# Assessing Innovation in Geothermal Energy Using Patent Quality Indicators

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***Keywords***

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## ABSTRACT

Study of patent literature helps in understanding technological developments, on-going research and emerging trends in the area of geothermal energy. This paper makes use of the various patent quality indicators to obtain insightful information on the technology development. Patent searches were conducted covering patents filed in 71 countries using a combination of keywords related to geothermal energy and appropriate International Patent Classification (IPC) codes over the entire period through 2010. The screening of the search results helped identify patent records describing different value chain segments in geothermal energy. Patent value indicators and analytics were used to obtain key insights on technology developments in geothermal energy.

## Introduction

Engineered or Enhanced Geothermal Systems (EGS) is an emerging technology and will likely require significant public and private funding for its development and commercialization. Since resources are typically limited, RD&D must be designed and conducted in economic, intelligent, and targeted ways. To this end, in-depth patent landscaping and analytics can be an important tool by establishing the state-of-the-art, reviewing technology evolution, identifying key players, and defining industry needs and/or critical gaps.

With these goals in mind, ADI Analytics LLC and Scitech Patent Art Services, Inc. have been conducting patent landscaping and analytics efforts to benefit a wide variety of stakeholders. Scientists and technologists can understand the current state to define future areas of R&D, policy makers can assess how their funding is helping development and evolution of technology, investors can identify leading companies and stakeholders, and project developers can identify new technologies to commercialize. This paper builds on our previous reports.[1]

Patent quality indicators such as originality, generality, technology cycle time, and citation velocity described in literature were applied in this study. The "patent trend change mining" (PTCM) approach, described by Shih et al.[2] and other papers,[3-5] uses these patent indicators in the association rule mining technique to study the changes in patent trends. The current paper applies patent indicators for identifying key technology areas through four quadrant charts. The definitions and significance of the indicators are as follows.

- Marketability (commercial value) is the average number of patent applications filed in various countries resulting from a specific patent application, or patent family size.
- Originality is the diversity of cited patents (backward citations) is a measure of the innovation value of a patent.
- Generality is the diversity of citing patents (forward citations) measures the scope of cross-field applications originating from a patent. It signifies the economic value of patents.
- Technology cycle time is the median age of the patents cited by a target patent and acts as a measure of technological progress.
- Citation velocity is the ratio of count of citing patents to count of years from date of publication of the patent. It reflects the technological significance of a patent.

## Methodology

Search strategies were developed based on literature survey as well as control patents identified during preliminary patent searches. The search strategy entailed Boolean search methodology which included a combination of keywords and their synonyms with relevant International Patent Classification (IPC) codes. The data covered granted patents and published applications from 71 countries including United States, European Union Asian

countries like Japan, China, Taiwan, etc, as well as PCT (Patent Cooperation Treaty) applications.

The major International Patent Classification (IPC) codes considered for the patent search 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) and G01N (Investigating or analyzing materials by determining their Chemical and Physical properties).

The search results were screened to identify patent records relevant to geothermal energy. The number of Derwent patent family records retrieved was nearly 5,500. The results were technically categorized according to their value chain (exploration, drilling, well completions, reservoir simulations, power plant). For each segment of the value chain, the patents were further analyzed using patent quality indicators such as citation velocity, patent family size, originality, generality and technology cycle time.

For each patent record, the values pertaining to citation velocity, originality, generality and technology cycle time were calculated using spreadsheet models. The parameters considered for calculating patent indicators are count of citing patents for the target patent (forward citations), count of cited patents (backward citations), publication date and IPC class codes for each cited and citing patents. Average values of these patent indicators were calculated for all major IPC codes in each of the value chain segments. These values were plotted on four quadrant charts to obtain insightful information on technology areas.

The patent quality indicators were calculated using following formulae.

