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An Evaluation of Risk Mitigation Approaches for Geothermal Development

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ABSTRACT

Governments around the world use a wide range of policy and regulatory instruments to support renewable electricity in different forms. Because of its high risk and significant up-front capital requirements, geothermal power stands out as a special case among renewable energy sources. Furthermore, the specific context of the country situation needs to be considered when developing and applying policy instruments aimed at catalyzing and incentivizing geothermal development. Risk reduction schemes for geothermal power projects work best when implemented as coordinated packages that recognize current conditions and needs, thus catalyzing geothermal development and providing the opportunity for geothermal developers to realize a rate of return on investment that is appropriate for location- and time-specific market conditions.

The focus of this analysis is the four main schemes that have been used historically in many countries to directly address geothermal resource risk: 1) Government (or government-backed entities) serving as the geothermal developer; 2) cost-shared drilling; 3) geothermal resource risk insurance; and 4) early-stage fiscal incentives (exemption from duties, tax credits, etc.). Each approach is analyzed in terms of its key features, pros and cons, operational and management oversight requirements, impacts on the pace and/or amount of geothermal power production, and the financial impact on stakeholders. Historical examples of how each scheme has been deployed in different countries are discussed, and the level of success for each scheme is evaluated.

Recognizing that related activities can improve the profitability of geothermal projects and thus encourage geothermal developers to accept some resource risk, the paper also discusses the relevance of developing adequate infrastructure (such as transmission lines to bring the power to market) and legislated incentives such as the Feed-In Tariff, Renewable Portfolio Standard, Production Tax Credit, and other tax credits or incentives. Although these approaches are not purely "resource risk mitigation" strategies, they increase the comfort level for investing in geothermal development, thereby making the risk incurred more tolerable, improving project profitability and easing the hurdle of project financing.

The combination of a favorable power price and tax incentives (including tax credits) can accelerate the pace of geothermal development in any country. But in the absence of such conditions, this analysis suggests that fiscal incentives for early drilling (cost-shared drilling) and having the government serve as the resource developer are both particularly effective in driving the pace of geothermal growth. If it can be obtained at a reasonable premium and/or in projects with high Feed In Tariffs, geothermal well productivity risk insurance can be selectively applied to help attract project investment in early drilling, but this approach is better-suited to the development drilling phase, which is characterized by an improved understanding of specific resource characteristics and risks.

1. INTRODUCTION

Renewable energy is being expanded globally as an integral part of a diverse power generation mix. Geothermal power is a clean source of energy that can provide reliable base-load power in countries and regions where the resource is available. As an indigenous renewable source of energy, geothermal confers important environmental benefits, and can also serve as a natural hedge against price volatility in tradable fossil-fuel commodities, thus stabilizing generation costs. Located in areas that are seismically active and/or with volcanic activity (notably including countries in the so-called "ring of fire" that surrounds the Pacific basin), the worldwide geothermal power generation potential is estimated (see, for example, Bertani, 2009) to be on the order of 70-80 gigawatts (GW) based on currently commercial technologies . However, only about 12 GW of this total potential is being exploited today, and many substantial geothermal prospects are still waiting to be developed.

Geothermal power development faces a combination of challenges that can include inadequate policies to support the development of the sector, the high up-front cost of developing the steam field and the power plant, a lack or paucity of transmission access that extends from load centers to geothermal sites, a lack of basic infrastructure that provide easy access to these areas, and in some countries, limited availability of technical expertise. Depending on the circumstances in a given country or region, some or all of these issues need to be addressed to enhance the investment climate and promote geothermal development. However, it is widely recognized that the high resource risk at the early stage of a geothermal project represents a unique and critical barrier that can effectively stall geothermal development at its inception, thus preventing major investment in geothermal power.

Geothermal is developed through a staged approach beginning with surface-based exploration, followed by discovery and exploration drilling to confirm the availability of the resource, a process that can typically take 2-3 years. Before operations can commence, another 3-5 years is required for additional drilling to build out the well field and construct the power plant. Once

operational, geothermal is a reliable and environmentally preferred fuel supply for long-term power generation at a relatively steady cost. However, the combination of 1) the need for significant up-front capital investment long before revenue is earned from electricity sales and 2) the high level of resource risk up to and during the early drilling stage can slow the pace of geothermal development and sometimes prevent projects from proceeding.

