Geothermal Heat Pump Systems for Strategic Planning on the Community Scale

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ABSTRACT

Climate Change and Energy Security are trends requiring energy efficiency developments. Take California's stringent policies and emission goals that set a minimum for emissions reductions, and lay the groundwork for future regulations that will call for carbon neutrality. The only way to achieve such goals is by strategic planning on the community scale. The most sustainable communities integrate as a single working system that allow for single-point-of-use-controls. These developments will be beneficial for energy conservation and emission reductions, and will also be more cost efficient. Technologies that are scalable on the community level such as geothermal heat pump systems (GHPS) are a key component to these developments. GHPS can be implemented to heat and cool an entire community, reducing energy consumption, emissions and water consumption, while also serving as a backbone for carbon neutrality and zero net energy. An integrated underground heat exchanger can be tied into multiple buildings, transferring BTUs from one zone to another. This results in a micro-utility and reduces capital costs by allowing fixed costs to be shared by the community. Ball State University is one example where GHPs will heat and cool the entire campus community, while reducing energy use, greenhouse gas emissions (GHGs) and operation and maintenance costs. Pringle Creek Community in Salem, Oregon is another example of a community under construction that utilizes a community scale geothermal heat pump system. If residential communities or even whole cities were to take such actions, the benefits experienced could have a significant impact on the quality of the environment and the local economy.

Introduction/Background

There is a growing, majority consensus amongst scientists and policy makers that Climate Change is real, and the problem is a direct result of the world's consumption of fossil fuel based energy resources. Other concerns regarding the U.S.'s dependence on fossil fuels revolve around the country's unending dependence on foreign oil for its energy requirements and the necessity for energy security. These issues have set in motion the gradual progression of initiatives, policies and regulations that will deter the country from relying so heavily on fossil fuels, and set goals for emissions reductions and reliance on alternative forms of energy.

California, a world leader in environmental stewardship and a political platform that sets the stage for regulation and policy on sustainability issues, is a perfect example of the direction the U.S. as a whole is heading in regards to energy solutions and GHGs. Over the last decade California has created a comprehensive collection of state policy/regulation that lays the groundwork to reduce greenhouse gas emissions and related energy consumption.

- CA SB 107, CA SB 2 – Accelerated and expanded upon CA SB 1078 to current requirements that investor owned utilities and electric service providers procure 33% of the total electricity from eligible renewable energy resources by 2020

- CA AB 1007 – Requires the California Energy Commission to prepare a state plan to increase use of alternative fuels
- CA SB 1 – Directs the California Public Utilities Commission and the California Energy Commission to implement the CA Solar Initiative which would entail a total of 3000 MW of new solar facilities in CA homes and businesses by 2017
- EO S – 1 – 07 – Implements a Low Carbon Fuel Standard, reducing at least 10% in carbon intensity of CA transportation fuels by 2020
- EO S – 06 – 06 – Directs state agencies to promote biomass use (Produce 20% of states biofuels in CA by 2010, 40% by 2020 and 75% by 2050 with a target of produced electricity from biomass reaching 20% of CA's RPS goals for 2010 and 2020)
- CA AB 32 – California Global Warming Solution Act – Requires the reduction of greenhouse gas emissions to 1990 levels by 2020

Although California has been chosen here as an example of the progress set in motion for sustainability, other states and the Nation as a whole have recognized its importance, and future policy/regulation will only expand on the current trend, leading towards carbon neutrality and zero net energy.

To meet goals set by these stringent policies/regulations, the design in which we attempt to meet our goals must change. Targeting only the energy-intensive sectors such as industry and agriculture will not satisfy the required reductions. Government and businesses have been targeting energy efficiency and renewable energy production on an individual building basis. This too will not satisfy current or future goals. To further our progress, the only logical step is to strategically plan for sustainability on a community level.

A sustainable community reduces energy consumption, using energy more efficiently, and integrates energy efficient and renewable technologies into one integrated system, a situation which emphasizes the importance of holistic design. This approach has been developed and demonstrated on an individual building basis. LEED certified and Zero Net Energy buildings are founded on such an approach. These types of buildings have been exponentially increasing over the past decade, and have been shown to reduce energy consumption compared to typical constructed facilities. Zero Net Energy buildings generate at least as much energy as consumed, and LEED certified buildings have proven to be 25-30% more energy efficient than a typical building[1]. This approach can also deliver more sustainable communities, and could prove to be more cost effective and possibly boost the local economy creating a profitable scenario.

