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Building Technical and Human Capacity in Emerging Geothermal Countries: Introducing a U.S. Initiative

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ABSTRACT

Under a cooperative agreement with the University of Nevada, Reno, the U.S. Department of State's Bureau of Energy Resources launched the Geothermal Development Initiative (GEODE) in 2017 under its Power Sector Program, which aims to provide a wide range of technical and advisory support to create solvent, reliable, transparent, and sustainable power sectors in countries around the world. Geothermal energy is an emerging sector in many countries globally, and has the potential to contribute to stable, clean, and baseload renewable energy electricity generation. The goal of GEODE is to harness that potential by assisting countries with overcoming barriers to geothermal resource development, including supporting the use of new and emerging technologies for managing exploratory risk, as well as providing capacity-building for host governments to effectively manage resource and project development.

GEODE's objectives include: (1) increasing the capacity of foreign governments to develop their geothermal resources by building internal expertise to manage the unique technical, regulatory, financial, and environmental issues associated with geothermal resource development and to instill best practices to address those issues; and (2) deploying innovative methods to help identify and develop blind geothermal resources (i.e., an area of geothermal potential that shows no signs of geothermal activity at the surface). At the initiation of the project, several countries were reviewed and assessed for their suitability. A number of qualitative criteria were used for country evaluation, including considerations such as current geothermal resource potential, demonstrated government support for renewable energy development, a relatively greenfield geothermal power sector, and little donor involvement to date. From this process, several countries were identified as potential partners. Over the duration of the three-year project, capacity-building activities to support these countries may include: (1) the provision of customized, technical training on aspects of geothermal energy development (depending on the specific needs, priorities, and interests of each partner country); (2) collaborative projects involving developing geologically-appropriate geothermal play fairway approaches to assess geothermal potential; and (3) technical exchanges between the partner country and U.S. geothermal stakeholders. This paper will review key challenges facing developing geothermal sectors, and how the GEODE initiative is addressing them.

1. INTRODUCTION

Emerging markets in Latin America, the Caribbean, Europe, Africa, South Asia, Asia, and the Pacific hold significant geothermal resource potential and also face high growth in power demand. Overcoming the technical and financial barriers to developing geothermal resources will better position countries and regions to meet this increased demand. Estimates suggest that from a technical perspective, as many as 40 countries have the potential to develop sufficient geothermal energy resources to meet their entire electricity demand (Energy Policy Institute, 2011). Global geothermal potential has been estimated to be as high as 70-140 GWe (Bertani, 2009), and the International Energy Agency (IEA) estimates that installed geothermal capacity could reach 200 GWe by 2050, with 100 GWe from hydrothermal systems, and 100 GWe from engineered geothermal systems (EGS) (IEA, 2011).

Despite its unique advantage as a ubiquitous resource with steady supply that can maintain or enhance grid reliability, geothermal energy accounts for less than 0.5 percent of global power supply, with only ~15.9 GWe of installed generation capacity at present (Huttrer, 2020). Creating enabling environments for increased private sector investment in geothermal development globally is essential to meeting the substantial investment requirements in generation needed during the next 20 years. If global potential is realized, geothermal could contribute to as much as ~3.5 percent of the world's electricity generation.

Key challenges to the widespread uptake of geothermal energy include: 1) resource exploration risk, 2) high-upfront capital costs associated with drilling and resource development, 3) challenging regulatory and governance environments, and 4) social challenges. The GEODE Initiative was established by the U.S. Department of State's Bureau of Energy Resources in 2017 to address these challenges, by cooperating with host governments to increase understanding of the application and benefits of geothermal energy. This is done via capacity-building activities that aim to:

(1) improve the technical and geoscientific knowledge base needed to guide geothermal exploration and the development of conceptual models that reduce exploration risk;
(2) share information on best practices for developing supportive policies and/or project mechanisms that encourage investment into geothermal development; and
(3) reduce institutional silos and encourage intra-governmental cooperation and knowledge sharing.

