Survey of Recent Market Trends for Geothermal With a Snapshot of Potential Additional Research Areas to Expand Deployment

Bethany Speer and Katherine R. Young

National Renewable Energy Laboratory

Keywords

Geothermal, electricity, power, finance, exploration, policies

ABSTRACT

This paper looks at financing barriers to geothermal resource exploration in the United States (U.S.) for electricity generation projects and analyzes why the market is not developing as quickly as international geothermal markets or as quickly as other renewable energy technologies in the U.S. Research opportunities and approaches to understanding these discrepancies are discussed, particularly whether government policies and programs are spurring development activities. Further analysis to understand policies, programmatic cost efficiencies, potential project revenues, and other economic impacts are recommended together with the preliminary conclusions.

Introduction

As part of the June 2013 issuance of the Climate Action Plan, President Obama announced a national goal to double renewable electricity generation from 2013 by 2020. Although the plan does not specify the amount of geothermal development, a doubling of geothermal installed capacity would require an increase from the current level of 3.8 GW to 7.6 GW, assuming steady capacity factors. However, it is unclear whether this goal can be met because the U.S. geothermal market has been growing slowly over the past couple of decades, installing only 0.8 GW in the 10 years since 2005. This is a striking difference compared with the global market, which is seeing rapid increases in project development. Cumulative installed capacity worldwide amounts to 13.3 GW, which could increase to as much as 18.3 GW by 2021, with much of this growth taking place in Asia, Latin America, Europe, and Africa (US EOP 2013).

In 2015, the Geothermal Technologies Office (GTO) of the United States Department of Energy (DOE) began a vision study (GeoVision) to analyze potential growth scenarios across multiple market sectors (geothermal electric generation, commercial and residential thermal applications) for 2020, 2030, and 2050 (US DOE 2016a). The GeoVision study is divided into specific topic areas and task forces led by team members from DOE national laboratories. One of those task forces, led by the National Renewable Energy Laboratory (NREL), focuses on institutional barriers to geothermal market growth.

Market barriers related to permitting, financing, transmission access, and obtaining long-term power purchase contracts explain some of the slow U.S. project development in recent years. A recent study from Wall and Young (2016) identified financing as the largest barrier. In that study, finance issues included accessing capital for project development and securing power purchase agreements (PPAs). A lack of effective project finance programs and market pull policies—such as renewable portfolio standards (RPS) that target geothermal technologies—may have hindered development. Adding to the complexity is significant variance across state electricity markets and policy frameworks, including vertically integrated markets versus deregulated, differing levels of ambition in RPSs, and varying availability of other incentives.

This paper presents a literature review and summary of the finance barriers, specifically those relating to early stage geothermal project development in the electricity sector. Section 2 serves as a brief primer, in which we look at the domestic and global geothermal markets, barriers to geothermal project development, and how geothermal projects are financed. Section 3 examines the types of policies that have been used to support exploration in the U.S. in the past as well as policies that have been used globally. This section also discusses the impact of geothermal exploration policies on project finance. Section 4 details preliminary conclusions and recommendations for further research.

2. The Geothermal Market

2.1 Project Development in the U.S. Market

Development of geothermal projects in the U.S. began in earnest in the 1960s, with significant growth in the 1970s owing to several federal- and state-level policies. Figure 1 illustrates annual generation and installed capacity from geothermal electricity power plants from 1990 through 2015. Current installed capacity is at 3.8 GW, with nearly all existing utility-scale electricity projects located in western states, especially California, Nevada, Alaska, Utah, Hawaii, Oregon, and Idaho, and utilizing hydrothermal technologies (GEA 2016). However, newer technologies such as enhanced geothermal systems and co-production wells may help spread the market to other regions with lower temperature or harder-to-access reservoirs within the timeframes being reviewed by the GeoVision study (US DOE 2016a).

The Geothermal Energy Association (GEA) reported 6.4 GW of geothermal projects in development between 2012 and 2015 (GEA 2016, 2014, 2013, 2012). NREL analyzed the status and barriers of 230 of these projects, totaling 4,812 MW of capacity (a subset of the 6.4 GW GEA estimates) (Wall and Young 2016)"publisher":"National Renewable Energy Laboratory (NREL. Based on a subset of projects that had sufficient additional information available (3,362 MW total), NREL analysts Wall and Young estimate that 784 MW have no apparent barriers and are likely to come online by 2020 (Figure 2). An additional 855 MW of projects have small hurdles to overcome but could potentially also be operational by 2020 (See Table 1 for further explanation). The remaining projects were considered "stalled," but could be developed with removal of significant barriers. About 65% of the analyzed ongoing and postponed projects are greenfield projects, with the remaining being near-field, expansion, or having an unknown status (Wall and Young 2016).

