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NATIONAL RENEWABLE ENERGY LABORATORY

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List of Acronyms

BMU	Ministry for the Environment (Germany)
BMWI	Ministry of Economy and Finance (Germany)
CHP	combined heat and power
CREST	Cost of Renewable Energy Spreadsheet Tool
D/E	debt to equity
DSCR	debt service coverage ratio
EEG	Erneuerbare-Energien-Gesetz
EGS	enhanced geothermal systems
EPAct	Energy Policy Act
EU	European Union
FERC	Federal Energy Regulatory Commission
FIT	feed-in tariff
GW	gigawatt
IPP	independent power provider
ITC	Investment Tax Credit
kWh	kilowatt-hour
LCOE	levelized cost of energy
MW	megawatt
NEA	National Energy Act
NREL	National Renewable Energy Laboratory
O&M	operation and maintenance
PPA	power purchase agreement
PTC	Production Tax Credit
PURPA	Public Utility Regulatory Policies Act
QF	qualifying facility
REC	renewable energy certificate
RFP	request for proposal
ROE	return on equity
RPS	renewable portfolio standard
RTO	regional transmission organization
SO4	Standard Offer No. 4
USGS	U.S. Geological Survey
WACC	weighted average cost of capital

Executive Summary

Developing power plants is a risky endeavor, whether the plants utilize conventional or renewable generation technologies. Feed-in tariff (FIT) policies can be designed to address some risks specific to geothermal power plant development, although they have not been used in the United States to date.

By April 2012, there were 11,224 megawatts (MW) of geothermal electric capacity installed in 24 countries (Holm 2010; GEA 2012). The United States leads the world with 3,187 MW installed. Despite these statistics, the cumulative amount of geothermal electricity generating capacity installed in the United States has expanded slowly in recent years, increasing approximately 2.3% annually on average since 2008 (GEA 2012). During 2011 and the first quarter of 2012, the addition of two new geothermal plants and the expansion of three existing plants added 91 MW of new capacity.[1] Geothermal market development faces a range of unique barriers related to the cost and uncertainty of resource exploration and confirmation drilling. In addition, geothermal projects face risks similar to other generation project development, including finding buyers for power, ensuring adequate transmission capacity, competing to supply electricity and/or renewable energy certificates (RECs), securing reliable revenue streams, navigating the legal issues related to project development, and reacting to changes in existing regulations or incentives.

Instead of addressing all these risks and all the policies in the same analysis, this analysis focuses on the design of FIT incentive policies for geothermal electric projects and how FITs can be used to reduce risks other than the physical risk of drilling unproductive exploratory wells. The guarantee of a stable revenue stream over the life of the generation plant lowers the risk that large investments in exploration and development will not yield an off-take agreement. The combination of a guaranteed purchase, a pre-determined payment price, and a standardized off-take agreement can relieve some of the cost, risk, and pressure associated with overall project development since the project does not need to compete for or negotiate a contract before final project costs are known. Addressing exploration risk[2] by incorporating some/all of the drilling costs in the FIT payment level can incentivize some amount of risk taking in the exploration phase. Policy risks should be considered too. The greatest risk associated with FITs—rapid and dramatic development in a timeframe too short to react and adjust—appears far less likely for geothermal projects due to: (1) longer development lead times and (2) geographic limitations on project locations. In short, policymakers should be able to see a problem coming with plenty of time to adjust. In sum, FIT policies can include risk-mitigating elements and can be tailored to support a few key financial risks of geothermal development.

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[1] In 2010, a single 15 MW project had been developed in the United States and was installed in Nevada (Jennejohn 2011).

[2] This study does not include a comprehensive look at policies that address exploration risks – just those that could be addressed in a FIT policy; another NREL study (underway in 2012) is examining specific policies that address exploration risks, specifically.

Global Experience with FIT Incentives for Geothermal Electricity

FITs are currently the most common national renewable energy policy in the world and are in place in over 50 countries. Despite international interest in FITs, there has been a limited focus on geothermal FIT design specifically. This report represents the first in-depth attempt to explore how these policy elements could be aligned to support geothermal development. There are currently no geothermal FITs in North America, although the Public Utility Regulatory Policies Act (PURPA) of 1978, which contains elements similar to FIT policies, supported over 1,300 MW of geothermal development by the end of the 1990s (Guey-Lee 1999). Around the world, 16 countries have established specific FIT incentives for geothermal. Based on a survey of international experience to date, we find that:

- More than a dozen countries are experimenting with FIT policies that are specifically tailored for geothermal technologies. Countries have introduced FITs that target small scale geothermal plants, combined heat-and-power geothermal applications, specific types of geothermal resources (e.g., enhanced geothermal or low-temperature plants), specific geographies (e.g., islands), and domestic content.
- Geothermal FIT payment levels vary widely across countries from \$0.08/kilowatt-hour (kWh) in Uganda to \$0.48/kWh in Switzerland (both for 20-year contracts). This range reflects resource differences, variations in local electricity prices, as well as different policy objectives (e.g., whether to support certain resource types) in different countries and different approaches to rate setting.
- There is a lack of empirical evidence about the impact of the varied FIT designs on market development. Geothermal market growth under FITs has been slow to date for a variety of reasons. These include the fact that many of the FITs are comparatively new, and that some of the prices are too low to support the comparatively poor quality, or expensive local resources. A key take-away from the international survey is that the presence of FITs alone has not driven results comparable to the results achieved for wind and solar power under European FITs, or to those achieved for geothermal under PURPA in the United States.
- A variety of rate-setting approaches are currently used.
    - Examples in Germany and Spain demonstrate that the FIT rate-setting process can be used to reflect technology-specific risks and costs.
    - Different approaches to FIT rate setting have been taken in different countries.

FIT Policy Design to Support Geothermal Development in the United States

The report provides an in-depth, qualitative discussion on how FITs can be designed specifically to support geothermal power plant development in the United States. For comparative purposes, this report adopts investor security as a perspective for discussing each option in order to analyze the relationship between policy design and risk reduction.[3]

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[3] In order to create the conditions for geothermal deployment, the perspectives of multiple stakeholders will need to be taken into account and appropriately balanced. These include, for example, end users and ratepayers,

The report identified key issues relating to geothermal FITs in the United States, listed in Table ES-1 below. Each policy design issue is evaluated based on its potential to lower investor risks.

Table ES-1. Summary of Geothermal FIT Design Issues and Options

Policy Design Issue	Design Option Potential for Lowering Investor Risk
Integrating FITs with Geothermal Targets	Setting mandatory and specific targets for geothermal can improve investor confidence in a government's commitment to geothermal procurement.
Technology Eligibility and Differentiation	The choice of eligibility or differentiation does not have direct impact on project risk. What matters from an investor risk perspective is whether the FIT rate available to geothermal generators of various sizes and types is sufficient to cover operating expenses and meet investors' required returns.
Incorporating Exploration Expense into FIT Rates	Accounting for exploration costs and risk when setting the FIT rate (i.e., by building exploration cost and probability of success assumptions into the rate setting model) can be an avenue for reducing investor risk and encouraging the flow of capital into geothermal development. Assurance of a financeable contract that enables the recovery of an estimate of incurred exploration expenses provides a signal to the market to invest, notwithstanding the fact that actual exploration experience is likely to differ from the estimate and that some exploration efforts will fail to produce a viable thermal resource.
Standard Pricing and Off-Take Contracts	FITs provide generators with standardized off-take contracts that can reduce power project risk and transaction costs. This has the potential to reduce investor return requirements and increase the pool of available capital.
Payment Structure	Fixed FIT prices are lower risk (from the investors' perspective) than payment streams that vary over time and are uncertain (Corfee et al. 2010).
Contract Duration	To the extent that post-contract market revenue projections are utilized in setting a FIT payment level, longer contract durations reduce investor risk by reducing the proportion of lifetime revenues exposed to market price risk. If, however, FIT payments are designed to attain target investor returns prior to contract termination, investors should be indifferent to contract duration, all else being equal.
Policy and Contract Timing	The presence of a stable FIT policy that could be relied on for a period of several years by an early-stage, exploration-phase geothermal investor could decrease overall risk, thus reducing/eliminating developer risk premiums for request for proposal (RFP) bids.
Payment Indexing Over Time	Indexing payments to inflation, drilling costs, and/or other relevant indicators reduces the risk that project revenues will be inadequate.
Adjusting the Policy	Adjustments that are made infrequently and on a schedule that is known in advance and using a process that is as transparent as possible increases investor confidence.

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policymakers, and industry in addition to investors. A full multi-stakeholder analysis is beyond this scope of this report, however.

Analyzing the Impact of Policy Design Choices on the Levelized Cost of Energy from Geothermal Electricity Generators

This report provides a quantitative analysis using the National Renewable Energy Laboratory's (NREL) Cost of Renewable Energy Spreadsheet Tool (CREST) model to illustrate policy design impacts on the levelized cost of energy (LCOE) for geothermal electricity. The purpose of this analysis is not to determine the precise cost of a specific geothermal system. Rather, the analysis identifies considerations that can inform policymakers about how different FIT policy design choices can address some of the geothermal-specific risks that contribute to the LCOE, and thus how FIT design can be used to lower the LCOE of geothermal energy.

The quantitative analysis focuses on the interaction of FITs with several key variables:

- Exploration success rate
- Duration of the confirmation stage
- Investor return requirements (equity and debt, if applicable) during each phase of development
- FIT contract duration
- The project's total installed cost (including operations and maintenance costs).

The results show a connection between the investor return requirement, the amount of time it takes to complete a geothermal project (the amount of time this capital is deployed), and the LCOE. The impact that long-term, price-certain contracts with creditworthy counterparties have on project financing is also explored. Such contracts can help make project-level equity and debt more accessible and on more favorable terms. FIT designs that reduce revenue risk and contract price risk can reduce the associated investor risk and return requirements at each development phase. The availability of a long-term, price-certain FIT can shorten the geothermal development cycle by removing the need to compete for a power purchase agreement (PPA), which can also translate into a lower LCOE. Longer FIT contract durations can also achieve a lower LCOE. With regard to the impact of policy design on LCOE, this analysis shows that policies that reduce the duration and return requirements of early-stage development activities will have the greatest impact. Increasing geothermal contract lengths and introducing mechanisms that reduce the cost of permanent equity and debt also have a significant impact on LCOE. The approach to setting payment levels under FIT policies (e.g., whether and how exploration and confirmation success and return requirements are taken into account when calculating payments) is also shown to have a direct and meaningful impact on geothermal LCOE.

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1 Introduction

Geothermal electricity[4] represents a significant source of potential renewable electricity in the United States and it has several comparative advantages over other types of generation. Geothermal energy is a renewable resource that provides baseload, rather than intermittent, power at high availability and capacity factors (i.e., at or above 90%) (Green and Nix 2006). Geothermal power is a cost-effective alternative to non-renewable energy sources, primarily in western states where the strongest resource is concentrated, and has been used to effectively as a strategy to diversify state electricity portfolios since 1960 (Mines et al. 2010). However, developers of hydrothermal geothermal power plants face a unique and added challenge compared to other renewable energy technologies. In addition to securing sites, permits, and contracts (all required to attract financing), geothermal developers also must find and confirm a commercially-exploitable thermal resource. The expense of drilling, and the potential to expend substantial capital without yielding a developable well, leaves geothermal developers with substantial exploration risk. Because of such project uncertainties, many geothermal resources remain undeveloped. The unique characteristics of geothermal electric development have important implications for effective policy design of geothermal projects.

This report explores how FITs have been, and can be, designed to account for the unique characteristics of geothermal project development, particularly reducing investor risk in the power plant. NREL is currently working on a separate report that explores policies to encourage geothermal exploration. This report explores international experience with geothermal FITs to date and discusses design considerations for geothermal FITs in the United States. The report uses NREL's CREST[5] to quantitatively examine the impacts and tradeoffs of different geothermal FIT designs. The analyses explore, for example, how different FIT designs can take development risk into account and the impact that reducing the cost of capital by decreasing investor risk could have on project economics. The report is organized as follows:

- Section 2 provides a high level summary of U.S. geothermal energy, including geothermal resources, market trends[6], and policies. The section also reviews the barriers and risks that constrain geothermal energy development and the potential for different FIT design options to overcome them.
- Section 3 defines FIT policy characteristics, reviews international experience with geothermal FITs in 16 countries (none in North America), and compares current FIT payment levels in these countries. Examples of the geothermal payment level setting process are detailed for Germany and Spain.
- Section 4 provides an in-depth, qualitative discussion on how FITs can be designed to address U.S. considerations for geothermal energy development.[7] For comparative purposes, this section adopts investor security as a benchmark for discussing each option,

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[4] This report does not consider geothermal heat pumps; it concentrates on geothermal electricity production.

[5] The Cost of Renewable Energy Spreadsheet Tool (CREST) can be found at https://financere.nrel.gov/finance/CREST

[6] A more detailed exploration of geothermal technology trends and market development can be found in other publications (e.g., Mines et al. 2010; GEA 2012; Beerepoot 2011).

[7] A number of studies discuss a broad range of FIT design issues, options, and considerations in detail (Couture et al. 2010; Grace et al. 2008).

but there is great flexibility in how geothermal FITs can be structured, designed, and evaluated.

- Section 5 presents a quantitative analysis of the design tradeoffs identified in Section 4. Specifically, this section utilizes the CREST model to illustrate the impact of various policy design choices on LCOE. These include the impact of strategies to reduce exploration, permitting, and financing risks.
- Section 6 contains conclusions and discussions of key findings.

2 Overview of Geothermal Development Considerations and Risks

2.1 Overview of the U.S. Geothermal Market

The United States has a significant presence in the global geothermal energy market. As of April 2012, there are 11,224 MW of geothermal electric capacity installed worldwide (GEA 2012). The United States has the highest amount of geothermal capacity, with 3,187 MW installed (Figure 1). Of an estimated $2 billion in new financial investments made in geothermal energy in 2010, $0.7 billion, or 35%, was invested in the United States (McCrone et al. 2011).[8] Despite these statistics, the cumulative amount of U.S geothermal electricity installed has expanded slowly in recent years, increasing an average of 2.3% each year since 2008. From 2011 through the first quarter of 2012, two new projects and three expansions at existing facilities added 91 MW of geothermal capacity in the US (GEA 2012).

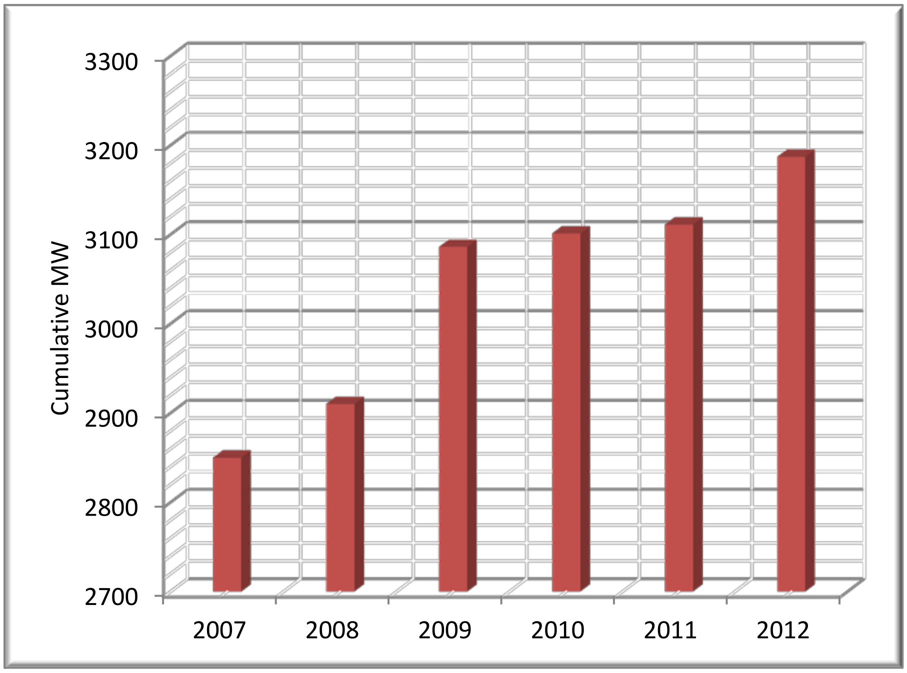

Figure 1. Cumulative installed U.S. geothermal electricity capacity (2008-First Quarter 2012)

Source: GEA (2012)

The growth of the geothermal market stands in contrast to the U.S. wind and solar markets, which have grown significantly during that same time period (EERE 2011). Figure 2 shows annual U.S. electricity production for wind and geothermal over the last decade. In 2004, for example, the amount of electricity generated by geothermal power plants was slightly higher than the amount of electricity generated by wind energy. By 2011, however, the total amount of wind generation was over seven times higher than the total amount of geothermal generation.

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[8] This figure excludes corporate and government research and development spending.

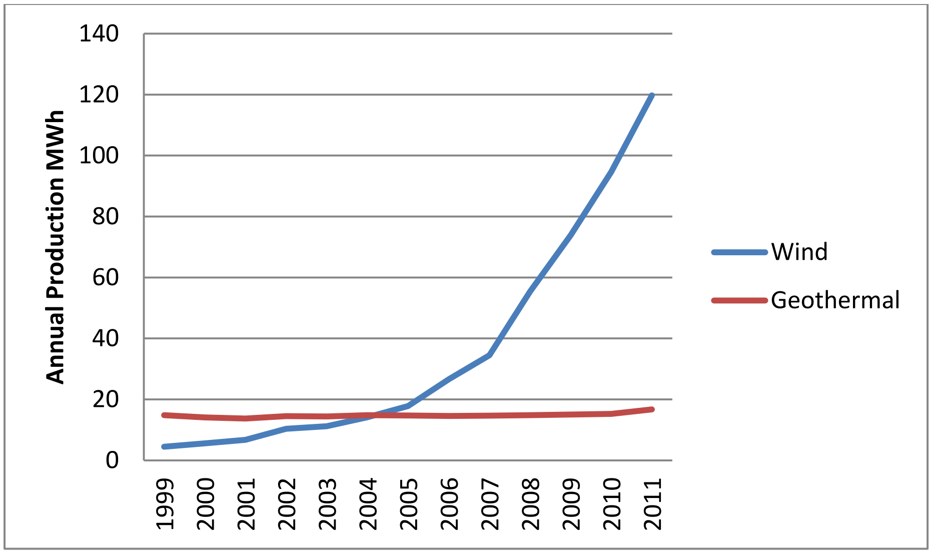

Figure 2. U.S. electricity generated by wind and geothermal plants (1999-2011)

Source: U.S. EIA (2012)

Geothermal growth has been slow compared to other renewable technologies, but there is significant potential to expand the market. The section below briefly reviews the U.S. geothermal resources available for electricity generation.

2.2 U.S. Geothermal Resources

The exact amount of available geothermal energy is unknown, but recent estimates have demonstrated that U.S. geothermal potential remains vast and largely untapped. The different types of potential resources include[9]:

- Hydrothermal resources. Hydrothermal systems are naturally occurring underground geothermal reservoirs. Hydrothermal reservoirs can either be dominated by hot water or steam.[10] Hydrothermal reservoirs are continuously recharged as heat flows into the reservoir from greater depths. If identified hydrothermal resources were developed to their full extent, the U.S. Geological Survey (USGS) estimates that that an additional 6.5 gigawatts (GW) of geothermal electricity capacity could be brought online across 11 western states, Alaska, and Hawaii (Williams et al. 2008). The USGS also estimates that there is an additional 30.3 GW of unidentified hydrothermal resource.
- Deep or enhanced geothermal systems (EGS).[11] EGS resources are engineered reservoirs that can be created by fracturing rock deep in the earth. Water is then injected into the

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[9] In addition to these three resources, there are also geopressured geothermal reservoirs that consist of deposits of pressurized hot fluid that typically contain dissolved methane. Geopressured geothermal resources can potentially be harnessed to produce energy from both the heat and hydraulic pressure of the reservoir. The methane can also be recovered and used for energy. Total geopressured resources are unknown, but early studies have estimated that there may be 10-40 GW in the Gulf of Mexico alone (Hunt, 1981).

