

GATES: A Geothermal Acceptance Tracking and Evaluation System Using Multi-Source Social Sensing

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Breakthrough energy technologies rarely fail in the reservoir; they fail in the community. Public acceptance of energy technologies plays a critical role in their successful implementation. Conventionally, researchers measure public acceptance after a site is chosen through time-consuming, costly surveys. Recent advances in social sensing, the use of web-harvested big data to understand human perceptions and behaviors, offer a promising avenue for rapidly and efficiently assessing public attention and acceptance. However, social sensing has not been widely applied as an acceptance instrument for energy technologies.

This study proposes GATES, a Geothermal Acceptance Tracking and Evaluation System using multi-source social sensing. GATES harmonizes three sources: Google Trends, geotagged U.S. X/Twitter posts, and Guardian articles. Rule-based filtering first removes automated seismic alerts, which account for 91 percent of naive place-name retrieval. Awareness is operationalized as relative search attention to geothermal energy compared with competing energy topics, whereas expressed acceptance is assessed from text through affective tone and stance, classified as support, opposition, or neutrality toward geothermal energy. Text then passes through two analytic layers. The lexical layer uses VADER to measure sentiment, Dunning's log-likelihood to identify distinctive vocabulary, and pointwise mutual information to construct term-association networks. The schema-constrained local large language model labels each document for relevance, stance, frame, and stated barrier at temperature zero with a fixed seed. This procedure reproduces 100 percent of relevance labels and 90 percent of stance labels across hardware platforms.

Results show that Google Trends placed geothermal searches at approximately one-ninth of heat-pump and one-fifth of solar searches. Search patterns varied seasonally and geographically: household terms peaked in February and tracked state heating degree days (Spearman's $\rho = 0.724$), whereas broader terms peaked in April, concentrated in warmer states, and aligned with the school calendar. Enhanced geothermal systems (EGS), engineered reservoirs designed to extract heat from hot rock with limited natural permeability, remained near the search floor. Among relevant X/Twitter posts, support increased from 25.0 to 32.1 percent (2021–2022), opposition remained near 12 percent, and climate framing rose from 42.7 to 51.5 percent; cost was the leading stated barrier (11 percent), versus seismicity (4 percent).

GATES provides a relatively low-cost, reproducible, and national-scale measure of geothermal-related attention and expressed stance. The workflow can extend to hydrogen hubs, carbon storage, and advanced nuclear energy.

Keywords: geothermal energy; public acceptance; social sensing; natural language processing; enhanced geothermal systems