Figure 1 presents a conceptual view of the various stages in geothermal power development and the associated changes in the level of risk and typically required range of capital investments. In new ("green field") geothermal projects, the highest risks are faced during the early stages of surface reconnaissance and exploration drilling (Stages I & II). During these early stages of development, there is considerable uncertainty regarding the flow capacity and temperature of the resource; i.e., the ability to drill commercially productive wells that will supply a specified generation capacity for a specified length of time is poorly known. This leads to uncertainty in the likely overall cost to extract the geothermal fluids and inject back the heat-depleted brine to replenish the reservoir. This uncertainty is considerably reduced after drilling and testing have confirmed the resource availability (following Stage II), which in turn allows the financial feasibility of proceeding with investment in subsequent development stages to be ascertained.

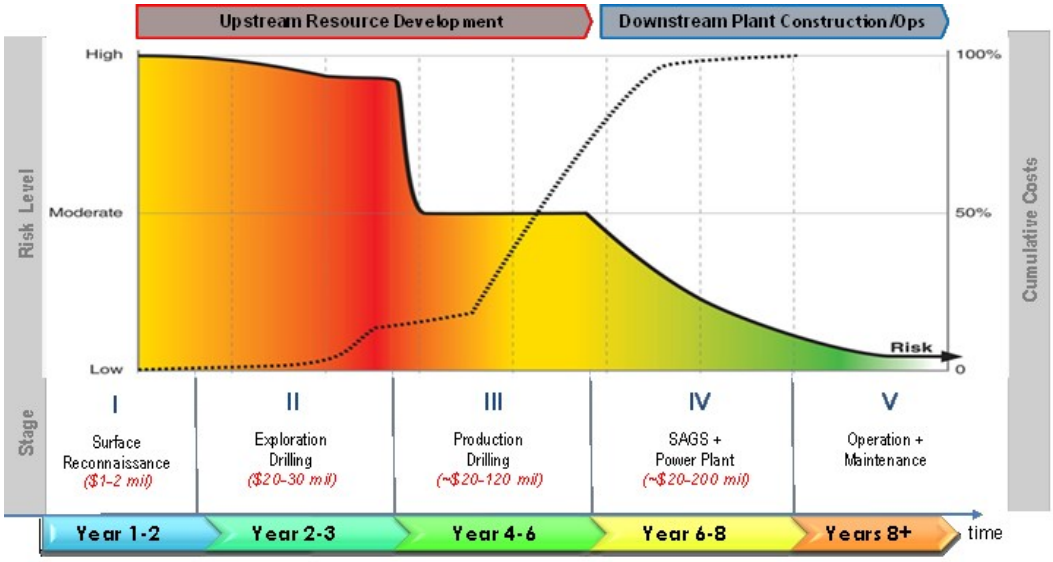

Figure 1: A Conceptual Representation of Risk During the Development Stages of a Geothermal Development (adapted from ESMAP Geothermal Handbook, World Bank, 2012)

A typical exploration campaign and initial test drilling program of 3-5 geothermal wells carries a cost ranging from $20-$30 million. While modest in comparison to the total cost of a developing all of the stages of a geothermal project, the inability to raise funds for exploration and initial drilling can delay or sometimes even stall geothermal projects. Raising the necessary risk capital can be particularly challenging for private-sector geothermal developers, since exploration drilling is typically funded with owner equity, which can be lost if the project turns out not to be feasible. Therefore, real or perceived "resource risk" has become a common barrier to advancing geothermal development around the world, including in many Latin American and Caribbean countries.

In a few countries, including those with abundant hot springs and other surface geothermal manifestations that provide evidence of attractive geothermal resources (e.g., in the Philippines, Indonesia, and the United States), some early geothermal projects were explored and developed by large, private energy companies with limited government support. However after developing the most promising fields, the pace of development slowed because of resource risk and the high level of up-front investment needed. Since most developers could not take on such exposure to risks with owner equity, particularly in developing countries, many shied away from making early stage investments in exploring geothermal "green fields." Therefore various forms of public sector support have been provided in countries that sought to promote such investments and develop their geothermal resources. Such support has been critical to overcoming barriers to geothermal development that the private sector alone may not have been able to address.