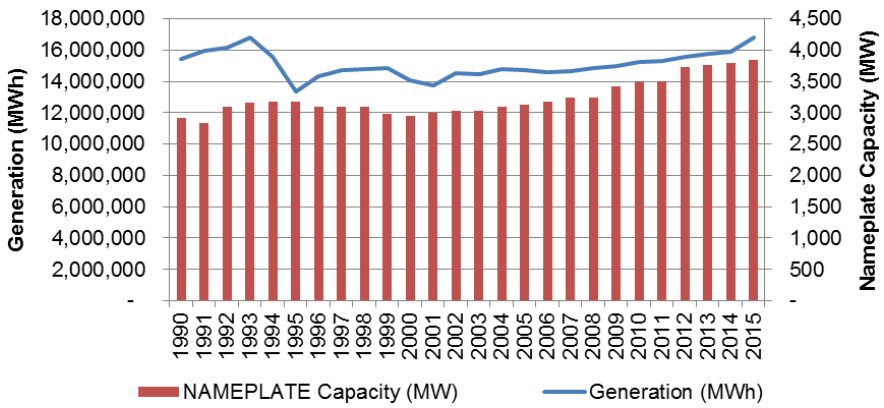

Figure 1. Installed Capacity and Generation, 1990—2015 (US DOE EIA 2016a; US DOE EIA 2016b).

2.2 Comparison with Global Markets

While the U.S. geothermal market has slowed down in terms of additional installed capacity, international markets are quickly expanding. Globally, there were 13.3 GW of installed geothermal capacity as of January 2016, including 18 projects (313 MW) that came online in 2015 (GEA 2016). Projections indicate that the global geothermal market could reach 14.8 GW to 18.3 GW by 2021. Current installed capacity is spread across 26 countries, with the top 23 countries indicated in Figure 3. With 1.4 GW of installed capacity and over 4 GW of planned capacity, Indonesia could soon overtake the U.S. as the global leader

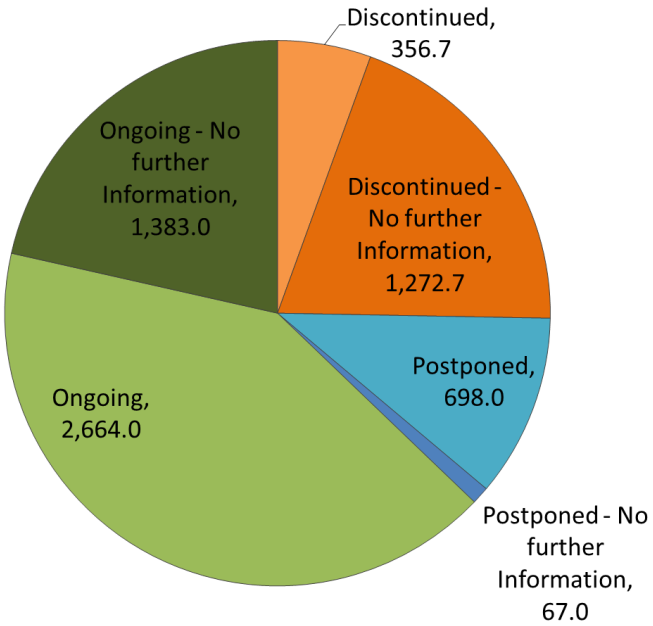

Figure 2. Breakdown of geothermal capacity (MW) listed as in development between 2012 and 2015 (Wall and Young 2016).

in terms of installed capacity (BNEF 2015; GEA 2016).[1] Of these top geothermal markets, the only developed countries with significant planned[2] capacity (apart from the U.S.) are Iceland (575 MW planned), New Zealand (285 MW planned), Germany (95 MW planned), Australia (59 MW planned), and Japan (57 MW planned) for a total of 2,343 MW to 2,711 MW, as shown in Figure 3.[3] Thus, a significant portion of market growth may occur in developing countries, especially in Latin America, Africa, and Asia.

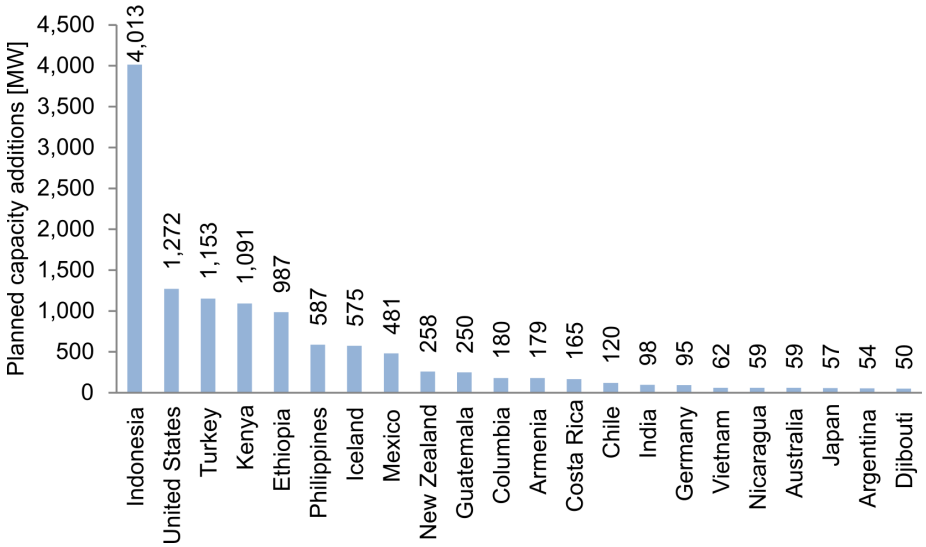

Figure 3. Capacity under development by country (MW) (GEA 2016).[a]

[a] GEA reports the capacity under development in the United States to be 1,272 MW. Wall and Young (2016) estimate ongoing and postponed projects to be 4,812 MW. That estimate includes data from SNL Financial and financial or company filings, as well as GEA. The data are also an accumulation of projects over the course of 2012, 2013, and 2014.