Although there are currently very few examples of sustainable communities, those that exist have targeted energy efficiency as a first measure. This includes energy efficient construction, involving higher efficiency systems such as HVAC. The building sector consumes 41% (2010) of all primary energy in the U.S., and accounts for nearly 74% of all electricity use[2]. This makes buildings and homes a prime target for energy reduction within a community. And,

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[1] [NBI] New Buildings Institute: "Energy Performance of LEED® for New Construction Buildings".March 2008.

[2] [DOE] Department of Energy: Buildings Energy Data Book, http://buildingsdatabook.eren.doe.gov/ChapterIntro1.aspx

because HVAC systems account for anywhere between 40-60% of a building's or home's energy use, HVAC energy reduction will be a major contributor.[3]

One of the benefits in sustainability practices on the community level is the ability to utilize technologies that are scalable and often unfeasible on a smaller scale. One such application is geothermal heat pump technology. Geothermal heat pump systems are versatile and scalable, and with efficiencies reaching in the range of 300-600%,[4] these systems have been a critical component in sustainable design and "green building". Four out of the 8 listed case studies on the DOE zero-energy building database utilize geothermal heat pump systems, and over the past two years (2010 and 2011) four of the top ten buildings earning green project awards from AIA/COTE have utilized these systems. Strategic planning for sustainability on the community level has become a part of efforts in reducing greenhouse gas emissions and resolving energy security issues, and GHPs have become a key component in these developments. One example of such a community is Pringle Creek Community in Salem, Oregon, which contains multiple zero net energy and LEED platinum homes, utilizing a geothermal heat pump system for approximately half of the community's properties.

As an energy efficient HVAC system, geothermal heat pump systems (GHPs) have a long history of application for energy efficiency purposes. This paper will examine the potential use of geothermal heat pump systems technology on the community level. This paper will explore the benefits and barriers that exist for these systems on a community scale. The paper will also take into consideration the intricacies of design and engineering and the economics involved. Additionally, examples of geothermal heat pump system application on the community scale will be provided and examined.

Community Scale could vary widely in size and GHPs' capacity. A community could be defined as a handful of homes or on a larger scale a community with multiple homes, commercial properties, k-12 and high schools, etc. For the purposes of this paper, assume any community scale project will require a minimum sum of all individual components of 1000+ ton capacity geothermal heat pump system, including a collection of multiple homes, commercial buildings, schools and other structures.

Engineering and Design of Community Scale Geo Systems

A community-scale geothermal system can mean two different things. In one alternative, shown in figure 1A, a large ground loop or loops supply a community-scale Central Utility Plant that distributes hot and chilled water directly to multiple facilities for direct heating and cooling. This is the type of system under construction at Ball State University, and it works best for campus-like settings under a single ownership. In the other alternative, shown in Figure 1B, a Community-Scale Ground Loop (**CSGL**) system distributes condenser water to individual building, but users of this resource are responsible for providing their own heat pump equipment and pumping to heat and cool their facilities. This is most applicable for a public-utilities model.

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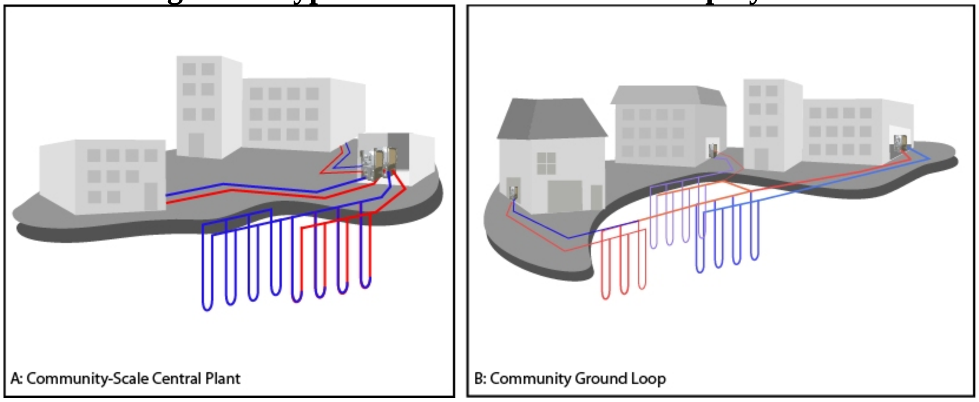
[3] [DOE] Department of Energy: "Heating, Ventilation and Air Conditioning". 2008. http://www1.eere.energy.gov/buildings/commercial/hvac.html