This paper presents a comparative assessment of key approaches that have been implemented to mitigate geothermal resource risks throughout the world in order to address early stage uncertainty and mobilize investments in geothermal exploration and early drilling. Such efforts have played a catalytic role in helping scale-up geothermal development by confirming resources and unlocking the potential in many fields. Different risk mitigation schemes are evaluated based on their contextual relevance, funding needs, administrative requirements, level of success and suitability for implementation, including in the Latin America and Caribbean (LAC) region. The work was undertaken to assist World Bank client countries in LAC to make informed decisions about implementing the most effective support mechanisms to expand the utilization of geothermal energy and diversify their power generation mix.

2. GEOTHERMAL RESOURCE RISK MITIGATION SCHEMES ANALYZED

Herein the focus is mainly on the support mechanisms in various countries that were specifically designed and used to address geothermal resource risks, particularly in Stages I and II (as illustrated in Figure 1 above). However, there are other complementary activities that can improve the overall profitability/feasibility of geothermal projects, which in turn can encourage geothermal

developers to accept some resource risk as a result. These activities primarily include financial and other incentives for power generation such as Feed-In Tariffs (FITs), Renewable Portfolio Standards (RPS) and tax credits, and the development of adequate associated infrastructure (such as transmission lines to bring the power to market). Governments may consider such options, when appropriate, as tools to incentivize the development of geothermal resources. However, because the benefits of such incentives are mostly realized in later stages of the development process, they are often insufficient to offset early stage resource risks and potential financial losses to geothermal developers. Therefore, these incentives alone are typically do not sufficiently incentivize investment in exploration and confirmation drilling of geothermal resources.

Therefore, a number of countries have taken more targeted action through specific schemes to address resource risks and mobilize investments towards exploration and confirmation drilling. These approaches have varied from country to country based on the division of participation between the public and private sectors during the different development stages. In a given country, resource risks typically shift toward the party that is better placed to handle it at each stage, leading to advancement and often a scale-up of geothermal development.

Herein we focus on four specific mechanisms that have been used in various countries to mitigate geothermal resource risk:

- Government acting as geothermal developer (including through state-owned enterprises and government-backed entities)
- Cost-shared exploration drilling as a mechanism to mobilize private investment
- Geothermal resource risk insurance
- Early-stage fiscal incentives (exemption from duties, tax credits, etc.)

For each approach, the following key aspects are presented, discussed and analyzed:

a) the key features of the approach
b) the pros and cons of the scheme
c) the operational / management oversight requirements for implementing the scheme
d) where the scheme has been applied internationally
e) the impacts of the scheme on the pace and/or amount of development of geothermal power generation capacity
f) the financial impact on stakeholders

The results are described in the following sections.

2.1 Government as Geothermal Developer Throughout All Development Stages

The government or government-supported agencies of a country or region can absorb much of the resource risk by exploring and developing the geothermal resource themselves. Government involvement in geothermal development can take various forms, but has been most successful in cases where government has either: 1) complete control at all stages of a geothermal project where private participation is limited; or 2) control over resource confirmation and steam field development only, with Independent Power Producers (IPPs) building and operating geothermal power plants. In addition, there have been a few cases of resource development by private entities and power plants owned and operated by governments. For the purpose of the analysis in this section of the paper, we only consider cases where the government develops both the upstream (steam field) and downstream (power plant and other surface facilities) elements as a "total" project developer. Instances where the government develops only a part of the project with the expectation of a private developer undertaking the remaining development is an approach more comparable to cost sharing, which is discussed in the next section.

By mobilizing large-scale funding from public sources, government involvement can serve as a backstop for absorbing geothermal resource risks and enhance the viability of projects in markets that may otherwise be less attractive for international investors looking to mobilize private capital. Accelerated geothermal growth has occurred wherever government has made a clear commitment to support geothermal development and has had sufficient capacity to provide the necessary financial support. This was the case in The Philippines and in Mexico, which rank second and fourth in the world (respectively) in terms of installed geothermal capacity.

As shown in Table 1 below, the government has served as the total project developer in a significant number of geothermal developments around the world, leading to the development of nearly more than 3.5 GW of geothermal power – about a third of the current installed worldwide capacity. In all of the countries listed in Figure 3, the financial capacity of the public sector was applied to all stages of geothermal development, from the high risk early-stage drilling through to construction and operation of power plants.

