Closer to Zero

Unlocking ground source heat pump technology potential for U.S. homes and businesses

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9/14/2015

Ground source heat pumps (GSHPs) are a mature technology that can contribute to overall economic prosperity, energy security, and environmental stability in the United States. The authors of this paper conducted primary, qualitative interviews with both experts and end-users of ground source heat pumps, as well as an in-depth literature review. This paper explores the benefits of this technology as well as barriers to market growth. We propose a set of policy-based recommendations, and outline gaps in current research worth funding.

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Summary

Ground source heat pumps (GSHPs) are a mature technology that can contribute to overall economic prosperity, energy security, and environmental stability in the United States. The authors of this paper conducted primary, qualitative interviews with both experts and end-users of ground source heat pumps, as well as an in-depth literature review. This paper explores the benefits of this technology as well as barriers to market growth. We propose a set of policy-based recommendations, and outline gaps in current research worth funding. Among the policy-based solutions, **we recommend encouraging states to allow utilities to own the ground loop under demand response initiatives and for this to be rate recoverable.** Basic research funding needs include greater investment in the development of lower cost ground heat exchangers, and the design of tools (maps, databases, assessments), also aimed at reducing the cost of installing the system for consumers. Further, **we recommend investment in gathering data on improvements to indoor air quality and health benefits, as well as on the potential for GSHP to reduce heat island effect in cities.**

The wider deployment of ground source heat pumps will have positive long-term economic effects for consumers of energy, as well as being a proven means for reducing carbon emissions. For these reasons, we believe that it is important to continue the 30% investment tax credit for Ground Source Heat Pumps that was enacted in the Emergency Economic Stabilization Act of 2008. Currently, the incentive is available for units placed in service from January 1, 2008 until December 31, 2016. **We recommend extending this tax credit through September 2021. Similarly, an investment tax credit of 10% of the installed cost is available for commercial buyers through 2016, which we believe should be extended through September 2021.**

Finally, ground source heat pumps are an important contributor to buildings seeking Zero Net Energy (ZNE) status. **We respectfully request that the U.S. Department of Energy be directed to provide a leadership role in establishing a voluntary ZNE framework—based on existing standards, guidelines, and practices—to facilitate ZNE as the norm for building design and construction**. This would provide the building industry and consumers with an accepted set of market definitions, nomenclature, metrics, and implementation guidelines needed to achieve economies of scale and meet the demand and expectations for these high-performance buildings.

Glossary of Acronyms

(ASHRAE) American Society of Heating, Refrigerating, and Air-Conditioning Engineers

(EEI) Edison Electric Institute

(EPRI) Electric Power Research Institute

(EO) Executive order

(GSHP) Ground source heat pump

(IGSHPA) International Ground Source Heat Pump Association

(ITC) Investment tax credit

(NRECA) National Rural Electric Cooperative Association

(ORNL) Oak Ridge National Laboratory

(RECs) Renewable energy companies

(ZNE) Zero Net Energy

Introduction

Ground source heat pumps (GSHP)[1] are a mature technology – in use since the late 1940s – that should have a greater role to play in contributing to overall economic prosperity, energy security, and environmental stability in the United States. As business-owner, Harold Turner put it:

> ***"I happen to be a Republican, a conservative Republican. I believe in energy independence and an economically sound [policy] – we need all things on the table. One thing people forget about is geothermal – not relying on fossil fuels."***

In order to understand the current state of this technology, the industry, and its market conditions; the authors of this paper conducted interviews with both experts and end-users of ground source heat pumps, as well as an in-depth literature review. We found a remarkable amount of consensus that GSHPs bring enormous benefits to both consumers and communities, but require regulatory assistance to overcome the market barrier of high initial capital investment requirements. **Ground source heat pumps, in wider deployment, have the potential to reduce carbon emissions on a large scale, reduce Federal spending on energy, aid compliance with future air regulations such as the Clean Power Plan, and support community resiliency-building efforts.**

[1] Also known as *geothermal*, *geo-exchange*, *earth-coupled*, *ground-source*, or *water-source* heat pumps.

Background

GSHPs use the constant temperature of the earth as the exchange medium instead of the outside air temperature. Because shallow ground temperatures are relatively constant throughout the United States, geothermal heat pumps (GSHPs) can be used effectively almost anywhere in the country, however, “in extremely cold climates the advantages of GSHP will be accentuated,” according to Abigail Daken, Environmental Engineer at U.S. Environmental Protection Agency (EPA). In these climates, GSHPs reach high efficiencies, in the range of 300% to 600%, on the coldest winter nights. In comparison, air-source heat pumps on cool days reach a range of only 175% to 250%.

