

## **NOTICE CONCERNING COPYRIGHT RESTRICTIONS**

This document may contain copyrighted materials. These materials have been made available for use in research, teaching, and private study, but may not be used for any commercial purpose. Users may not otherwise copy, reproduce, retransmit, distribute, publish, commercially exploit or otherwise transfer any material.

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted material.

Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specific conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement.

This institution reserves the right to refuse to accept a copying order if, in its judgment, fulfillment of the order would involve violation of copyright law.

## Assessing Innovation in Geothermal Energy Technologies: A Review of the Patent Landscape

Uday Turaga<sup>1</sup>, Vishakha Shembekar<sup>1</sup>, Anil Kumar Kacham<sup>2</sup>, Laxminarayana Vemula<sup>2</sup>,  
Balakrishna Uppala<sup>1</sup>, Harita Achanta<sup>1</sup>, and Uma Parameswaran<sup>2</sup>

<sup>1</sup>ADI Analytics LLC, Houston, Texas, USA

<sup>2</sup>Scitech Patent Art Services Inc, Hyderabad, India

[turaga@adi-analytics.com](mailto:turaga@adi-analytics.com)

### Keywords

*Geothermal energy, hydrothermal, enhanced geothermal systems, power generation, patent filings, patent family size, citations per patent, patent landscape*

### ABSTRACT

Geothermal energy is now enjoying a resurgence driven by a number of factors including heightened interest in renewable energy, increased project activity, and greater investments in research and development (R&D). Of these, innovation is a critical driver receiving greater attention thanks to an increase in both public and private funding. Patents play a key role in sustainable technology development and economic growth. Patent literature is highly sophisticated technology information freely available to the public. Hence, study of the patent filing activities across the globe, provides insights about major filers, company activities, technology trends, emerging areas, etc.

Patent searches were conducted covering patents filed in 71 countries. The search was conducted for the period January 1836 to December 2010 using a combination of keywords related to geothermal power generation and relevant International Patent Classification (IPC) codes. The search results have been screened to identify patent records describing hydrothermal (HT) and enhanced geothermal systems (EGS) technologies. The results have been appropriately categorized further and mapped to derive valuable insights.

### Introduction

Patent landscape is desirable for planning research in any area of pertinent technology which plays a key role in commercializing new researches and inventions. With this in mind, patent statistics are recognized as useful indicants of inventive activities and of technologies. Patents act as information resource as they contain detailed, public information about inventions that could be matched with other indicants which finally provide great insights.

The primary motivation for this paper is the desire to have a complete landscape of patenting activity in geothermal energy to uncover possibilities for technology development, cooperation, and transfer and to highlight areas in which further research might be carried out.

The entire report is described in 4 sections. Section 1 is the introduction to the patent landscaping of geothermal energies. Section 2 covers the complete methodology. Section 3 comprises of all major findings. Section 4 contains the conclusions.

### Methodology

The current study is based on a search conducted for patent filings since 1836. The requisite data was mined from Thomson Innovation using International Patent Classification (IPC) codes. This database covers patents and published applications of 41 global issuing authorities including United States, European Union, PCT (Patent Co-operation Treaty) applications and Asian countries like Japan, China, Taiwan, etc. The number of patent family records retrieved was 5,702. These records are categorized manually and set to mapping. The patent maps have been used to derive insights.

The major International Patent Classification (IPC) codes considered for the search of patents include F24J000308, F03G0004 (Devices for producing mechanical power from geothermal energy), E21B (Earth or Rock Drilling), C09K0008 (Compositions for drilling of boreholes or wells), G01V (Gravitational Measurements), G01N (Investigating or analyzing materials by determining their Chemical and Physical properties).