In countries where government could not maintain a high level of support and investment into geothermal development, the geothermal industry sometimes grew slowly and may even have become stalled at various stages. Such was the case in Kenya and Nicaragua, where few of the many known resources have been drilled and developed. Resource risk has not been the only hurdle; other barriers have compounded the challenge, including real or perceived country risk, logistical challenges, inadequate infrastructure, and insufficient availability of capital. These barriers have tended to limit the amount of geothermal development achieved by government entities, although Kenya and Indonesia are making considerable progress at present. Some governments may simply not have the necessary financing available to invest in geothermal development. Lack of sufficient sector knowledge about geothermal development, complex bureaucratic procedures, and inter-agency conflicts have also hindered the ability of some governments to develop geothermal power at the desired pace.

Geothermal development is a multidisciplinary endeavor that requires not only technical knowledge of the resource but also an understanding of financial, regulatory, utility-related, and political issues. Government or government-backed agencies with a mandate to develop geothermal therefore either require human capacity with expertise across this broad range, or the ability to periodically seek support from external consultants and academic researchers to identify, evaluate, develop and monitor geothermal

fields, and/or to provide peer reviews of government's progress with geothermal development. When geothermal development by the public sector involves multiple government agencies, departments or ministries, bureaucratic procedures and "turf wars" have actually slowed the pace of development, despite intended aspirations to the contrary.

Table 1: Government-Led Development of Geothermal Generation Capacity

Country	Number of Fields Supported	Resulting Installed Capacity (MW)
Costa Rica	2	177
El Salvador	2	149
Nicaragua	1	70
Mexico	4	980
France (Guadeloupe)	1	15
Indonesia	5	417
Philippines	5	608
New Zealand	2	220
Iceland	6	664
Turkey	1	15
Ethiopia	1	8
Kenya	1	290 (140 more being developed)
TOTALS:	**31**	**3,613**

Successful government developers achieve their geothermal goals through the combination of:

- coordinated policies that support well-trained in-house expertise,
- access to appropriate equipment, and
- access to funding.

Mexico, New Zealand, The Philippines and Costa Rica are some examples where qualified government-backed developers have expanded their geothermal portfolios, sometimes with consulting support from international specialists.

Government or publicly supported enterprises that undertake full-scale geothermal development of the (upstream) resources as well as the (downstream) power plants typically assume all of the risks associated with geothermal projects, including the early stage exploration risks. Even when development financing is made available, the typically associated sovereign guarantees mean that the governments ultimately bear risk of project failure. An exception would be when some of the project costs are supported through earmarked grants from development partners outside the country, in which case, some of the risk of project failure would be borne by the grant provider.

2.2 Cost-Shared Drilling to Mobilize Private Investment

Cost-shared drilling has successfully reduced resource risk in several countries, and has helped mobilize risk capital towards geothermal exploration/resource confirmation. It can be particularly suitable where governments seek to engage the private sector in geothermal development. Cost-shared drilling typically takes one the following two forms:

- Exploration drilling that is cost-shared between the public and private sectors. In this scenario, the government provides some portion of the risk capital that is required for early-stage exploration drilling, with the goal of leveraging the remaining funds from private sources on the basis of a developer's reduced exposure to project failure due to resource risk.
- Government-led exploration drilling to facilitate later private project development. In this scenario, government agencies may carry out surface reconnaissance and exploration drilling to reduce resource risk, thus facilitating the entrance of private companies to develop the remainder of the well field (i.e., to continue the project through the phases of production drilling, power plant construction and operation).

2.2.1 Cost-Shared Exploration Drilling

In a typical cost-shared exploration drilling scheme, the government covers the cost of some part of exploration usually by providing a grant to a private developer to carry out drilling activities. By doing so, it reduces the exposure of the private developer to potential project failure due to resource risk. The goal is to sufficiently reduce the risk to qualified private developers so that they are incentivized to undertake the development and to by mobilizing the remaining risk capital. In a cost-shared exploration scheme, the government and the private developer share the risk of project failure if the geothermal resource is determined to be unsuitable for further development.

Cost-shared exploration drilling was implemented successfully in Japan. During a number of periods over the past several decades, Japanese developers benefitted immensely from a cost-sharing scheme that included a cost-share of up to 50% for exploration

wells, and a 20% cost-share on production and injection wells. This cost-sharing hastened the installation of a most or all of the 536 MW of geothermal power that is operating in Japan today. In the United States, developers were able to confirm productive conditions at several fields that were later developed for a total of about 150 MW. In both countries, the national geological survey initially identified the most promising fields that would be eligible for cost-shared drilling, but the drilling and development were carried out by the private sector. The government reviewed the drilling plans and confirmed the private developer's ability to successfully execute the program. In the United States, public disclosure of drilling results was required, while such data disclosure was not a requirement in the Japanese scheme.

