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Supply chain, gaps, EGS, geothermal, at-scale, drilling rigs, seismic crews, casing, tubing, liners

ABSTRACT
We present a preliminary analysis of the supply chain issues associated with rapid market penetration of EGS in U.S. Assuming that geothermal capacity will produce 10% of U.S. power needs in 2030, demand and supply of key supply chain segments—seismic exploration crews, drilling rigs, and casing and tubing—are estimated and analyzed. Drilling rigs are likely to be constrained in supply, while casing and tubing and seismic crews are unlikely to pose supply chain constraints.

Introduction
Engineered or Enhanced Geothermal Systems (EGS) have the potential to produce enormous volumes of electric power. However, industry will have to overcome a number of technology development and commercial deployment problems before this potential is realized. Toward understanding industry challenges and supporting EGS development and commercialization, we are studying the economics of EGS in a project funded by the U.S. Department of Energy. Our efforts include (1) developing an independent estimate of its costs, (2) understanding how those costs will change with market penetration, (3) assessing the industry’s innovativeness through patent analytics, (4) evaluating new process configurations, and (5) supporting student education and outreach. This paper is one outcome of Tasks 4 and 5.

Meaningful commercial deployment of any new technology is impossible without corresponding advances in its larger ecosystem. Supply chains are a critical component of the ecosystem and must expand and mature as new technologies gain market share. Moreover, as supply chains expand and gain scale to support a new technology, they can drive meaningful reductions in the cost of new technologies. Given this impact on overall economics, supply chain issues in EGS and the geothermal industry are of interest to us. Supply chains can be analyzed in both the short- and long-term. While constraints can occur in both timeframes, (e.g., the handful of geothermal rigs currently available cannot support dramatic growth;) our focus is long-term.

Capacity Growth Assumptions
We began our work by assuming the ambitious target of geothermal capacity accounting for 10% of U.S. power supply by 2030. Achieving this goal will require total geothermal plant capacity of almost 61 gigawatts (GW) by 2030, which will be a dramatic increase from the 3.1 GW of capacity currently installed in U.S. In principle, these projections could be achieved given that the “estimated potential based on conventional technology” is 74 GW. Further, project development has picked up with nearly 200 projects announced although not all of them have been confirmed. Finally, such rapid penetration was achieved by wind power in the recent past.

Even so, achieving these targets, in practice, will be very difficult and will depend on the convergence of a number of factors, e.g., technology development, resource availability, regulatory and policy support, and access to financing. In any case, we

![Figure 1. Growth in capacity assumed for geothermal to supply 10% of U.S. power in 2030.](image-url)
conduct this analysis assuming these capacity forecasts. Further, we assumed that hydrothermal resource capacity will grow at historical rates. Co-produced and geopressed resources will play a marginal role because of various reasons including technology challenges and limited commercial interest. Finally, we assume that the balance will be EGS, which will be the primary driver toward because achieving the assumed target capacity as shown in Figure 1.

**Value Chain Segmentation**

Expert elicitation and value chain analysis helped identify supply chain segments critical to industry growth and most likely to suffer constraints. A wide range of experts was consulted, including drilling, completions, and reservoir engineers, academic researchers, project developers, and business developers. These analyses resulted in the following conclusions:

1. **Exploration** – Although exploration includes a large suite of tools, equipment, and methods in addition to seismic analysis, no single component was considered different enough to be considered as a potential independent constraint. So our approach considers exploration as a single activity supported by “seismic crews” – an assumption that was validated by experts who suggested viewing exploration as a whole and not by individual categories of equipment, tools, or methodologies primarily due to the sporadic and irregular nature (e.g., relative to drilling and completions) of those activities. Figure 2 shows results from a high-level analysis confirming that there will be no dearth of seismic crews to support geothermal industry growth sufficient to supply 10% of U.S. power by 2030.