GSHPs use the ground as a heat sink in the summer, and as a heat source in the winter; they rely on the relative warmth of the earth for their heating and cooling production. GSHPs do not create heat rather they move it from one area to another. They are a ‘fuel less’ solution, which has implications for both carbon emissions and heat reduction in areas that traditionally depend on air conditioning in the summertime. There are four basic types of ground loop systems: three of which -- horizontal, vertical, and pond/lake -- are closed-loop systems. The fourth type of system is the open-loop option.

- *Horizontal ground loops (generally the most economical) are best for newly constructed buildings with sufficient land.*
- *Vertical installations or compact horizontal "Slinky™" installations work with existing buildings because they minimize the disturbance to the landscape.*

All of these approaches work well in both residential and commercial building applications of varying size and complexity. **In particular, they can be well suited to both schools and Federal installations.** One of the largest installations we investigated was the Sussex County Emergency Operations Center in Delaware, where facilities engineer Steve Hudson told us, “I think it is one of the best things we did at the center, and this was one of the best decisions we made.” Steve praised the reliability and performance of the system, which are both critical for sustaining emergency responsiveness, “[It was] 10 times cheaper and [gave] 10 times better performance.”

The proper selection of a loop type depends on the climate, soil conditions, available land, and local installation costs at the site. Many factors can affect the final cost and feasibility of the project:

- *Geology: composition of soil and rocks can affect heat transfer*
- *Hydrology: ground or surface water availability plays a role*
- *Land availability: The amount of land, the landscaping, and the location of underground utilities or sprinkler systems.*

Relative to air-source heat pumps, **GSHPs are quieter, last longer, need little maintenance, and do not depend on the temperature of the outside air**. GSHPs improve humidity control by maintaining about 50% relative indoor humidity, making them very effective in humid areas. This is important for southern parts of the United States, where the energy consumed to cool buildings is disproportionate to that of the northern States due to humidity.

Benefits

Economics

The long-term economic argument in favor of ground source heat pumps is a good one:

> ***"Depending on factors such as climate, soil conditions, the system features you choose, and available financing and incentives, you may recoup your initial investment in two to ten years through lower utility bills."*** [2]

They accomplish this return on investment because **GSHPs use 25% to 50% less electricity than conventional heating or cooling systems**, according to research presented by the International Ground Source Heat Pump Association (IGSHPA), a non-profit, member-driven organization headquartered on the campus of Oklahoma State University in Stillwater, Oklahoma. **GSHPs also save money, both in operating costs and maintenance costs.** Boyd Lee, from the Caddo Electric Cooperative, also in Oklahoma, presented the following figures:

- Replace one electric heat pump with geothermal ground source = reduce 2.8kw demand ($267/year); reduce 4000-6000 kwh/year ($160-240/year)
- Replace one gas heat system with geothermal ground source = reduce 2.8 kw demand ($267/year); reduce 2000-3000 kwh/year ($120-200/year)

Richard Soper, former President of Bosch Thermotechnology Corporation, put it thusly in an interview:

> ***"Long term vision, strengthen the envelope, put in some form of heat pump, geothermal full stop, if you can balance it with photovoltaic you've now got a comfort system and you've reduced your utility bill to whatever you invest!"***

Energy savings

According to researcher Xiaobing Liu, a researcher at Oakridge National Laboratory (ORNL) in Tennessee, "GSHP technology can save 30% of energy in commercial buildings – residential buildings can save as much as 40-60% for space heating/cooling/water heating." He went on to tell us that, in a case study implemented at the headquarters for the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) the second floor uses GSHP, while the first floor uses a different system. "The GSHP system uses 44% less energy for the heating/cooling than the VRF system on 1st floor."

Savings from ground source heat pump systems may vary by building, depending on climate, the comparable base HVAC/water heating system, and other factors, but according to Liu, *in all the case studies reviewed they found energy savings*. Further, according to Abigail Daken, who evaluates GSHPs for the EPA's ENERGY STAR Program, savings from GSHPs, though impressive, appear to be largely understated, "Most [systems also] provide production of hot water for residential. Savings claims do not include hot water, but if they did savings [figures] would be higher."