[4] [DOE] Department of Energy: Geothermal Heat Pumps. Updated 2011. http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12640

Figure 1: Types of Geothermal Heat Pump Systems



There are a number of motivations and advantages for providing a community-scale ground loop:

- A utility can finance construction of the community ground loop and collect fees for its use, avoiding the initial high capital-cost hurdle of single-facility systems.
- A CSGL provides access to highly efficient geothermal heating and cooling to a community, where single-facility ground loops would be impractical. The CSGL allows flexibility in locating wellbore fields in available spaces.
- A CSGL can take advantage of diversity in users' heating and cooling profiles. A high diversity can significantly reduce loop field size compared to multiple single-facility systems.
- Additional thermal capacity can be added to a CSGL distribution system as needed.
- A CSGL distribution system can link together diverse sources of geo-exchange to take advantage of available resources not available to single-facility systems. Potential geothermal resources include closed loops, open-loops, surface water loops, or heat exchangers connected to municipal or waste-water streams.
- Auxiliary thermal sources or sinks can be added to the CSGL distribution system to help balance annual loads to provide long-term maintenance of design loop temperatures.

There are two distinct components of the CSGL system. The first component is the ground-coupled heat exchanger (**GCHX**) itself. This typically consists of a vertical loop well bore field, but it could also include other resources as noted above. There is ample experience with the design and installation of GCHXs of various types for the single-facility systems. The GCHXs for community systems are essentially the same. An important difference, however, is that well fields can be placed in parks, schools, under parking lots or parking garages. Ground water or available surface-water resources, or water streams associated with municipal or waste-water facilities can also be incorporated where available.

Maintaining proper loop temperatures can be a challenge throughout most of the US, where net annual heat loads to the loop can be quite high. Cooling towers or dry coolers can be added as needed. These can be operated efficiently during winter months and at night, with the ground loop providing thermal storage for summer time and peak time loads. Other options to reduce loop temperatures could include snow melt in areas with snow removal requirements.

The other component, which is unique to the community-scale geo system, is the CSGL distribution system. This consists of the piping infrastructure that connects the GCHXs to potential users. There is little history for CSGL distribution systems to multiple owners. Some of the challenges in designing and developing a CSGL distribution system are:

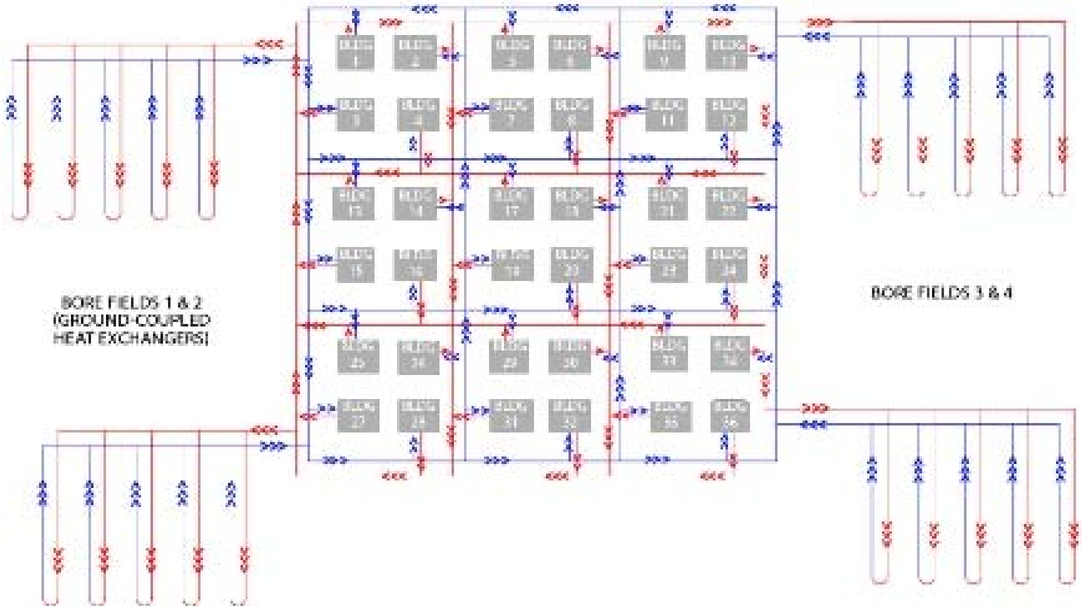
- To take advantage of the diversity in heating and cooling uses, the system needs to be designed so that the GCHXs are evenly shared among the diverse users of the CSGL.
- The distribution system has to be installed along with other utilities in existing utility rights-of way. This would be a particular challenge for retrofitting an existing community.
- The distribution system needs to be robust to avoid taking the entire system down if one part of it is damaged or needs to be taken out of service.