Some the growth of geothermal capacity in emerging economies could be attributed to market policies and financial mechanisms that are favorable to geothermal. For example, Indonesia has offered feed-in tariffs (FITs) and price-based tenders, which may have contributed to the significant number of projects in development in that country (Meier et al. 2015). Many of the projects in international markets are being financed at least in part by international, regional, and national development banks and organizations that provide concessional finance[4] and risk mitigation tools, such as loan guarantees (BNEF 2014). Global geothermal energy exploration financing by multinational banks has increased from 6% in 2012 to 17% in 2015 (GEA 2016). Some projects receiving development bank support include:

- A $1.17 billion USD project in Sarulla, Indonesia with $328 million in capital and a political risk guarantee provided by the Asian Development Bank (ABD) and the Japan Bank for International Cooperation (JBIC) (BNEF 2014)
- A $560 million USD loan for three geothermal projects in Costa Rica provided by the Japanese International Cooperation Agency (JICA) (BNEF 2014)
- A $150 million investment by the European Bank for Reconstruction and Development (EBRD) in Germencik, Turkey (BNEF 2015).
- A $115 million USD World Bank risk mitigation program in Casita-San Cristobal, Nicaragua (GEA 2016)
- A $50 million USD loan for the development and exploration phase of the Rantau Dedap geothermal project in Indonesia (ABD 2014)
- A $31.2 million USD World Bank drilling project in Lake Assal, Djibouti (GEA 2016)

Given the opportunities in international markets, especially emerging markets, U.S. geothermal developers, engineering firms, and drilling service companies are increasingly looking to investments outside the U.S. These companies may also be able to benefit from programs provided by U.S. development organizations such as the Overseas Private Investment Corporation (OPIC), the Export-Import Bank, and the U.S. Agency for International Development (USAID) (BNEF 2014).

2.3 Barriers to Project Development

As noted, the slowed growth of the geothermal market in the U.S. may be due in part to several barriers that developers face. These include challenges related to complex permitting processes, financing, and transmission access (Wall and

[1] It is noted that the GEA-reported value for capacity in development in the U.S. in 2016 (1,272 MW) is slightly less, but similar to, the value reported by NREL (1,640 MW) for likely and potential ongoing projects between 2012 and 2015.

[2] Estimates of planned capacity are from GEA analysis. See the GEA reference for a definition of the terminology "planned."

[3] See previous footnote, which compares GEA and NREL estimates for U.S. market growth.

[4] Concessional loans are provided at far lower than market rates for eligible projects, for longer terms, and with conditions that allow grace periods for payments.

Young 2016). As shown in Table 1, financing was identified as the largest barrier, affecting 45% of the analyzed capacity, while stalling of project development owing to complex permitting processes affected 31% of this capacity. Because of the significance of this barrier, identifying solutions for overcoming this challenge to project development could have a dramatic impact on geothermal deployment. Wall and Young (2016) break "finance" into several sub-barriers, including access to capital and PPA acquisition.

There are a variety of financing challenges faced by geothermal projects. While larger companies can use their balance sheet to finance exploration projects, smaller companies and municipalities often have a difficult time trying to finance these early project phases. Once the resource is proven, however, accessing capital for power plant development is easier because of the low-risk nature of the later stages of development. Another challenge is related to the acquisition of PPAs, which is a critical component to accessing financing for power plant development. PPAs require proven resource and transmission studies. Given the expensive, high-risk, and time-consuming nature of proving the resource, geothermal projects have a more difficult time meeting these PPA prerequisites than other technologies. Additionally, the long development timeframes make geothermal less desirable to utility offtakers as compared with other renewable energy technologies. Moreover, preferential policies (e.g., RPS set-asides) for non-geothermal renewables increase the disparity. In recent years, solar and wind technology costs have greatly decreased, bringing down PPA prices, and making it more difficult for geothermal projects to compete; see Figure 4 (Serota 2015).

Geothermal's baseload and flexible nature, however, could provide benefits to utilities, potentially justifying the higher PPA prices.

Table 1. "Projected Capacity, In Megawatts, of Ongoing or Proposed Projects." (Wall and Young, 2016).

Progress Barrier	2020 Viability			
	STALLED: Needs Barrier Intervention	POTENTIAL: Needs Expedited Development	LIKELY: Needs No Additional Support	TOTAL 2020 VIABLE CAPACITY
Financing	1,049	375	93	***1517***
PPA acquisition	220	177	93	***490***
Capital budgeting	334	50	-	***354***
Access to capital	484	18	-	***502***
Change in ownership	11	130	-	***141***
Permitting	515	237	265	***1,017***
Cultural	425	-	-	***425***
Unspecified delays	40	120	265	***425***
Community	-	117	-	***117***
Environmental	50	-	-	***50***
No obvious barriers	-	-	398	***398***
Transmission	-	170	-	***170***
Resource	108	44	25	***178***
Uncertainty	58	44	-	***102***
Economics	50	-	25	***75***
Legal	50	25	-	***75***
Technology maturity	-	5	-	***5***
Construction	-	-	3	***3***
Totals	**1,722**	**856**	**784**	***3,362***