[10] Hot water dominated hydrothermal resources are far more common that steam dominated hydrothermal resources.

[11] The German Energy Agency defines EGS as "The use of deep heat reservoirs with few or no water resources...Crystalline and dense sedimentary rock at depths of three to six kilometres with high temperatures (over 150 °C) can serve as reservoirs. These are accessed via two or more boreholes drilled deep into solid rock. Hydraulic and chemical stimulation processes (Enhanced Geothermal Systems, EGS) are used to make cracks and

fractures, heated through contact with the rock, and re-circulated to the surface. The Massachusetts Institute of Technology (MIT) estimated that the extractable portion of available EGS heat energy would exceed 2,000 times the annual consumption of U.S. primary energy in 2005 and that 100 GW could be developed by 2050 if sufficient investment were committed (MIT 2006). The USGS, meanwhile, estimates the available EGS resource to be 500 GW (Williams et al. 2008).[12]

- Co-produced resources. Hot water is often pumped up from underground as part of the oil and gas exploration process. This water could be captured and harnessed to produce geothermal energy in small-scale power plants connected to the distribution network (McKenna and Blackwell 2005; Hurlbut 2012). The total amount of co-produced geothermal resources is uncertain and has not been recently or comprehensively studied on a nationwide basis (Augustine et al. 2010).

Today, the vast majority of geothermal electricity generation comes from hydrothermal resources, a minimal amount from co-produced resources, and only experimental plants use EGS. Given these potentially available resources, there is significant potential for the United States to scale-up its production of geothermal electricity. Market development, however, has been slow because of the presence of project risks and obstacles, as described below.

2.3 Obstacles to Geothermal Power Plant Development

Geothermal generation project developers face many of the same types of risks that any power plant project will face, such as:

- Development Risk (Timing). The project will not achieve milestones (e.g., permitting, siting, and interconnection), will be delayed, and/or not completed.
- Development Risk (Contracting). The renewable energy project investor incurs significant cost on site control, engineering, permitting, and other development activities, as well as legal and other costs associated with competing for, or negotiating, a PPA, prior to knowing whether it will successfully secure a PPA, RECs and other commodities with a creditworthy buyer (i.e., off-taker). Investments in such development-stage are fully at risk, and therefore have commensurate return requirements.
- Contract price risk. The PPA price, which may be set (or proposed in a competitive solicitation) based on preliminary estimates and committed to before project development

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fissures in the rock. Cold water is then pumped at high pressure down an injection well into the rock, where it is heated and returns to the surface via a second borehole. This hot water in turn heats a working fluid with a low boiling point (so-called Kalina Cycle and Organic Rankine Cycle, ORC), producing steam for a turbine. Heat can also be fed into district heating networks via a heat exchanger" (German DENA 2012). The U.S. Department of Energy's definition of EGS is not that different: "Enhanced geothermal systems (EGS), also sometimes called engineered geothermal systems, offer great potential for dramatically expanding the use of geothermal energy. The EGS concept is to extract heat by creating a subsurface fracture system to which water can be added through injection wells. Creating an enhanced, or engineered, geothermal system requires improving the natural permeability of rock. Rocks are permeable due to minute fractures and pore spaces between mineral grains. Injected water is heated by contact with the rock and returns to the surface through production wells, as in naturally occurring hydrothermal systems. EGS are reservoirs created to improve the economics of resources without adequate water and/or permeability" (DOE 2012).

[12] This estimate is limited to 11 states in the western United States and to the geothermal resource located at depths of between 3 and 6 km.

activities are complete and project costs are fully known, may not be sufficient to cover actual costs.[13]

- Construction risks. The project will be delayed because of slow construction or negatively impacted because of construction costs overruns.
- Technology risk. The technology does not perform as expected.
- Resource risk. The renewable energy resource is not as strong as projected.
- Market revenue risk. The revenue received by the project may be volatile over time, which may negatively impact project economic performance.
- Political (regulatory or legislative) risk. The policy framework under which the project was developed may be altered, which may negatively impact project revenues or operations.

These risks can constrain project development and increase the cost of capital to finance projects if not adequately addressed. For geothermal projects, the project risks outlined above can be magnified or compounded by the characteristics of the geothermal exploration and development process:

- Development timetable. The length of time to develop a geothermal project is longer than other renewable energy generators and is typically 4-7 years (NREL 2011; Richter 2009). The development process is complex and involves several distinct stages: exploration, confirmation drilling, production drilling, and power plant construction. The duration and complexity of these activities creates significant opportunity costs compared to the development of other technologies with shorter development cycles and greater opportunities for success.
- Complexity of siting and permitting. The geothermal siting and permitting process can be challenging because of a lack of clarity in resource ownership rights and because geothermal development may require complex interactions with overlapping federal and state regulatory bodies (Doris et al. 2009; Fish and Heaps 2009).
- Transmission capacity. The best geothermal plants are often located far from large load centers. Geothermal power plants are faced with the choice of either using existing transmission capacity, which is often constrained, or attempting to build new transmission capacity, which is typically prohibitively expensive to build to serve a single power plant. A key challenge with new geothermal development, therefore, is identifying the transmission infrastructure that will bring the power to market (Hurlbut 2012).
- Development and exploration costs. The upfront costs of developing geothermal projects are substantially higher compared to other energy generation technologies, and can account for 40%-50% of total geothermal project costs in the United States. (Cross and Freeman 2009; Deloitte 2008).
- Exploration risk. While the development process is expensive, it is not guaranteed to be successful; geothermal projects have an exploration success rate of 10%-40% (Augustine

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[13] Costs that can diverge from estimates made at the stage of competing for a PPA include capital costs, operating costs, fuel costs, costs of securing permits, engineering, or costs associated with PPA pursuit.

et al. 2010; Hance 2005). In other words, geothermal prospecting may incur significant costs from surface exploration and exploratory drilling and yield only "dry" wells. (Importantly, the actual probability of dry wells depends on the hydrothermal application.[14]) This contributes to the upfront cost; drillers need to make higher returns on each successful well to make up for the dry wells. As a result of these risks, geothermal exploration may be supported by government programs or by industry participants with substantial balance sheets and a long-term outlook on geothermal electricity markets. In either case, this capital can be very difficult to obtain (Richter 2009; Salmon et al. 2011).

2.4 Addressing Geothermal Barriers and Risks Through Policy

The combination of the duration, complexity, cost, and other risks inherent of geothermal development means that geothermal power plants are challenging to build and finance. Geothermal projects typically require policy support in order to decrease project risks and overcome barriers.[15] Policies can be used to decrease the risk and complexity of geothermal project development and financing.

There are numerous policy tools that can be used to reduce exploration and development risk and improve access to capital. These could include improved research and development, government risk sharing (e.g., publicly-funded or managed exploration, co-investment, drilling insurance, etc.), the development and coordination of inventories of geothermal data, and inter-agency coordination (Deloitte 2008; Doris et al. 2009; GEOFAR 2009a). This report does not focus on policies geared to directly address exploration risk since these were explored in other research efforts, including a forthcoming NREL report.

This report instead focuses on analyzing policy options that establish revenue certainty and ensure known access to a revenue stream if exploration proves successful, removing not only the transaction, bid security, and legal costs of pursing a PPA, but mitigating a variety of the aforementioned risks.[16] Decreasing risks can increase investor confidence and reduce the time for financing. Recent studies have estimated that targeted renewable energy policy can reduce risk, lower the cost of capital required to finance wind and solar projects, and result in a 10%-50% decrease in the levelized cost of energy of renewable generation (Varadarajan et al. 2011;

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[14] Geothermal projects that drill new wells to expand the utilization at existing, well-quantified sites are the least likely to have dry wells because the resource is well characterized (however there likely will be other issues like more quickly depleting the overall resource that feeds both plants). Geothermal projects that "step-out" and are adjacent to existing sites are more likely to have dry wells than co-located plants since the resource is nearby, but may not continue outside of the existing plant's footprint. Rapid depletion of the shared resources at both sites may also be an issue. Next, greenfield wells at locations with surface manifestations appear to have a higher probability of dry wells than "step-out" facilities since the resource is not characterized at the required depths. Finally, "blind" geothermal that is not near other facilities and does not have a surface manifestation are the most likely to have dry wells (DOE, Geothermal Technologies Program 2011).

[15] Some of these barriers and risks described in this report, such as the construction, technology risks, and resource risks are difficult to address through policy (Corfee et al. 2010; de Jager and Rathmann 2008). Construction and technology risks can be addressed through contracts and warranties with installers and manufacturers, whereas resource risks can be addressed through in-depth resource assessments.

[16] Recent studies have argued that multiple policy instruments that take into account specific national technology and market developments must be combined in order to successfully support geothermal development (e.g., Miethling 2012).

de Jager and Rathmann 2008). This report focuses on policies that can address the following risks:

- Market revenue risk. Market revenue risk occurs when the price paid to the generator varies over time or when the future availability of a revenue stream (or other cash-equivalent benefit stream) is unclear. Reliance on spot electricity markets for revenues is one form of market revenue risk. The temporary nature of federal incentives, including the Production Tax Credit (PTC) for example (i.e. reauthorized for 1-4 years at a time), can also create a net cash flow risk for geothermal investors and developers with long development timelines (Salmon et al. 2011).[17] Market revenue risk can be diminished by policies that provide geothermal developers with stable, long-term payments that are known in advance. Alleviating this risk can significantly improve investor security and reduce the cost of capital (Deutsche Bank Climate Change Advisors 2009).
- Development risk. Development risk reflects the fact that a project may or may not find a buyer for its power, RECs, and/or other commodities before expending significant development capital on siting, engineering, and permitting. This could result, for example, from the absence of a policy stimulating demand for geothermal power, shortage of viable counterparties, loss of a competitive procurement, or failure to conclude a successful power purchase agreement negotiation with a prospective buyer. This risk can be reduced through policy by assuring that a project can rely on access to a PPA if it can find a technically and economically viable resource and secure necessary permits.
- Contract price risk. Even when a mechanism is in place to provide a geothermal developer with an opportunity to compete for a PPA (such as under an renewable portfolio standard (RPS) in a western U.S. vertically-integrated electricity market), it is common that developers may need to offer price proposals before development contingencies have been fully resolved and therefore before project costs are fully understood. As a result, developers typically either build in a risk margin to account for these risks, or incur additional expenses to attempt to hedge uncertain costs. Alleviating the need to build in risk premiums or hedging costs can reduce the viable PPA price (Wiser et al., 2006).[18] From the policymaker's perspective, this risk may be daunting – how does one set the "right" payment level? Some countries, like Switzerland, require that developers participating in the FIT provide cost data so that they have a database of cost information that grows over time and can be used to inform future payment levels (Couture et al. 2010).
- Legal risk. Legal risk refers to the risk of legal delays, costs, and failures during the process of competing for and negotiating a power purchase agreement. These risks can be diminished by policies that provide incentives that are available on a standard offer basis under standardized contracts.

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[17] The production tax credit, for example, has often been extended for one to two years at a time, insufficient to span geothermal project development timelines.

[18] Many projects fail not because they do not secure a PPA, but because a PPA at a price bid is insufficient to get the project financed (i.e., to give investors their expected return).

- Political risk. Exposure to policy changes impacts a geothermal developer's prospects and cannot be hedged by project investors. The longer development horizons of geothermal power leave investors more exposed to such risks than investors in wind or solar power. These risks can be lessened by policies that provide incentives that are available on a standard offer basis under standardized contracts, particularly if such incentives are established for a sufficient duration to allow for geothermal development cycles. Buyers often seek protection from such risks under PPAs, which can shift substantial risk to project owners. Standard PPAs without such political 'outs' can therefore reduce investor risk.

Several recent studies have surveyed non-exploration geothermal policies in the United States and evaluated their adequacy for mitigating risks, addressing barriers, and driving market development of new (or incremental) geothermal electricity facilities. NREL (Doris et al. 2009), for example, reviewed state policy and concluded that:

- With few exceptions, current renewable energy policies are not sufficiently tailored to provide new geothermal power plants with the specific types of support they require. RPSs for new generation support inter-technology competition, which, in practice, has primarily favored new wind energy for reasons that may span differences in resource availability, development timeline, and exploration/development risk. By 2010, 91.2% of the new renewable energy capacity motivated by RPS policies was wind, whereas only 1.4% was geothermal (Barbose 2011). These specific values are influenced by the fact that state RPS programs are distributed nationally but geothermal development has been thus far limited to the western United States.
- The policies that specifically support geothermal are often limited in their ability to meaningfully impact the geothermal market due to funding or eligibility (e.g., project size) restrictions.

In markets such as California's where geothermal power plays a material role in RPS compliance, the policies are structured to include existing resources in utility RPS procurements.[19] In many cases, these geothermal resources were originally developed under the PURPA. The feasibility of expansions at existing geothermal facilities has also been investigated as a result of the long-term utility procurements associated with RPS programs. In this case, the potential availability of a long-term contract provides the opportunity to develop a financing plan for expansion, but the short lead-time afforded by the RFP process presents a continuing challenge to long-lead time resources like geothermal. This issue is compounded for geothermal developers seeking financing for greenfield development.

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[19] Policies involving utility long-term contract procurement requirements, such as RPS mandates placed upon regulated utilities in western United States markets, can mitigate electricity market risk, but by failing to ensure market access, they expose developers to most aspects of development risk and contract price risk. FITs offering guaranteed access at known prices under standard contract terms can substantially reduce these aspects of power project risk. In addition, such competitive procurement policies fail to avoid many of the costs avoidable under a FIT, such as proposal preparation, cost estimation, hedging to lock in costs underpinning a bid (when possible), risk premium, bid security, and legal and other costs relating to contract negotiation.

The NREL study identifies FITs as one possible policy approach that could expand or improve the existing policy landscape.[20] FITs have been identified in studies by Deutsche Bank and others as one of the most effective policies for mitigating key renewable energy project development risks, attracting investment capital, and scaling-up renewable energy markets (Deutsche Bank Climate Change Advisors 2009). While experience is early, FITs can be designed to target geothermal generators and reduce geothermal project risks; specifically, geothermal FITs can be structured to:

- Pay generators with a fixed, long-term price for electricity, RECs, and/or other commodities, which can decrease market revenue risks. Projects do not need to compete for or negotiate a contract before final project costs are known, reducing contract price risk. Projects under such circumstances may also not be subject to contractual milestones that could lead to contractual penalties, forfeiture of security payments, and termination of the off-take agreement if there are project delays.
- Require utilities (or other entities) to purchase geothermal output on a standard offer basis, which can ensure contract access. This removes the risk that investments in exploration and development will not yield an off-take agreement. This certainty may also attract a broader pool of capital providers to finance both the exploration and operations periods, thereby potentially lowering capital costs.
- Provide generators with standardized contracts that can reduce transaction costs.

FITs might help the U.S. geothermal market achieve accelerated expansion goals, as a complement to policies designed specifically to address exploration risks. FITs that address revenue, market, development, legal, and political risks can have a positive impact on the decision of geothermal developers to move forward with geothermal exploration by removing some of the uncertainties of the development process in advance and accelerating development times.

There are, however, limitations and challenges with FIT policies. First, FIT payments are typically set administratively rather than through competitive processes. Similar to tax credits, rebates, and performance-based incentives, policymakers need to carefully set the “right” price that most fully meets their FIT policy objectives. Setting a price too low may yield less development than desired whereas setting the rate too high may lead to overpayment and more development than desired. Second, without a competitive mechanism to help determine or benchmark incentive levels, the setting of FIT prices typically requires intensive data gathering processes. Third, periodic reviews are necessary to help ensure that the payment levels reflect market conditions and policy objectives accurately. Finally, some FITs have been designed without caps on the amount of generation to be developed (e.g., Germany). This approach can create uncertainty with regard to total policy impact and policy cost, and in some cases (involving short lead-time generation with ample resource potential), has led to substantial rate impacts (e.g., photovoltaics in Spain). In order to address these concerns, there are mechanisms that can be used to limit market growth and contain costs, such as caps and payment level adjustment mechanisms (Kreycik et al. 2011).

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[20] Other approaches that include geothermal specific policies and carve-outs, improvements to existing policies, and agency coordination are outside of the scope of this analysis.

The remainder of this report focuses on geothermal FIT design considerations and the risk implications of different design options in greater detail. This report does not revisit or summarize broader discussions of how FITs compare and contrast with other policy types. The next section explores FITs by first defining what they mean and then examining their application in support of geothermal energy in other countries.

3 Global Experience with FIT Incentives for Geothermal Electricity

3.1 Defining FITs

Although there are no geothermal FITs in North America, there are currently 16 countries that have established specific FIT incentives for geothermal.

FITs, also referred to as *standard offers* or *CLEAN contracts,*[21] are currently the most common national renewable energy policy in the world and are currently in place in over 50 countries (REN21 2011). FITs have driven the rapid scale-up of renewable energy technologies around the world and have supported 87% of the global photovoltaic capacity and 64% of global wind energy capacity as of 2010 (Tringas 2011).

Several recent publications have catalogued and described the primary FIT design considerations (Couture et al. 2010; Grace et al. 2008; Klein et al. 2008; Mendonça et al. 2009). What is clear from these studies is that FITs are complex policies that can be implemented in a wide variety of forms. In fact, no two FITs have been implemented in the same way. The complexity of FITs is attributable to the fact that they are not a single policy focused on the payment level, but rather a package of regulations and incentives, which can contain all of the following elements:

- Interconnection rules. The term "feed-in" tariff derives from the 1991 law in Germany that first guaranteed independent power producers the right to connect to and feed their electricity into the grid. FIT policies may include requirements that utilities interconnect renewable generation ("guaranteed interconnection"), that renewable energy advance ahead of conventional generation in the interconnection queue ("priority interconnection"), and/or that the cost of interconnection or grid upgrades be passed through to ratepayers (Rickerson et al. 2011; Tweedie and Doris 2011).
- Purchase and dispatch requirements. FIT policies may also require that utilities not only purchase all of a generator's output[22], but then also prioritize its delivery ahead of non-renewable generation. If renewable generation must be shut down or curtailed by the grid operator for technical reasons (e.g., in order to ensure grid security), some FIT policies further guarantee that generators will receive payment for the electricity they were unable to sell[23] (Rogers et al. 2010).
- Standardized contracts. FIT policies may include provisions that require utilities to offer standard and simplified contracts to generators, rather than requiring generators to negotiate contracts on a case-by-case basis (Couture et al. 2010).
- Pre-determined long-term payments. FITs typically include a standard offer for a known payment to generators, available on a first come, first-served basis. FIT payment levels are usually set administratively, rather than relying on competition or market mechanisms, and are typically offered for durations of 15 to 20 years (Couture et al. 2010).

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[21] Clean Local Energy Accessible Now, see e.g., Caperton et al. (2011) and Farrell (2011)

[22] Similar to a "must take" contract

[23] Similar to a "take or pay" contract

- Other policy objectives. Additional FIT policy features could include clear transmission cost allocation, cost of system upgrades, cost caps that limit total policy cost, forecasting obligations for variable generation, bonus payments to encourage generation where the electric system most needs it (e.g., urban areas, radial ends of distribution systems), bonus payments for innovative technologies, and repowering of old sites (Couture et al. 2010).

Despite international interest in FITs, there has not yet been much research that focuses on geothermal FIT design specifically. This report represents the first in-depth attempt to explore how these policy elements could be aligned to support geothermal development. As a first step, geothermal FITs internationally were surveyed in order to identify lessons learned. While it is too early to mathematically quantify the impact of geothermal FITs on accelerating project development, some early observations provide some useful insights.

3.2 FITs in North America

FITs have only recently appeared in North America. Ontario established its current FIT policy in 2009 as a replacement for its earlier Renewable Energy Standard Offer Program (RESOP) (Ontario Power Authority 2011). Nova Scotia followed in Ontario's footsteps by establishing its Community Feed-in Tariff (COMFIT) in 2011 (NSUARB 2011). A number of U.S. states have introduced FIT legislation during the past several years, but only California, Hawaii, and Vermont have enacted FITs (Couture and Cory 2009; Rickerson et al. 2008). Additionally, several cities[24] have enacted FIT policies.