[2] http://energy.gov/energysaver/articles/choosing-and-installing-geothermal-heat-pumps

IGSHPA figures support this, and claim two major water-related benefits for GSHPs. The first benefit derives from pre-heating direct hot water (DHW) whereby, “some GSHPs can save you up to 50% on your water-heating bill by preheating tank water.” Meanwhile, water savings from systems for commercial buildings compared to evaporative chillers is significant in that they deliver 2.5 gallons/hour/ton of cooling capability. **These benefits also accumulate in multi-family housing as well as commercial office buildings.**

Greenhouse Gas (GHG) reductions

As far back as twenty years ago, it was recognized that growing the GSHP market share in terms of serving heating and cooling needs would have significant positive effects on the environment and the economy. Specifically, the DOE, EEI, NRECA, EPRI, IGSHPA, EPA, and several utilities called for GSHP market mobilization. The goals were to:

- *Reduce greenhouse gas emissions by 1.5 million metric tons of carbon annually by the year 2000*
- *Increase GHP annual unit sales from 40,000 to 400,000 by the year 2000*
- *Save over 300 trillion Btu annually*
- *create a sustainable market for GHPs, not dependent on utility-provided rebates or government incentives*[3]

Xiaobing Liu told us that, “GSHP is the winner in most locations for CO2 reductions based on previous studies at granular scale.”

Performance

Everyone we spoke to agrees, the mechanical performance of ground source heat pumps is excellent. Estimated system life is 25 years for inside components, and over 50 years for the ground loop. Jack Cowan, a builder of Zero Net Energy (ZNE) custom homes in Memphis, is a fan of the systems and told us they are, “the ultimate mechanical system in terms of performance.”

Steve Hudson from Sussex County Emergency Operations Center said:

> ***“I saw the entire solution as being simple, there are fewer things that can go wrong.”***

According to Abigail Daken, “The general average [GSHP] in the market is better than air source heat pumps. The best of both types [rank] similarly, with GSHP slightly above.”

Comfort

Another key area where ground source heat pumps make sense for consumers is in the arena of general well-being. From thermal comfort, to neighborhood aesthetics, to noise pollution, GSHPs solve problems for homeowners and communities alike! For areas concerned with resale value, GSHPs eliminate the need for rooftop HVAC systems, which can be an eyesore. This also returns valuable rooftop space for other purposes. Similarly, with no outside condensing units, there is no concern about noise outside the

[3] ORNL (2008) “Geothermal (Ground-Source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers”

home. Indoors, a two-speed GHP system is so quiet that users often do not even realize it is operating! In new construction, GSHP hardware requires less space than that needed by a conventional HVAC system, so that equipment rooms scale down, freeing space for more productive uses. GSHP systems also provide excellent "zone" space conditioning, allowing different parts of the home to be heated, or cooled, to different temperatures.

Market Share: barriers to growth

Given all of the benefits outlined above, there is a society-wide good to seeing that market share grow, in terms of environmental mitigation, quality of life, and economic growth. However, key barriers to rapid growth of industry remain. Richard Soper, former President of Bosch Thermotechnology Corporation, told us in an interview that, depending on which calculation method one uses, the market share for ground source heat pumps in the United States are between 1-2%, or about 50,000 units per year. Abigail Daken told us, “my understanding is that residential sales are flat, commercial sales are steady.”

High first costs for consumers

Estimates by two installers of ground-source heat pumps from Maine, Jeff Gagnon and Jim Godbout from Green Architects’ Lounge series on the Green Building Alliance website, Gagnon estimated the cost of a residential GSHP system (including the cost of a drilled well) at $30,000 to $42,000, while Godbout gave an estimate of $40,000 to $50,000. The initial investment for a GSHP system is greater than that of a conventional system. However, when you consider the operating costs of a geothermal heating, cooling, and water heating system, energy savings can offset the initial difference in purchase price.

Limitations of GSHP installation infrastructure

Some barriers to installation exist at the state levels, due to particular jurisdictional assignment of authority over such aspects as drilling and water oversight as in California. In other places, geology can impose constraints, such as in Tennessee, which has three distinct geological regions. Space constraints exist in many urban areas, where denser building precludes the deployment of horizontal ground loops, which are less expensive because they do not require extensive drilling. Horizontal installations are simpler, requiring lower-cost equipment. Where land is limited or regional soil conditions include extensive hard rock, a vertical installation may be the only available choice. Vertical installations cost more due to the added expense of drilling over trenching, but because the heat exchanger is buried deeper, vertical systems are usually more efficient. The GSHP industry is mature and can scale up quickly – but market weakness is due to the fact that –unlike other utility infrastructure types – building owners must pay for the external (ground) portion of GHP system. If you discount having to pay for external infrastructure, the indoor component is roughly same cost as conventional space conditioning system.