Other examples of cost-shared exploration drilling are summarized below.

- A risk mitigation strategy is being applied in Eastern Africa through the Geothermal Risk Mitigation Facility (GRMF), a fund set up with the support of international development partners to cost-share 50% of the first one or two wells in a field.
- A similar facility is being considered established by multiple development partners (including the World Bank) to catalyze geothermal development in the Latin America region.
- Australia implemented a scheme similar to that in Japan, and cost-shared grants did mobilize private efforts to undertake exploration drilling. Unlike Japan, the funds were directed toward "Enhanced Geothermal Systems" (EGS) projects (i.e., those that require significant enhancement of permeability to enable adequate heat recovery) rather than conventional hydrothermal projects, which make up nearly 100% of the geothermal power generation capacity worldwide. A combination of two factors led to a program of cost-shared drilling at the national and state levels: 1) EGS is not a commercially proven technique; and 2) many of the potential geothermal areas in Australia are remote, requiring considerable transmission infrastructure that further undermines the financial feasibility of geothermal operations.

Cost-shared exploration drilling creates additional liquidity in risk capital that is often scarce, unduly costly, or both. Following the resource confirmation, the private developer is expected to continue to develop the well field and construct the power plant. Repayment schemes can be considered in which the developer refunds all or part of the government's cost-share for a commercially successful well, although there is no evidence of such application to date.

Cost-shared drilling is particularly effective when some or all of the following conditions are present:

- the government has a goal of increasing the amount of geothermal generation capacity quickly, intends to do so with private-sector participation, and has implemented policies in support of that goal;
- the government has limited geothermal capability and/or funding for geothermal development, and instead seeks to mobilize private expertise and investment to unlock a nation's geothermal potential;
- there is adequate experience and skills with regards to geothermal development on the part of the developers, and those who receive cost share funds are selected in a transparent manner with clear criteria including the capacity to mobilize their share of the risk capital for exploration drilling; and,
- when resources are successfully confirmed, the recipients of the cost-share are committed to developing the multiple post-exploration stages until the project is operational (as opposed to selling the development rights to another investor after increasing value due to cost-shared drilling).

In the cost-shared drilling scheme described above, risks are shared between the government and the developer, and both have a vested interest in creating a successful project.

Cost-shared drilling is a straight-forward approach that provides public funding to cover all or a portion of the costs to drill early exploratory wells in order to confirm geothermal resources. Since post exploration, resource risks can remain although less so than before it would be reduced, some programs have extended the cost sharing to subsequent drilling of production and injection wells required for a project as well. The cost-shared drilling risk mitigation method requires a significantly smaller public funding commitment than full government development, leverages private equity and expertise, and enables the government and developer to share potential losses. Since funding under this approach is typically in the form of a grant, cost-sharing partially underwrites the geothermal resource risk using through public resources by reducing the developer's exposure to potential losses. It also reduces the required amount of risk capital for exploration, and has a catalytic impact since it lowers the developers' burden for raising the remaining funds for drilling. Cost-shared drilling does not guarantee the success of a project; following exploration drilling, some projects will be determined not to be viable for full-scale development despite public funding. In such cases, the investment by the government may not be recoverable when it is provided as a grant. It may be possible, however, to include an arrangement that would require successful projects (those determined to be feasible) to repay some of the government's cost-share investment, thereby offsetting part of the public funding losses from unsuccessful projects. In either case, cost-shared drilling has been demonstrated to successfully reduce resource risks and thus speed up development by catalyzing private participation in the sector.

2.2.2 Government-Led Exploration Drilling To Facilitate Development by the Private Sector

With this approach, government agencies carry out surface reconnaissance and exploration drilling to advance development and reduce investor risk by confirming the geothermal resources. For geothermal resources that are successfully confirmed, these risk-reduced development opportunities are offered through various market engagement modalities to private developers to undertake the subsequent stages of development. This approach facilitates private investments owing to the greater level of certainty about the commercial viability of the project (since the geothermal resources are confirmed in advance by the government). However, the government bears all of the risks during the exploration drilling stage under this approach, and will need to absorb any losses that are incurred as a result of unsuccessful drilling. In some cases, part ofr all of the costs incurred by the government for exploration drilling have been recovered through different mechanisms when of offering risk-reduced prospects to the private sector for development.

