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The transformative potential of geothermal heating in the U.S. energy market: A regional study of New York and Pennsylvania

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HIGHLIGHTS

- EGS district heating potential evaluated for 2894 towns in New York and Pennsylvania.
- Supply curves developed using estimated levelized cost of heat (LCOH) for each town.
- Geothermal district heating has cost-saving potential in NY, PA and the US.
- Initial candidate communities, R&D targets, and deployment strategies identified.

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ABSTRACT

Enhanced Geothermal Systems (EGS) could supply a significant fraction of the low-temperature (<125 °C) thermal energy used in the United States through Geothermal District Heating (GDH). In this study we develop a regional model to evaluate the potential for EGS district heating in the states of New York and Pennsylvania by simulating an EGS district heating network at each population center within the study region and estimating the levelized cost of heat (LCOH) from GDH for each community. LCOHs were then compiled into a supply curve from which several conclusions could be drawn.

Our evaluation revealed that EGS district heating has the potential to supply cost-effective energy for space and water heating in several New York and Pennsylvania communities in the near future. To realize wider deployment, modest improvements in EGS technology, escalation of natural gas prices, and/or government incentives will likely be required to enable GDH to compete with other heating alternatives today. EGS reservoir flow rates, drilling costs, system lifetimes, and fluid return temperatures have significant effects on the LCOH of GDH and thus will provide the highest return on R&D investment, while creative implementation strategies can help EGS district heating overcome initial cost barriers that exist today.

1. Introduction

As the world progresses into the twenty-first century the importance of considering the political, economic and environmental implications of a secure and sustainable energy supply has become fully apparent. While debate rages in the U.S. about the exact nature and extent of our energy concerns, most will agree that a "business as usual" approach is not in the best long-term interest of the United States for a range of economic, geopolitical, and environmental criteria.

Although geothermal resources have a long history of utilization as a global energy source, their potential, particularly in the U.S., has often been undervalued and misunderstood. It is within this context that we sought to evaluate the potential of using geothermal heat directly, as a source of heat itself rather than electricity. Demand for relatively low-temperature heat for space heating, water heating, and other thermally-driven processes is significant in the United States. Annual demand for thermal energy utilized below 125 °C represents about 25 exajoules (1 EJ$=10^{18}$ J), or 25% of the total primary energy consumed in the country (Fox et al., 2011; Tester, 2011)—demand which is predominantly met by

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burning natural gas or oil. Using geothermal energy directly for low temperature heat provides an opportunity for re-imagining the way energy is supplied and used in this country in a way that could offset a significant fraction of gas and oil consumption and lower our carbon footprint.

Like other renewable energy options, geothermal has been frequently viewed as a long-term option—one that may eventually play a significant role but that currently lacks regional availability or the favorable economics required to make it a serious contender. Additionally, many believe that only the type of high-grade hydrothermal resources characteristic of the Western U.S. are viable for development. However, if Enhanced Geothermal System (EGS) technology is successful it would enable us to extract geothermal heat virtually anywhere in the U.S.—particularly closer to major load centers—from lower grade geothermal resources that lack one or more of the key characteristics found in natural high-grade hydrothermal systems. That heat could be used in direct-use and combined heat and power (i.e. co-gen) applications to help supplant a portion of our national heating demand and reduce consumption of natural gas and other fossil-derived heating fuels.

Construction of new geothermal district heating (GDH) systems in America's communities will require significant long-term investment in infrastructure and the political will of our local and national leaders to sustain the effort for long enough to realize its net economic benefits—especially when faced with less costly short-term alternatives such as low-cost natural gas. However, one could argue that the time to invest in our future is now, given that the infrastructure in many American cities and towns is old and needs to be replaced if the U.S. is to remain globally competitive. With the recovery of the U.S. economy continuing its sluggish pace, transformational infrastructure changes that prepare our communities for the twenty-first century may be precisely what is needed to reaffirm the U.S. position as a global leader driving change rather than responding to it. Geothermal district heating could be a crucial part of that renewal—one that we should not overlook.

To illustrate the potential impact of geothermal resource use for district heating in the U.S., a regional study was carried out, using New York and Pennsylvania as a representative region, by evaluating the suitability of GDH in each community in the two states. The estimated cost of installing a geothermal district heating system in those communities was used to develop a series of supply curves for projecting the future potential of GDH under a range of economic and regulatory conditions. Readers must be warned, however, that the work here in no way represents a *prediction* of what the future holds—rather it presents a vision of what the future *could be if* the U.S. implements and sustains a focused strategy to develop EGS technology and deploy geothermal district heating as it updates its infrastructure on a national scale.