Originality: $1 - \sum_{j \in S_B} B_j^2$

$B_j$ = $\frac{\text{Number of cited patents belonging to Class J}}{\text{Number of cited patents}}$

$S_B$ : The set of classes of cited patents

Generality: $1 - \sum_{j \in S_F} F_j^2$

$B_j$ = $\frac{\text{Number of citing patents belonging to Class J}}{\text{Number of citing patents}}$

$S_F$ : The set of classes of citing patents

Technology Cycle Time (TCT): The TCT of a target patent is the median age of the patents cited by the target patent.

Citation velocity: Ratio of count of citing patents to count of years from date of publication of the patent.

## Findings

Figure 1 is the plot of originality versus generality that depicts patent quality in terms of innovation and economic value. The IPC class codes considered for the plot are from all segments of geothermal value chain. It is observed that technologies on drilling and completions have high originality and generality values. This signifies that the patents under these classifications have high innovation and economic values. Within drilling, technologies such as drill bits with polycrystalline inserts, button type inserts and

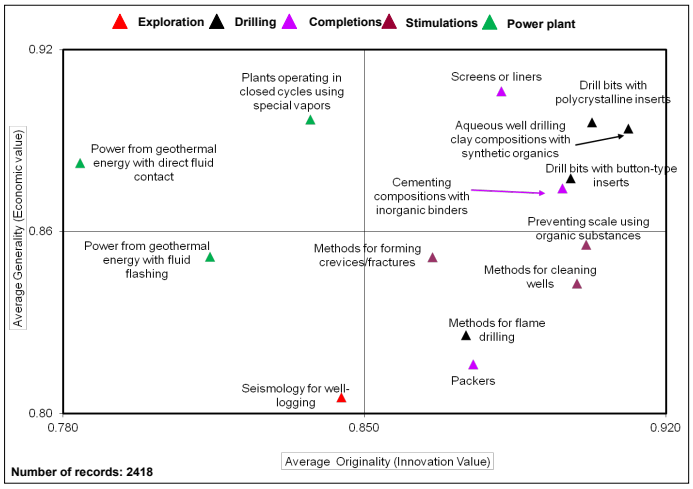


**Figure 1.** Geothermal value chain segments - originality vs. generality.

clay compositions with synthetic organics have high innovation as well as economic value when compared to all the technologies within the geothermal value chain.

Figure 2 shows the average values of technology cycle time and citation velocity of the technologies (based on number of patent records) across the value chain. As seen from the graph, technologies in the area of seismology for well logging are experiencing rapid progress. However, these technologies have less impact on the market which is evident from the low citation velocity. Similarly, technologies on scale prevention using organic substances have shorter technology cycle time and lower citation velocity. Although drill bit technologies on polycrystalline inserts and button-type inserts appear to have high impact on the market, their technology progress is moderate.

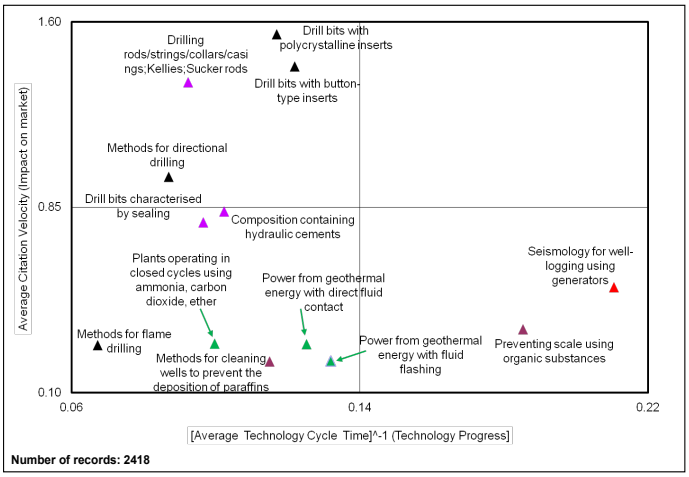


**Figure 2.** Geothermal value chain segments - technology cycle time vs. citation velocity.

Figure 3 depicts technology cycle time and citation velocity for exploration technologies. High citation velocity and rapid technological progress are observed in the area of seismology techniques used for well logging. Technologies on prospecting techniques through optical and electric methods seem to have slow technology progress and low impact on the market.