There are several cases in which government's action to reduce the early exploration risks have paved the way for subsequent larger scale participation by the private sector. For example:

- In the San Jacinto-Tizate development in Nicaragua, the geothermal resource was proven with publicly funded exploration drilling before the development rights were relinquished to a private developer for undertaking production drilling, well field expansion, and construction of the power plant and associated facilities.
- Similarly, in Guatemala, drilling by the government reduced risk and was a successful catalyst that encouraged private participation in geothermal development at Zunil and Amatitlan.
- The Olkaria III geothermal development in Kenya is another example where a public power developer (KenGen) undertook initial exploration drilling before offering that sector to a private developer who took over and progressively developed 100 MW of installed capacity.
- In Turkey, a government agency (MTA) explored and undertook the early drilling to various extents in numerous geothermal fields that were later awarded to private entities for further development through an auction approach.

Cost-shared exploration drilling projects are also completed, currently underway or planned for the near future in Djibouti, Ethiopia, Dominica, and Saint Lucia, with the support of the World Bank and other development partners.

Examining the Turkey case further, Tables 2 and 3 below (Tevfik Kaya, personal communication) present information from existing geothermal projects and those under construction in Turkey as of October 2014, indicating which have benefitted from earlier drilling by MTA, either in or near to the field that was later developed. In many cases, MTA drilled at least a discovery well; in a few fields, MTA drilled more than one well. In some fields, MTA's drilling demonstrated subsurface temperature but not commercial productivity; however, even this served to reduce some of the risk for later developers. For existing projects, Table 2 illustrates that at least 60% (250.5 out of 410.7 MW) have benefitted from cost-shared exploration drilling in the field by MTA. For projects that are planned or under development, Table 3 illustrates that at least 25% (90 out of 370 MW) have benefitted from cost-shared exploration drilling in the field by MTA.

Table 2: Existing Geothermal Project in Turkey (as of October 2014)

Project Name	Province-Location	Installed Capacity (MW)	Start-up Year	Initial Drilling by MTA?
Kızıldere 1	Denizli-Sarayköy	15.00	1984	Y
Dora-1	Aydın-Salavatlı	7.50	2006	Y
Bereket	Denizli-Sarayköy	6.50	2007	Y
Germencik 1	Aydın-Germencik	47.50	2010	Y
Tuzla	Çanakkale-Tuzla	7.50	2009	Y
Dora-2	Aydın-Salavatlı	12.00	2010	N*
Kızıldere 2	Denizli-Sarayköy	60.00	2014	Y
		20.00	2014	Y
Irem	Aydın-Germencik	20.00	2014	Y
Pamukoren 1+2	Aydın-Pamokoren	44.00	2013	Y
Gumuskoy 1	Aydın-Germencik	6.60	2013	N
Gumuskoy 2	Aydın-Germencik	6.60	2014	N
Sinem	Aydın-Germencik	22.50	2012	Y
Deniz	Aydın-Germencik	22.50	2012	N*
Dora 3U1	Aydın-Salavatlı	21.00	2013	N*
TR1	Manisa-Alasehir	24.00	2014	N
Dora 3U2	Aydın-Salavatlı	20.00	2014	N*
Germencik 3	Aydın-Germencik	25.00	2014	N*
Kerem	Aydın-Germencik	22.50	2014	N*

* MTA exploration well nearby (but not within the project area)

When a government undertakes full early stage geothermal exploration drilling, it injects risk capital into market that may not otherwise be available. However, following the resource confirmation, private market conditions should be sufficient for providing the financing for the subsequent stages of development by the qualified private developers. Some developing countries may not have such an investment climate, which can undermine the ultimate geothermal development objective. Since the entire exploration drilling cost (and exploration risk) is borne by the government, significant funding is required. It is possible to recover some of the public funds from subsequent private developers who recognize the value of exploration drilling and the resulting mitigation of risks.