A good analogy for a robust distribution system is the municipal water distribution system. These systems are highly networked, so that if one part is shut down, the affected area can be isolated without disrupting a larger area.

A schematic illustration of a distribution system that addresses these challenges is shown in Figure 2. The distribution system would be placed in existing utility rights-of-way serving the community. Connecting intersecting supply lines and return lines creates a networked distribution system. Water make-up and shut-off valves distributed through the network provide robustness to the system in the event that one section is damaged or needs to be taken off line.

The system should be designed so that pressure drops through the distribution system are significantly lower than pressure drops across the GCHXs. This would ensure that thermal loads to the distribution system are dispersed among the available GCHXs to take advantage of load diversity. In a distribution system such as this, the pumping power could be provided entirely by the individual users, reducing the maintenance requirements of the CSGL owner.

Figure 2: Schematic Layout of a Community-Scale Distribution System



Barriers and Benefits

The level of complication involved in planning a geothermal heat pump system on the community scale gives rise to multiple benefits and barriers that need to be examined with the technology's application. Some of these benefits and barriers will be general to community scale heating and cooling applications, while others will be specific to GHPs.

Aggregated Loads (Benefit)

With any heating and cooling system, a community scale approach is going to allow for the aggregation of loads. This tends to lead to improved efficiencies and lower costs per unit capacity. This is a significant advantage with geothermal heat pump systems. GHPs gather, store and provide energy in concert with a building's energy requirements, and are capable of being tied into multiple buildings, transferring Btus from zone to zone and building to building. If properly designed, a community scale GHPs will remove energy from a zone that's being cooled and route that energy to an area requiring heating. This will tend to lead towards higher efficiency systems.

The size of the CSGL (well bore field) is a direct consequence of the interaction between the earth and the buildings, and load aggregation amongst a group of buildings and homes will reduce the size of the required well bore field. Since the installation process (drilling) of the well bore field accounts for a large portion of the high install costs associated with GHP technology, the capital costs involved in community scale system installation will be reduced on a per unit capacity basis.

Economies of Scale (Benefit)

As with most anything on a larger scale, communities will be able to take advantage of the economies of scale. Currently, if a residential home owner were to install a GHPs it could cost anywhere in the range of $50-100+ per foot ground loop (This would incorporate any costs for the outside portion of the GHPs). A commercial size GHP system of 100+ ton capacity is typically in the range of $15-25 per foot ground loop. Considering a community development that will require a higher capacity of 1000+ tons of heating and cooling, costs should decrease significantly. As an example, BSU's second phase consists of 680 boreholes at a depth of 500 ft, and costs for the outside portion of the GHPs is approximately $11/ft. Although not as economically beneficial as larger capacity systems, costs for a handful of homes would still be more favorable then on a home by home basis, allowing shared fixed costs, such as mobilization, site work, engineering and project management.

Equipment Efficiency (Benefit)

Generally speaking with most heating and cooling equipment, efficiencies tend to increase as the capacity is increased. With residential homes or small scale projects, the geothermal heat pump system performance is usually restricted by scale, and taking advantage of load diversity and load aggregation on the higher capacity systems will lead towards higher efficiencies. Higher capacity systems leave much room to design more optimal performance systems. Additionally, higher capacity systems rarely run at full capacity which tends to allow the system to operate at higher efficiencies.

Load Diversity (Benefit)

District heating and cooling and central plant systems have become popular and are regularly used for university campuses and downtown municipalities. These types of systems take advantage of load diversity, not only on a room by room basis, but building by building. This is a major factor in all the fore mentioned benefits. As a closed loop system, geothermal heat pump technology takes full advantage of load diversity in their design, reducing the quantity of infrastructure necessary and the overall expenses compared to working on each structure individually.