The experience with FITs in the United States and Canada, however, has been of limited relevance to geothermal either because geothermal is not eligible to participate, is not a viable local resource, or because the programs impose size limitations (e.g., for distributed, on-site generation) that would effectively exclude most geothermal electric generation.[25]

The closest analogue to large-scale FITs for sizable project in the United States is PURPA of 1978. Under PURPA, utilities were required to purchase power offered by "small power production facilities[26]" at the utilities' full avoided cost. The calculation of avoided cost was left to state discretion. Under PURPA, California created the Standard Offer No. 4 (SO4) contract, which defined avoided cost as a 10-year schedule of escalating payments (Pierce and Livesay 1994). The GTP Blue Ribbon panel noted that SO4 "drove geothermal exploration in the 1980s…Private industry was willing to take more drilling risk because of the higher electricity price (EERE 2011)." In total, PURPA supported 1,346 MW of geothermal capacity, including 1,295 MW in California, 237 MW in Nevada, and 35 MW in Hawaii (Guey-Lee 1999). A more detailed discussion of PURPA and geothermal development can be found in Appendix C.

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[24] E.g., Gainesville, Florida; Sacramento, California; and San Antonio, Texas.

[25] It is important to note that some of the FIT design options described in Section 3.1 are not currently feasible in the United States. Priority interconnection and dispatch rules, which are a feature of European FITs, are not currently allowed in the United States because FERC requires that interconnection service and access to transmission be non-discriminatory for projects over which it has jurisdiction (Fink et al. 2010). Groups such as the Regulatory Assistance Project (2010) have, however, suggested that priority interconnection and dispatch be introduced in the United States. And, these design features can be used by international readers of this report.

[26] According to PURPA, a small power production facility "means a facility which is an eligible solar, wind, waste, or geothermal facility...and has a power production capacity which, together with any other facilities located at the same site…is not greater than 80 megawatts." See http://uscode.house.gov/download/pls/16C12.txt.

PURPA demonstrated that the combination of a guaranteed purchase and a fixed price could attract investment in geothermal development. PURPA was controversial, however, because the prices that were paid under long-term contract were judged to be too high in retrospect for many projects (Hirsh 1999).[27] The effectiveness of PURPA subsided as avoided costs levels decreased with the dramatic fall in natural gas and oil prices. The Energy Policy Act of 2005 (EPAct) further restricted PURPA by exempting utilities that allow non-utility generators access to competitive markets from having to sign new PURPA contracts upon a demonstration to the Federal Energy Regulatory Commission (FERC) (Elefant 2011). Since PURPA provided generators with guaranteed market access and, in the case of SO4, a fixed price for power, many analysts refer to PURPA as the world's first FIT (Lipp 2007; Mendonça et al. 2009; REN21 2011). It is important to note, however, that PURPA was not tailored specifically to support geothermal energy and questions remain as to whether a more targeted policy design could better decrease geothermal development risk while providing generators with lower payments.

3.3 International FITs

International experience with geothermal-specific FITs is limited, but lessons learned to date can inform policy design for geothermal electricity. This analysis of these FIT policies focuses on several key issues:

- A high-level comparison of FIT payment levels for geothermal across different countries
- The impact of geothermal FITs on the development of new capacity worldwide
- Approaches to account for development and exploration costs when setting the FIT payment level

In order to gather data on geothermal policies, reviews of original FIT legislation (or translated legislation) were conducted if readily available in English, Spanish, or German. When laws were not either readily available and/or un-translated, secondary sources that summarized policy content (EGEC 2011; Rickerson et al. 2010) and websites such as RES LEGAL[28] were consulted. In total, 16 countries were identified with FITs specifically for geothermal.[29]

3.3.1 FIT Payment Levels and Impacts by Country

The two tables below contain a high-level summary of the geothermal electric FITs surveyed. Table 1 summarizes geothermal FITs in European Union (EU) member states, whereas Table 2 summarizes geothermal FITs in non-EU countries. The following data is shown for each country:

- FIT payment structure refers to whether the payment is made as a fixed amount for electricity or whether it is paid as a premium on top of the wholesale price for electricity.

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[27] There has also been controversy regarding the payment levels under some FITs, particularly with regard to FITs for photovoltaic systems in countries such as Spain (Couture 2011).

[28] http://www.res-legal.de/en.html

[29] Several countries have policies that are sometimes referred to as FITs but that set a ceiling price for renewable generation, rather than a floor price. Kenya, for example, sets a ceiling price of 8.5 cents/kWh for geothermal (Ministry of Energy 2010). The contract rate must then be negotiated on a case-by-case basis. In Indonesia, generators must compete for power purchase agreements and the price of the power purchase agreements cannot exceed $0.097/kWh (MEMR 2011). These are not considered FIT policies for this analysis.

- Requirements for FIT payment. The types of geothermal plants that are eligible for FIT payments vary by country. Some of the countries specify constraints such as a minimum efficiency or a maximum project size, whereas other countries set forth multiple payment levels differentiated based on project size, resource temperature, or geographic location. Some countries allow bonus payments for plants with certain desirable characteristics (i.e., specific technology, ability to achieve commercial operation within a specified period of time). If a specific plant meets all of these characteristics, then it can claim all of the bonus payments, incremental to the base FIT payment.
- FIT payment duration refers to the number of years that a geothermal plant is paid the FIT incentive. This ranges from 10 years (e.g., Turkey) to 20 years (e.g., Germany and France).
- Geothermal FIT payment refers to the amount of money received for every kilowatt-hour generated under the FIT. This amount is listed in both Euro (€) and in U.S. dollars (US$). Currency conversion throughout this report is based on the Euro-USD exchange rate of 1.4 on November 1, 2011.
- Geothermal Cumulative Installed Capacity refers to the total cumulative installed geothermal electric capacity in the country.
- Cumulative Geothermal Capacity Supported by FIT indicates the total cumulative amount of installed geothermal electric capacity that receives payments under the FIT policy. As can be seen in the table, the amount of geothermal capacity supported by FITs to date has been limited and this is discussed in greater detail in Section 3.3.2.

Table 1. Geothermal Electric FITs in the European Union (EU)

Country	FIT Payment Structure*	Requirements for FIT Payment	FIT Payment Duration (Years)	Geothermal FIT Payment (€/kWh)	Geothermal FIT Payment (US$/kWh)	Geothermal Cumulative Installed Capacity (MW) (2010)	Cumulative Geothermal Capacity Supported by FIT (MW) (as of 2010)
Austria	Fixed	Minimum 60% power plant efficiency	13	0.075	0.11	1.4	1.2[30]
Czech Republic	Fixed	None	20	0.18	0.25	0	0
	Premium	None		0.15	0.21		
France	Fixed	Continental France (< 12 MW)	15	0.2	0.28	16.5	16.5
		Bonus payment for system efficiency (< 12 MW)		0.08	0.11		
		Overseas Territories (OT) (< 12 MW)		0.13	0.18		
		OT bonus for system efficiency (< 12 MW)		0.03	0.04		
Germany	Fixed	Base rate	20	0.25	0.35	7.5	7.5
		Bonus payment for EGS		0.04	0.056		
Greece	Fixed	Low temperature geothermal	20	0.15	0.21	0	0
		High temperature geothermal		0.099	0.14		
		Bonus payment if generator does not receive other subsidies		0.2	0.28		
Italy [31]	Fixed	< 1 MW	15	0.2	0.28	843	0
Spain	Fixed	< 50 MW	20	0.073	0.10	0	0
Slovakia	Fixed	< 10 MW	15	0.196	0.27	0	0
Slovenia	Fixed	< 5 MW	15	0.153	0.21	0	0
	Premium	< 10 MW	15	0.093	0.13	0	0

* FIT payment structure refers to whether the payments are fixed over time or whether they are premium paid on top of wholesale electricity prices.
Sources: (Bertani 2010; BMU 2011b; EGEC 2011; Holm et al. 2010; IGA 2011)[32]

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[30] The Blumau and Altheim plants receive the Austrian FIT. The 200 kW Simbach-Braunau plant, which is a joint Bavarian-Austrian project on the border with Germany, receives the German FIT (personal communication, Dr. Johan Goldbrunner November 21, 2011).

[31] Italy's current geothermal capacity is not attributable to the FIT. Instead, Italy's capacity was primarily built by the (previously) state-owned enterprise, Enel, which assumed the risk for the entire development process from exploration to power plant construction. It is unlikely that the FIT will be utilized in the near future because current projects in the pipeline are above 1 MW (GeothermEx 2010; Holm et al. 2010).

[32] National Renewable Energy Action Plans were also consulted for each country. Available from: http://ec.europa.eu/energy/renewables/transparency_platform/action_plan_en.htm .

Table 2. Geothermal Electric FITs in Non-EU Countries

Country	FIT Payment Structure*	Requirements for FIT Payment	FIT Payment Duration (Years)	Geothermal FIT Payment (€/kWh)	Geothermal FIT Payment (US$/kWh)	Geothermal Cumulative Installed Capacity (MW) (2010)	Cumulative Geothermal Capacity Supported by FIT (MW) (as of 2010)
Croatia	Fixed	<1 MW	12	0.18	0.25	0	0
		>1 MW		0.17	0.24		
Ecuador	Fixed	Mainland	15	0.093	0.13	0	0
		Islands (Galapagos)		0.102	0.14		
Serbia	Fixed	N/A	12	0.075	0.11	0	0
Switzerland	Fixed	<5 MW	20	0.34	0.48	0	0
		<10 MW		0.3	0.42		
		<20 MW		0.23	0.32		
		>20 MW		0.19	0.27		
Taiwan	Fixed	N/A	20	0.12	0.17	3.3[33]	0
Turkey	Fixed	Base rate	10	0.07	0.10	81	0
		Bonus: Steam or gas turbine domestic content		0.009	0.01		
		Bonus: Generator and power electronics domestic content		0.05	0.07		
		Bonus: Steam injector or gas compressor domestic content		0.05	0.07		
Uganda	Fixed	N/A	20	0.05	0.07	0	0

Sources: (Bertani 2005; Bertani 2010; Electricity Regulatory Authority 2010; Gipe 2011; Holm et al. 2010; IGA 2011; Kolarevic 2009)

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[33] A 3-MW single-flash unit was installed in Qingshui in 1981 and a 300 kW unit was later installed at the same field. Both systems ceased operations in 1994 (Bertani 2005).

3.3.2 Lessons Learned from International FITs

A high-level review of the policy design and implementation details of global geothermal FITs provides several insights:

- A diversity of geothermal FIT designs. It is noteworthy that of the approximately 50 countries that have enacted FITs internationally, approximately one-third have crafted specific incentive levels targeting geothermal development. Of these, each of the different countries has designed their FITs to reflect different policy objectives and geothermal resource characteristics. These include a focus on small scale projects (Italy), minimum plant efficiencies (Austria), specific resources (e.g., EGS Germany and low temperature in Greece), different geographies (e.g., islands vs. mainland in Ecuador and France), and domestic content (Turkey). These design considerations can serve as useful benchmarks as policymakers in other countries consider their own customized designs.
- A broad range of remuneration levels. The diversity of FIT designs is also reflected in the manner in which the FIT payment levels are set. Figure 3 compares the highest rate paid for geothermal in each country by calculating the net present value[34] of the revenue that would be paid to a one megawatt geothermal plant for the duration of the FIT contract as a means of comparing contracts of different lengths. This illustrates, for example, that the overall value of geothermal in the Czech Republic is higher than that in Croatia. Although both countries pay generators €0.18/kWh, generators receive this payment for 20 years in the Czech Republic instead only 12 years in Croatia.[35] As can be seen in the figure below, the value provided to generators varies widely. This reflects the fact that some countries have established payments designed to reflect the generation costs of comparatively expensive technologies, such as EGS in Germany or smaller-scale, island-based systems in France.[36] Other countries, such as Serbia, have set payment levels more conservatively in order to target only lower-cost generators (Kolarevic 2009). The examples of Germany and Spain are discussed in greater detail in Sections 3.3.3.1 and 3.3.3.2.

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[34] Assuming a 7% discount rate and a 72% net capacity factor.

[35] The net present value of the total payments for one kilowatt-hour generated each year under the Czech FIT is €1.91 whereas the net present value of the total payments for one kilowatt-hour generated each year under the Croatian FIT is €1.43.

[36] All of France's overseas departments, with the exception of French Guiana, which is on the mainland of South America, are islands.

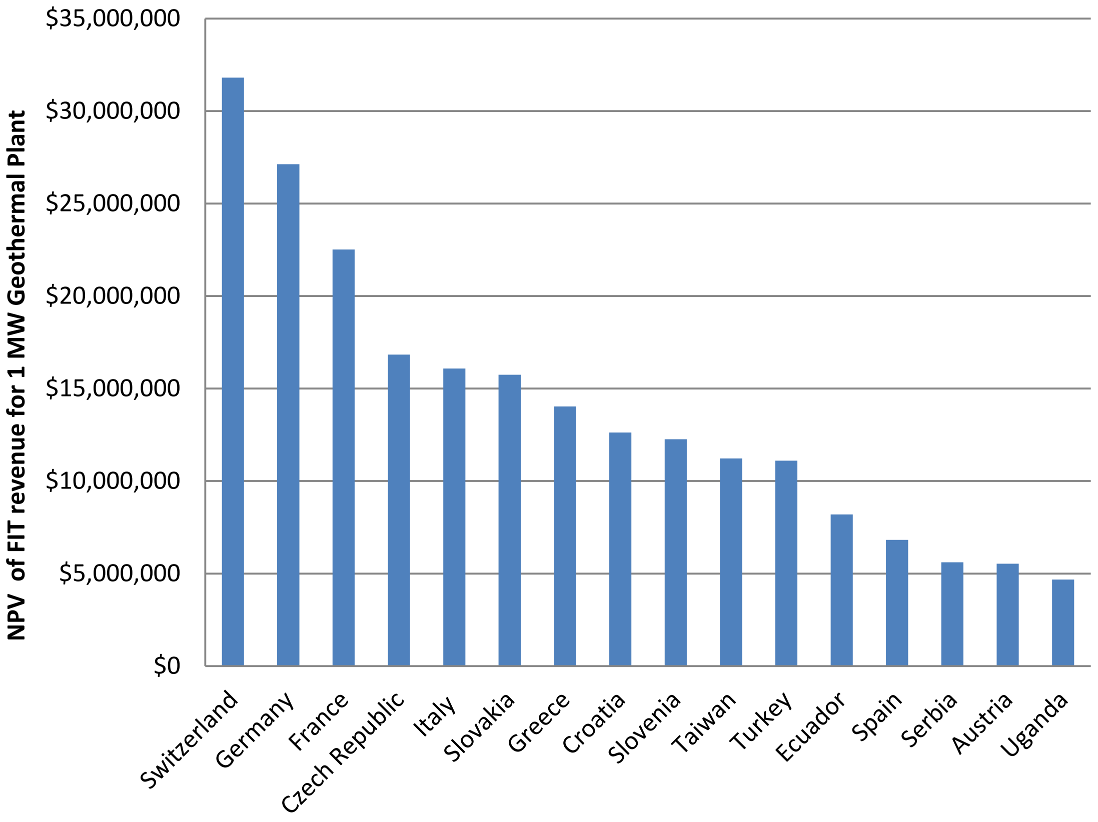

Figure 3. Comparison of FIT revenue NPV for 1-MW geothermal plant

Source: Calculations based on Figure 1 and Figure 2 (72% net capacity factor, 7% discount rate)

- A lack of empirical data on FIT impacts. Although the range of different designs is a useful benchmark, there is currently a lack of data with which to compare the impact of different design decisions. Despite the success of PURPA in the United States (and SO4 in particular), response to international FITs to date has been limited. Only the FITs in Austria, Germany, and France have supported new geothermal capacity and, in these cases, the total amount of new generation has been under 20 MW. [37]

There are several likely reasons for the lack of market response to geothermal FITs thus far. First, many of the countries in Europe have comparatively low levels of hydrothermal resources and are attempting to support EGS, which is an emerging technology (not fully commercial) and therefore has proven expensive and challenging to develop to date (GEOFAR 2010). Second, several of the geothermal FITs are comparatively new (or have been recently amended); geothermal developers have not yet had time to react given the long development lead times required of geothermal projects. As a result, policymakers have not had the benefit of calibrating their policies according to established policy track records (as they have been able to do with wind and solar FITs). Third, the payments offered under the FITs may be insufficient to support geothermal development because the payments are too low to compensate for the price of the

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[37] Conversely, none of the countries ranked in the top 10 for total geothermal capacity has a geothermal FIT in place except for Italy, whose FIT targets only generators 1 MW and under. In order, the top 10 countries include United States, Philippines, Indonesia, Mexico, Italy, New Zealand, Iceland, Japan, El Salvador, and Kenya.

geothermal resource or because of other country-specific risks (e.g., political risk or currency risk) (GEOFAR 2011; Goldbrunner 2010). Fourth, the presence of other technical and non-technical barriers to geothermal development (e.g., unmitigated exploration risks or lack of transmission) may serve as a barrier despite the presence of otherwise attractive payment levels (GEOFAR 2009b; Hurlbut 2012). Finally, some of the FITs are available only to small projects whereas geothermal project development has focused on larger-scale projects (e.g., Italy).

A key take-away from the international survey is that the presence of FITs alone has not driven results comparable to those achieved for wind and solar power under European FITs or to those achieved for geothermal under PURPA in the United States. On the other hand, international experience demonstrates that many countries are experimenting with crafting policies that are more specifically tailored to geothermal than North American policies (e.g., RPS and PURPA) have been in the past. Geothermal FIT policies are continuing to evolve and mature and there remains room for innovation and further research into international designs. FITs can be designed to take country-specific geothermal resources and risks into account and may be part of a broader package of geothermal risk mitigation policies, including exploration support or expedited permitting (Miethling 2011).

Unlike many of the countries in the international survey, the United States has a strongly identified and unexploited hydrothermal resource as well as a significant amount of as-yet unidentified hydrothermal resource. It is reasonable to assume, especially given the experience with PURPA, that appropriately crafted and targeted FITs in the United States could have a greater impact on market growth than in other parts of the world.

3.3.3 Approaches to Setting FIT Payment Levels

A primary step to establishing targeted FITs for geothermal is determining the payment levels that will be offered to generators. As explored in a recent NREL report, a broad range of approaches can be used to set payments for FITs or other performance-based incentives (Gifford et al. 2011). The key considerations when developing FIT payment levels include:

- Basis for setting payment levels. Payment levels can either be set based on the generation cost of a certain technology (a “cost based” approach) or pegged to measures of value such as the avoided cost of energy and/or avoided externalities.
- Contract length. As shown in Tables 1 and 2, the contract length varies widely between FITs. For generation cost based payments, the contract length can have an impact on the $/kWh payment to the generator. Shorter contracts require a higher payment than longer-term contracts to achieve the same rate of return.
- Model for setting payment levels. Different jurisdictions utilize different spreadsheet models to set their payment levels. The key policy choices related to model design are whether to employ cash flow forecasts or recovery factor analyses and whether to utilize a pre-tax or after-tax analysis. In a separate effort, NREL surveyed international FIT practices and U.S. policy requirements, and developed an after-tax discounted cash flow model called CREST[38] that includes a geothermal model (Gifford et al. 2011).

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[38] Available for download at https://financere.nrel.gov/finance/content/CREST-model

- Type of input data. Models for setting payment levels can range from high-level and comparatively simple to highly complex models. The number of inputs and the granularity of those inputs can to a great extent determine model complexity. For example, modelers can choose to use a single input for "installed cost" or they can choose to break installed costs into labor cost, detailed equipment costs, and other upfront (e.g., development, permitting, financing-related) costs.
- Input selection. A range of values that can be considered "reasonable" for each input. Policymakers have a choice as to whether they select values at the upper or lower ends of these ranges. To a great extent, these choices will determine how aggressive or conservative[39] the ultimate FIT payment level is and thus the volume of new generation that will be able to participate under the policy.