![Figure 2: Forecasted demand and supply of seismic crews for geothermal to supply 10% of U.S. power by 2030.](image)

2. **Drilling** – Drilling accounts for the largest share of costs and project time. So it was considered as a critical activity. Several experts mentioned long lead times, quality issues, and scarcity of resources for drilling equipment, in particular rigs and casing and tubing. However, in the case of other components such as drilling fluids and chemicals most experts felt that they were much more readily available and less costly. This expert feedback led us to focus our analysis on capital equipment associated with drilling with emphasis on drilling rigs and casing and tubing.

3. **Reservoir Stimulation** – A number of components, e.g., chemicals, proppants, fracture fluids, and downhole and pressure pumps, are critical to reservoir stimulation. Although most of these components are widely used by the oil and gas industry, their application to EGS is uncertain primarily due to the reservoir temperature and geochemistry. Obtaining a better understanding of these issues is the focus of a number of on-going research and development projects and it is premature to assess their likely evolution and impacts on the supply chain. As a result, we did not conduct an in-depth assessment of this supply chain segment.

4. **Power Plants** – Above-surface components, e.g., power plants, were considered mature from a technology and supply chain perspective – albeit some, e.g., turbine orders can be slow to fulfill – capable of meeting additional demand with incremental improvements. As a result, this segment of the value chain was not analyzed in this project.

Following the value chain segmentation, we evaluated each of the identified segments using a simple supply-demand model. We estimated demand for key components necessary to satisfy the capacity growth assumption. This was followed by estimating supply based on historical growth rates. Adjustments were then made to demand-supply estimates for a variety of factors, e.g., growth rates, potential innovation, market issues, and productivity improvements. Based on these, we identified gaps in demand and supply for key components. Highlights of results from these analyses are presented in the following sections.

**Drilling Rigs**

Drilling rigs are likely the most capital- and lead time-intensive resource utilized across all geothermal projects. In order to understand the supply chain issues of geothermal energy, it is important to understand supply and demand issues around rigs. Further analysis of the current industry supply and demand of rigs relevant to the geothermal drilling industry was performed during the course of this study.

These analyses suggest that in order to handle the required depths and to drill to depths of rock formations specific to EGS drilling, the rig must have a minimum of 2,000 horsepower (HP) to drill to depths of 3,000 - 10,000 meters. Further, based on current market segmentation, only 5% of the current rig supply meets these HP specifications. Since a significant portion of these 2,000+ HP rigs are currently being used for oil & gas drilling, the limited existing supply of suitable rigs indicates a definite constraint on
rig supply in the current marketplace. We assume that these trends are unlikely to change until there is a substantial change in demand for EGS drilling as indicated in Figure 3.

Casing and Tubing

Another category that was evaluated within drilling was Oil Country Tubular Goods, commonly referred to as OCTG. Tubular products span a wide range of global industries such as automotive, mechanical, construction, nuclear, refining, and drilling for oil, gas, and geothermal. Therefore, the global demand for tubular products steel remains relative high in comparison to needs in any particular segment as well other types of equipment used in drilling geothermal wells (see Figure 4).

Even so, new energy resources such as EGS will put a significant demand on the OCTG supply industry to find technological innovations that will address the high temperatures and other severe conditions notwithstanding the fact that pipe quality has continually increased and migrated toward higher API grades. Similarly, supply growth has exceeded demand growth in recent years due to new capacity from China as well as existing suppliers.\textsuperscript{vi}

![Figure 4. Forecast of demand and supply of tubulars and casing in million tons per year for geothermal to supply 10% of U.S. power in 2030.](image)

Conclusions

We have conducted a preliminary analysis of the supply chain issues associated with rapid market penetration of EGS in U.S. Assuming that geothermal capacity will produce 10% of U.S. power needs in 2030, demand and supply of key supply chain segments – seismic exploration crews, drilling rigs, and casing and tubing – are estimated and analyzed. Drilling rigs are likely to be constrained in supply, while casing and tubing and seismic crews are unlikely to pose supply chain constraints. In addition to refining our work on identifying key constraints, we are analyzing their implications on the industry and identifying policy options to support simultaneous development of the supply chain.

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References


\textsuperscript{iii} http://thinkgeoenergy.com/archives/7913.