Integration and Control (Benefit)

GHPs are a highly versatile HVAC system, and are capable of tying into any energy plan. These systems work in concert with renewable technologies such as wind and solar, and are capable of being integrated with such technologies as one working system with a single-point-of-use-control. Using monitoring and controlling technologies, the operation of GHPs can be constantly updated and optimized to ensure the community is utilizing its energy on HVAC requirements as efficiently as possible.

Capital Costs (Market Barrier)

The most recognizable market barrier for geothermal heat pump systems has always been the initial costs. Capital costs for a geothermal heat pump system installation on a community scale will be quite significant, and could result in termination of a project if the right type of funding is unavailable. Ball State University’s geothermal heat pump system project, the largest system in the U.S. once completed, cost approximately $70 million. Ball State was able to fund most of its project through state bonds (~$40 million) and contribution from the reinvestment recovery fund (~$5 million). There are options for third party financing that would cover all capital expenditures and delegate ownership of the system, including all maintenance and operation, to a third party. Although this option is viable, community residents might be hesitant to allow outside ownership. Another option, mentioned in an earlier section, local utility providers could finance the construction of the community system, creating a geothermal utility. This would allow for residences to experience reductions in their monthly utility bills while utilities manage the demand side energy use and collect fees for system use.

Disruptive (Market Barrier)

For community retrofit projects, installation of the underground heat exchanger could disrupt the homeostasis of that community. Drilling is a very loud and messy process, and the projected life time for a project could be years if the system being installed is sizeable. This could prove to be a deterrent for the community.

Existing Equipment (Market Barrier or Benefit)

A typical geothermal heat pump system installation involves replacement of aged boiler and chiller equipment with GHPs rather than a conventional HVAC system. Replacing aged equipment allows for some costs for GHPs installation to be offset. Take Ball State University's project, the campus was to replace two aged coal-fired boiler plants. While the installation of GHPs costs were upward of $70 million, costs were only $15 million more than replacing their current system with GHPs rather than conventional equipment. The result is an incremental payback period of 7.5 years which is relatively small compared to the 50 year lifespan of the underground heat exchanger. Typically however, with communities, not all current equipment will be at the end of its operational life, and those costs cannot be offset.

Proximity (Market Barrier)

Community scale GHPs will require an excessive amount of trenching and piping to connect all the buildings and homes that reside within the defined community parameters. This will lead to complications involving costs, pumping parasitics and energy requirements and thermal losses. Complications due to thermal losses could lower the overall operating efficiencies, and possibly exclude some structures or limit the size of the community able to connect to the same system. As well, the trenching will add cost to system installation, and if there is an excessive amount of trenching, those costs could result in an economically unfavorable situation. This problem could be resolved by working with local utility providers and a common trench for all utility connections, allowing for utilities and those residing in the community to share those fixed costs. This resolve may not be available for retrofit projects where utility infrastructure is already in place. Another problem may arise in circulating the working fluid through the system. With excessive piping, energy requirements to run the circulating pumps may increase the operation costs significantly.

Heat Loss/Buildup

Over time, the geothermal heat pump system will have extracted or accumulated heat energy from or to the ground, and could potentially cause the overall ground temperature to change. This will have an environmental impact on the ground, and result in lowered efficiencies of the system. Careful consideration of this process will need to be taken on a community scaled project. On an individual building basis, this is usually resolved by increased spacing between boreholes, or implementing a hybrid system solution to balance the loads. These solutions can be enhanced and carried over to a community level project.

Financing (Market Barrier)

The amount of capital required to commence on such a large scale project will require alternative business models. One such option would be third-party financing and ownership. Residents within the community may not be responsive to this option due to necessary reliance on third parties for critical services involving maintenance and repair. Models with a more substantial community ownership may prove to be more favorable. Collaboration with the municipality could provide a solution to develop and manage such as system. A third option would be for the local utility provider to finance and maintain ownership of the system. This would eliminate capital costs for the residences of the community, and reliance for maintenance and repair services would be provided by utilities that already have a track record in this area for water, electric and gas services.