As seen in Tables 1 and 2, the manner in which policymakers choose the basis for geothermal payment level setting and select modeling inputs can result in widely different FIT payment levels. Given the magnitude of the costs and risks of exploration and development, a key choice for U.S. policymakers will be whether and how these costs are incorporated into the development model.

The two primary approaches to setting FIT payment levels are to base the payment on a measure of value (e.g., avoided cost) or to base the payment on expected generation cost of eligible projects (Grace et al. 2008). In North America, the current state FIT in California and the municipal FIT in Sacramento are based on avoided cost (plus adders reflecting externalities), whereas the remainder are generation cost-based policies. Cost-based FITs dominate world FIT policy methodology. This report focuses on generation cost-based FITs in order to highlight the wide number and variety of policy choices that could have implications for geothermal projects. The development of value-based payments could be the focus of future research.

This section reviews the geothermal policymaking and approach to setting payment levels in two countries, Germany and Spain, in order to explore this and other issues in greater detail.

3.3.3.1 Geothermal FIT Policy and Payment Level Setting in Germany

Germany's fleet of installed geothermal capacity remains comparatively small. The first system was installed in 2003 and there were five systems totaling 7.5 MW by the end of 2010 (BMU, 2011a). Compared to the U.S. generation fleet, these systems are very small scale and embrace less common approaches such as Kalina cycles, EGS, and combined heat and power systems (GEOFAR 2010).

Germany's renewable energy FIT has been in place since 1991. The first tariff for geothermal power was introduced in 2000 with the passage of the Renewable Energy Law: the Erneuerbare-Energien-Gesetz (EEG).[40] The initial 20-year tariff level was set at 8.95 €cent/kWh (12.53 ¢/kWh) for systems up to 20 MW in size and 7.16 €cent/kWh (10.02 ¢/kWh) for systems larger than 20 MW. The EEG included annual decreases in the available FIT payment for most

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[39] Conservative FIT rates are rates that are set at a level to encourage the lowest cost projects. Aggressive FIT rates are set to enable a broader range of systems to enter into the market (Grace et al. 2008). Policymakers can choose to set their FIT rates along the spectrum from conservative to aggressive rates, depending on their policy objectives (Gifford et al. 2011).

[40] The Erneuerbare-Energien-Gesetz or EEG

generators according to a fixed schedule (i.e., a degression schedule[41]). Geothermal payments were not subject to degression, however, in order to account for long development lead-times. The first geothermal power plant in Germany was built under the FIT in 2003.

The German Ministry of Economy and Finance (BMWI) and the Ministry for the Environment (BMU)[42] co-financed the first geothermal electricity plant in order to gain a better understanding of geothermal economics.[43] Based on the experiences with the first power plant and additional research, policymakers concluded that the tariff levels under the EEG were too low to support geothermal market expansion, especially for small-scale generators (Jacobs 2012). In the 2003 FIT progress report, the BMU recommended adjusting the tariff to better account for geothermal plant economies of scale (BMU 2003). The revised EEG of 2004 introduced two additional size categories below 20 MW, according to the table below:

Table 3. Size Categories and Tariff Payment Levels under Revised German EEG (2004)

Geothermal plant size	€/kWh	$/kWh
< 5 MW	0.15	0.21
5 MW – 10 MW	0.14	0.20
10 MW – 20 MW	0.0895	0.13
> 20 MW	0.0716	0.10

The 2004 law also introduced a new degression of 1% annually, but delayed the start of the decrease until 2008 to account for the lengthy development timeline.

In 2007, the BMU again released a progress report that evaluated the adequacy of German FIT payment levels. The report concluded that an additional increase in the tariff levels would be necessary in order to account for higher actual drilling costs resulting from increased activity in the oil and gas sector (BMU 2007). The revised 2008 EEG introduced simplified size categories with higher payment levels as can be seen in the table below; one goal was to provide revenue to cover the assumed project drilling costs. The law also included bonus payments for systems that went into operation before 2016, that used combined heat and power, and that used EGS technology. These bonuses are additive such that an EGS CHP system that is under 10 MW and installed prior to 2016 would receive €0.27/kWh (0.38 $/kWh) for 20 years.

Table 4. Simplified Categories and Tariff Payment Levels for 2008 German EEG Revision

Geothermal plant size	€/kWh	$/kWh
< 10 MW	0.16	0.22
> 10 MW	0.105	0.15
Bonus: Installed prior to 2016	0.04	0.06
Bonus: Combined heat and power	0.03	0.04
Bonus: EGS	0.04	0.06

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[41] A degression schedule reduces the fixed rate available to new generators built at a later date as opposed to reducing the rate available to a particular generator over time.

[42] *Bundesministerium für Umwelt Naturschutz und Reaktorsicherheit*

[43] The 230 kW Neustadt-Glewe plant, which was Germany's first geothermal power installation, utilized an Organic Rankine Cycle to generate electricity from lower-temperature water. The project added a power plant in 2003 to an existing geothermal heat plant. The cost of the power plant installation was €1.6 million (GEOFAR 2010).

On January 1, 2012, the German FIT was again revised to include a single payment level for geothermal projects of €0.25/kWh (0.35 $/kWh) for 20 years. EGS plants are eligible for a €0.04/kWh (0.056 $/kWh) bonus payment. The rates from 2007 were consolidated into one higher rate, and the new rate reflects that drilling costs had been more uncertain than anticipated[44] and that financing costs were higher than previously modeled because of larger project risks. Degression is set at 5% a year but does not begin until 2018. This latest version of the German geothermal FIT payment values are captured in Table 1.

The key parameters used to calculate the German FIT payment level in 2011 are contained in Table 5 below. It is noteworthy that drilling costs are assumed to make up the largest share of the installed cost for geothermal plants in Germany. These drilling costs are based on experience from six geothermal projects with 11 production wells between them (total 47,000 meters of drilling) (Jacobs 2012). For each project, drilling costs amounted to between €20 and €28 million ($28-$39 million).

Table 5. Key Parameters for Calculation of German FIT

Debt to equity ratio	59/41
Return on equity	12.3%
Interest rate	6%
Weighted average cost of capital	9.3%
Contract length	20 years
Installed costs	10,900 € per kW installed (15,260 $/kW)
Inflation rate	2% per year
Drilling costs (% installed costs)	47
Power plant costs (% installed cost)	27
Development costs (% installed cost)	6
Labor	100,000 € per year ($140,000 per year)
Full load hours per year	8,000

Source: BMU (2011a)

It should be noted that the weighted average cost of capital of 9.3% reflects costs of capital for the exploration, power plant construction, and operation phases. The German government analysis assumed that the exploration phase is 100% equity financed, with a 20% return on equity (ROE) (BMU 2011a). At the end of the development process, it is assumed that the project will secure permanent financing with a debt to equity (D/E) ratio of 70/30, an 11% ROE and a 6% interest rate. The weighted average return on equity from exploration to construction is 12.3% and the weighted average D/E ratio is 59/41.

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[44] In almost all cases, the initial drilling cost assumptions from previous years had been exceeded by 70% (BMU 2011a). In order to further reduce drilling risks, the German government also created a grant program to support drilling parallel with the adjustments to the FIT.

3.3.3.2 Geothermal FIT Policy and Payment Level Setting in Spain

Spain's FIT has gained international attention because it has supported a strong and sustained wind energy market growth (GWEC 2011) and because it created an unprecedented (and short-lived) solar photovoltaic market boom in 2008 (Ciesielska et al. 2011).

Most of the Spanish FIT payment levels are based on the generation costs of each specific technology. Geothermal, however, does not receive a cost-based payment and instead receives a general payment available to "emerging" technologies such as wave power, ocean thermal energy conversion technologies, and tidal power (Jacobs 2012).

The payment available to geothermal power plants in Spain has remained relatively stable over the years. The initial emerging technology tariff of 6.73 €cent/kWh (9.42 ¢/kWh) was enacted into law in 1999. From 2004-2007, the tariff was set at 90% of the average retail electricity rate, which was 6.49 €cent/kWh (9.09 ¢/kWh) in 2004 and 6.6 €cent/kWh (9.24 ¢/kWh) in 2005 and 2006. In the 2007 amendment to the FIT law, the fixed emerging technology tariff payment level was set at 6.89 €cent/kWh (9.65 ¢/kWh) (Jacobs 2012). The available payment level, which is indexed to inflation, has since increased to 7.441 €cent/kWh (10.42 ¢/kWh) in 2011.

The FIT payment level is available for the first 20 years of operation. After the first 20 years, geothermal generators are eligible for a slightly lower payment level that is available for the remainder of their operational life. Currently, the payment level available after the 20th year is 7.0306 €cent/kWh (9.84 ¢/kWh).

No geothermal power has been developed to date in Spain (Sanchez-Guzman and Garcia-de-la-Noceda 2010). This is primarily because Spain does not have strong hydrothermal resources on the mainland[45] and likely because the current emerging technology FIT payment level is not high enough to support hydrothermal or EGS development.

3.3.3.3 Lessons from Germany and Spain

There are several key lessons from experiences in Germany and Spain.

- Policy objectives matter. The manner in which policy objectives are interpreted through policy design can have a dramatic impact on the payment levels that generators receive. Germany's decision to provide a bonus payment for EGS (separately from hydrothermal), for example, resulted in much higher payment levels than Spain's technology neutral payment level for emerging technologies.
- Exploration risk can be considered. The payment level setting process can be used to reflect exploration and development risks. Setting the payment level based on generation cost enables policymakers to specify the degree to which exploration risk is assumed to be a project cost driver. In Germany, for example, these risks are reflected in the significant share of project costs that derive from the development and exploration phases and in the financial assumptions. Incorporating a greater degree of exploration and development risk into the payment level results in higher payment levels that can allow a broader range of potential projects to be developed (but also creates higher policy costs if there is a significant volume response).

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[45] Hydrothermal exploration is ongoing in the Canary Islands (Hidalgo 2011).

- Generic FIT payments may not be effective. The experience in Spain demonstrates that generic FIT payments not set based on generation cost may be too low to support geothermal development, particularly in countries without a strong hydrothermal resource.

4 FIT Design to Support Geothermal Development in the United States

4.1 Integrating FITs with Geothermal Targets

FITs can be designed specifically to support geothermal energy development in the United States, by considering FIT design issues that are specifically relevant to the unique characteristics of geothermal power plant development and operations in the U.S. context.

Many FITs are directly linked to national or state energy targets. The 2008 FIT law in Germany, for example, explicitly specifies that the intent of the FIT is to meet the national renewable electricity target of at least 30% by the year 2020. FITs can also be linked explicitly to targets for individual technologies. The linkage of FIT policies with mandatory renewable energy targets gives investors a better sense of the policies' horizons and increases investor security (Deutsche Bank Climate Change Advisors 2011). If geothermal FITs are established, they can be explicitly linked with mandatory geothermal targets through law or regulation.

While there is not a national U.S. renewable electricity target, there are currently 29 states that have mandatory RPSs and 8 states that have voluntary goals. FITs are one of the potential mechanisms that can be utilized to achieve RPS targets and objectives (Cory et al. 2009). Fourteen states have established specific targets for solar electricity and several have established specific goals for other technologies or applications (e.g., wind, distributed generation, etc.). At present, however, opportunities to integrate geothermal FITs with existing RPS targets are limited since no targets specific to geothermal energy exist.[46]

Policy design assessment for lowering investor risk. Setting mandatory and specific targets for geothermal can improve investor confidence in a state's commitment to geothermal procurement. Setting specific mandates for geothermal can also form the basis for states to set geothermal-specific payment levels under PURPA and reduce concerns about states' ability to set premium wholesale rates.[47]

4.2 Technology Eligibility and Differentiation

FITs can consider technologies in two distinct ways. Eligibility refers to whether a certain technology, ownership type, or project size is allowed to participate in (or is excluded from) a

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[46] In New Mexico, carve-outs exist for solar and wind and geothermal shares a combined target with biomass, certain hydropower facilities, and selected other renewables (Doris et al. 2009).

[47] If carefully structured, the relationship between FITs and RPS targets may help mitigate concerns about whether states have the authority to set FIT rates. According to federal law, states do not have jurisdiction to set premium payment rates for wholesale power. States do, however, have authority under PURPA to set rates based on avoided cost. Recent guidance from FERC seems to indicate that state targets for renewable electricity can allow PURPA rates to be set at the avoided cost of meeting those targets. To the extent that states have set a technology-specific target, avoided cost can be defined as the cost of that specific technology for purposes of meeting the target (Cory 2011; Elefant 2011; Hempling et al. 2010). RPS laws do not set payment rates for specific technologies, but they can set targets for specific technologies. PURPA allows states to set rates, but not above avoided cost. By combining RPS technology-specific targets (under state law) with PURPA rate setting authority (under federal law), states could achieve results very similar to setting technology-specific FIT rates,but only for projects that register as qualifying facilities (QF) under PURPA. This arrangement may not apply for utilities or regional transmission organizations (RTO) that are exempt from signing new PURPA contracts, i.e., a utility would have to voluntarily agree to sign such a FIT/RPS contract.

given policy, whereas technology differentiation refers to how FIT payment levels are targeted to certain technologies, sizes, ownership models, or locations. As can be seen in Tables 1 and 2, international FITs generally have few eligibility requirements outside of overall project size caps, but are differentiated in ways that reflect diverse policy objectives. U.S. policymakers would be able to customize FITs to support different types of geothermal installations in a number of different ways. Based on recent U.S. development trends, FIT differentiation strategies could include:

- Geothermal resource type. In order to support the different types of geothermal resources that are currently being explored, including hydrothermal, EGS, co-produced and geopressured, FIT payment levels could be tailored and differentiated to have a different payment level for each resource type. Such an approach acknowledges that each of these applications has different cost structures and would ensure that each receives adequate revenue for project development, but not more than is required (e.g., payments appropriate for EGS might result in overpayment for other applications).
- Project size. A broad range of geothermal project sizes are currently under development in the United States, with a significant percentage of proposed plants smaller than 50 MW (Jennejohn 2011). Since economies of scale can exist as projects get larger, FIT payments could be differentiated by size in addition to technology. As shown in Table 2, Switzerland uses four project sizes: <5 MW, 5-10 MW, 10-20 MW and 20+ MW.[48]
- Resource vintage. Geothermal development is proceeding both at existing and new geothermal fields. The risks and costs of identifying and developing a greenfield geothermal site are markedly different from those involved in expanding an existing site or building on an identified reservoir. Tariff differentiation could take this difference into account as well.

Policy design assessment for lowering investor risk. The choice of eligibility or differentiation does not have direct impact on project risk, although it will impact which projects are more attractive to investors. The primary concern from an investor perspective is whether the payment available is sufficient to cover operating expenses and meet the required returns for the project.[49]

4.3 Incorporating Exploration Expense in FIT Payment Levels

Setting FIT payments often includes assumptions about the cost of measuring the available resource (e.g., wind speed, solar insolation, and wood fuel availability). For geothermal, establishing resource availability and adequacy requires going beyond desktop study or relatively inexpensive meteorological measurements, requiring costly field-based study, which often includes significant exploration and test well drilling activity. These resource assessment activities can comprise a much greater share of total project cost and a greater portion of the overall development timeline than for other renewable energy technologies. For geothermal,

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[48] When offering higher payments for smaller projects, it is important to design a FIT to avoid gaming such as carving a larger project into smaller phases to access higher payments than would be merited by the combined project scale.

[49] It is also important that the eligible geothermal technologies be explicitly defined if it is the intent of policymakers to support a specific type of plant. For example, policymakers may wish to specify which geothermal electric configurations are eligible (e.g., hydrothermal, EGS, co-produced, and geopressured) and perhaps include or exclude geothermal heat or heat pumps.

there is also a greater risk that these initial resource exploration activities will not produce a viable project. Multiple locations may need to be explored before a specific project location enters the design and permitting process. As a result, the manner in which estimates of exploration expense are incorporated into FIT payment setting models is a serious consideration. Options for incorporating exploration expense include:

- Include estimated total exploration costs. Incorporate an assumed exploration success rate, investor return requirement, and commensurate level of exploration expense explicitly in FIT payment setting. Using this method, the developer's exploration risk is reflected through a higher FIT payment level. Different assumed exploration success rates and investor return requirements can be selected to establish different FIT payments for regions with existing geothermal facilities compared to those which have yet to be proven. The modeled exploration costs and return requirements are a policy choice and can reflect a preference for more aggressive or conservative payment setting.
- Include a fraction of estimated exploration costs. Attributing only a portion of actual exploration expenses to a project by assuming developers will cost-share exploration costs, exploration costs could be spread over several power plants, or that a portion of the costs could be decreased by other public-sector cost sharing.[50]
- Ignore exploration costs. No exploration costs assumed in payment setting.

Policy design assessment for lowering investor risk. Acknowledging and accounting for exploration costs in FIT payment setting is one of the most effective ways to reduce investor risk and encourage the flow of capital, from both existing and new sources, into geothermal project development. Assurance of a financeable contract that enables the recovery of reasonably incurred exploration expenses provides a signal to the market to invest, notwithstanding the fact that not every exploration is expected to produce a viable thermal resource.

4.4 Standard Pricing and Standardized Off-Take Contracts

While competitive solicitations play a critically important role in the renewable energy market place, their cyclical and often fast-moving announcement, bidding, and negotiation schedule favors renewable energy technologies with shorter development lead times than geothermal projects. Developing a long-term, standard offer price and standard contract for specified eligible facilities is an effective tool for supporting long lead-time projects. Standard offer prices and contracts can reduce the expense associated with periodic solicitations by removing the bid security, legal, bid preparation, and other transaction costs of pursuing a competitive PPA.

Policy design assessment for lowering investor risk. FITs provide generators with standardized prices and contracts that can reduce the contract price risk, transaction costs, and uncertainty of PPA negotiation. This has the potential to reduce investor return requirements and increase the pool of available capital.

4.5 Payment Structure

As shown in Table 1, FITs can be structured as fixed "all-in" prices (that include the power and the attributes, or renewable energy certificates) or premium payments that float on top of (and

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[50] In order to support this approach, such supplemental policies would need to be confirmed or developed in tandem with the FIT and their relationship formally linked.

are additive to) wholesale market prices.[51] In general, premium payment options are utilized to encourage generators to participate in wholesale electricity markets in order to support deeper and broader competition, and to encourage generators to respond to market signals. Geothermal power plants are baseload generators and unlikely to adjust their behaviors based on market prices. Moreover, several electricity markets in the United States do not have competitive wholesale markets with liquid spot prices. As a result, premium payments may not be a practical option for geothermal FITs in some locations.

Policy design assessment for lowering investor risk. From the perspective of investors, fixed prices[52] are lower risk than premium payments that leave greater uncertainty because the total payment level varies with market prices.

4.6 Contract Duration

Geothermal plant life is typically assumed to be at least 30 years (Lovekin and Pletka 2009; PT Castlerock Consulting 2010). As can be seen in Table 1, international FITs are paid out over 10-20 years, with the exception of Spain which guarantees a payment for the entirety of project life (albeit at a lower payment level after year 20). As shown in Figure 6 in Section 5, under a cost-based FIT, a longer contract length would lower the $/kWh payment paid to generators since project costs would be spread out over a longer period of time. A longer-term contract would therefore create greater opportunity for geothermal contracts to serve as an effective hedge against fossil fuel prices (or even create immediate savings if the avoided cost rises above the tariff payment).

Longer contract durations also provide increased revenue certainty for project investors. This is likely to increase the number of investors willing to finance geothermal projects and reduce the cost of capital. Reductions in the cost of capital would stem from both the increase in the number of active investors and the reduction in risk provided by the long-term, stable cash flows.

Policy design assessment for lowering investor risk. To the extent that post-contract market revenue projections are utilized in setting a FIT payment,[53] longer contract durations reduce investor risk by reducing the proportion of lifetime revenues exposed to market price risk. If, however, FIT payments are designed to attain target investor returns prior to contract termination, investors should be indifferent to contract duration.[54]

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[51] A third option is the "spot market gap" structure in which the generator is guaranteed a fixed revenue and paid the difference between that fixed revenue (akin to the strike price in a contract-for-differences) and the wholesale market price over time (Couture and Gagnon 2010). This approach creates a similar risk profile, from an investor perspective, to a fixed, all-in price structure.

