholesale. Historic districts and preservation now prevail in many urban settings these days. Even the LEED® system, the widely adopted building sustainably rating system, has recently been updated to accommodate building renovations with the addition of LEED®-EB, or "existing building" metrics.

It is an ironic and interesting challenge to consider that achieving a high level of energy efficiency is particularly difficult in a historic renovation setting. Most of the usual energy conservation measures (ECMs) that work well for new construction are too intrusive for preservation projects. Typical building envelope improvements such as high efficiency windows and wall insulation impact historic window aesthetics and can wreak havoc on century-old, handcrafted finishes. Exterior facades are difficult to "retro-insulate". The challenges are numerous. Building design teams are faced with limited effective, high impact efficiency options and significant costs.

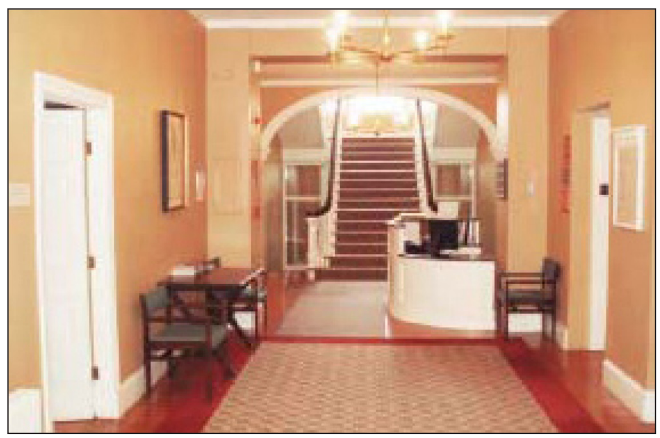

Figure 2. The interior of Fay House contains many period architectural details worthy of preservation. (Photograph courtesy of Venturi, Scott Brown and Associates, Inc.)

THE SOLUTION UNDERFOOT

Squeezed between historic preservation and project energy efficiency objectives, more and more exotic and expensive solutions were considered at the Fay House. What one might consider "passive" ECMs, which usually play a large part of high-impact efficiency gains, could not gain enough efficiency to meet project goals alone. More "active" ECMs and renewables were needed to meet project objectives. Solar thermal and solar PV were evaluated, but again, for this historic setting, they were found infeasible due to preservation requirements, aesthetic challenges, and little area being available on the roof. High efficiency condensing boilers and adsorption chillers were possible, though very expensive, and not an ideal outcome considering the aesthetic impact of water vapor plumes that would occur at both ground and roof level. What about integration of the Fay House renovation to the nearby Byerly Hall geothermal system, which appeared to be underutilized?

The Byerly Hall geothermal system, consisting of five geothermal wells, had been in service for approximately three years providing the foundation of that building's energy efficiency strategy. Could the Fay House building also be incorporated into the system, creating a district geothermal system able to provide a high level of energy efficiency to *both* buildings? Finding out involved looking back at performance of the existing system, then looking into the future and assessing how a multiple-building system would perform. If the assessment proved positive, then the challenge of both historic preservation and high-impact efficiency gains would be met using already available and constructed resources right underfoot.

Figure 3. A bird's eye view of Radcliffe Yard showing the five well Byerly System (on the right) and the two well Gym system (on the left.) Haley & Aldrich, Inc.

CREATING A GEOTHERMAL DISTRICT

Geothermal has little in common with other ECMs or renewables such as solar and wind. Understanding, evaluating, and engineering most ECMs and other renewables is a fairly straightforward, almost "plug and play", analysis handled through simple calculations and linear models. What is the annual electric power output in kWh generated by a solar panel? That's a simple function of location, area, and a few other factors which are practically independent of any other information associated with the building. How much more efficiency would an improved R-value in the building envelop provide? That's a simple input change to a building energy model.

A geothermal system on the other hand is a "living and breathing" extension of the building's HVAC system linking, and dependent upon, everything from the way the building is used by its occupants to the deep and sometimes changing geologic environment. What is the efficiency of a geothermal system? Some in the industry would have you believe that a geothermal system provides a certain coefficient of performance (COP) and energy efficiency ratio (EER). Based on our peer review of numerous projects across the country, most analyses simply take these as fixed and unchanging. Perhaps more troubling as design professionals, many designs are based on simple rules of thumb (e.g., 2 tons/well, etc) which have no engineering relevance. In fact, the efficiency of a geothermal system varies during the year and over time, with changing use and many other factors and good design is much more complex than rules of thumb. As a result, hugely oversized and hugely undersized geothermal systems are not uncommon.

This situation begs two questions: (1) how does one, then, evaluate the efficiency gains and geothermal system size appropriate for a multiple building district; and (2) is it all worth it, and why? The second question, to clients, is obviously the more important. In about half of our projects, after some considerations using objective criteria and getting to the bottom of what the client is really after, the answer can be "no", and we advise our clients to consider other ECMs and renewables. In the other half, however, use of geothermal provides not only cost effective life cycle improvements but provides uniquely high-impact efficiency gains, usually much more than can be provided with most conventional ECMs. For projects that require both high-impact efficiency gains and historic preservation, geothermal is one of the few viable choices.

To answer the first question, the evaluation begins with a thorough understanding of past geothermal performance involving analysis of groundwater temperatures, system flow, energy consumption and previous building use and weather patterns. Because the Byerly building was periodically assisted with central plant steam, the effects of this input was also considered in the evaluation. The second stage of the evaluation involved thorough heating and cooling load profile modeling for both buildings which would make up the future geothermal district. The third stage involved combining past performance information with the district load profile to arrive at an understanding of the district system performance.