General Benefits and Barriers

Geothermal heat pump systems can reach efficiencies as high as 600%, and usually provide energy reductions ranging from 30-70% during heating modes and 20-50% during cooling modes, making these systems one of the most energy efficient HVAC systems available to architects, engineers and building owners. The reductions of greenhouse gas (GHGs) emissions is a direct result of the amount of energy reduced, so GHPs provide a significant reduction in GHGs. Additionally, GHPs only use electricity as a power source, and therefore eliminate all on-site fossil fuel use for combustion processes associated with heating purposes. The result is zero on-site emissions. GHPs are associated with multiple other benefits, including but not limited to:

- Water Conservation: GHPs are typically closed loop systems, and while most residential AC equipment and commercial scale equipment such as evaporative cooling consume large amounts of water, GHPs use zero on-site water.
- GHPs lower base loads and flatten peak time energy profiles.
- Hot water needs: During cooling periods, GHPs take advantage of the heat rejected from the building or home for domestic hot water use, or additional load capacity could be added to the system to provide hot water during any thermal mode.
- Lower Maintenance and Replacement Costs: GHPs consist of three basic moving parts, the circulating pumps, the compressors and the fans. This makes for a highly simplified system, easy and inexpensive to maintain. As well, GHPs are highly durable with an ASHRAE rated lifespan of 26.2 years for the heat pump and a 50 year warranty on the HDPE piping which makes up the underground heat exchanger.
- Unlike other renewable energy technologies (Wind, Solar) which are heavily incentivized by the federal government, GHPs rely primarily on operational and maintenance savings to provide reasonable payback periods.

The most commonly recognized market barrier for GHPs is the high install costs. Although typical payback periods are in the range of 5-10 years, depending on multiple factors, the capital costs involved in system installation are usually a deterrent. Other market barriers include but are not limited to:

- Lack of knowledge by the general public, building owners, architects and engineers
- Limited experience, training and education amongst GHPs designers, installers, etc. There are very few highly qualified GHPs designers and installers in today’s workforce
- Lack of financing options (e.g. Solar PPAs). There has been some movement on this front, and once financing is available for these projects, the GHP industry is sure to have faster growth.

Feasibility and Economics

GHPs rely on the earth's constant temperature located a few meters below the surface. This source of energy is available year round at every building's point of use. Therefore, there are very few factors that would prevent a geothermal heat pump system installation from being a viable option. One such restriction is availability of land space. Due to the inherent nature of geothermal heat pump systems, a sizeable quantity of land is necessary for the installation of the underground heat exchanger. This quality of the systems creates situations, such as a high rise in the middle of a downtown urban setting, an unrealistic option for GHPs implementation. However on a community scale project, with availability of parking lots, parks, open fields, etc., more options will be available for well bore field(s) locations.

The most influential restriction has been/is economic feasibility. As with any renewable energy or energy efficiency project, if the ROIs are too low, the decision to follow through on a project is going to be negative unless the project is one mandated by government regulation. Qualifying a community as a candidate for geothermal heat pump system installation will follow similar key criteria and economic evaluation as for an individual building's. However, there will be subtle nuances. The following is criteria to consider when evaluating the feasibility of GHPs.

Community Size and Utilization

As previously mentioned in the benefits and barriers section, larger scale geothermal heat pump systems will tend to decrease costs on a per unit basis. This occurrence is accounted for with load diversity; load aggregation and community shared fixed costs such as mobilization, project management and engineering fees. There will be a wide variety of diverse load profiles amongst structures in a community which will lead to a highly beneficial scenario when compared to an individual building basis, reducing necessary infrastructure and installation costs.

Community Design/Energy Profile

Geothermal heat pump systems and energy efficient measures in general will flatten a community's peak time energy profile, and reduce the overall base load. In turn, operational costs are reduced, and project costs can be recovered through energy (operation) savings. Current power sources and utility rates are going to be highly influential in the expedience in recovering the project's capital expenditures. Regions which are reliant on expensive fuels such as propane will tend to have higher operational savings. As well, areas that have high cooling requirements and high electric rates will also lead towards higher savings. Locations that utilize natural gas and have low electricity rates will tend to have trouble generating enough in energy and utility savings to justify project expenses.

Regions that are primarily heating dominant and use natural gas as an energy source will prove to be difficult to financially justify. GHPs convert all heating functions from fossil fuel based energy sources to electric energy sources, and with the current natural gas rates this conversion could potentially result in higher operating expenses.