[52] There are also different ways to structure fixed price payments. Offshore wind payments in Germany, for example, are designed with higher payment levels upfront and lower payment levels in later years in order to "front load" project revenues. This enables projects to more quickly pay off their debt (Couture et al. 2010).

[53] I.e., the FIT rate calculation presumes revenue post-contract rather than recovering all up-front investment during the term of the FIT.

[54] Different types of investors may have different perspectives on whether shorter or longer-term durations are preferable. Some investors may wish to realize their expected return in a shorter period of time whereas other investors (e.g., pension funds) may wish to invest in contracts with long-term revenues in order to better match their long-term liabilities.

4.7 Policy and Contract Timing

Core characteristics of geothermal development, particularly long development horizons and the presence of substantial exploration risk, make aspects of policy timing particularly important. To have its greatest benefit in mitigating developer risk and therefore reducing financing costs, a FIT policy would (1) be of sufficiently long duration to be available upon project commercial operation to a developer investing in exploration-phase activities and (2) set and hold a FIT price available during the operation of a geothermal project well in advance so a geothermal developer could make exploration and development investment decisions based on specific and reliable revenue expectations. Such a FIT policy could reduce or eliminate the need for developers to build in a risk premium due to competitive RFP processes.

Establishing FIT cost-containment mechanisms, such as volume caps, price adjustment mechanisms, and/or automatic triggers for policy review, appear to help avoid FIT oversubscription and provide greater certainty about policy outcomes (Kreycik et al. 2011). It is worth noting that the experiences with oversubscription have been primarily with FITs established for solar and wind power, technologies with substantially shorter lead times and greater rates of technological advance (price evolution) than geothermal. For this reason, the potential for an explosive project development response to a geothermal FIT would appear far lower than for solar and wind; policymakers should have adequate time to adjust. Nonetheless, cost containment and policy review mechanisms appear to be a standard practice for FIT implementation today. If caps are implemented for geothermal, it is useful to acknowledge the policy tradeoffs. On the one hand, implementing volume caps and typical price adjustment mechanisms can undermine the benefit of assured market access and can increase developer risk. On the other hand, holding a price and access open for as long as 4- 7 years in advance (i.e., the development horizon for a geothermal plant) could restrict the establishment of meaningful cost control practices.

Policy design assessment for lowering investor risk. At a minimum, the presence of a stable FIT policy that could be relied on by an early-stage geothermal developer investing in exploration-phase activities could decrease developer risk. A policy designed to balance investor risk mitigation with policymaker/regulator needs to minimize ratepayer risk might have some or all of the following characteristics:

- Long duration. Be established for a sufficiently long duration to span the period for securing a long-term revenue stream from exploration decision to commercial operation.
- Developer queue with capacity cap. If a capacity cap is established for a geothermal FIT, it may be accompanied by a developer queue to provide regulators with a means to track development progress in response to the FIT while providing developers in the queue with the ability to rely on access to the FIT. This might include developer registration for a specific number of MW, accompanied by a modest $/MW deposit to maintain a queue position. First registrants in such a queue might receive a longer assured access to known price than developers later in the queue. To avoid speculative queuing and allow for

removal of developers unprepared to move forward, an increasing deposit might be required over time to maintain a preferred queue position[55].

- Adequate lead time for policy adjustments. Allow regulators to establish or modify quantity/cost caps and tariff prices with a lead-time that balances the needs of policymakers to contain costs and the value to developers of assured access to a FIT at known price. For projects whose remaining development activities are expected to extend beyond this lead-time, their investors will need to understand that caps might be reached (if applicable) and that adjustments might be made to the nonetheless cost-based tariff. The lead-time could be fixed (e.g., 4 years), or might be adjusted within a range based on the MW in the queue.

4.8 Payment Indexing Over Time

In some jurisdictions, the FIT payment (or a portion thereof) is adjusted annually to account for inflation. Since renewable generators such as solar and wind have small operation and maintenance (O&M) expenses, some analysts have argued that they do not require annual inflation adjustments (Boonin 2008). Geothermal plants, however, can have proportionately higher O&M expenses. In addition to power plant maintenance, geothermal power plants also require well field maintenance. Geothermal field production, for example, will decline over time depending on factors such as plant capacity and the rate of natural reservoir replenishment. In order to compensate for geothermal resource declines, power plants drill additional “make-up” wells to boost production. It has been estimated that annual make-up drilling costs correspond to 5% of initial drilling cost (Hance 2005). During the past several years, the cost of drilling has been particularly volatile, rising up to 64% in the United States between 2004 and 2008 and then subsiding by 30% between 2008 and 2010 (Augustine et al. 2010; Lovekin and Pletka 2009). Given both the significance of make-up drilling costs and the volatility, an alternative to using a general inflation rate as an index for FIT payment adjustment is to index geothermal payments to follow the cost of drilling over time, provided that a representative, independent, and visible drilling cost index is available.

Policy design assessment for lowering investor risk. Given the potential size of geothermal maintenance O&M expenses, indexing a portion of a FIT payment to inflation, drilling costs, and/or other relevant indices would reduce project risk and assure investors that long-term O&M costs were considered.

4.9 Adjusting the Policy

There are a range of different approaches to adjusting FIT policies over time in order to reflect changing market conditions and policymaker objectives. Adjustments can be characterized by what triggers the adjustment and the type of adjustment that is made. Triggers can include milestones such as the installation of a certain amount of capacity or the passage of a specified amount of time. The type of adjustments that can be made include an automatic adjustment to the available payment level, a hard cap on the policy after which no new FIT contracts are available,

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[55] There is a tradeoff when considering caps, queues, and security deposits. On the one hand, creating a “high bar” for entering the queue by establishing high security deposits, etc., could better ensure that only “serious” projects will enter the queue. On the other hand, high barriers to entry may shut out or deter smaller developers from participating in the market. This barrier to entry may constrain the achievement of specific economic development or industrial objectives (e.g., the encouragement of local developers or the deployment of innovative new technologies).

or the instigation of a full policy review (Deutsche Bank Climate Change Advisors 2011). In Germany, for example, an automatic price decline is triggered every year, whereas a full policy review is triggered every four years (BMU 2011b). Policy adjustments are a key concern for technologies such as solar photovoltaics (PV) that have short development timelines, an almost universally available resource, and the ability to scale-up rapidly. Since geothermal development timelines are long, however, time-based policy adjustments may not be necessary and instead the policy can link adjustments to the achievement of capacity targets or make them contingent upon the outcomes of periodic review.

Policy design assessment for lowering investor risk. An ideal policy would have infrequent adjustments made on a schedule that is known in advance and would utilize a process that is as transparent as possible.

4.10 Setting Geothermal FIT Payment Levels in the United States

Depending on a given state's policy objectives, its geothermal resource, and other factors such as barriers, risks, and existing policies, actual FIT designs could vary widely. We considered the ability of a policy design element to lower investor risk as a simple analytical metric to distinguish between different design options. The evaluation criteria used to choose between different FIT designs will also vary from state to state and may give weight to stakeholder groups beyond investors (e.g., ratepayers). Moreover, this section does not attempt to compare or contrast FIT designs with other policy types.

Table 6 summarizes several of our findings.

Table 6. Key Findings Regarding FIT Policy Design in the United States

Policy Design Issue	Design Option Potential for Lowering Investor Risk
Integrating FITs with Geothermal Targets	Setting mandatory and specific targets for geothermal can improve investor confidence in a state's commitment to geothermal procurement. Setting specific mandates for geothermal can also form the basis for states to set geothermal-specific payments under PURPA and reduce concerns about states' ability to set premium wholesale rates.
Technology Eligibility and Differentiation	The choice of eligibility or differentiation does not have direct impact on project risk. What matters from an investor risk perspective is whether the FIT payment available to geothermal generators of various sizes and types is sufficient to cover operating expenses and meet investors' required returns.[56]
Incorporating Exploration Expense into FIT Payments	Accounting for exploration costs when setting the FIT payment (i.e., by building exploration cost assumptions into the price setting model) reduce investor risk and encourage the flow of capital into geothermal development. Assurance of a financeable contract that enables the recovery of some level of estimated exploration expenses provides a signal to the market to invest, notwithstanding the fact that not every exploration is expected to produce a viable thermal resource.
Standard Pricing and Off-Take Contracts	FITs provide generators with standardized off-take contracts that can reduce power project contract price risk and transaction costs. This has the potential to reduce investor return requirements and increase the pool of available capital.
Payment Structure	Fixed FIT prices are lower risk (from the investors' perspective) than premium FIT payments, reducing the uncertainty associated with exposure to fluctuating market electricity prices.
Contract Duration	If post-contract market revenue projections are utilized in setting a FIT payment, longer contract durations reduce investor risk by reducing the proportion of lifetime revenues exposed to market price risk.
Policy and Contract Timing	The presence of a stable FIT policy that could be relied on for a period of several years by an early-stage, exploration-phase geothermal investor could decrease overall risk, thus reducing/eliminating developer risk premiums for RFP bids.
Payment Indexing Over Time	Given the potential size of geothermal operations and maintenance expenses, indexing to inflation, drilling costs, and/or other relevant indices would reduce the risk that project revenues will be adequate.
Adjusting the Policy	Adjustments that are made infrequently and on a schedule that is known in advance and using a process that is as transparent as possible increases investor confidence. Geothermal policies may not need to be adjusted as frequently as technologies with rapidly declining costs such as solar PV, or with shorter development timelines like solar PV and wind.

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[56] Different technologies, for example, may have different technological risk profiles. Technological risk, however, should be reflected in the financial assumptions utilized to set the cost based rate and should therefore be reflected in the rate itself.

5 Analyzing the Impact of Policy Design Choices on the Levelized Cost of Energy from Geothermal Electricity Generators

5.1 Using LCOE to Inform FIT Payment Level-Setting

FITs are typically set using either a constant price over the term of the contract, or a fully- or partially-escalating payment. This analysis uses the nominal LCOE as the evaluation metric for illustrating the quantitative impact of FIT policy design choices.[57] The nominal LCOE is the constant payment, expressed in nominal cents per kWh, which is sufficient to cover all of the costs of building and operating a power plant over its economic life, including meeting the minimum return requirements of investors. An LCOE has the equivalent economic effect over the analysis term (i.e., same net present value) as a time-varying payment stream covering the total cost of building and operating a generating plant over its life. This section takes a cost-based approach to FIT payment-setting and calculates a long-term contract value,[58] which will enable the modeled geothermal project to secure financing by both covering its operating expenses and meeting investors' minimum return requirements. For these purposes, the calculated LCOE over the duration of the FIT is equal to the assumed FIT payment.

While assuming that the calculated LCOE is equivalent to the FIT payment can provide valuable insights for the purposes of this report, the cost of geothermal projects will vary based on a range of factors including project technology, size, and resource quality. Furthermore, the broader policymaking context may include additional objectives, such as rapid deployment, diversity in project size or location, or least cost deployment, which may result in selecting a FIT payment that is more aggressive or more conservative[59], respectively (as noted in Section 3.3.3). For these reasons, a single calculated LCOE model result can be used directly as the FIT payment, but policymakers may wish to use analyses such as this one to inform a FIT payment-setting process taking into account both cost variation and policy objectives. With this caveat, the terms LCOE and FIT payment (and references to ranges of these values) are used interchangeably for the remainder section.

5.2 Objectives: Understanding the Potential Impact of FIT Design Choices

A FIT represents not only the availability of a long-term contract, but also a potential shift in investor confidence with respect to geothermal investment. While the technical risk of identifying a viable resource remains (i.e. exploration risk), a FIT or similar policy alleviates the risk of whether a viable contract will be available to provide a means to sell the output and attract financing.

To provide a simplified illustration: if the probability of successful exploration for an economically-viable geothermal plant in a specified region is thought to be 33%, and the

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[57] This analysis and the associated model are intended to be used primarily by policymakers considering FITs to support geothermal electricity development. In addition, this analysis and model may also be used by stakeholders in the policymaking process, including geothermal developers, financiers, and utilities.

[58] A 20-year FIT is assumed in this analysis. Sensitivities are also included that test the change in LCOE for FITs of 10, 15, 25, and 30 years.

[59] The term 'aggressive' in this usage connotes a FIT rate intended to support a range of viable geothermal installations, while a 'conservative' FIT would only support the most cost-effective geothermal installations.

developer believes it has a 1-in-3 chance of securing a long-term power contract, then the developer's probability of recovering its exploration investment and securing permanent financing to construct and operate a power plant is 33% * 33% = 11%. With a FIT available to guarantee access to a cost-based revenue stream, the risk of contracting and permanent financing is removed (i.e., 100%) and the odds of the developer's recovery of exploration capital increase to 33%, the probability of successfully identifying a viable resource. A simple understanding of risk and reward tells us all we need to know: the investment with an 11% probability of success will need to have a higher return potential than the investment with a 33% probability. The higher risk environment will also make it more difficult to attract the capital necessary to fund development activities. The cost of investment capital available to a geothermal project will behave similarly: the cost of capital decreases as the probability of success increases. Similarly, the availability of capital will increase as probability of success increases.

Competitive procurement for long-term contracts can mitigate only some of this risk, providing the possibility of access to a long-term fixed revenue stream with a credit-worthy entity but without the assurance of either the payment level or access to the revenue (both dictated by whether the project wins the competitive processes). Where binding policy support is not in place over a horizon long enough to earn a commercial return, or where long-term contracts are not offered, there is even less assurance of access to a revenue stream sufficient to attract financing.

It is difficult to precisely project the degree to which financing costs might be reduced. Using a range of representative geothermal cost data and 'what if' analysis, the potential impact on LCOE of reducing financing risk to geothermal developers was explored. It is intended to meet several objectives for policymakers with respect to LCOE analysis and FIT payment-setting, including:

- To identify the range of LCOEs that result from different assumptions about the cost, duration, and financing terms of geothermal development;
- To use these LCOE results to consider how to craft geothermal (FIT) policy that brings the greatest reduction in geothermal LCOE;
- To illustrate how a geothermal FIT can increase the availability of and/or reduce the cost of investment capital necessary to finance the exploration, development, and construction of geothermal facilities.

These objectives are accomplished herein by identifying a range of geothermal cost, financing, and operational input assumptions and conducting sensitivity analyses to establish a continuum of LCOE results for representative geothermal projects. Varying key inputs such as development duration and financing terms demonstrate potential market responses to different FIT designs.

The resulting range of LCOE values is a proxy for the potential continuum of FIT payments that might be considered in particular circumstances and locations. Examining the sensitivity analysis can help policymakers identify FIT designs and other incentives that help minimize geothermal LCOE while making investment attractive.

5.3 Methodology: Literature Review and CREST Modeling

5.3.1 Literature Review

A range of geothermal cost, performance, and financing inputs was developed through a detailed literature review. Publicly available geothermal cost research was compared and used to develop the series of inputs for LCOE modeling. A summary of the literature review is provided in Appendix A.

5.3.2 The CREST Model

Geothermal LCOEs were subsequently calculated using the CREST model. NREL developed CREST—an after-tax discounted cash flow model—based on a survey of international modeling practices and U.S. policy requirements (details captured in Gifford et al. 2011). A geothermal-specific version was released in 2011 and was used for this analysis.

CREST is an economic cash flow model designed to enable PUCs and the renewable energy community assess projects, design cost-based incentives (e.g., feed-in tariffs), and evaluate the impact of tax incentives or other support structures. CREST is a suite of three analytic tools, for solar (photovoltaic and solar thermal), wind, and geothermal technologies, respectively and it can be downloaded at https://financere.nrel.gov/finance/content/crest-cost-energy-models. The CREST models were designed for use by state policy makers, regulators, utilities, beginning developers or investors, and other stakeholders. Inputs include the variables under study in the sensitivities and scenario analysis (e.g. installed costs, O&M costs, financing assumptions, contract duration, etc.). The models allow users to:

- Estimate the Year One cost of energy (COE) and levelized cost of energy (LCOE) from a range of solar, wind and geothermal electricity generation projects
- Inform the process of setting of cost-based incentive rates
- Gain understanding of the economic drivers of renewable energy projects, which lead to the calculated COE and LCOE
- Understand the relative economics of generation projects with differing characteristics, such as project size, resource quality, location (e.g. near or far from transmission) or ownership (e.g. public or private).

5.3.3 Enhancements to Geothermal CREST

The co-authors of this report were also the architects of the CREST model. As part of the scope of this report, NREL directed several enhancements to the geothermal CREST model to facilitate the analysis contained herein. Specifically, adjustments were made so that the capital structure (combination of debt and equity) and cost of invested capital (equity return requirement and debt interest rate, if applicable) can be specified separately for the exploration drilling,[60] confirmation drilling, site construction, and permanent financing phases.

Because CREST allows model users to input different financing assumptions for each phase of geothermal development, policymakers can test the sensitivity of geothermal LCOE to the availability and cost of capital.

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[60] The exploration and confirmation phases are assumed to be 100% equity funded and does not include a provision for debt financing.

5.3.4 Modeling the Phases of Geothermal Development and Financing

The development of a geothermal power plant includes at least four distinct activities, modeled in this analysis over three phases of development. For cost estimating purposes, and based on the literature review, this study views geothermal development as including the following four activities, each with its own financing assumptions:

- Exploration – desk-top studies, initial surface exploration, temperature gradient drilling, and, in some cases, deep exploratory drilling[61]
- Confirmation – continued deep exploratory drilling, resource assessment, and initial production wells
- Well Field Construction – completion of well field drilling, including remaining production wells and injection wells
- Power Plant Construction – including interconnection.

The manner in which geothermal development is financed influences LCOE and FIT payment-setting. Geothermal projects typically involve different financing sources at different phases of project development (Deloitte 2008; Richter 2009; Salmon et al. 2011). These sources come in different ratios (e.g., debt to equity) by phase, and have different risk profiles and terms (e.g., return requirements, interest rates, and repayment schedules). For the purpose of this analysis, the CREST model analyzes geothermal development as having three financing phases, each with its own cost and financing assumptions. Equity investments are assumed to fund both the exploration and confirmation drilling phases. While some forms of debt (including so-called mezzanine debt, which has characteristics of both debt and equity) may have once been available for confirmation drilling and related activities, this analysis assumes that debt is first introduced at the well field and power plant construction phase once the availability and adequacy of the geothermal resources has been entirely proven, and once revenue expectations have been established. Well field and power plant construction are assumed to be financed at the same time, on the same terms, and occur more or less in parallel.

5.4 Inputs for Calculating Geothermal LCOE

As described in Section 3, a key component of the FIT payment-setting process is determining the range and complexity of modeling inputs.[62] The CREST model used for this analysis allows for an appropriately-detailed set of installed cost, performance, incentive, and financing assumptions. Each modeling input will have a continuum of possible values. Selecting which points on the continuum are used for modeling can be tied to policymaker preferences for more aggressive or conservative tariffs.

It is important to understand that the inputs and associated LCOEs are intended to be illustrative rather than representative of the cost of a specific operating or proposed geothermal project. The most important function of this analysis is to explore the relative change in LCOE caused by changes in each of the factors explored in the sensitivity analyses, and not the absolute value of

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[61] Geothermal market participants do not universally agree on the distinction of exploration and confirmation costs, particularly as it relates to deep exploratory drilling.

[62] A recent NREL study provides a detailed discussion of modeling inputs and their context (Gifford et al. 2011).

the calculated LCOE itself. A range of assumptions has been used for this report that, based on the literature review, should capture the majority of project costs and characteristics.