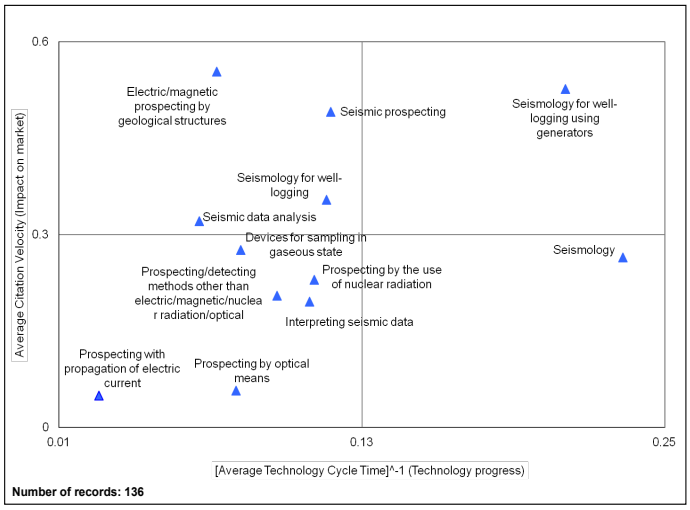


**Figure 3.** Exploration - technology cycle time vs. citation velocity.

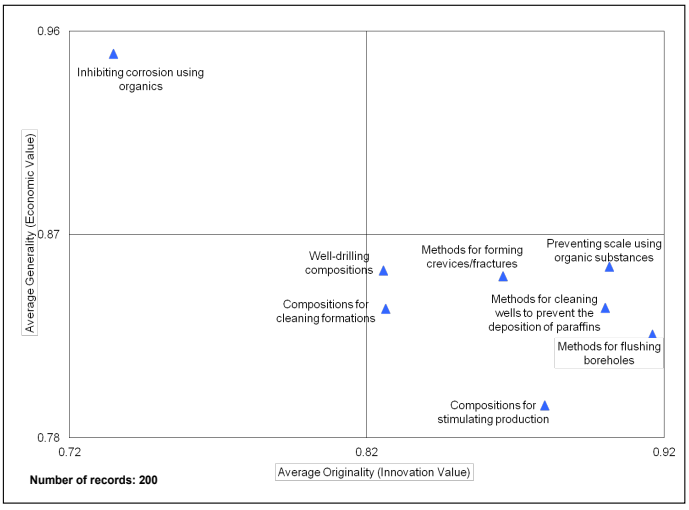


**Figure 6.** Reservoir stimulation - originality vs. generality.

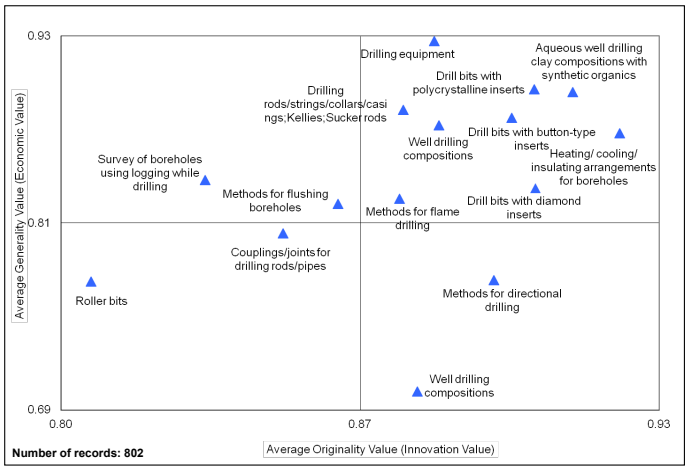


**Figure 4.** Drilling - originality vs. generality.

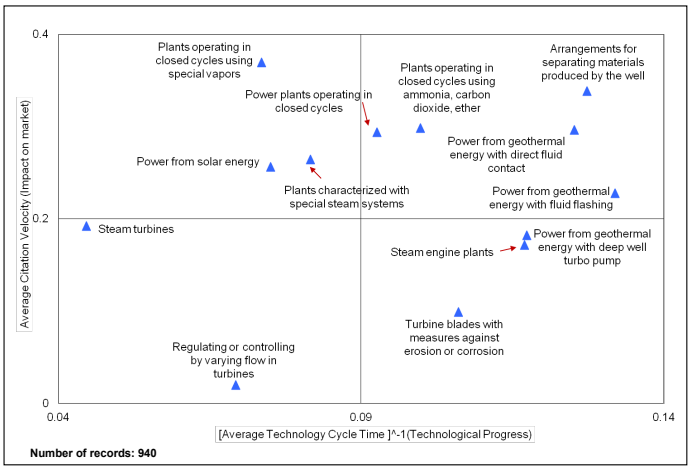


**Figure 7.** Power plant - technology cycle time vs. citation velocity.

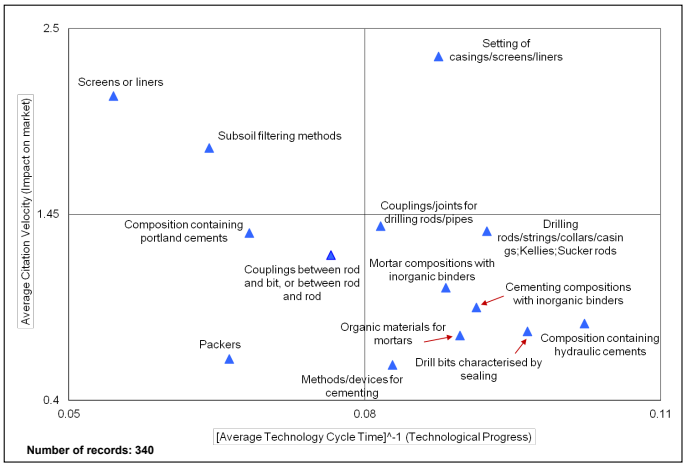


**Figure 5.** Well completions - technology cycle time vs. citation velocity.

Figure 4 is a plot of originality and generality for drilling technologies. Technologies related to drill bits with polycrystalline/ button-type inserts have high innovation values and economic values. Other key technologies with high originality and generality include drilling compositions, insulation arrangements, drilling equipment and flame drilling.

A plot of technology cycle time and citation velocity for completion technologies is shown in Figure 5. Compositions containing hydraulic cements/ with inorganic binders reveal faster technology progress but low impact on the market. Technologies on setting of casings, screens and liners depict accelerated technology progress with high impact on market.

Figure 6 shows a four quadrant chart prepared with originality on x-axis and generality on y-axis. Though methods for cleaning/ flushing wells and scale prevention have good innovation value, these technologies have less economic value. Corrosion inhibition methods using organics have high economic value but these technologies lack innovation value.

Figure 7 shows technology cycle time and citation velocity for power plant technologies. From the figure, it is observed that the technologies on separation of materials from the well, geothermal power through direct fluid contact/ fluid flashing show rapid technological progress and have high impact on market.

## Conclusions

1. Among all the value chain segments in geothermal, technologies in drilling and completions have high innovation and economic values. Technology progress is faster in the areas of seismology for well logging and scale prevention using organic substances.
2. Technologies related to drill bits with polycrystalline/ button-type inserts have high innovation values and economic values.
3. Technologies on setting of casings, screens and liners depict accelerated technology progress with high impact on market.
4. Corrosion inhibition methods using organics have high economic value but these technologies lack innovation value.
5. Technologies on separation of materials from the well and geothermal power through direct fluid contact/ fluid flashing show rapid technological progress and have high impact on market.

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