### Findings

#### *Patents Across the Value Chain*

Figure 1 depicts classification of the total number (5,702) of geothermal patents across the technology value chain. Exploration was the focus of 168 patents, 782 patents relate to Drilling, 337 patents relate to Completions, 241 patents relate to Reservoir Stimulation, 703 patents relate to Power Plant technologies and the remaining 3471 patents relate to patents focus on direct use of

Sections	Exploration (168)	Drilling (782)	Completions (337)	Reservoir Stimulation (241)	Power Plant (703)
Categories	<ul style="list-style-type: none"> <li>Seismic (62)</li> <li>Geochemical (23)</li> <li>Geophysical (19)</li> <li>Gravity (4)</li> <li>Magnetic (3)</li> <li>Electric (24)</li> <li>Subsurface temperature (24)</li> <li>Others (12)</li> </ul>	<ul style="list-style-type: none"> <li>Drilling equipment (268)</li> <li>Drilling process (138)</li> <li>Measurement tools (202)</li> <li>Compositions (174)</li> </ul>	<ul style="list-style-type: none"> <li>Well completion components (170)</li> <li>Well cementing (118)</li> <li>Sealing (49)</li> <li>Zonal isolation methods (2)</li> </ul>	<ul style="list-style-type: none"> <li>Fracturing (39)</li> <li>Treating (151)</li> <li>Telemetry (43)</li> <li>Well monitoring (6)</li> </ul>	<ul style="list-style-type: none"> <li>Hydrothermal power generation systems (501)</li> <li>Enhanced geothermal power generation systems (202)</li> </ul>

Figure 1. Patenting across the geothermal value chain.

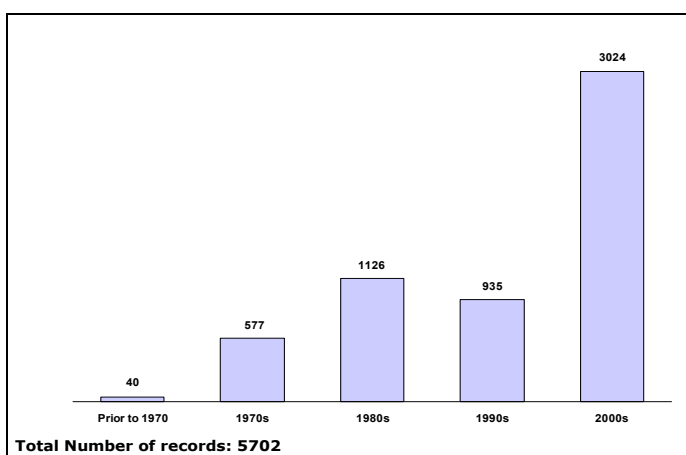


Figure 2. Patenting trends over time.

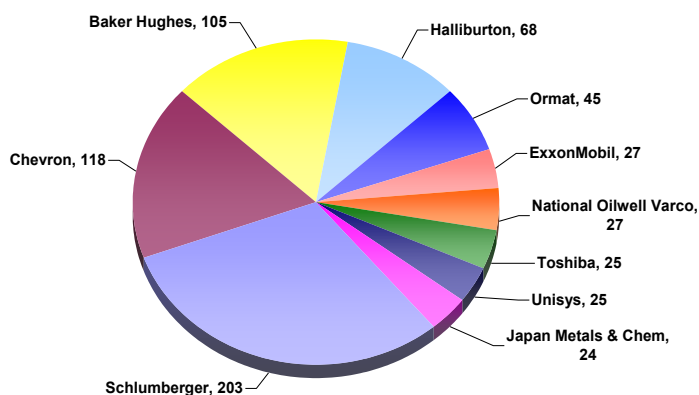


Figure 4. Patenting activity by company.