5.4.1 Exploration Success, Confirmation Duration, and Project Cost Inputs

As described in Section 4.3, incorporating expected exploration expenses in the FIT payment-setting process is critical to establishing investor confidence and spurring investment. The success of geothermal exploration can vary widely, including the difference between exploring for the expansion of production in an area where geothermal resources have already been found and exploring in unproven territories. It is assumed that the costs of specific exploration efforts will be the same whether or not they are successful. For instance, drilling an exploratory well to a certain depth should cost about the same whether or not it yields a viable resource. Table 7 below defines the range of exploration success rates considered. These exploration success rates represent the probability, on average, that a series of exploration expenditures will result in the identification of a viable resource. These rates also denote the number of exploration wells drilled and associates "hit rate." For example, a rate of 50% denotes identification of the geothermal resource on the second exploration well. By comparison, a rate of 10% denotes that a resource is not identified until the 10th exploration well drilled. The costs associated with exploration activities are provided later in this section and include both drilling and non-drilling[63] activities. The exploration success rate is used to determine the total cost incurred before a viable resource is identified. This analysis does not include a scenario in which exploration capital is exhausted and no geothermal resource is found because LCOE cannot be calculated for such a scenario. Clearly, however, such outcomes are possible and perhaps warrant a probability assignment by project developers and investors.

Table 7. Range and Definition of Exploration Success Rate

Input Category	← Range of Input Values →			
	Low Cost			High Cost
Exploration Success Rate (%)	50%	33%	25%	10%

Sources: Hance (2005); Augustine et al. (2010)

The expected duration of the confirmation drilling phase could also be considered during the FIT payment-setting process. Excluding the costs associated with this phase from consideration in establishing a FIT would likely yield too low a revenue stream for many investors. As described in Section 5.3.4, the confirmation phase is assumed to include continued deep exploratory drilling, the completion of the resource assessment, and the drilling of initial production wells. This phase is assumed to be financed using 100% equity contributions. Without the benefit of a FIT, it is possible that certain development expenditures might be delayed, and the project timeline thus extended, until the project proponent successfully identifies and negotiates a PPA sufficient to enable permanent financing. Such delay makes the project less attractive to investors, who may compensate for this risk by requiring a higher return on invested capital. This translates into a higher LCOE than for a project that is able to proceed through development more efficiently and expeditiously due to the presence of a FIT that provides investors with power plant revenue certainty, even while the resource assessment is being completed.

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[63] Non-drilling exploration costs are held constant for the purpose of this analysis.

Table 8. Range of Confirmation Phase Duration

Input Category	← Range of Input Values →		
	Low Cost		High Cost
Confirmation Phase Duration	1.5 years	2 years	3 years

Sources: Augustine (2012)

Table 9 below summarizes the range of assumed geothermal project cost inputs, by development phase. These values are based on the aforementioned literature review and are described in more detail in Appendix A. The range of exploration cost represents differing industry opinion regarding the cost of exploration assuming an average 25% success rate. This analysis employs both the range of exploration cost uncertainty and the range of success rate uncertainty.

Table 9. Range of Geothermal Cost Inputs

Cost Category	← Range of Input Values for Cost Uncertainty[64] →		
	Low Cost		High Cost
Exploration Costs ($/kW)	$100	$175	$225
Confirmation Costs ($/kW)	$300	$550	$750
Site Development Costs ($/kW) **(well-field + power plant construction)**	$2,000	$3,000	$4,000
TOTAL	$2,400	$3,725	$4,975
Fixed O&M ($/kW-yr)	$40	$50	$60
Variable O&M (cents/kWh)	2.25	3.50	4.50

Sources: Exploration Costs: Sison-Lebrilla and Tiangco (2005), Hance (2005), Salmon et al (2011)
Confirmation Costs: Sison-Lebrilla and Tiangco (2005), Hance (2005)
Site Development Costs: Sison-Lebrilla and Tiangco (2005), Hance (2005), Geothermex (2010), Augustine et al. (2010)
Fixed O&M: Sison-Lebrilla and Tiangco (2005), Hance (2005), O'Donnell et al. (2009)
Variable O&M: Hance (2005), O'Donnell et al. (2009), Lovekin and Pletka (2009), Augustine et al.(2010), Geothermex (2010)

Table 9 also includes operations and maintenance (O&M) cost estimates. This study's literature review finds that fixed and variable O&M cost categories are often inadequately defined, and that the two categories frequently overlap with each other from study to study. According to O'Donnell et al. (2009), fixed expenses include power plant operations and maintenance while variable O&M includes field, general O&M, and rework; make-up wells; and relocation injection wells. The O&M cost estimates are based on the literature review more broadly, but may be best

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[64] Assumes illustrative 50 MW project. Per literature review (see Appendix A), exploration assumes 25% success rate, confirmation assumes 60% success rate, and all costs assume economies of scale associated with a 50 MW project.

aligned with the allocation of costs described by O'Donnell. Additional detail on all cost estimates can be found in Appendix A.

5.4.2 Financing Inputs

Beginning in 2008, the global financial downturn shrank the pool of investors available to renewable energy projects. The decline in federal income tax liability associated with deep recession triggered a reduction in the number of viable tax equity investors—those able to effectively monetize the substantial tax benefits generated by renewable energy project investments. Despite this trend, this analysis assumes the continued availability of the Investment Tax Credit[65] (ITC) and assigns equity rates of return that are intended to represent the investor's efficient use of both cash and tax benefits.

At the same time, the economic downturn triggered among lenders the perception of increased market risk. This resulted in a shortening of loan tenors (durations), an increase in lender debt service coverage requirements, and an overall decline in the amount of debt offered to any individual project (Salmon et al. 2011). Debt remains available at the construction stage, with lenders requiring a 25%-45% equity contribution (Salmon et al. 2011). The inputs to this analysis are intended to reflect the current availability of debt, consistent with the literature review. The aforementioned enhancements to the geothermal CREST model account for perceptions of market risks by differentiating capital sources and return requirements by development phase. The table below summarizes the range of financing inputs.

Table 10. Range of Geothermal Financing Inputs, by Development Phase

Project Phase	Capital Structure	← Range of Input Values for Return or Interest Rate →		
		Low Cost		**High Cost**
Exploration	100% Equity	50%	100% total return	2X (200%)
Confirmation	100% Equity	15%	30% annual return	45%
Site Development (Construction Financing)	35% Equity 65% Debt	15% 5.5%	Equity @ 20% annual return Debt @ 7.5%[2] interest rate	25% 10%
Site Development (Permanent Financing)	45% Equity[1] 55% Debt	10% 5.5%	Equity @ 15% annual return Debt @ 7.5%[2] interest rate	20% 10%
		DSCR[66] 1.60 times coverage <u>Financing Term</u>: 18 yrs <u>PPA Term</u>: 20 yrs		

Sources: Salmon et al. 2011; Hance 2005; REFTI 2011

1) Includes cash, tax and developer equity

2) Use of the same interest rate assumption for both construction and permanent debt represents the balancing of two different risk profiles. Construction debt bears the risk of non-completion, but over a short time period. Permanent debt bears the risk of operations, but over a much longer time period. For this analysis, these risks and terms are assumed to balance and market interest rates for both activities are assumed to be the same.

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[65] A federal Investment Tax Credit of up to 30% of eligible expenses is available to geothermal electricity projects coming into service on or before December 31, 2012. Thereafter, the geothermal ITC is expected to revert to its historic level of 10%.

[66] DSCR stands for debt service coverage ratio.

5.4.3 Other CREST Inputs Required for Calculating LCOE

Using CREST for this LCOE analysis requires defining additional assumptions about the plant's specifications and operation. These estimates can be found in Appendix B along with additional detail on the literature review. As with the estimation of installed costs, these assumptions are intended to provide a reference case rather than be representative of any specific operating or proposed facility.

Among these additional inputs is the assumption that the modeled geothermal project will operate for 30 years, but receive payment through a FIT only through the first 20 years. Rather than ignore the revenue potential of the last 10 years, the CREST model allows the user to include an electricity price forecast that it then applies to any gap between the assumed FIT contract duration and the project's useful life.[67] For this analysis, an illustrative electricity market price forecast is provided in order to account for project revenue for years 21 through 30, inclusive. The market price trajectory is calculated using a year-one rate of $40/MWh (in 2012) and an escalation rate of 2.0% (and again, is generic and does not represent actual electricity price projections of any particular location).

5.4.4 Explaining the Range of Possible Inputs

The range of input values presented above is insufficient to provide FIT payment-setting insight on its own. These values provide the foundation for a sensitivity analysis that quantifies the change in LCOE with variation in selected key inputs. The range of financing inputs represents—for illustrative purposes—the potential reduction in cost of capital associated with the establishment of a FIT, which can increase investor certainty and translate into reduced risk. Of course, the magnitude of reduction of any input will be situation specific, personnel specific, and difficult to project. However, the calculation of LCOE over a wide range of plausible inputs, selected from detailed cost studies, reveals which inputs have the greatest impact on LCOE and therefore the greatest risk reduction opportunities. This analysis might help policymakers consider which FIT policy design options are most attractive, depending on their FIT policy goals.

5.5 Reference Case Results

A reference case was derived by modeling LCOE in CREST using the central estimate of each input value described above, and a 25% exploration success rate. The reference case is valuable for comparison purposes only; its LCOE is neither intended to reflect the cost of any specific project nor represent a recommended contract rate. The calculated LCOE for the reference case was 10.85 cents/kWh.

5.6 Sensitivity Analyses: LCOE Results and Lessons Learned

The purpose of this analysis is not to determine the precise cost of any given geothermal system, but rather to demonstrate the impact that a FIT might have on geothermal LCOE.

This is done by changing key inputs from the reference case one or two at a time in order to understand how each factor impacts the cost of geothermal electricity. With these impacts measured, policymakers can gain insight into how a FIT might effectively decrease some of the

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[67] Importantly, investors may not make the same assumption. Many investors —particularly debt lenders—prefer to assume revenues only exist during the length of the PPA and thus require that financing term be shorter than PPA term (to protect themselves so they are fully paid back even if the project underperforms in the early years).

risks that contribute to the LCOE. Policymakers can also gain insight into how to differentiate FIT payments between areas where geothermal has already been proven and areas where it has not. The former may be assumed to have a higher exploration success rate and therefore a lower LCOE and a lower required FIT payment to attract investment.

We conducted a series of sensitivity analyses[68] that explore changes in LCOE by varying:

- The exploration success rate
- The duration of the confirmation stage
- The FIT contract duration
- Total project cost
- Investor return requirements (equity and debt, if applicable) by development phase.

The result of these sensitivity analyses is a range of geothermal LCOE extending from 8.65 to 13.85 cents/kWh, relative to the reference case LCOE of 10.85 cents/kWh.

The impact on LCOE due to a reduction in soft costs and transaction costs that might result from the availability of a FIT, as discussed in Section 4, could also be examined. While we have not attempted to quantify such costs herein, the impact of reducing these costs, which ultimately reduce the cost subject to permanent financing, is embedded in the examination of the sensitivity of LCOE to total project cost.

5.6.1 Exploration Success Risk

Changes in exploration success rate and return requirements represent the impact on LCOE of a range of investor risk perception with respect to the earliest phase of geothermal development. If the presence of a FIT can provide the earliest investors with a greater degree of confidence that a geothermal resource, if validated, will result in a financed and constructed project, then such investors may be willing to make their capital available with lower expected return requirements to reflect the later reduction in risk due to the presence of a guaranteed long-term contract. If achieved, this reduction in the cost of capital can be translated into lower FIT payments.

The reduction in perceived risk by exploration investors assumes that some projected quantity of exploration expenses are explicitly reflected in the payment-setting process, and that the exploration success rate assumptions used to set the FIT payment align with the geothermal developers own view of a project's development prospects. Consider an example in which two developers, A and B, expect the same cost for exploration activities, but have differing views of expected success rate. Developer A assumes that six exploration wells will need to be drilled in order to identify one productive well. Developer B has a different market outlook and instead assumes that only three wells will be necessary before a "hit" is achieved (a 33% success rate). These two developers have different views on their probability of success, and thus on

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[68] The selected sensitivities included herein are intended to represent those variables most likely to respond to the presence of a FIT. Sensitivities to other variables may yield additional insights about the drivers of geothermal power, as a result of factors other than FITs. For example, geothermal LCOE will be highly sensitive to large variations in capacity factor. Annual production, however, is not expected to vary significantly based on the presence of a FIT.

geothermal LCOE. If the policymaker sets the FIT payment by assuming that one out of every two exploration wells yields a productive resource (a 50% success rate), then neither developer will find it attractive to invest unless the presence of the FIT changes their market outlook. If the FIT payment is established assuming a cost equivalent to four exploration wells for every one productive well (a 25% success rate), then Developer B may find it attractive to invest while Developer A may not. If the FIT payment is established assuming a cost equivalent to seven exploration wells for every one productive well (a 14.3% success rate), then both developers may find it attractive to move forward with project development. This connection between exploration success and FIT payment-setting is illustrated in Figure 4.

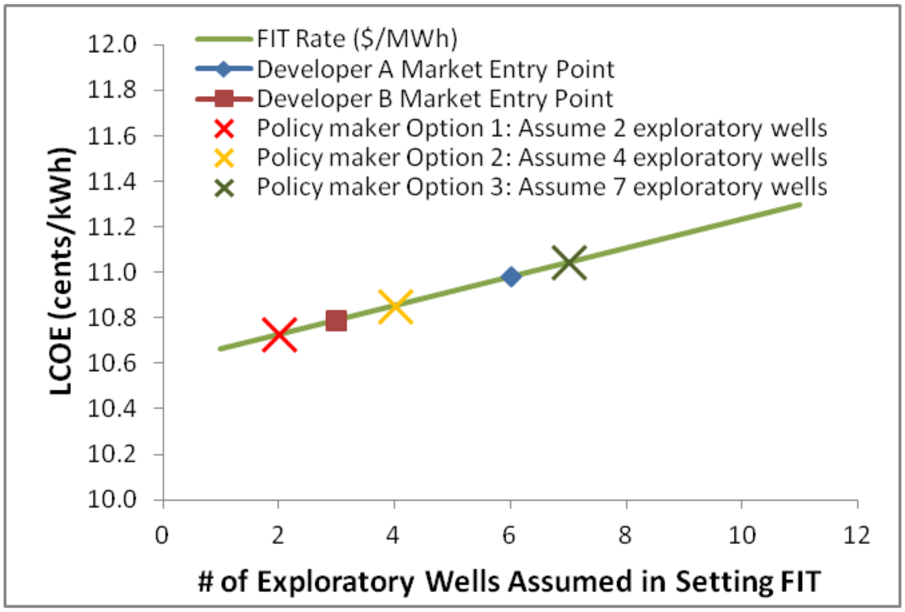


Figure 4. Illustration of connection between exploration success and FIT payment setting

Figure 4 suggests that the more exploration costs are built into the FIT, the higher the LCOE. This view is incomplete, however, as it ignores the expectation that the inclusion of more exploration cost in the FIT might lower the perceived risk to exploration investors. While difficult to quantify, it is important to consider how increasing the amount of exploration cost in the FIT, combined with guaranteed access to a cost-based revenue stream might reduce the expected return. Using a simplified example, a FIT that assumes it necessary to drill two exploration wells (a 50% success rate) might attract investors with a 200% return requirement. A FIT that assumes it necessary to drill seven exploration wells (a 14% success rate) might attract an exploration investor with a 50% return requirement. By making the act of geothermal exploration far less speculative, it is possible that the required LCOE to attract investment may reflect a lower exploration return. This interaction might cause the line in Figure 4 to flatten out as the number of exploratory wells assumed in the FIT increases, rather than increase linearly as currently shown. In other words, the cost of capital might decrease as the overall probability of success increases.

5.6.2 Confirmation Drilling Risk

Like exploration activities, confirmation drilling, which includes continued deep exploratory drilling, resource assessment, and initial production wells and therefore contains many exploration-type risks, is equity funded in today's market. While it is possible that lenders will show willingness to bear resource risk in the future, they are currently considering investment only in projects that have demonstrated 100% of the projects' required thermal resource. As a result, the cost and availability of confirmation capital is expected to behave much like exploration capital and be determined by the resource and project risk perceived by equity investors and the duration of time investors believe their capital will be exposed to these risks. Where resource risk is perceived to be relatively high and confirmation activities are expected to be spread over three or more years, the cost of capital available to fund such activities increases dramatically. Where resource risk is assumed to be lower and confirmation activities expected to take not much more than a year (as in the expansion of an existing facility), the capital required to fund this aspect of development is expected to be less costly and easier to secure. For this reason, the impact of the duration of the confirmation period and the cost of confirmation capital on LCOE are considered together in this analysis.

Figure 5 shows the impact on LCOE of changes in both confirmation drilling duration and cost of capital together. Confirmation drilling started at a base case of 2 years, and ranged from a low cost sensitivity of 1.5 years, to a high cost sensitivity of 3 years. The cost of capital inputs are detailed in Table 11 and included varying levels of equity rate of returns (as low as 10% for low-cost permanent financing up to 200% for high cost exploration), and debt interest rate (5.5% for low cost and up to 10% for high cost). While the ratio of debt to equity ratio is held constant, it differs by project development stage, based on when debt lenders are interested in financing project development. For example, exploration and confirmation drilling are too risky for debt lenders, so these phases are assumed to be 100% equity financed.

The example shows that a "lower return requirement and shorter contract duration" case (that uses 1.5-year confirmation phase duration and a 15% annual return requirement), results in a required LCOE of about 9.25¢/kWh. When a 3-year confirmation phase duration and 45% annual return requirement are assumed in the "higher return and longer contract duration" case, the required LCOE reaches almost 14¢/kWh. This impact is driven by both the magnitude of the confirmation stage costs (roughly three times greater than exploration costs according to Table 9) and the influence of compounding those costs over time.

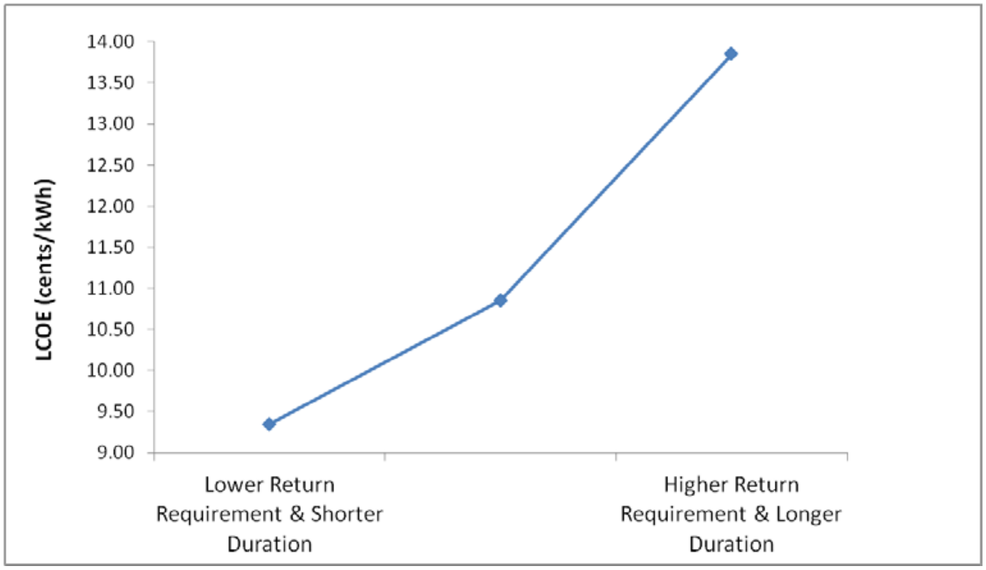


Figure 5. Sensitivity of LCOE to change in both confirmation duration and return requirement

When investors have confidence in the availability of a financeable contract at a known payment level, it is more likely that they will proceed rapidly with early development activities, shortening the non-technical aspects of the geothermal development cycle, which in turn might reduce LCOE. As a result, if a FIT were able to create investor confidence and shorten the time necessary to attract and deploy capital for development activities, then project LCOE might be reduced.

If by providing the guaranteed availability of a financeable contract at known payment level, a FIT could enhance investor confidence resulting in (1) shortened development times (increased likelihood of proceeding expeditiously with confirmation after exploration yields potentially viable resource) and (2) lowered perceived risk (reflected in lower threshold equity cost of capital expectations), then a FIT could have the potential to substantially reduce the required LCOE to attract investment.