Table 3: Geothermal Projects Under Development in Turkey (as of October 2014)

Project Name	Province-Location	Installed Capacity (MWe)	Start-up Year	Initial Drilling by MTA?
Germencik 2	Aydın-Germencik	47.5	2016	N*
Ken	Aydın-Germencik	22.5	2015/2016	N*
Germencik 4	Aydın-Germencik	25	2015	N*
Germencik 5	Aydın-Germencik	25	2015	N*
Zorlu Alasehir	Denizli-Sarayköy	50	2015	N
		10	2015	N
Tosunlar	Denizli-Sarayköy	3	2015	N
Sultanhisar	Aydin Sultanhisar	44	2016	Y
Pamukoren 3	Aydın-Pamokoren	44	2015/2016	N*
Umurlu	Aydin Umurlu x2	24	2015	Y
TR2	Manisa-Alasehir	24	2016	N
Tuzla	Canakkale-Tuzla	8	2015	N
Dora 4	Aydin-Salavatli	21	2015/16	N
DST1	Denizli-Sarayköy x2	22	2015/16	Y

* MTA exploration well nearby (but not within the project area)

The government-led exploration drilling scheme is effective under similar conditions to that of the cost-shared drilling approach. It works best when: 1) the government has clearly defined goals and the intention to mobilize private sector expertise and financing; and 2) there is interest and capacity of qualified private developers to participate in the subsequent geothermal development. The selection of qualified developers with clear criteria through a transparent process would help maximize the value and impact of the public investments. In addition, a government-led exploration drilling scheme to facilitate private project development also requires the following conditions.

- the government must have sufficient capability to undertake on its own and manage the surface reconnaissance and exploration drilling activities and resource confirmation in accordance with industry standards; and
- the government has the funding to cover the full cost of surface reconnaissance and exploration drilling in order to confirm the geothermal resources, and can afford to absorb potential losses should some developments prove to be commercially unviable.

A government led exploration drilling and resource confirmation scheme may attract more private developers since it provides more certainty and greater risk cover than under a cost-shared exploration drilling approach. However, if the exploration drilling is not carried out in-line with industry and international standards, it may erode market confidence and make it more costly and challenging to attract qualified private developers. In the case of inadequate government capacity and experience to successfully carry out exploration drilling, a cost-shared approach may be more suitable and less costly. Cost-shared exploration drilling can also be a better approach to assist developments where the governments have already relinquished development rights to the private sector, but progress has been stymied due to resource related risks.

2.2.3 Other Approaches Used by Governments to Facilitating Private Participation

There are several other ways in which governments have leveraged public investments to mobilize private participation and financing in geothermal development. In several instances, the public sector has taken the full responsibility of developing the upstream geothermal well field, whereby it underwrites the risk of exploration and production drilling, before private developers are invited to participate. This type of approach goes beyond addressing the higher risk exploration stage and extends to try and reduce the full resource risks by completing the entire upstream development before mobilizing IPPs to develop the downstream power plant and associated surface infrastructure. Since the government is taking on a larger development role, the required funding for surface reconnaissance, exploration and production drilling, will be higher than either the cost-shared or government led exploration drilling approaches described previously. This could considerably reduce risk and potentially make the downstream project more attractive to a larger pool of IPPs. However, since the government entity that develops the well field often continues to operate it through the duration of the project, this approach may also introduce a different type of commercial risk to the IPP since it is now dependent on a public entity to supply steam to its power plant on an ongoing basis.

Two examples of this mechanism are illustrative:

- The steam resources for the 27.5 MW Miravalles III project in Costa Rica was developed and supplied by the state electric utility, Instituto Costarricense de Electricidad (ICE), and the power plant is operated by an Independent Power Producer (IPP) under a Build-Operate-Transfer (BOT) agreement. However, in this case, ICE is also the electricity off-taker, which reduced the risk to the IPP of potential steam supply issues that could create a conflict with its obligations for producing electricity.
- In Kenya, the Government-backed Geothermal Development Company (GDC) is taking responsibility for all resource development activities, and will sell steam to IPPs on an ongoing basis for generating electricity to be sold to Kenya

Power and Light Company – a separate electricity distributor. To accelerate geothermal development, GDC is also considering other PPP models, such as bringing in the private sector to undertake the initial drilling in selected fields. However, since GDC's efforts have not yet led to power generation from geothermal, the impact of this approach cannot be conclusively evaluated.

2.2.4 Privatization of Government-Developed Geothermal Assets

In several instances, government or government-backed entities that develop and operate complete geothermal facilities (*i.e.*, both upstream and downstream operations) have been fully or partially privatized when they are sufficiently mature and are capable of accessing capital markets. In El Salvador (LaGeo), The Philippines (Energy Development Corporation), and more recently in New Zealand (Mighty River Power), public sector developed geothermal capacity was later divested to different degrees to leverage private participation in geothermal projects. While privatization of public geothermal assets can be a strategic decision that a government can make in order to leverage private investments and free up its own resources, it is initially a publicly financed geothermal scheme, similar to what is described earlier in this paper. Although later divestiture has mobilized private expertise and capital, these developers can face challenges similar to other private developers in mobilizing future risk capital.