Capacity-building efforts through the GEODE Initiative are not one-time efforts to generate short-term gains, but rather strategies to support ongoing improvement and progress towards creating a sustainable, functional geothermal resource sector, as well as the socialization of international best practices and norms in geothermal exploration and development. The ultimate goal is to empower governments to understand their resources sufficiently in order to manage them responsibly for the benefit of their people.

2. GENERAL CHALLENGES FACING GEOTHERMAL SECTORS

Many factors contribute to a lack of investor confidence in geothermal energy, and through this, an underdeveloped geothermal sector in a given country. Some of these factors, like resource risk, are specific to the technology, and are universally present no matter where development occurs. Other factors, like political uncertainty or social license to operate, may be unique factors present in countries with emergent resource sectors. Approaches to address these challenges may vary, but all are equally important to consider.

2.1 Resource risk

The geological exploration risk (resource risk) for geothermal resources presents a challenge to developers and investors alike. Geothermal resources are each unique, and the presence of geothermal systems reflects complex interactions between local geology, regional tectonics, subsurface fluids and their chemical constituents, and the thermal regime. These interactions influence the two key risk components of a geothermal resource – temperature and permeability (or productivity). Other risk parameters include depth of the resource (which affects the drilling costs), fluid chemistry (which affects the corrosion or scaling potential), and reservoir size (volume).

Locating and delineating a geothermal resource requires a systematic exploration program to effectively reduce the geologic uncertainty, improve the chances of success, and ensure that funding is spent in the most appropriate manner (i.e., new data are not collected unnecessarily in areas that are not prospective, and/or not duplicating previous data collection efforts). Following best practices in geothermal exploration will ensure that all of the resource risk elements are considered, that any relevant and material data is organized and easily searchable, and that their uncertainty can be appropriately estimated to present to potential project investors. (IGA, 2014).

2.2 Financial burden of upfront capital requirements

Upfront capital requirements are a major barrier to geothermal resource development. Geothermal exploration and development is risky and requires upfront investment in drilling wells (up to 40 percent of total project costs) to define and prove the resource, long before a power plant is built and electricity is sold to market. In the early stages of a geothermal project, it is still possible that resource exploration will determine that no commercial resource exists, and the initial investment is lost. Estimates for the costs of a typical exploration campaign involving a test drilling program of three to five geothermal wells could range from $20-$30 million (Sanyal et al., 2012). If the test drilling results are promising, further investment in commercial-scale production wells is required, which can be an additional $20-120 million depending on the project. After this point, surface equipment and a power plant are needed, which can cost the same again. Funding for initial exploration studies and test-drilling can come from private or public-sector sources, although raising such risk capital can be particularly challenging for private-sector geothermal developers since drilling is typically funded with owner equity that is lost in the case of a unsuccessful exploration program (Sanyal et al., 2012). The commitment of the public sector, including the government, international donors, and financial institutions, is an essential element of success in mobilizing capital (Gehringer and Loksha, 2012). Sole reliance on private capital for geothermal field development is rare, even in developed countries.

2.3 Regulatory and permitting challenges

Land status, and inefficiencies in state and federal regulatory processes, can present challenges to geothermal explorers and developers by prolonging the development timeline. In the United States, projects can take eight to ten years to go from the initial exploration phase to commercial electricity production (Young et al., 2019). This long timeframe is partly a product of the necessary resource evaluation and development, but can also reflect delays in project permitting at the various stages of project development, as well as in securing project financing. Depending on land status and location, permits may be required from multiple state and federal agencies, which may not be working together in a streamlined manner, and the complex time-consuming nature of this permitting process can delay project progress and affect investment (Young et al., 2019). Multiple or repeated permitting phases can also delay project development. For example, in the United States, multiple environmental reviews may be conducted during the development of a project, as required by the National Environmental Policy Act (NEPA) (Young et al., 2014). Although there are different levels of NEPA review that may be required depending on the nature of the proposed activity, these serve to delay project development. In the case of the United States, streamlining such permitting processes was identified as a future federal priority in the recently released GeoVision report (DOE, 2019).