5.6.3 FIT Contract Duration

Longer contract durations facilitate lower LCOEs by extending the period over which equity investments and debt obligations are repaid. Through FITs, this benefit is realized as long as the contract price is known for the duration of the agreement. This report and quantitative analysis assumes a 20-year FIT throughout. The sensitivity of LCOE to FIT duration was also tested for FITs of 10, 15, 25, and 30 years. Geothermal projects operating beyond the FIT term are assumed to collect (forecasted) wholesale market revenues. No other payments are assumed during this period.

The impact of FIT contract duration on LCOE is shown in Figure 6. As shown, LCOE is highest for shorter duration FIT contracts, and the total impact between 10 and 30 years is approximately 15%. The impact on LCOE levels out as the FIT contract duration extends and it virtually flattens out for FIT payments of 25 and 30 years. These results may illustrate why most FIT policies are between 15–20 years—most of the benefit is realized in this time period and extending the FIT longer than 20 years does not provide a marked additional benefit in reducing the LCOE. However, a longer FIT duration may expand the pool of investors interested in geothermal project development, a factor that is difficult to capture quantitatively.

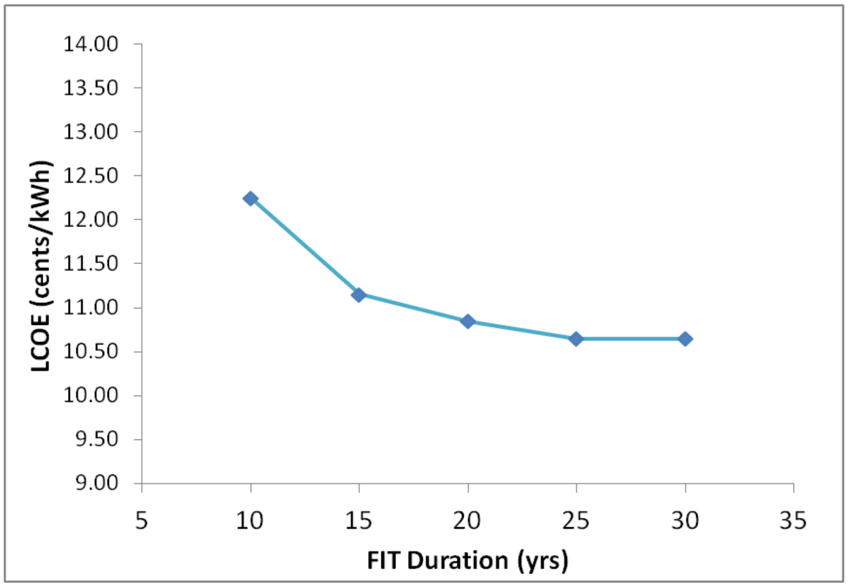


Figure 6. Illustration of relationship between contract duration and LCOE

5.6.4 Installed Cost and Investor Return Requirements

The cost of geothermal electricity is influenced by the installed project costs, as well as by the availability and cost of permanent financing. Installed project costs were detailed in Table 9, and ranged from $2,400/kW for the low cost case to $4,975/kW in the high case. These cost estimates are assumed to include all permanent financing transaction costs (e.g., bank fees and reserve accounts) as well as payments to "cash out" the investors who supported all previous development phases. To this end, total project costs are impacted by the return requirements of each development stage. If the surety of a FIT reduces the cost of capital at any point in the development process, the impact of this should be felt, albeit potentially modestly, as a reduction in total project cost.

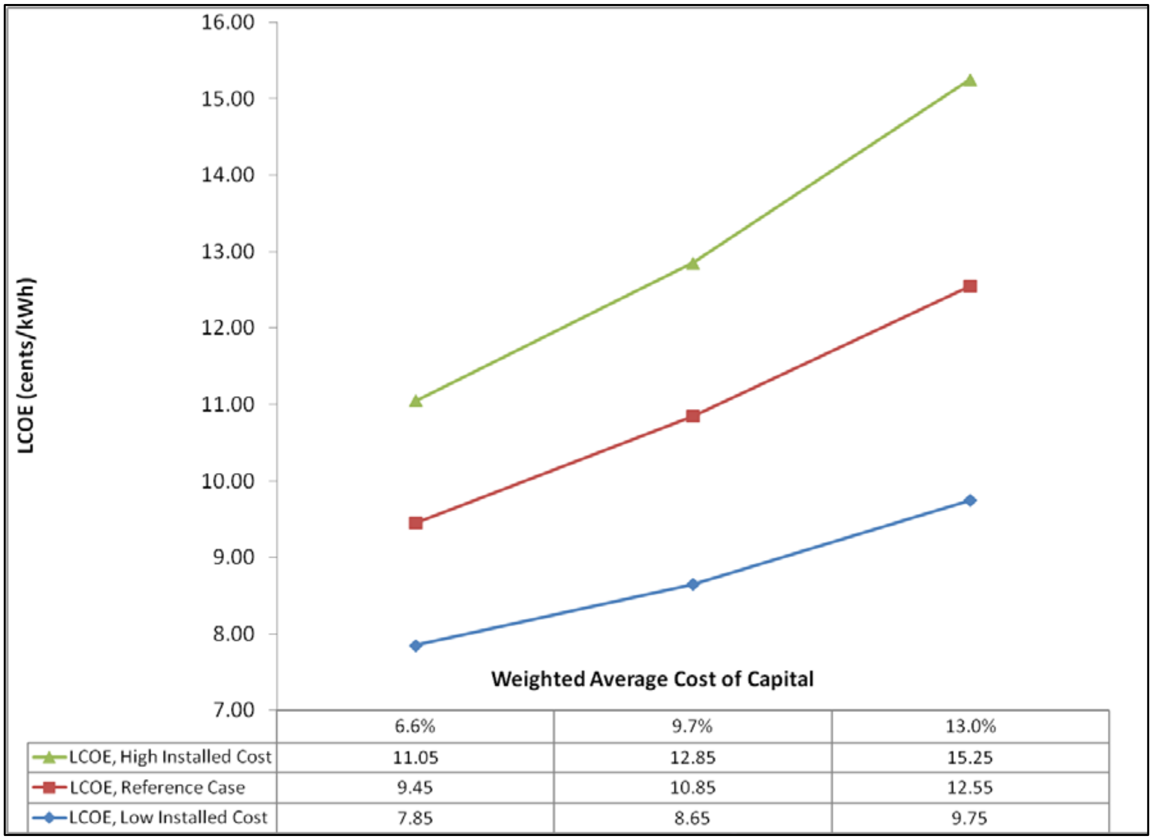
Permanent financing assumptions are shown in Table 11. This is comprised of the long-term debt and equity that enable the payoff of construction financing and fund the ongoing operation of the geothermal project; their required return is expected over an extended period of time. For debt, this period is most likely to match (or be a few years shorter than) the length of the FIT. For equity, the investment period is the project's useful life, unless a sale of the asset is negotiated at an earlier date. To illustrate the impact of cost of capital on LCOE for a range of different project installed costs, the costs of equity and debt are combined into the weighted average cost of capital (WACC), a proxy for the total cost of permanent financing.

Table 11. Cost of Capital Assumptions for Lower and Higher Cost Sensitivity Analyses

	Lower Cost of Capital		Higher Cost of Capital
Permanent Equity (includes cash, tax, and developer equity)	10%	15%	20%
Permanent Debt (18-year tenor on 20-year PPA)	5.5%	7.5%	10%
Weighted Average Cost of Capital (50/50)	**6.6%**	**9.7%**	**13.0%**

Figure 7 shows the impact of the WACC as well as the capital cost on LCOE. As shown, the range of possible installed costs (Low = $2,400/kW, Reference = $3,725/kW, and High = $4,975/kW) greatly impacts the LCOE. Figure 7 illustrates three important points:

- For any given installed cost, the WACC impacts the LCOE significantly; if a FIT can reduce perceived risk, this relationship suggests that a FIT might materially reduce LCOE. For example, if the presence of a FIT enabled a 100 basis point savings on the WACC, the Reference Case in this analysis would be reduced from 10.85 to 10.45¢/kWh (a reduction of 3.7%).
- If a FIT could reduce or eliminate various cost components, such as contract price risk premiums, bid security, legal, bid preparation, other transaction costs, or the cost of capital at either the exploration or confirmation phases, the LCOE would drop accordingly. For instance, a 5% drop in installed cost for a reference-level installed cost project would yield a roughly 0.3¢/kWh reduction in LCOE.
- The higher the installed capital cost, the greater the impact on LCOE of reducing the WACC.



	6.6%	9.7%	13.0%
▲ LCOE, High Installed Cost	11.05	12.85	15.25
■ LCOE, Reference Case	9.45	10.85	12.55
◆ LCOE, Low Installed Cost	7.85	8.65	9.75

Figure 7. Sensitivity of LCOE to change in cost of permanent financing, shown at three different levels of installed cost

5.7 Summary of LCOE Sensitivity Results

Figure 8 summarizes each sensitivity analysis by showing the range of FIT payment outcomes associated with the inputs tested (x-axis), and ranking their impacts on FIT payment relative to one another (y-axis). The input with the greatest impact on FIT payment occupies the highest position on the diagram. The array of input assumptions associated with these LCOE outcomes are based on the literature review and provided in the tables throughout this section. Additional detail is available in Appendix A.

Importantly, this analysis only considers the potential impact of a FIT policy and does not compare FITs to other policies, and therefore cannot conclude if a FIT is the best policy to achieve all of the desired objectives. Further analysis is needed to compare FITs to other policies for their effectiveness and cost efficiency.

Policies that spur decreases in the cost of capital at any development stage (by increasing investor confidence, increasing the pool of available capital, or other means) and help to reduce development delays are expected to have a sizable impact on LCOE. These impacts are demonstrated particularly at the confirmation phase, as it has been defined in this report. The duration of price-certain, creditworthy contracts (such as FITs) are also expected to have a notable impact on LCOE. This analysis also concludes that there are factors, such as total installed cost, which have the potential to impact LCOE similarly but are only modestly influenced by the presence of a FIT through reductions in fees and transaction costs typically associated with contract identification and negotiation, competitive bidding procedures, and/or permanent financing. Beyond the general nature of FIT policies to increase investor certainty, specific policy design choices regarding the manner in which exploration and confirmation success and return requirements are included in FIT payment-setting are also shown to have a direct and meaningful impact on geothermal LCOE. Each of these outcomes can be achieved, either directly or indirectly, through the establishment of a long-term, price-certain FIT. Policymakers can use this approach to prioritize FIT design characteristics that best support their objectives.

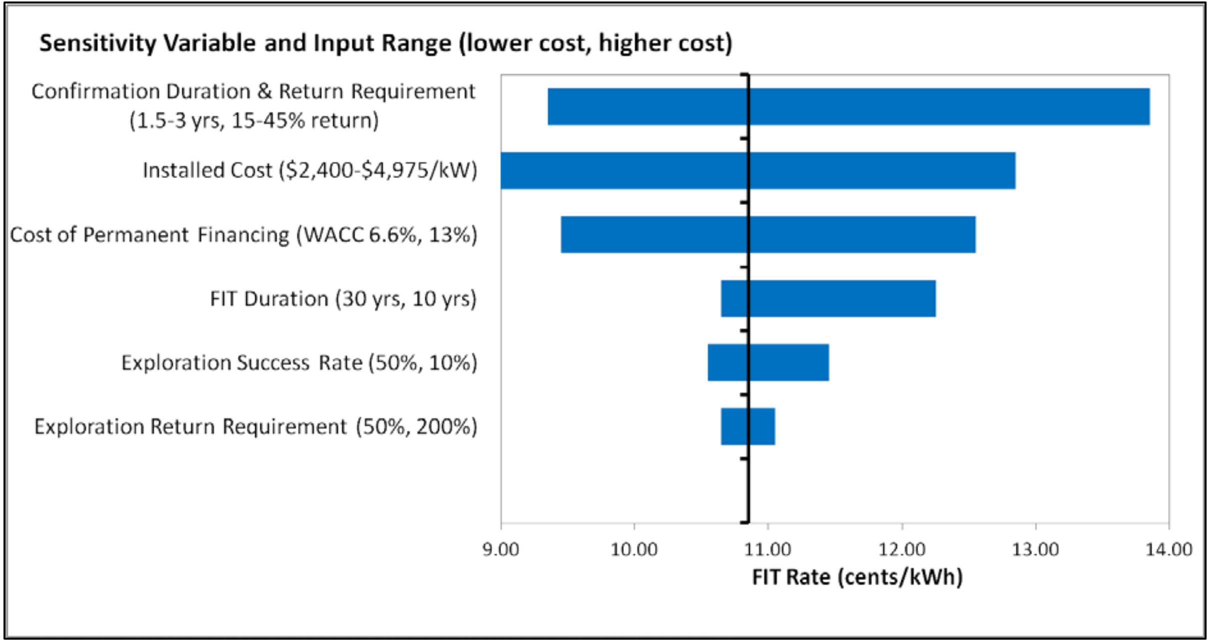


Figure 8. Relative impact on LCOE (and thus FIT Payment Level) of each sensitivity analysis

It is important to emphasize that this analysis comprises a “what if” analysis. While the directionality of impacts—the relationship between risk and return—are well-understood, the literature provides limited data on the quantitative impacts of these types of risk reduction on required investor returns. In addition, the specific impacts may differ by investor and at different times and circumstances. While actual FIT impacts on specific project LCOEs are difficult to determine, this analysis demonstrates that reductions in LCOE could result from careful choices in FIT design and implementation.

FITs have the potential to reduce the cost of capital by increasing investor confidence. In addition, the knowledge that a long-term price-certain contract is available for all qualifying generators may also help to avoid delays in the development process and interruptions in funding caused by the search for, and negotiation of, a financeable power purchase arrangement. In this vein, a well-developed FIT policy could result in compounding LCOE reductions. To this end, it is important to consider the role that an established and predictable program for long-term contracts plays in a project’s ability to secure the most competitive financing.

While not demonstrable through a quantitative analysis, it is expected that the reduction in perceived risk that generates reductions in LCOE would also increase the pool of investors interested in funding the geothermal sector. The potential result is both equity and debt, which are more accessible to geothermal developers and perhaps on more favorable terms. The results demonstrate the positive impact of lower return requirements and shorter development cycles on geothermal LCOE. Further, the presence of a FIT may drive changes in investment terms for geothermal that perpetuate the potential LCOE differences shown in this analysis. In other words, once FITs are shown to reduce development risk, contracting risk, and the perception of overall market risk, it is increasingly likely that reductions in investor return requirements will follow as competition for geothermal investments increases, continuing the trend shown in this sensitivity analysis.

6 Conclusions

Geothermal electricity represents a significant and underutilized source of renewable electricity in the United States. Geothermal power plant developers face challenges beyond those experienced by other renewable electric facility developers. This analysis focuses on ways to address risks other than the physical risk of drilling unproductive exploratory wells, particularly through the design and implementation of geothermal-specific FIT policies. The unique characteristics of geothermal electricity development have important implications for the design of effective policy frameworks and incentives intended to support geothermal exploration and production.

6.1 International Experience Provides Opportunity to Tailor Geothermal FITs to U.S. Market

Despite international interest in FITs, there has been a limited focus on geothermal-specific FIT design. Sixteen countries have established specific FIT incentives for geothermal, but most are relatively new or limited in scope (e.g., project size limitations). FITs have been introduced that not only target geothermal development, but that target small scale plants, combined heat-and-power applications, specific types of geothermal resources, and specific geographies. While performance-based incentive structures have played an important role in the growing U.S. renewable energy industry, they have not provided the long-term certainty and basis for financing necessary to create a new wave of geothermal development. By studying international tariffs and policy design choices, this report concludes that geothermal FITs can help facilitate the development of geothermal power plants by the private sector, when they are carefully designed and especially for proven resources. Because geothermal FITs are relatively new, more analysis could help target FITs to the unique risks of geothermal power projects.

6.2 FIT Policy Design Provides Opportunities to Support Geothermal Deployment and Attract Additional Investment Capital into Geothermal Exploration and Development Activities

The report finds that the key issues relating to geothermal FITs in the United States include:

- Linking FITs to specific geothermal targets to demonstrate a state’s commitment to geothermal procurement
- Targeting the FITs to specific types of geothermal resources (e.g., hydrothermal versus EGS) and differentiating payment levels by technology to meet investors’ required returns
- Incorporating exploration expense and risk in FIT payment-setting methodology and payment levels to attempt to increase investment in inherently risky activity of geothermal exploration
- Creating standard pricing and standardized off-take contracts to reduce risk and transaction costs
- Structuring and setting the FIT payment to reduce risk
- Reducing market price risk by targeting appropriate contract duration
- Considering longer-term, stable FIT policies and FIT contracts

- Indexing payments to inflation, drilling costs or other relevant indicators
- Exploring scheduled and transparent policy adjustments over time.

We conclude that the availability of a FIT is likely to increase the likelihood of successful geothermal power plant development, financing, and operation relative to situations in which long-term, price-certain contracts are not guaranteed to qualifying generators. Importantly, the analysis did not complete a comprehensive analysis of ways to mitigate exploration risks using FITs or other policies.

6.3 FIT Policies can be Designed to Address Key Issues that Have a Significant Impact on LCOE: Confirmation Phase Duration and Equity Cost, Cost of Permanent Financing, and FIT Duration

The assurance of a long-term, price-certain contract is expected to provide geothermal projects with access to a broader spectrum of less-expensive capital. If the cost of capital can be reduced at each stage of development, reductions in LCOE will result. When establishing return requirements, investors will consider both the nature of the risk and the expected duration that their capital will be outstanding. Longer development and/or contracting time horizons translate into greater risk and a higher target return requirement for the pre-operating phase. By comparison, as the FIT contract duration increases, the LCOE is expected to decrease as debt and equity investments can be recovered over a longer period of time while maintaining revenue certainty. The illustrative quantitative analysis in Section 5 identifies the duration of the confirmation phase, the cost of confirmation phase equity, and the cost of permanent financing and FIT duration as the highest-impact inputs that can be influenced by FIT policy design.

The availability of a long-term, price-certain FIT contract is guaranteed upon commercial operation and can help to shorten the geothermal development cycle by removing a lengthy and uncertain negotiation for a competitive PPA. In this case, significant benefits can be realized in the form of a lower LCOE. Similarly, if the availability of a FIT can increase the pool of available investment capital, then both competitive forces and a real reduction in the risk profile of geothermal investments is expected to result in a lower cost of capital for permanent equity and debt. This analysis demonstrates the impact of such a trend in the form of lower LCOEs. Ultimately, lower LCOE would mean a lower FIT payment level, lower geothermal project development costs, and lower overall costs to ratepayers.