1.1. The thermal energy spectrum

During the last decade the United States' total energy consumption has fluctuated between just under 95 to just over 100 quadrillion BTU's ("quads"), or 100–105 exajoules (EJ), since 2000—accounting for 20–25% of the world's total annual consumption (EIA, 2001). Of this primary energy input, *more than half of it is wasted* or otherwise not utilized in today's energy generation, transmission and delivery framework (LLNL, 2012). Two main reasons for this are (1) the inherent thermodynamic limitations associated with burning fossil fuels to generate electricity and (2) the widespread mismatch of energy sources with appropriate end-uses.

Most state-of-the-art gas-fired, combined cycle thermal power plants have a maximum thermal-to-electric efficiency of around 60%—that is they can convert 60% of the heat energy produced by fuel combustion into usable electricity (Tester et al., 2012). Co-gen plants can increase this efficiency by making use of the rejected heat produced during fuel-to-electricity conversion for space heating or industrial processes, but even these systems "waste" some heat. Further losses occur during the electricity transmission process—on average around 10% for the U.S. transmission and distribution infrastructure. In the transportation sector, automobile and other vehicle engines have much lower efficiencies than power plants for converting thermal energy from fuel combustion into usable mechanical drive (typically around 30%).

The other cause of wasted energy is a result of the widespread mismatch of temperatures at which combustion-based energy sources supply heat with the temperatures required for many end-use applications. Fox et al. (2011) analyzed the "thermal spectrum" of energy use in the United States over the last 40 years (Fig. 1) and determined that a large portion of our primary energy is used to power processes that can be driven by heat energy at relatively low temperatures—*one-third of our total energy is used for processes that require temperatures less than* 260 °C. Geothermal systems operating today produce fluids with temperatures ranging from about 75 °C to 300 °C, which would be ideal for meeting these direct use needs.

For example, space and water heating, which account for roughly 15% of total U.S. energy consumption (when electrical losses are included), require relatively low supply temperatures of only 40–60 °C. Yet in the United States this heat is still predominantly provided by fossil fuel combustion. Fossil fuels, capable of burning at temperatures in excess of 2000 °C, have a significant work-producing potential, or exergy. Using such high-grade fuels to provide heat for low-temperature processes, we are using them in a highly inefficient manner—degrading their exergy without realizing any benefit from their high potential. In some cases, energy for space and water heating is provided by resistance heating using electricity, which results in even greater exergy and primary energy losses due to the inherent inefficiencies in the way electricity is produced and delivered.

Many common industrial processes—such as drying, evaporation, concentration, distillation and steam generation (used for thousands of processes)—also require relatively low temperatures yet are almost invariably fueled through fossil-fuel combustion or electricity. The U.S. manufacturing industry is responsible for the vast majority of this low-temperature process heat use, with estimates ranging from 4.7 to 6.8 quads annually, or more than 5% of total U.S. energy demand (Fox et al., 2011, DOE EERE 2012).

In order to improve our current energy transmission and distribution system we must embrace the concept that all energy

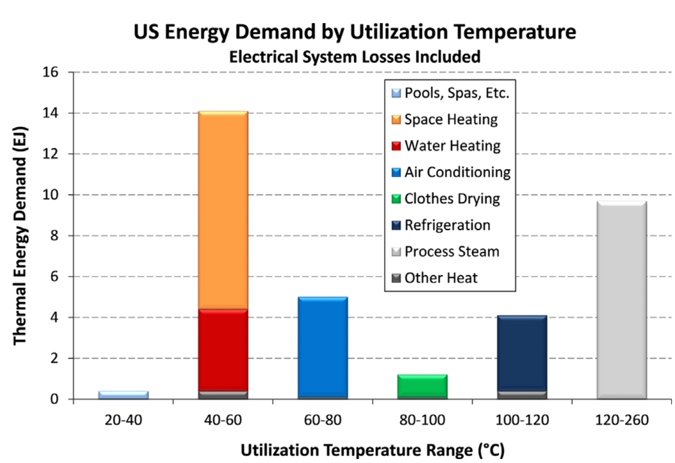

Fig. 1. Thermal spectrum of energy use in the United States. Adapted from Fox et al., 2011.