Solutions

Policy Asks

Congress and the Federal government have repeatedly taken steps to encourage the deployment of geothermal. Congress granted the authority for U.S. Department of Agriculture to provide long-term financing via the Rural Utilities Service to renewable energy companies (RECs) nationwide to provide ground source heat pump infrastructure to residential and commercial customers.

> ***"The Energy Efficiency and Conservation Loan Program allows USDA Rural Utilities Service (RUS) borrowers to implement energy efficiency upgrades for consumers through the use of loans for energy audits and energy efficiency upgrades, including weatherization, HVAC improvements, high efficiency lighting and conversions to more efficient or renewable energy sources, such as consumer-scale solar power and ground source heat pumps."***

Similarly, Tribal entities are eligible for grants and loans under the U.S. Department of Energy's Tribal Energy Program in order, "to evaluate and develop their renewable energy resources and reduce their energy consumption through efficiency and weatherization." **Encouraging the market growth of geothermal is clearly within the strategic oversight of Congress and compatible with other mission areas of the Federal Government.**

We believe that it is important to **continue the 30% investment tax credit (ITC) for ground source heat pumps** (and other renewable energy technologies) that was enacted in the Emergency Economic Stabilization Act of 2008. While the 30% investment tax credit served as a temporary accelerator specifically for the residential sector, the economic downturn the Emergency Economic Stabilization Act was intended to ameliorate persisted for longer than expected, and has had an impact on market growth in this sector. Manufacturers of geothermal technology are continuing to pursue efforts to reduce costs, offer alternative financing options, and leverage new approaches to ground loop installations – i.e. as utility owned assets. However, significant market barriers still exist, as discussed above.

Currently, the incentive is available for units placed in service from January 1, 2008 until December 31, 2016. We recommend that policymakers consider another short-term extension to give the renewable energy industry (e.g., solar, wind, geo) additional time to reach grid parity in key electricity markets. **We recommend extending this tax credit until September 2021.** Similarly, an investment tax credit of 10% of the installed cost is available for commercial buyers through 2016, which we should also be extended through September 2021.

Finally, ground source heat pumps are an important contributor to buildings seeking Zero Net Energy (ZNE) status. Executive Order (EO) 13514, "Federal Leadership in Environmental, Energy, and Economic Performance," was signed by President Obama on 5 October 2009. This executive order requires that all new federal buildings, starting in 2020, must be designed to achieve "zero net energy" by 2030. **We respectfully request that the U.S. Department of Energy be directed to provide a leadership role in**

establishing a voluntary ZNE framework—based on existing standards, guidelines, and practices—to facilitate ZNE as the norm for building design and construction. This would provide the building industry and consumers with an accepted set of market definitions, nomenclature, metrics, and implementation guidelines needed to achieve economies of scale and meet the demand and expectations for these high-performance buildings.

Research Funding Asks

Money is needed for basic research initiatives to advance this technology. This includes the following areas:

> **Heat exchangers**: Among areas that could benefit include funding directed at developing a lower cost ground heat exchanger, one that can be easily installed and reduce costs.
>
> **Payback periods:** Research shows that because the current building trend is towards reducing the need for heating and cooling with efficient building envelopes, and decreased internal loads, it is more difficult to calculate a reasonable payback period, especially for residential installations.
>
> **Post-installation evaluations**: Many residential energy experts — including Marc Rosenbaum, Andy Shapiro, and Henry Gifford — have underscored the lack of performance data on *installed* residential GSHP systems.
>
> **New and improved tools**: We also have a need to, "design tools (maps, databases, assessments) which can then reduce cost of installing the system, "according to Xiaobing Liu, researcher at Oak Ridge National Laboratory.

According to Liu, "[We see] very similar barriers with solar & wind; but those technologies are more successful because they can easily monetize/account for the future electricity savings so it makes financing options more available, it is easier to create a business plan, and they have made a better case for investing in R&D. At this point we still do not know with certainty how much money and energy is saved. Also, we do not even have a method to confirm/create such calculations."

Future Direction / Long-Term Focus

Ground source heat pumps, in wider deployment across the country, have the potential to reduce United States carbon emissions on a large scale, reduce Federal spending on energy, aid compliance with future air regulations such as the Clean Power Plan, and support community resiliency-building efforts. At the same time, they are attractive, effective in a variety of settings, and have lower maintenance costs for operators. In addition to the acknowledged benefits outlined in this white paper, research also remains to be done on whether the installation of GSHPs can empirically improve indoor air quality, contribute to better learning outcomes, and potentially reduce heat island effect in cities. Ground source heat pumps will have a vital role to play in achieving United States energy goals in the next decades.

Acknowledgements

This research was supported by Bosch North America.

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