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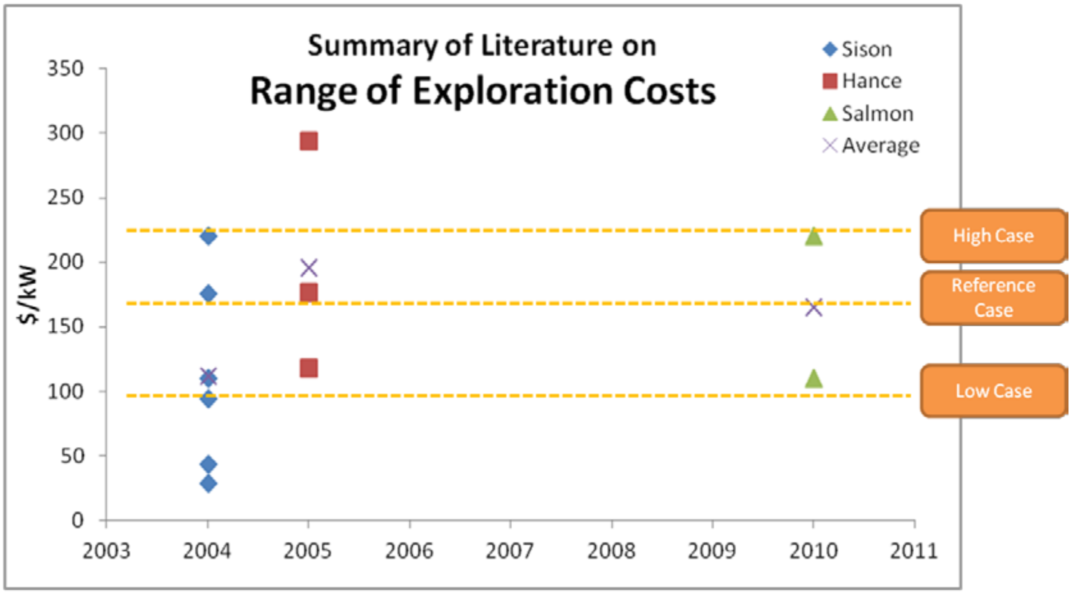
Appendix A: Summary of Literature Review on U.S. Geothermal Costs

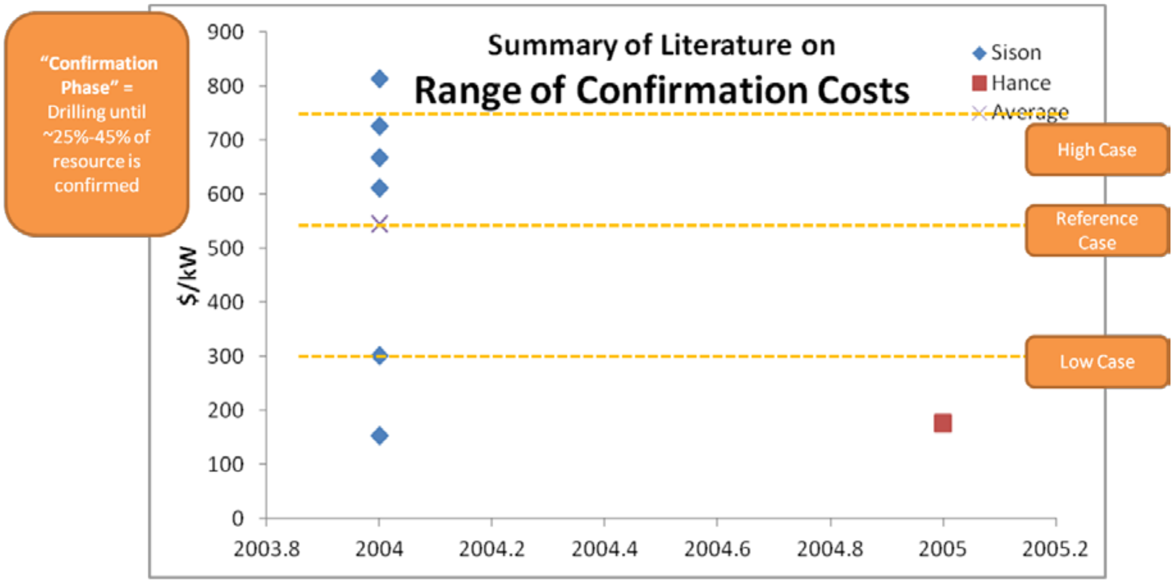
The cost, performance, and financing inputs employed in the LCOE analysis were developed through a detailed literature review. Publicly available geothermal cost research was compared and used to develop the low case, reference case, and high case estimates for the LCOE modeling. Cost comparisons and case definitions are shown in Figures A-1 through A-6.

(All data adjusted to 2010$; shown on graph in year of study)



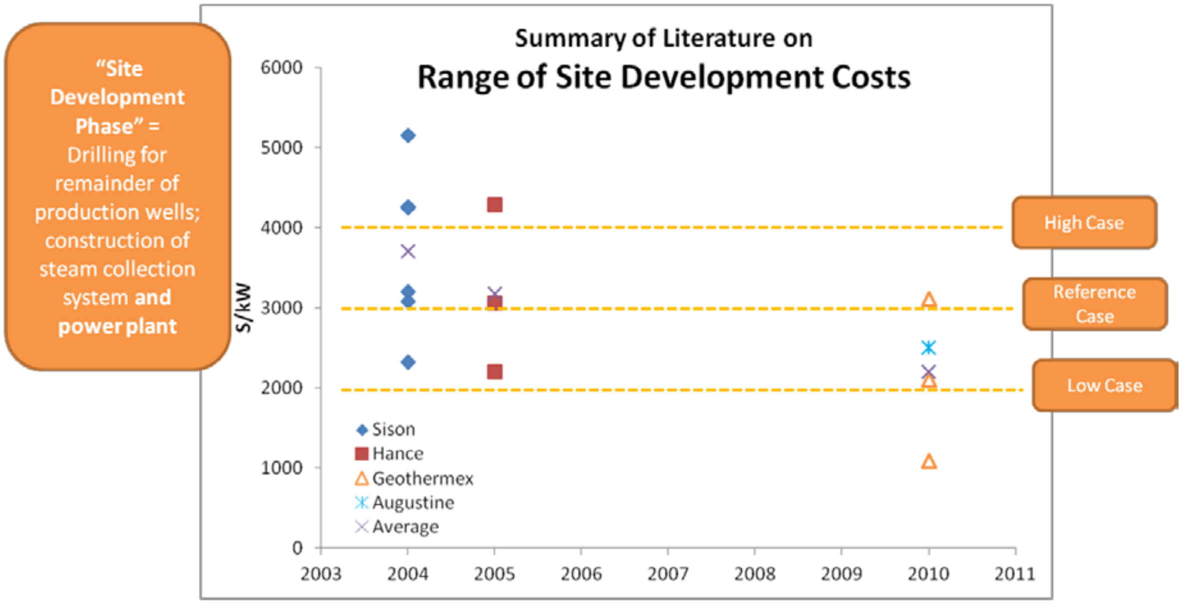
	Reference Case	**Low Sensitivity**	**High Sensitivity**
Exploration Costs Modeled ($/kW)	**$175**	$100	$225

Figure A-1. Range of exploration costs



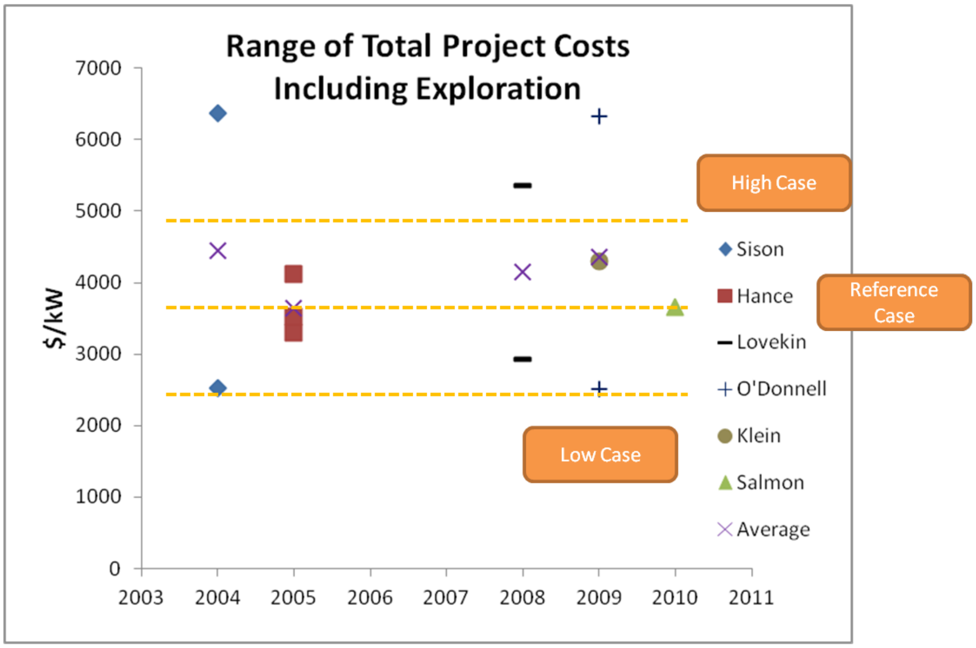
	Reference Case	Low Sensitivity	High Sensitivity
Confirmation Costs Modeled ($/kW)	**$550**	$300	$750

Figure A-2. Range of confirmation costs



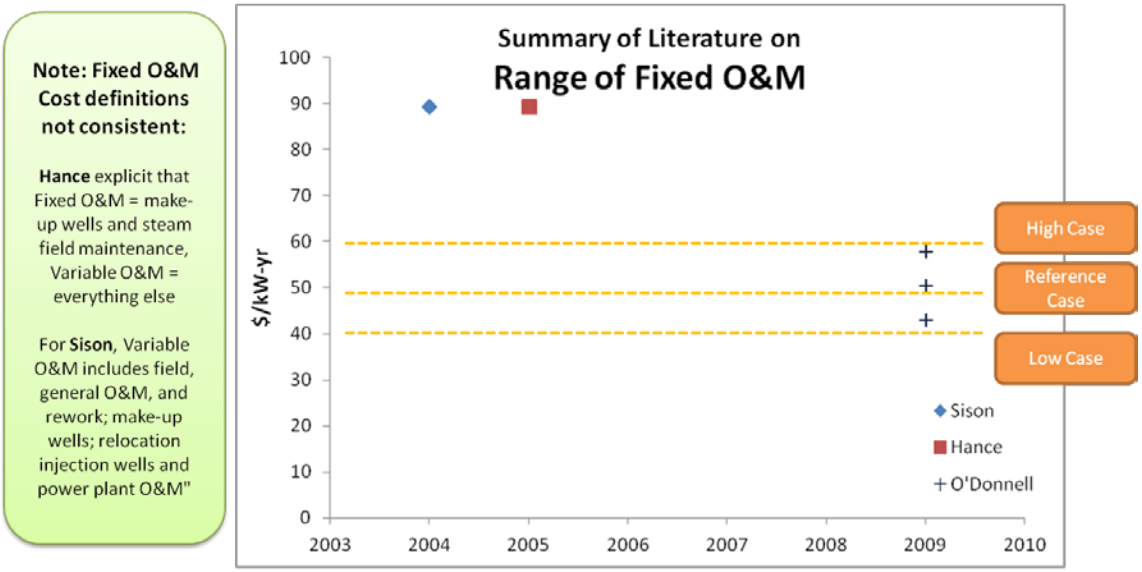
	Reference Case	Low Sensitivity	High Sensitivity
Site Development Costs Modeled ($/kW)	**$3,000**	$2,000	$4,000

Figure A-3. Range of site development and construction costs



	Reference Case	Low Sensitivity	High Sensitivity
Total Project Costs ($/kW)	**$3,725**	$2,400	$4,975

Figure A-4. Range of total project costs (including exploration)



Note: Fixed O&M Cost definitions not consistent:

Hance explicit that Fixed O&M = make-up wells and steam field maintenance, Variable O&M = everything else

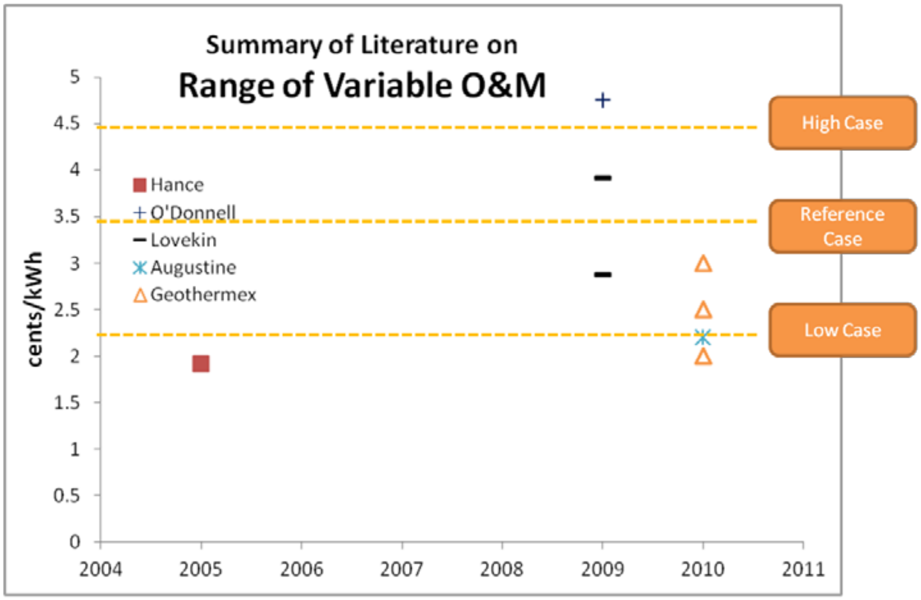
For **Sison**, Variable O&M includes field, general O&M, and rework; make-up wells; relocation injection wells and power plant O&M"

	Reference Case	Low Sensitivity	High Sensitivity
Fixed O&M Costs Modeled ($/kW)	**$50**	$40	$60

Figure A-5. Range of fixed O&M costs

Variable O&M Cost Inadequately Defined, and frequently overlaps with Fixed O&M Cost Definition:

For KEMA (O'Donnell), Variable O&M includes field, general O&M, and rework; make-up wells; relocation injection wells"



	Reference Case	Low Sensitivity	High Sensitivity
Variable O&M Costs Modeled (cents/kWh)	**3.50**	2.25	4.50

Figure A-6. Range of variable O&M costs

Appendix B: Summary of Additional CREST Modeling Inputs

Calculating LCOEs requires defining additional assumptions about the plant's specifications and operation. These assumptions are intended to be central estimates rather than representative of any specific operating or proposed facility.

Table B-1. Project Size, Performance, and Development Inputs for LCOE Modeling

Input Category	Reference Case	Potential Range	Notes and Sources
Nameplate Capacity	**50 MW**	2–100 MW	Most values between 15 and 50 MW Hance (2005), O'Donnell et al. (2009), Salmon et al. (2011), Klein (2009)
Net: Gross Capacity Ratio	**80%**		20% for "auxiliary loads"
Availability Factor	**90%**	80%–95%	Hance (2005), Lovekin and Pletka (2009), O'Donnell et al. (2009), Sison-Lebrilla and Tiangco (2005), Klein (2009)
Project Useful Life	**30 Years**		Hance (2005)
Annual Degradation of Thermal Resource	Assumes that combination of plant sizing and make-up wells keeps plant operating at capacity. Cost captured in O&M estimates.		
Exploration Well Success Rate	**25%**	10%-50%	20%-25% Hance (2005) 35% for "Hydro" Augustine et al. (2010)
Exploration Period Duration	**3 Years**	2–4 Years	NREL professional analysis experience
Confirmation Well Success Rate	**60%**		Hance (2005)
Confirmation Period Duration	**2 Years**	1.5–3 Years	NREL professional analysis experience
Production Well Success Rate	**75%**		NREL professional analysis experience
Construction Duration (Well Field and Power Plant)	**2 Years**		NREL professional analysis experience
Royalties	**4%**		Hance (2005)

Appendix C: Geothermal Power Under PURPA

The Public Utilities Regulatory Policy Act is a federal law passed as part the broader National Energy Act (NEA) of 1978. Against the backdrop of the oil crises of the 1970s, during which energy prices tripled in 1974, the goal of NEA was to decrease national dependence on imported oil. The goal of PURPA was to increase the amount of electricity purchased from independently-owned renewable energy and cogeneration plants. PURPA required utilities to a) purchase energy and/or capacity from non-utility generators[69] and b) purchase the commodities at rates based on utilities' avoided cost. In order to be eligible under PURPA, renewable energy generators had to be less than 50% owned by utilities, smaller than 80 MW of installed capacity, and have at least 75% of the total energy input provided by renewable energy (e.g., in the case of biomass plants co-fired with fossil fuels). PURPA rapidly expanded non-utility generation in the United States. By 1996, PURPA had supported the development of approximately 12,600 MW of renewable power, of which 11% was geothermal capacity in three states (Guey-Lee 1999). The majority of the geothermal capacity supported by PURPA was concentrated in California, as can be seen in Figure 15 below.

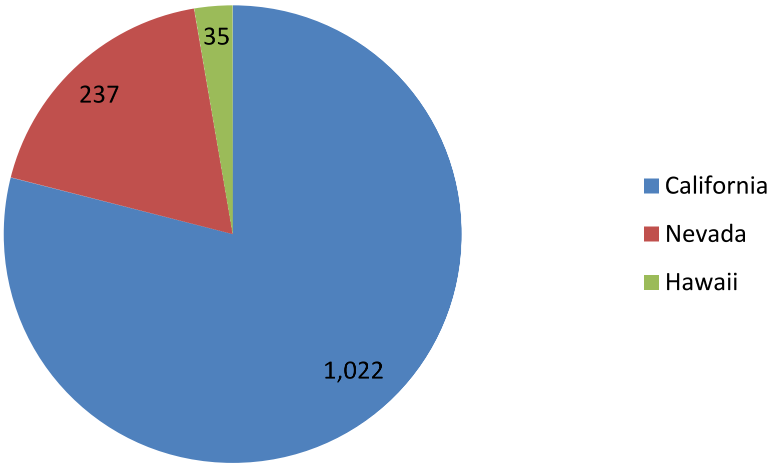


Figure C-1. Installed geothermal capacity under PURPA (MW)

Source: Guey-Lee (1999)

The Federal Energy Regulatory Commission, which was responsible for certifying eligible generators under PURPA, left the definition of utility avoided cost to each state. Different states defined avoided cost in different ways. California created several standard offer power purchase contracts that generators could choose from. Standard Offer No. 4 (SO4), which defined avoided cost as a 10-year schedule of escalating payments, drove a boom in renewable energy development (Pierce and Livesay 1994). California supported approximately 25% of all

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[69] Generation from many PURPA plants was purchased under "must take" provision, which meant that the utility was obligated to purchase everything that a generator could produce but that generators were exempt from having to provide operating reserves and ancillary capacity services (Hurlbut 2012).

renewable energy generation under PURPA, of which the largest percentage (~40%) was geothermal (Guey-Lee 1999). The price paid under PURPA for geothermal varied widely from state to state. The average price paid for geothermal plants in California was 12.44 ¢/kWh, for example. By contrast, the average price paid in Nevada was 5.31 ¢/kWh (Guey-Lee 1999).

Nationwide, PURPA stimulated exploration drilling at more than 50 prospects between 1979-1985, many of which were subsequently developed. Many of the geothermal sites developed under PURPA benefitted from federal cost-share programs, including both grants for exploration and confirmation drilling and loan guarantee programs (DOE 2008). The remaining exploration activity was primarily financed through equity from large oil, gas, mining, and utility companies (GeothermEx 2010). As the U.S. DOE's Geothermal Technologies Program Blue Ribbon Panel concluded, "Private industry was willing to take more drilling risk because of the higher electricity price" (EERE 2011, p. 8), in addition to the other programs and incentives.

Following the initial renewable energy market growth under PURPA, a decline in the price of oil, the entry of lower-cost natural gas power generation into the electricity market, concerns over excess generating capacity, and a sharp drop in the cost of commercial loans dramatically decreased the avoided cost of most utilities. This not only reduced the prices offered under PURPA but also created controversy about the pricing of existing PURPA contracts. By 1995, the average wholesale price of electricity was 3.53 ¢/kWh, whereas the average price for non-utility generators under PURPA was 6.31 ¢/kWh (Guey-Lee 1999). PURPA was amended in 2005 to remove the mandatory purchase obligation and requirement that utilities pay avoided cost-based rates in states where generators have "nondiscriminatory access to competitive markets or open-access transmission services provided by a regional transmission operator" (Elefant 2011). While utilities in some jurisdictions have applied for these PURPA exemptions, utilities in other states have continued to procure renewable energy under PURPA. In Idaho, for example, PURPA supported the development of the Raft River geothermal plant, which came online in 2008 (Doris et al. 2009).

PURPA was similar to modern FITs in that it allowed IPPs to connect and sell power to the grid. PURPA has also been crediting with not only jumpstarting renewable energy development, but also inspiring FITs in countries such as Denmark and Germany. Unlike many modern FITs, however, the price paid under PURPA was based on avoided cost, rather than on the generation cost of specific technologies.