2.4 Social license to operate

Although geothermal energy is one of the cleanest, lowest-impact renewable energy sources available, it can still face challenges with community and socio-political acceptance. In some locations, geothermal resources are culturally sensitive or considered sacred (e.g., Puna, Hawai'i (Stickler, 2013); Japan (Kubota, 2015), and Java, Indonesia (Darmawan, 2017)), so communities may oppose geothermal development. Overcoming public acceptance challenges requires a clear communication plan with local and regional stakeholders far in advance of any resource development, invited involvement of community or tribal leaders in the decision-making process, as well as targeted strategies to demonstrate economic, social, environmental, and quality-of-life benefits to the local community (Wallquist and Holenstein, 2015). Socio-politically, geothermal energy can also experience challenges due to a relative lack of familiarity compared to other renewable energy sources such as solar, wind, or hydro (Young et al., 2019). This can have follow-on effects, such as lack of internal advocates for geothermal energy in local, state, and federal government agencies, and even basic acknowledgement that geothermal energy is an option.

3. ADDDITIONAL CHALLENGES FACED IN EMERGENT GEOTHERMAL SECTORS INTERNATIONALLY

In addition to the challenges discussed in Section 2.0, emergent geothermal sectors in developing countries can face additional challenges that may further inhibit or hinder sector establishment and growth. These are outlined as follows.

3.1 Availability of appropriate geoscience datasets to support exploration

Assessing the resource potential of a geothermal prospect usually starts with a comprehensive literature review, to identify and capture all existing geoscientific, environmental, and land-use information for the area. Accessing existing information can support the development of an initial conceptual model, which is used to prioritize new data acquisition during the exploration phase (both type of data and location of new surveys) and ideally, reduce duplicated efforts (and costs). In some instances, there may be little pre-existing data to uncover during this literature review phase, however, much of the time there are data but they are not accessible (e.g., held privately), or discoverable (not included in any online data inventories or reports, so they cannot be searched).

Governments have a central role to play in reducing early-stage exploration risk and encouraging investment via data custodianship. In geoscience agencies (e.g., national or state geological survey organizations), this role usually includes conducting research into the characteristics of geothermal systems in country, collecting and interpreting geoscience data for known resources, and finally (not always), making those data available to the public (free or for purchase). Such 'pre-competitive' information is a valuable resource for prospective investors and resource developers, having reduced some initial exploration risk and helping to define potential resource opportunities and targets. However, systematic capture and dissemination of such data does not always occur in countries with emergent geothermal sectors. This can be due to financial reasons (i.e., lack of funding to do it), bureaucratic reasons (e.g., lack of strategic direction for the agency), perceived national security reasons if data are shared, or lack of awareness of the long-term benefits of such a program (i.e., return on investment).

Ideally, existing, pre-competitive data and information are stored in online inventories and database systems (e.g., hosted by government agencies), and there is a mechanism to request, download, or purchase such data. In countries where investment in energy resource projects is dominated by foreign investors, online data accessibility and discoverability is even more important. Many countries with emergent geothermal sectors do not have sufficient data systems in place, which can hinder exploration progress and investment interest. Even in developed countries with mature resource sectors, streamlined data management systems to support public and industry access are extremely difficult to do well.

3.2 Political uncertainty

Economic growth and political stability are correlated and interwoven. Prospective geothermal developers and investors are unlikely to make the substantial upfront investment necessary if there is concern about their ability to later recoup their investment by building a geothermal power plant and selling electricity. This issue is compounded because of the long timeframes associated with geothermal energy production (from beginning to end, full-size projects can take between five and ten years to complete (Gehringer and Loksha, 2012)). A project could very well, and often does, span political administrations within a country. What was once a priority for one government may not be so for another. Even in countries with stable governments and political transitions, this can still be an issue. While geothermal energy generally enjoys wide support as a baseload renewable and avoids some of the controversies associated with conventional hydrocarbons, political uncertainty is still an important issue to consider as it is often cited as one of the most important issues affecting investment in emerging renewable sectors, which includes geothermal in countries with developing sectors and no history of successful development (Meijer, 2007).