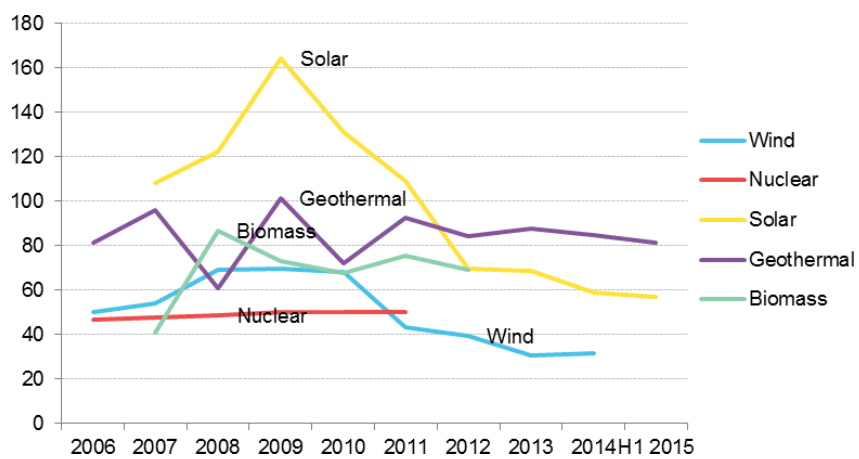

Figure 4. Average PPA price by technology, by origination year, 2006 through the First Half (HI) of 2015 ($/MWh) (Serota 2015).

2.4 Geothermal Project Finance

As mentioned, finance is a significant barrier for geothermal projects due in part to the complex, multi-phase project development that requires different types of capital and investors. Another factor is the high risks associated with the exploration phases, as indicated. There are two general stages of financing geothermal projects: short-term financing for the exploration phases and long-term financing for the construction and operations phases.

Short-term financing is used during the pre-survey, exploration, test drilling, and planning phases of geothermal development. For short-term financing, there are four ways in which geothermal developers have typically financed the exploration phases, including:

- Private equity placements on a project portfolio[5]
- Trading corporate equity on exchanges[6]
- Balance-sheet financing[7]
- Mezzanine finance (for the later test drilling stage)[8] (Salmon et al. 2011).
- Long-term financing brings in project-level debt for the plant construction, start-up, and operations and maintenance phases (Salmon et al. 2011). Prior to the financial crisis, tax equity was used to pay off construction loans and cost developers about as much as a loan,[9] given the low risks (Salmon et al. 2011). This is likely the case today, post-crisis, in cases where such tax equity is available.

To access long-term financing, geothermal projects must have the following in place:

- A PPA with a creditworthy offtaker (which requires a demonstrated resource, an interconnection study, and an interconnection agreement).
- Sufficient funding for production-well drilling, including:
  - A reasonable assumed success rate
  - A reasonable estimated drilling cost per well that reflects the required well depth and subsurface geology,
  - Funding to cover an adequate number of injection wells,
- Time and investment to obtain all necessary permits,
- A reasonable all-in cost of plant construction assuming use of an engineering, procurement, and construction (EPC) contractor,
- A reasonable development and construction time horizon (Salmon et al. 2011).

There are several challenges with both short-term and long-term financing for geothermal projects. First, due to a lack of current policies that provide support in the early phases of project development, developers must address perceptions of high risk in early stages, often through internal risk mitigation measures (e.g., portfolio approaches, contingencies, insurance). Project risks are very high in the early exploration stages, although the costs are much more significant in the production well drilling and construction phases. Another challenge is a lack of strong policies that provide for significant market development and that are perceived as having longevity.[10] Finally, economic downturns, such as the 2007-2009 economic crisis, can have a profound impact on the conditions for financing geothermal projects. This results in fewer tax equity providers due to increased conservancy and reduced taxable income, developers being required to have higher debt coverage-to-service ratios, and financiers requiring higher levels of equity stakes from developers (Salmon et al. 2011).

Thus, if policymakers seek to scale up development of geothermal projects beyond current sites, they will likely need to consider public investments via policies and other financial incentives, since reliance on commercial capital alone is not viable even in a developed country (World Bank 2012).

[5]"A private placement is the sale of securities to a relatively small number of select investors as a way of raising capital. Investors involved in private placements are usually large banks, mutual funds, insurance companies, and pension funds. Private placement is the opposite of a public issue, in which securities are made available for sale on the open market (Investopedia 2016)."

[6]Exchanges are a "market in which shares are issued and traded…Also known as the stock market, it is one of the most vital areas of a market economy because it give companies access to capital and investors a slice of ownership in a company with the potential to realize gains based on its future performance" (Investopedia 2016). .

[7]Balance sheet financing is a combination of corporate debt and retained earnings, and may be an option for more well-established companies (Salmon et al. 2011).

[8]Mezzanine finance is a quasi-debt, quasi-equity structure with interest rates much higher than typical debt that includes an equity option.

[9]The price of debt is expressed as interest, whereas the price of equity can be expressed as an expected rate of return. Financial analysis can be used to determine equivalent interest and price of equity costs/values.