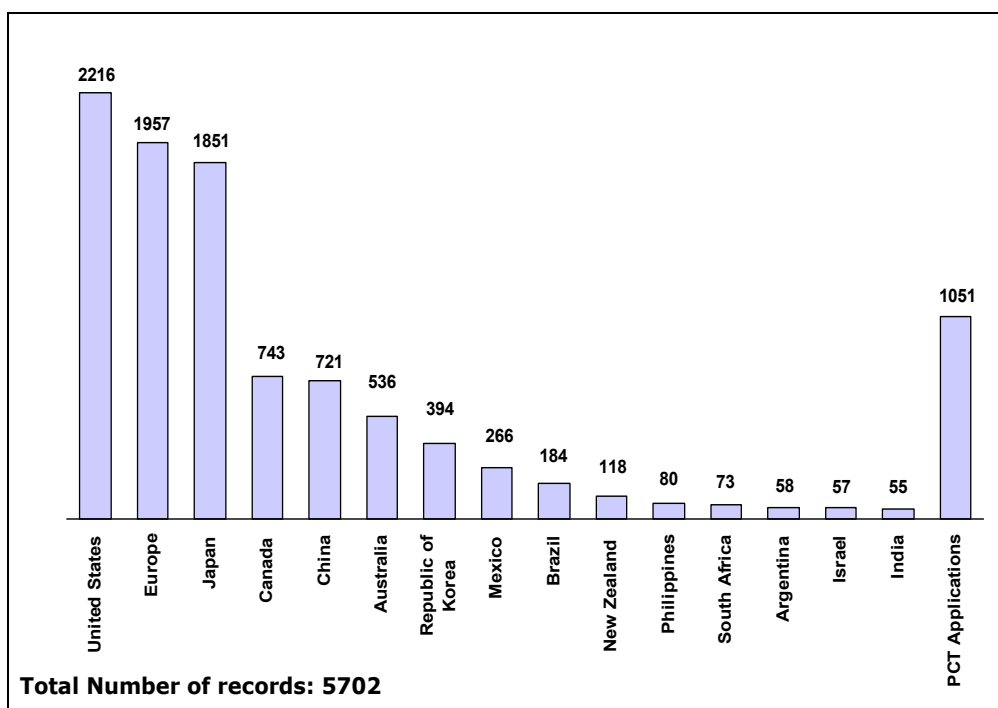


Figure 3. Trends by Country or Region.

geothermal heat. Each technical category was sub-categorized and been mapped.

### Patenting Over Time

It is evident from the patent filing activity of Figure 2 that research and development in the geothermal area has increased tremendously in 2000s after the dip in 1990s. It may be noted that many more applications could have been filed in the recent years but may not have been covered in this study as they are yet to be published. This trend reflects the strong government and industry interest in geothermal energy in recent years.

### Region-Wise Patenting Trends

Figure 3 shows the patents filed in different countries or region. Patents filed through European Patent Organization (EPO), and those filed directly in European countries are shown as “Europe.” As is evident from Figure 3, United States and Europe dominate the patent filings in the geothermal area of study. Asian countries such as Japan, China, Republic of Korea, Philippines and India have good number of patent filings.

### Patenting Activity by Assignees

We have also analyzed the patent data sets to assess major assignees. Figure 4 shows that the bulk of the patents are held by either companies or with strong businesses in geothermal energy, e.g., Ormat and Chevron, or exploration and production services, e.g., Schlumberger, Baker Hughes, and Halliburton.

### Technology Maturity

Basic science builds the foundations for technological innovation. Patent applications deriving references primarily from non-patent scientific and technical literature could be said to focus on basic science, while those with reference obtained mainly from patent documentation could be said to focus on applied technology.