3.3 Lack of appropriate governance

Capacity constraints in public institutions often constitute a deterrent to private investment in geothermal energy development. Although energy resources provide countries tremendous opportunities for economic growth, they are notably difficult for governments to manage responsibly, inclusively, and transparently. The unique technical and economic factors associated with energy development make energy sectors particularly prone to mismanagement. Poor energy sector governance can lead to less private sector interest, creating a cycle of underdevelopment from which it is difficult to escape. It is therefore important that the public institutions responsible for planning and managing the development of the sector and for engaging private developers are capable, predictable, well-defined, and seen as credible by investors (Gehringer and Loksha, 2012). Governments need the capacity to manage their geothermal resources responsibly. Improving the capacity of governments to understand the technical, financial, legal/regulatory, environmental, and social aspects of responsible sector management helps empower them to achieve the maximum benefit for their people.

3.4 Intra-governmental cooperation and institutional silos

Depending on the country, organizations that are responsible for encouraging geothermal resource development in a country (e.g., geoscience agencies, regulatory agencies, state governments, federal offices/departments, etc.) may not always cooperate or work together in a streamlined manner. Insufficient communication or perceived competition (e.g., 'turf-wars') can hinder progress. This is not uncommon, even in developed countries, and often arises from an approach to regulation and governance that is developed over decades. For example, institutions originally responsible for oil and gas development may later be given authority to manage geothermal exploration given the energy form's subsurface nature, while a separate entity at the federal level may later be tasked with developing a power purchase agreement (PPA), and a separate state or provincial entity may regulate the ability of developers to actually drill. If these entities are not working cohesively and harmonizing their approaches, this can hinder development and prolong the geothermal development timeline.

Additionally, between and within geoscience organizations, there can be institutional silos that may result from geographic separation of an agency or organization (e.g., with regional offices), perceived competition, or simply bureaucratic reasons. These serve to limit the interaction and effective knowledge exchange between these scientists working on related resource projects, limit the sharing of data and information, and delay the development of strategic initiatives to do so. This lack of coordination may result in duplicated efforts, data that are not captured and stored appropriately or in a timely manner, and lost potential benefits of a 'pre-competitive' data sharing-approach to attract investors. Given the multi-disciplinary nature of geothermal energy research, involvement and coordination by the entire spectrum of geoscience and engineering entities involved in managing a country's resource base is crucial to success.

4 CAPACITY-BUILDING ACTIVITIES SUPPORTED BY THE GEODE INITIATIVE

4.1 Best-practices and innovative exploration approaches to reduce resource risk

As geothermal sectors have developed internationally over the last century, explorers have learned key lessons about the most effective approaches to use to reduce the resource risk and successfully target a geothermal system. This involves systematic data collection from regional and local scales, including the review and compilation of existing data prior to initiating a focused exploration program. An integral aspect of this process is building conceptual models of the geothermal system, in terms of subsurface temperature distribution, fluid flow patterns, likely permeability distribution, and resource size. The conceptual model requires constant updating and revising as new data or information become available and helps to inform the next steps of the exploration program (e.g., see IGA, 2014). Historically, many geothermal resources were discovered via obvious surface manifestations (e.g., hot springs, fumaroles, or mud pots), which provided the initial indication of a resource prospect beneath. However, many tectonic settings and environments (e.g., the Great Basin region of the western U.S., and the Puna in Chile and north-west Argentina) host blind geothermal systems that have no (or limited) surface thermal manifestations. Key challenges for the exploration and development of these blind hydrothermal systems include locating/predicting areas that have geothermal potential, well targeting, and identifying sites within an area that have sufficiently high temperatures and permeability to support commercial flow rates of hot geothermal fluids in a production well.

New approaches are now being developed to help delineate potential blind geothermal systems and evaluate geothermal potential on a regional scale, including specifically the geothermal play Fairway Analysis (PFA) methodology. Play Fairway Analysis combines a geostatistical workflow with available geoscientific datasets (geology, geophysical, geodetic, geochemical, etc.) with the aim of reducing the exploration risk for blind geothermal resources (e.g., Faulds et al., 2016, 2019). Application of geostatistical data integration approaches, combined with expert-driven development of conceptual resource occurrence models to guide the dataset weighting schemes used in a workflow, enables the generation of predictive maps of geothermal resource potential. These map products can be used to rank prospective areas (in terms of overall favorability), guide future data acquisition requirements to reduce geologic uncertainty, and also to site test wells for resource confirmation.