[10]Developers, investors, and financiers must have confidence that policies and programs provided by national, regional, or international organizations are reliable and that there will not be any sudden or retroactive changes; and that they will be in place for a sufficiently long timeframe for the plant to be completed and qualify for the program.

3. Geothermal Policies

Various policies have been used, and are currently in use, in the U.S. to support geothermal resource development. The following is a review the types of policies that are available globally that target early-stage project development and discuss how such policies impact project finance.

3.1 Geothermal Policies and Incentives in the U.S.

U.S. federal and state programs (Table 2) are credited with having catalyzed initial private sector engagement in the market and developing many of the currently operating geothermal fields. The first generation of these policies was initiated in the 1970s—spurred on in part by the energy crises—and was continued through the 1980s. These policies consisted mostly of loan guarantees, cost-share programs, and resource insurance for exploration phases, and they stimulated risk taking by the private sector. One of the key exceptions in terms of impact was the resource insurance program. With its high 2–5% premiums, the program was not widely utilized (World Bank 2010; Speer 2012).

Table 2. U.S. Federal Geothermal Exploration Policies (Speer et al. 2014).

Year	Policy Name	Notes
Loan Guarantees		
1974	Loan "Guaranty" Program	The original geothermal loan guarantee program was enacted with passage of the *Geothermal Energy Research, Development and Demonstration Act* in an attempt to catalyze private lending to geothermal projects.
2009	Section 1705 Loan Program	This program was enacted by the Recovery Act as an addition to the 1703 Loan Program. The 1705 program was originally funded with $6 billion, but this amount was later reduced to $2.5 billion and included some modifications compared to the 1703 program.
Lending Support Mechanisms		
1980	Loans for Geothermal Reservoir Confirmation Program	Authorized by Congress, the program was intended to provide exploration loans to both geothermal power and heat projects. Power projects could borrow a maximum of 50% of project costs, but they were not to exceed $3 million. Although authorized, the program never received congressional appropriations.
Grants and Cooperative Agreements		
1977	Program Opportunity Notices (PONs)	This program offered a cost-share to geothermal heat projects for exploration drilling and the demonstration of geothermal energy uses, including combined heat and power.
1978	Industry-Coupled Case Studies Program	This cost-share mechanism covered 20% to 50% of the exploration and reservoir confirmation costs. In exchange, developers had to provide drilling and well data.
1980	User-Coupled Confirmation Drilling Program	Along the same lines as the Industry-Coupled program, the User-Coupled program provided cost-share grants to conduct exploration drilling for geothermal heat projects. The government's portion of the expenses ranged from 20% to 90%, depending on the degree of success achieved in the drilling.

In addition to the policies outlined in Table 2, another key federal policy was the Public Utility Regulatory Policies Act (PURPA). PURPA provided a guaranteed electricity purchase at the utility's avoided cost, which at that time, was high given commensurate natural gas prices (World Bank 2010). In effect, PURPA was a precursor to the feed-in tariff, although it is no longer effective at driving geothermal development due to changes to the policy and depressed natural gas prices since the initial commencement of the policy (Doris, Kreycik, and Young 2009).

As a reaction to the 2007-2008 economic crisis, the U.S. federal government put in place several programs to incentivize renewable energy development, including geothermal. These incentives focused on supporting the operations phases of geothermal plants and did not target exploration activities.

The Federal Investment Tax Credit (ITC), the 1603 Cash Grant, and (to a lesser extent) the Production Tax Credit[11] provided some of the income assurance required to finance geothermal projects. The ITC and the PTC not only affected the cost of geothermal project development, but also altered financial structures.[12] Often third-party tax investors were brought in to monetize the tax credits, for which most geothermal project developers did not have sufficient tax liability to efficiently utilize. Given that the PTC is received only once a project is operational, it has been less of a driver for geothermal project development, for which the early stage risks are most challenging. The 1603 Cash grant enacted in 2009 may have impacted this trend by enabling project developers to make direct use of the ITC value regardless of tax liability.

[11]The PTC provides less incentive for geothermal exploration as it does not address the high initial risks associated with the early exploration phases and rather, in essence provides additional cash flow once the project is operational in the form of a reduced tax liability.

[12]The PTC and ITC also impacted financial structures for other renewable energy technologies, including solar and wind.

The 1705 Loan Guarantee Program was available to geothermal developers and reduced the cost of debt by 100 to 200 basis points (bps) (or an interest rate reduction of 1 to 2%) (Salmon et al. 2011). Few geothermal developers partook in the 1705 program, possibly due to the long, cost-intensive application process (Speer 2012). The 1703 Loan Guarantee Program remains operational. Although, up to the most recent call for applications in March 2016, for which the results are not yet known, the 1703 program has not supported geothermal projects (US DOE 2016b).

Current federal policies[13] include the:

1. 10% ITC for qualifying equipment excluding transmission;
2. Or Federal PTC for $0.023 kWh for the first 10 years of production;
3. And, the Modified Accelerated Cost-Recovery System (MACRS), a tax depreciation and bonus depreciations for systems put in service during 2019 or before and has been available in some capacity since 1986 (DSIRE 2016). MACRS can be combined with either the ITC or PTC.