HVAC Systems

For new construction, GHPs provide substantial economic benefits, and community scale capacities are comparable in costs to conventional HVAC. In some cases, GHPs' costs for new construction have been shown to be less than that for conventional HVAC. However, retrofit projects present a dilemma with the replacement of current HVAC equipment. The type of HVAC equipment being replaced, the age of the equipment and the ease in which the equipment is replaced could be negative or positive to a community project.

Unlike the individual building basis, not all of the existing equipment in a community will be past its operational life, and costs to replace that equipment cannot be offset. Additionally, replacement of certain types of HVAC equipment will not produce the substantial savings in energy that will lead towards favorable ROIs. A building/ community of buildings in a hot arid region that requires cooling for most of the year and utilizes a central plant chiller system with already high efficiencies is a good example of what type of situation will be financially difficult to justify replacement.

There is a positive aspect to a community retrofit project with GHPs. The heat pump portion of the GHPs is available in a comprehensive set of sizes, types and applications, and could easily replace any existing equipment without extensive work to the inside of a structure regardless of facility type. However, there will be certain situations where retrofits could prove to be difficult. As well, the well bore field can easily be tied into current equipment such as chillers' hydronic piping system, or GHPs could coexist with current equipment, utilizing a hybrid situation. This type of system would lower capital costs, but generate less in energy savings. This versatility presents multiple opportunities to work in a design that could have economic favorability. Contradictory, a wide variety of HVAC equipment is sure to exist across an entire community, and the engineering and design of GHPs on the community level will be increasingly difficult than on the individual building basis. This will lead to higher costs.

Any GHPs system will produce a reduction in annual maintenance costs. GHPs are known to have the lowest maintenance costs on a per annum per square foot basis than any other HVAC system. The simplicity of the system makes them easy to maintain and does not require extensive training to operate. On the community scale there will be excess expenses in the pumping process and equipment due to the quantity of piping and the distance of travel for the working fluid. This will lessen the difference in maintenance and operation costs between GHPs and conventional HVAC.

Geology

The regional geology is going to have an impact on costs of the system. Geology is going to affect the thermal conductivity of the ground which will help determine the size of the CSGL. Sands and Clays are typically less thermally conductive than hard rock such as granite and limestone. Higher thermal conductivities will lead to smaller bore field sizes. The other side of the equation is how geology will play into drilling costs. While hard rock will have a higher thermal conductivity and reduce the CSGL, hard rock could produce a situation where expensive drilling techniques will be required which would increase the per foot cost of drilling. On the community level, multiple thermal conductivity tests will be necessary to determine the geology and heat transfer capabilities of the ground across the community, but the effects of geology will remain the same from an individual basis. Additionally, because of the extent of community parameters, there will be available options to exploit that may not be available to individual facilities. Ground water may be available throughout the community that could be utilized for structures that would otherwise not be able to take advantage of these formations on an individual level. As well, there may be situations where large amounts of land space may be available within a community for horizontal installations which entails a less expensive installation process, and may not otherwise be available to individual buildings.

Financial Incentives

Federal, State and local utility incentives are available for geothermal heat pump systems that would otherwise not be for conventional HVAC systems. On the community level this provides tremendous opportunity to decrease capital costs. Federal incentives include the 10% investment tax credit or 30% personal tax credit for homes, and many utilities have programs which provide incentive on a per kWh and per kW reduction. There are also rebate incentives for equipment, providing incentive on a per ton basis.

Currently, there are very few community level GHPs installed or in progress. This presents opportunities in the research and development areas, which could provide opportunities for funding. As well, opportunities could present themselves for the community to work with and share some of the financial obligations with the local utility companies, which are currently under pressure to meet RPS and demand side management goals.

Local Economy

A community scale project will require a sizeable investment. While funding such a project will be difficult and could potentially strain the community’s budget, there will be a boost to the local economy. BSU’s project costs were upward of $70 million, and required the employment of several contracting firms. Once completed, community scale projects will require the creation of multiple full time jobs for operation, engineering, maintenance and administration. Additionally, to complete the project GHPs companies will find it necessary to acquire goods and services from vendors locally and across the country. The capital expenditures might be high and difficult to fund, but the end result is an investment in the community and a boost to the local economy.