Through GEODE, geothermal scientists are being trained in this approach, as well as in the supporting components that are required to successfully implement a PFA workflow (e.g., data management, compilation, developing long-term data acquisition priorities to support emergent resource sectors, geostatistical training for dataset preparation and interrogation, and ARC-GIS workflow development). Three partner countries (Argentina, Peru and Colombia) have been engaged with thus far and are receiving ongoing training in the application of geothermal PFA.

4.2 Engagement on sector governance to encourage private sector investment

The predictability of institutions governing geothermal development in any given country is a key component of the private sector's confidence and willingness to invest. One aspect that is particularly relevant for geothermal is developing robust, transparent Power Purchase Agreements (PPAs) and their supporting documents and regulations, to ensure that the PPA is fit for purpose and customized to geothermal resources and technologies. As needed in our partner countries, GEODE is facilitating the provision of advice and support on global best practices for developing a PPA and the key aspects that must be considered to ensure success of the sector.

4.3 Technical exchanges and project collaboration

Targeted training on technical geoscience topics is one other aspect of GEODE's capacity-building activities, to ensure that best practices and approaches for geothermal resource exploration and development are understood. However, to ensure ongoing teamwork and implementation of such training, conducting collaborative research projects and study tours with partner organizations serves to both facilitate knowledge transfer and training, while also support team building and the establishment of new working relationships within and between partner organizations. This contributes to reducing possible institutional silos and helps agency researchers be more effective and engaged with their work. Collaborative research projects are focused on implementing PFA projects (initial results from these efforts in our first partner country, Argentina, are presented in Lindsey et al., 2021). Study tours conducted to date include a training and field-based workshop held in Reno, Nevada (USA) in May 2019, with participants from Argentina's government geoscience agency (Servicio Geológico Minero Argentino (SEGEMAR)) and Argentina's energy secretariat (Figure 1). The field workshop aimed to visit key geological sites for geothermal energy resources in the western U.S., as well as operating geothermal power plants and direct-use facilities to learn more about above-ground technologies for geothermal resource utilization. More recent engagement activities include collaborative research with and technical training of geothermal researchers from Peru's government geoscience agency (Instituto Geológico Minero y Metalúrgico (INGEMMET), including an in-person workshop in Lima in late 2019 (Figure 2) and ongoing work towards completing a PFA in southern Peru in the Tacna, Arequipa and Moquegua regions. In late 2020, due to COVID-related travel limitations, a virtual introductory PFA workshop was presented to researchers from the Colombian government geoscience agency (Servicio Geológico Colombiano (SGC)) that was well received and may facilitate future collaboration opportunities between SGC and the Great Basin Center for Geothermal Energy. Future GEODE activities will be focused on engaging with new partners in the Asia-Pacific region: initial efforts include connecting with researchers from the Vietnam Institute of Geosciences and Mineral Resources (VIGMR) and identifying possible training needs and engagement activities that will likely begin in 2021.

Figure 1: Participants from Argentina's Servicio Geológico Minero (SegemAR) and the Secretariat of Energy with members of the Great Basin Center for Geothermal Energy on the field workshop in Nevada, USA (May 2019).

Figure 2: Geothermal researchers from the Instituto Geológico Minero y Metalúrgico (INGEMMET) and the Great Basin Center for Geothermal Energy at the conclusion of a geothermal training workshop in Lima, Peru (November 2019).

5 SUMMARY

Geothermal resources have the potential to make a substantial contribution to the world's electricity demand but face several challenges that hinder growth of the sector. These include resource risk, upfront financial burden, regulatory and permitting challenges, social acceptance, geoscience data availability, inadequate governance structures, political uncertainty, and institutional silos. The GEODE Initiative aims to build technical and human capacity in emerging geothermal sectors and address some of these challenges, through engagement, collaboration, training and provision of advice in foreign government organizations and agencies that are working in geothermal energy resource exploration or regulation.

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