Several states also provide incentives for geothermal power, primarily in the form of portfolio standards, with few cases of additional support (e.g., tax reductions) (DSIRE 2016). None of the state incentives have been noted as significant drivers, and are largely received only once the project is operational. In the case of two of the biggest current markets for geothermal, Nevada and California, state RPSs have been key drivers for renewable energy project development. However, solar photovoltaics (PV) are more likely to benefit from these state policies as project development time is shorter and many states have preferential benefits for solar projects (BNEF 2015). A number of other market factors in California, including energy efficiency, energy storage, and rate design proceedings have made the market less certain for geothermal development as there is less clear demand for new generation (Howarth and Fulmer 2015). Also, utilities are exceeding the RPS requirements ahead of schedule, potentially resulting in fewer opportunities for new contracts even as the RPS becomes more ambitious (CPUC 2016).

3.2 International Examples of Geothermal Exploration Policies

While U.S. geothermal projects do have access to a few federal and state programs, these are insufficient to significantly drive geothermal development to the level of ambition outlined in President Obama's Climate Action Plan of 2013, given current market barriers (US EOP 2013). Earlier analysis by Doris, Kreycik, and Young (2009) found that geothermal markets require "support during the exploration and project development phases to offset upfront costs and reduce risks."

Thus, if policymakers seek to spur market development, they may want to consider policies designed specifically to address the exploration phases, and that reduce the risk, reduce the amount of capital required, and/or lower financing costs. These policies may also make it easier to obtain lending in early stages of project development.[14] This is because, by lowering risks, it may be possible to bring debt into short-term financing could help lower the lifetime weighted cost of capital (WACC). Debt lowers the WACC for a project because debt is often less expensive than equity as debt is typically repaid first with project cash flows and is therefore less risky (Speer et al. 2014).

There are five key types of policies that have been used in various countries—including historically in the U.S.—to support the exploration phases of geothermal development.

Table 3. Policy Examples (Adapted from Speer et al. (2014), US DOE (2016b); Young (2016)).

Policy	Description	Examples	Characteristics	Potential Applicability to the U.S. Market
Loan Guarantee	As a third party to the transaction, a government agency or other public entity provides a guarantee of debt repayment to a lender in the even of borrower default. A fee is often required of the developer	U.S.; Germany	Loan guarantees can provide high leverage of private investment in case of low payouts but have thus far demonstrated limited results in the U.S. geothermal market	The Section 1705 Loan Program within the U.S. Department of Energy (DOE) provided $545.5 million in loan guarantees to geothermal projects, although similar programs for renewable energy projects may be unlikely due to the political environment following bankruptcies of a few loan guarantee recipients, however, these guarantees were provided to manufacturers and not generators. Designing loan guarantees to cover loans provided specifically for the exploration phase could spur more debt financing at a phase primarily funded with more expensive equity.

[13]In December 2015, the U.S. Congress 'extended the PTC for wind to 2019 and the ITC for solar to 2022,' however, no extension for either incentive was made for geothermal (BNEF 2015).

[14]One exception would be balance sheet finance that incorporates corporate borrowing.

Policy	Description	Examples	Characteristics	Potential Applicability to the U.S. Market
Drilling Failure Insurance	The developer pays a premium to access a government-provided partial-cost reimbursement. The reimbursement is paid in the event that the exploration phase does not result in a pre-determined level of success for a given project.	France; Multilateral banks and development agencies	Drilling failure insurance can provide high leverage of private investment when the number of claims is limited. Premiums may be cost-prohibitive for developers, and there is the potential for large public funding expenditures depending on the total value of the claims paid. A well-designed insurance program would be self-sustaining.	Policymakers could offer drilling failure insurance as an alternative to loan guarantees or lending support mechanisms to reduce the cost of financing. An insurance program would require a significant up-front allocation of funds to capitalize the insurance pool.
Lending Support Mechanisms	A government entity reduces the cost of the loan by buying down the interest rate, providing for a longer loan term, paying a portion of the interest, or offering some other loan support	Germany	In instances when the terms required by lenders may be prohibitive for the developer, government interest rate support could make loan terms more amenable. Government-supported loans (e.g., direct loans or public-private partnerships) could successfully leverage private investment at subsequent stages of development but may crowd out private investment in the exploration phase.	An interest rate subsidy could be less costly to the government than outright direct loans, but such a program would still require significant public investment. Public investment would be unrecoverable unless developers are required to pay back the interest subsidy once the resource is proven.
Grants and Cooperative Agreements (Grants)	A government entity or other institution offers cost-sharing schemes or other forms of direct payment intended to reduce the investment cost during the exploration phase.	U.S.; France; Multilateral banks and development agencies; Australia; Iceland; Japan	Grants and cooperative agreements can be effective for individual project development, but depending on the amount of support provided, they may result in limited leverage of private investments during the exploration phases, leading to significant public funding commitments. Grant-to-loan programs may be a more sustainable program with less investment of public funding. Grant programs, in general, may be more beneficial to small companies with small risk appetites than to large companies who self-finance exploration; additionally, if projects are not carefully selected, this type of program may encourage risky drilling and drive down aggregate industry success rates.	Grants and cooperative agreements successfully spurred initial growth of geothermal projects in the U.S. but may be limited in their ability to significantly impact overall market development today due to the low leverage of private investment and higher funding requirements. The grant-to-loan model may provide a more stable program, requiring only startup funds, then running self-sufficiently. An example is California's Geothermal Grant & Loan Program, which has been operating since the early 1980s.
Exploration-to-auction	A government entity undertakes exploration activities directly or contracts private firms to do so on their behalf. Proven resources are developed by government-owned enterprises or auctioned to private firms.	Iceland; Japan; New Zealand; Indonesia	Shown to be effective for project development in markets where little to no exploration activity is occurring. Government-led exploration provides lowest leverage of private investment and highest level of public investment, though money could be recovered through auctions. Could be beneficial to both large and small companies.	Despite historical federal support of geothermal exploration (i.e., the programs identified in Table 2), this policy may not be well suited to the Unites States at present given that it is not a market-oriented policy.