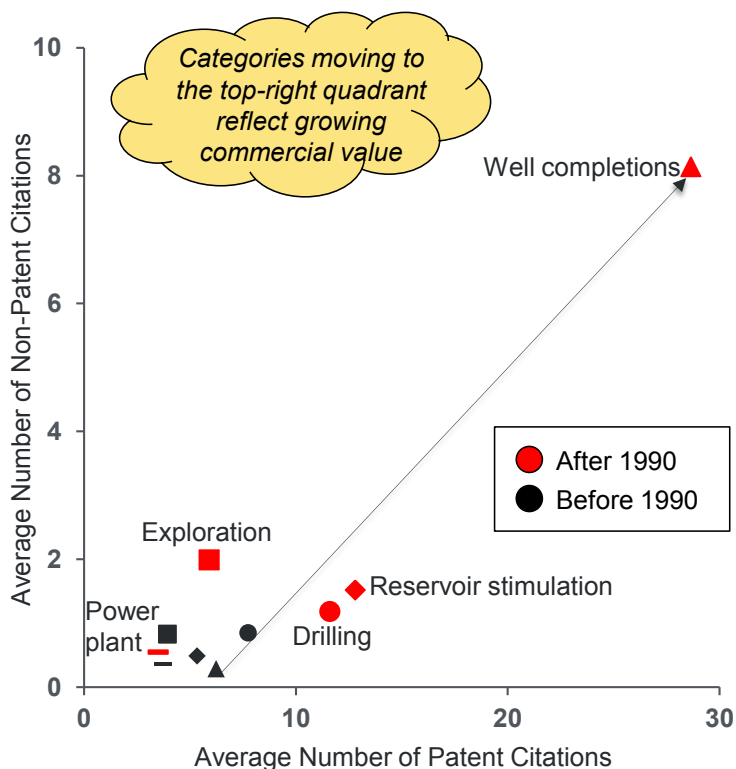


Figure 5. State of Technology.

Figure 5 shows how different parts of the geothermal energy value chain have developed in technology maturity over the past 20 years. It is clear that well completions technology has advanced significantly followed by reservoir stimulation, exploration, and drilling. Smaller advances have been made for power plant technology.

In other on-going analyses, the commercial value of a particular technology can be measured by evaluating the number of patent applications resulting from patent family size. How influential a patent application is within the patent system can be determined by examining the number of times that application is cited in subsequent patents, or citations per patent. An example of such analysis is provided in Figure 6, which shows the geographic spread of exploration-related patent portfolios (X-axis) versus their scientific and technological influence.

### Conclusions

This paper summarizing initial results from an on-going study focused on understanding patenting activity and trends in geothermal energy. Using public and private databases, we built detailed data sets of patents relating to various parts of the geothermal energy value chain. These data sets were analyzed using various techniques to understand patenting across the value chain, different regions, and key companies. Further, we have used data embedded in patents, e.g., citations and jurisdictions, to understand the commercial relevance, geographic spread, and technology influence of patent portfolios.

### Acknowledgement

This material is based upon work supported by the United States Department of Energy under Award Number DE-EE0002739.

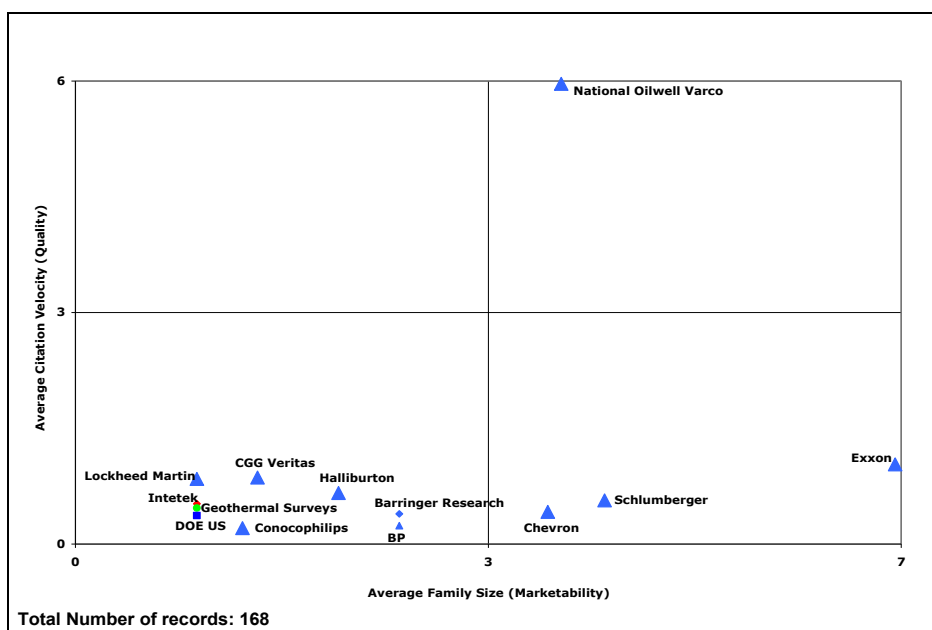


Figure 6. Patent portfolios' geographic spread vs. technology influence.

### Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