The existing 5 wells system consisted of four 1,500-ft deep standing column wells and a fifth 655-ft deep recharge well. The standing column design involves use of groundwater directly as the heat transfer medium in which water is pulled from the bottom of the well and returned to the top. Water is directed to the recharge well to help maintain efficient ground temperatures. Radcliffe was generally pleased with this system, as it performed well for Byerly. However, it became clear that the system was not fully utilized.

Once the three-stage analysis described above was complete, it became evident that the geothermal system, when put into operation to serve both buildings, would experience new thermal loadings. To validate system performance at these higher levels of use, a series of stress tests were implemented, to simulate both extreme summer and winter conditions, by systematically exposing a small subset of wells to high levels of utilization. Data from these exercises was subsequently used to validate our models at these more extreme conditions.

Radcliffe also took the opportunity to make a number of improvements to the geothermal system, to increase reliability and performance, including addition of heat exchangers, additional measurement and control points, and completely revised sequence of operations. These were designed by Haley & Aldrich using techniques honed by retrofitting both open and closed geothermal systems which are either underutilized and/or suffering from performance and reliability issues.

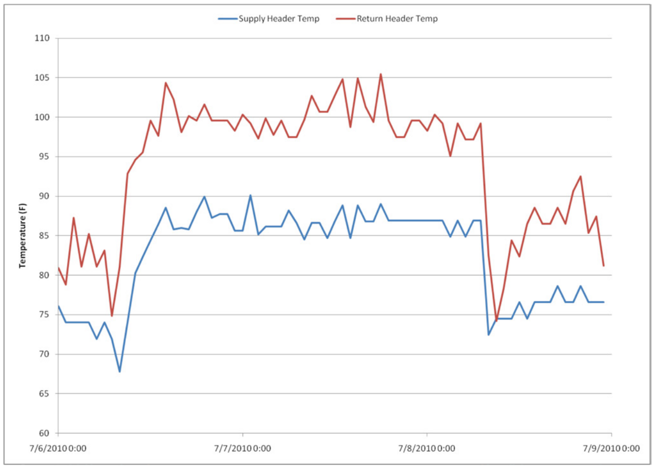

Figure 4. A plot showing some of the data used to analyze system performance. Haley & Aldrich, Inc.

PERMITTING GEOTHERMAL

Based on our experience developing geothermal systems across the country, Massachusetts is blessed with some of the most well-conceived and informed geothermal regulations in the United States. The Commonwealth's regulations thoughtfully consider closed, open, and other systems, drilling practices, well standards, and many other issues and practices related to drilling, underground construction, and heating and cooling applications. The most up to date guidance document is available at http://www.mass.gov/dep/water/drinking/uic.htm

An Early Adaptor's Full Circle

The final step to prepare the system for changeover from single building to district was to update the regulatory permits to reflect a different use than originally permitted. The original Byerly 5-well geothermal system was one of the first geothermal systems to be permitted by the Department of Environmental Protection (DEP) in Massachusetts through their drinking water well and underground injection programs. Our work with the DEP to permit the Byerly system, as well as several others at that time, lead to the formation of a special DEP task force to create new, streamlined permitting guidance for all geothermal systems in the Commonwealth. The district project will now benefit from this new, much more streamlined process as it goes through project changes.

The Radcliffe Institute for Advanced Studies, one of the early adaptors of innovative geothermal technology, has come full circle. The Institute helped foster enough critical mass and interest at the regulatory level to facilitate creation of new guidelines, which now have benefited projects across the Commonwealth and accelerating green design. Indeed, the Commonwealth's regulations are now being used in at least two other states as a model: a great example of how the Institute's leadership has affected positive change.

THE END GAME

Renovation of the Fay House will begin in May when the Radcliffe community breaks for the summer. When the Radcliffe community returns for the Fall semester, they'll see a geothermal district providing heating and cooling to both Fay House and Byerly Hall which uses half as much energy as compared to a common "efficient building" benchmark (e.g., American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 90.1-2007). This is a remarkable achievement especially considering the limited number of energy efficiency measures compatible with historic buildings. What the Radcliffe community won't see is condensing boiler and adsorption chiller water vapor plumes, nor other impediments to careful preservation. They also won't see disturbance to their historic Yard, as already constructed wells have been installed, buried, and covered by beautiful landscaping. A sustainable resource will now be more fully utilized, to the betterment of the Institute and the environment. What other underutilized geothermal systems out there could be modified to serve a district of buildings?

IS IT WORTH IT?

Much is said about the "payback" of geothermal systems, usually quoting select certain studies suggesting paybacks of "just a few years". These claims are often exaggerated and reflective of the best possible conditions only. Having designed, repaired and conducted expert witness work on numerous open and closed systems, we know that payback varies considerably, from 10 to 50 years. This considers tax benefits and true life cycle.

Much is also said about the beneficial effect of accelerated, 5-year MACRS depreciation, suggesting that nearly half of the system cost is effectively offset in tax benefits. Although accelerated depreciation helps, it's not accurate to claim nearly half of the system is effectively paid for. A valid life cycle cost analysis would have to consider the net of 10 year straight line conventional system depreciation for the system being replaced by geothermal. This diminishes this reported affect considerably.

Geothermal systems can be a powerful tool in building development and often provide a cost effective, high-impact energy efficiency gains. If you're a client or owner interested in efficiency and valid life cycle cost analysis it's wise to get experienced and objective advice with a potential geothermal option.