To design market-spurring policies while minimizing costs to taxpayers, policymakers should look at costs and benefits to developers and their agencies. Some programs, such as up-front grants may be the least expensive to operate, but they do not provide any form of reimbursement from developers, so money is moving in one direction—from the government to developers. Other programs, if designed carefully, could be self-sustaining. Examples include grant-to-loan and government-led, exploration-to-auction options. For each project that one of these policies brings online, the benefits should also include the millions of dollars in revenue to state and federal governments in the form of property taxes and royalties, the creation jobs, and (if quantified) the cost of carbon offset provided by the renewable resource.

There may be other, innovative policy options in addition to the applied cases highlighted in Table 3 that could support geothermal exploration. For example, tax credits or deductions that are applicable to exploration activities could reduce the cost of early-stage project development and thus the associated risks. Additionally, there could be incentives to encourage co-production of geothermal alongside oil and gas exploration. Policymakers should first define program goals and then design the policy/program accordingly, which could result in an innovative hybrid policy.

4. Recommendations for Further Analysis and Preliminary Conclusions

The following tasks identify objectives and approaches for additional research. The purpose of this research is to inform possible actions that the U.S. federal government and states can explore to accelerate financing and development of domestic geothermal projects. This effort could build on analysis from BNEF, EIA, GEA, and NREL to gather information on the current market activity and the availability of finance programs and funds to support geothermal market exploration. It could expand upon the case studies identified in Speer et al. (2014) and include a broader review of reports and program documents from development finance institutions (DFIs). Targeted interviews could also be conducted with leading DFIs with significant geothermal exploration programs, such as the World Bank, the Inter-American Development Bank, and the Asia Development Bank as well as with developers, investors, and other private sector representatives.

4.1 Mapping Existing Markets and Programs

One future activity that could be helpful would be to determine the portion of exploration activity in international markets that is supported by international, regional, and national development banks providing concessional finance and risk mitigation tools. The purpose of this analysis would be to provide lessons from international experience that could be applicable to the U.S. market. It would also be informative to identify other factors that may be driving markets, such as feed in tariffs, national utilities undertaking exploration activities, or strong geothermal resources that are largely under developed. This analysis would identify gaps and possible opportunities for development and trade-support organizations, such as USAID, Ex-Im, OPIC and others to address geothermal financing needs, such as creating mechanisms to support small and medium enterprises in undertaking early-stage project development activities.

4.2 Analyzing Polices and Programs for Market Efficacy and Impacts

Another identified area of research is the analysis of policies and programs for market efficacy and impacts. This study would take a deeper look at the specifics of each program to understand the potential programmatic and administrative costs, benefits, and impacts—both to the sponsor and to the developer. The assessment could include not only the potential for greenhouse gas reductions, but also the economic implications, such as the creation of jobs, revenue, taxes, and indirect and induced expenditures using an input-output model under various deployment scenarios.

This type of analysis would demonstrate how risks vary from program to program and the various challenges or opportunities with the different policy models. It could also include discussion of exit strategies where program offerings are reduced as policy goals are met. For example, if a certain number of megawatts are installed, successful wells drilled, or number of projects developed, the incentive is reduced, either in value or number available.

If geothermal is to compete in the future U.S. energy market, barriers related to financing must be overcome. There are a number of challenges including the complexity of the project finance structures and the high risks associated with early-stage exploration. However, there is significant geothermal development taking place in international markets. Though many projects in emerging economies are receiving some sort of financial assistance in the form of concessional loans and risk mitigation tools, there are also market policies in place that help to drive the market. U.S. policymakers could consider looking to these examples from other markets as well as examples of policies that were implemented domestically in the 1970s and 1980s to address the high risks associated with developing geothermal projects. When considering these policies, decision makers must carefully calculate the costs, risks, and benefits.

Acknowledgements

This work was supported by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE), Geothermal Technologies Office (GTO) under Contract No. DE-AC36-08-GO28308 with the National Renewable Energy Laboratory. The authors wish to thank the NREL review team, including Kendra Palmer, Emily Newes, Maggie Mann, and David Mooney. Any remaining errors or omissions are the responsibility of the authors. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

References

ABD. 2014. "Innovative ADB Loan to Help Unlock Indonesia's Clean Energy Potential." *Asia Development Bank (ABD)*. http://www.adb.org/news/innovative-adb-loan-help-unlock-indonesias-clean-energy-potential.

BNEF. 2015. "Week-In-Review." December 22, 2016 issues. http://about.bnef.com/newsletter/

BNEF. 2014. *H2 2014 Geothermal Market Outlook Report.* Subscription only. London: Bloomberg New Energy Finance (BNEF).