Examples of Community Level Geothermal Heat Pump Systems

Pringle Creek Community. Currently under construction, Pringle Creek Community occupies 32 acre and will include multiple types of structures both renovated and newly constructed with 179 homes that will be required to meet a minimum of LEED Gold certification. Many of the homes within the community will be zero net energy while others will reach LEED Platinum certification. The first model home constructed at Pringle Creek has the highest LEED rating in the country for homes (101 points), and utilizes an integrated design approach, taking advantage of geothermal heat pump system technology, high efficiency windows, solar hot water, solar PV and passive solar along with other energy efficiency measures. The home uses 35% of the energy a typical home of similar size.

The geothermal heat pump system for the community is an open loop system that takes advantage of a well designated for domestic water use and irrigation. The well delivers 59º F temperature water at a capacity of 280 gallons per minute. The system is utilized at half of the lots within the community and is 300% more efficient than a gas furnace for heating purposes.

The system will retrieve the water from the well and deliver the water through a supply piping system. The water then passes through the heat pump at each lot, allowing for heat extraction or rejection. The water is than passed through a returning piping system, and is either used for irrigation purposes or is returned to the aquifer through an injection well.

Ball State University. Ball State University currently has under construction the largest geothermal heat pump system in the U.S. once completed. The system will have a capacity of approximately 5000 tons, and will serve the heating and cooling purposes for 47 building over 731 acres. The underground heat exchanger consists of 3600 boreholes with depths ranging from 400-500 ft and diameters of 5-6 inches. The system includes two energy stations which will house large heat pump chillers, and two water supply lines: A hot water loop with a constant temperature of 150º F, and a cold water loop with a constant temperature of 42ºF. This system is a model of how a geothermal heat pump system could serve as a central plant utility for heating and cooling a community.

Capital expenditures for the project cost upwards of $70 – 75 million, with the majority of the funding coming from state bonds. The university is expected to save $2 million annually in operation costs. While the capital costs are upward of $70 million, the cost is only $15 million more than that for a conventional HVAC, resulting in a payback period of 7.5 years. In addition to the $2 million per annum in utility savings, the system will reduce the campus's CO_2 emissions by roughly 50% cutting an estimated 85,000 tons of CO_2 annually. The project is also estimated to produce approximately 2300 direct and indirect jobs with several contractors and suppliers already employed.

Conclusions

Policy and Regulation is becoming increasingly stringent concerning climate change and energy security issues, and planning sustainable communities will become a key component in producing solutions to meet goals set forth by these policies and regulations. While it has been evident the building sector accounts for a significant portion of the total energy consumed in the U.S. (39%), targeting this sector on an individual building basis cannot meet all the current or future goals. Constructing or retrofitting sustainable communities with an approach that minimizes energy consumption and integrates energy efficiency measures and renewable energy production is the next step in the evolution of "green building", and the next logical step towards meeting our energy and emissions goals. Taking these steps will require taking energy efficiency as a first measure, and geothermal heat pump system technology which is scalable, versatile and highly energy efficient is going to be a major contributor to these developments. Geothermal heat pump systems have already proven themselves to be useful and easily implemented in the holistic design approach with many of the ever increasing amount of LEED certified and ZNE buildings being constructed or retrofitted taking advantage of the capabilities and benefits geothermal heat pump systems provide. GHPs have continuously been a highly utilized technology for energy efficiency measures on an individual basis, and are sure to be an invaluable option for communities endeavoring to meet energy and emission reduction goals through integrated, sustainable design.

Geothermal heat pump systems are an easily scalable technology, and the transition from individual building capacity and design to the community scale has a low level of difficulty. Additionally, all the benefits associated with geothermal heat pump systems are transmitted to the community level, and in some cases even enhanced. To implement GHPs on the community scale, careful consideration of variables such as size, utilization, community parameters (proximity), climate and geology will be necessary in order to determine the economic feasibility of the systems on such a large scale. However, while the largest market barrier to these systems may possibly be the sizeable capital expenditures to design and install the systems, this barrier can also be the biggest benefit with the investment in system implementation boosting the local economy. As seen with Ball State and the 2300 direct and indirect jobs produced by the universities investment, a large scale community level geothermal heat pump system project could not only be economically favorable but also profitable for the community. Geothermal heat pump systems are proficient in reducing energy consumption, reducing greenhouse gas emissions and providing a stable foundation for carbon neutrality and zero net energy goals, and incorporation of geothermal heat pump technology in the strategic planning on a community level will have a tremendous impact, environmentally and economically.

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