BNEF. 2015. *H1 2015 Geothermal Market Outlook*. Subscription only. London: Bloomberg New Energy Finance (BNEF).

CPUC. 2016. "California Renewables Portfolio Standard (RPS)." *California Public Utilities Commission (CPUC)*. http://www.cpuc.ca.gov/RPS_Homepage/.

Doris, Elizabeth, Claire Kreycik, and Katherine Young. 2009. *Policy Overview and Options for Maximizing the Role of Policy in Geothermal Electricity Development*. Technical Report NREL/TP-6A2-46653. Golden, CO: National Renewable Energy Laboratory (NREL).

DSIRE. 2016. "Summaries of Federal Policies." *Database of State Incentives for Renewables and Efficiency (DSIRE)*. www.dsireusa.org.

Geothermal Energy Association (GEA). 2016. *2016 Annual U.S. & Global Geothermal Power Production Report*. Washington, DC: Geothermal Energy Association (GEA). http://www.geo-energy.org/reports/2016/2016%20Annual%20US%20Global%20Geothermal%20Power%20Production.pdf.

GEA. April 2014. 2014 Annual U.S. & Global Geothermal Power Production Report. Washington, DC: GEA. Accessed September 9, 2015. http://geo- energy.org/events/2014%20Annual%20US%20&%20Global%20Geothermal%20Power%20Prod uction%20Report%20Final.pdf.

GEA. April 2013. 2013 Annual US Geothermal Power Production and Development Report. Washington, DC: GEA. Accessed September 9, 2015: http://geo- energy.org/pdf/reports/2013AnnualUSGeothermalPowerProductionandDevelopmentReport_Final .pdf.

GEA. April 2012. Annual US Geothermal Power Production and Development Report. Washington, DC: GEA. Accessed September 9, 2015. http://geo- energy.org/reports/2012AnnualUSGeothermalPowerProductionandDevelopmentReport_Final.pdf.

Howarth, David, and Mark Fulmer. 2015. "Project Finance Newswire." *Project Finance Newswire*.

Investopedia. 2016. "Equity Market." *Investopedia*. http://www.investopedia.com/terms/e/equitymarket.asp.

Meier, P, M Vagliasindi, M Imran, A Eberhard, and T Siyambalapitiya. 2015. *The Design and Sustainability of Renewabl Energy Incentives: An Economic Analysis*. Directions in Development--Energy and Mining. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/20524.

Salmon, J.P, J Meurrice, N Wobus, F Stern, and M Duaime. 2011. *Guidebook to Geothermal Power Finance*. NREL/SR-6A20-49391. Golden, CO: National Renewable Energy Laboratory (NREL). http://www.nrel.gov/docs/fy11osti/49391.pdf.

Serota, N. 2015. "H2 2015 PPA Market Outlook: Buyers Market." Presentation presented at the Bloomberg New Energy Finance (BNEF), London.

Speer, B. 2012. *Geothermal Brief: Market and Policy Impacts Update*. NREL/TP-6A20-53288. Golden, CO: National Renewable Energy Laboratory (NREL). http://www.nrel.gov/docs/fy13osti/53288.pdf.

Speer, B, R Economy, L Lowder, P Schwabe, and S Regenthal. 2014. *Geothermal Exploration Policy Mechanisms: Lessons for the United States from International Applications.* Golden, CO: National Renewable Energy Laboratory (NREL). http://www.nrel.gov/docs/fy14osti/61477.pdf.

US DOE. 2016a. "Geothermal Vision Study." *Office of Energy Efficiency and Renewable Energy (EERE)*. http://energy.gov/eere/geothermal/geothermal-vision-study.

US DOE. 2016b. "Loan Programs." *United States Department of Energy (US DOE)*. http://www.energy.gov/lpo.

US DOE EIA. 2016a. "State Electricity Profiles: United States Electricity Profile 2014." *United States Department of Energy, Energy Information Administration (US DOE EIA)*. http://www.eia.gov/electricity/state/unitedstates/.

US DOE EIA. 2016b. "Electric Power Monthly: Table 1.1.A. Net Generation from Renewable Sources: Total (All Sectors), 2006-March 2016." *United States Department of Energy, Energy Information Administration (US DOE EIA)*. http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_01_a.

US EOP. 2013. "The President's Action Plan." *Executive Office of the President, United States (US EOP)*. http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf.

Wall, A, and K.R. Young. 2016. *Doubling Geothermal Generation Capacity by 2020: A Strategic Analysis*. Golden, CO: National Renewable Energy Laboratory (NREL). http://energy.gov/sites/prod/files/2016/01/f28/NREL%20Doubling%20Geothermal%20Capacity.pdf.

World Bank. 2010. *An Assessment of Geothermal Resource Risks in Indonesia*. Washington, DC: World Bank. https://www.ppiaf.org/sites/ppiaf.org/files/publication/REPORT_Risk_Mitigation_Options_Indonesia.pdf.

World Bank. 2012. *Geothermal Handbook: Planning and Financing Power Generation*. Washington, DC: World Bank. https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/FINAL_Geothermal%20Handbook_TR002-12_Reduced.pdf.

Young, Katherine. 2016. Personal communication with industry representative: Conversation with undisclosed company representative. Golden, Colorado.