The countries that have used these various cost-sharing mechanisms and an estimate of the geothermal capacity catalyzed as a result are summarized Table 4 below. As can be seen, approximately 3 GW of geothermal power have been developed as a result of the cost-sharing and similar risk mitigation mechanisms described above.

Table 4: Estimated Geothermal Generation Capacity Resulting from Cost-Sharing Schemes

Country	Number of Fields Supported	Resulting Installed Capacity (MW)
Costa Rica	1	30
El Salvador	1	44
Guatemala	2	52
Nicaragua	1	70
Indonesia	1	60
Philippines	5	1,260*
New Zealand	6	547
United States	6	150*
Turkey	5	215*
Japan	15	534*
Kenya	1	100
TOTALS:	**44**	**3,062**

* Estimated Capacity

2.3 Geothermal Resource Risk Insurance

Geothermal risk insurance is designed to insure the productivity of a well, which can be stated in terms of MW capacity or a combination of flow rate and enthalpy. After initial resource due diligence is carried out by the insurer, the developer and the insurer jointly establish the success criteria. Based on the likelihood of payouts, the insurer will then set a premium that must be paid up-front for by the developer to secure the policy. Although the drilling process itself can also be insured, in this paper it is assumed that only the productivity of the well is covered; it is the responsibility of the developer to ensure that the drilling target is reached. Following the drilling, the results are then confirmed through various tests. If the result falls outside the range of success agreed to by the two parties, it would trigger a payment from the insurer to the developer to cover its "losses." Although single wells have been insured in the past, the current trend is to cover the aggregate output of a group of wells.

There has been limited application of such insurance schemes to date for two main reasons: 1) geothermal development is a globally small sector, and insurance companies have, to date, been unable to amass an appropriate scale for such coverage to be efficient (i.e., a sufficiently large portfolio to spread the risk); and 2) given the significant uncertainty during the exploration stage, the premiums are typically high and may not be affordable to some developers. On the other hand, with an insurance policy, a developer may be able to attract risk capital that would not otherwise have been available.

Several countries have attempted to apply this method (most notably France and Germany) with modest success. Driven in part by its high Feed-in-Tariff (FIT) for geothermal power, Germany has had some success in implementing this type of insurance product. Efforts are underway to implement similar insurance products in Turkey, Kenya, and the United States. Countries with nascent geothermal development programs but few wells drilled may consider other approaches to reducing resource risks first, such as cost-shared exploratory drilling, and use resource risk insurance in the production drilling stage as a way to balance investment risks after more is known about field characteristics and the geothermal resource.

Insurance reduces the risk of inadequate drilling results for the developer and incentivizes geothermal development by mobilizing equity capital that would otherwise not be invested due to the perceived exposure to potential financial losses. Although this scheme does not have to rely on government funds and is typically financed by private entities, a very limited number of companies presently offer such a product around the world. To cover the high uncertainty during exploration drilling and remain solvent,

insurers must charge relatively high insurance premiums, increasing the required overall upfront investment above and beyond the cost of the exploration drilling. In the early 1980s, such an insurance scheme was offered by a company in the United States, but no developer applied to participate in the scheme because of the high premiums required. At present there are less than a handful of insurers worldwide that appear to be willing to underwrite geothermal resource risk and uncertainty, and specialized circumstances (such as the availability of high feed-in tariffs in Germany) have been needed to create a market for this type of insurance product.

To date, a few tens of MWs at most have been developed and catalyzed through the application of geothermal risk insurance. It may have helped mobilize some investments in exploration in Germany but the high (~$US 0.30/kwh) FIT has likely played a more significant role in accelerating geothermal development than the insurance product itself.

Insurance schemes are also relatively complex to implement, operate and monitor. Once a field has been chosen by a developer, there are many requirements (which vary by insurer) to qualify and obtain geothermal risk insurance. The project goes through a rigorous due diligence process to first qualify; all permits, licenses, approvals, documentation of access, exploration, and drilling plans must be in place and provided to the insurer for review. The limited availability of actuarial data globally for geothermal wells and the inherent uncertainty of exploratory drilling make it difficult to establish premiums and predict potential payouts in a portfolio. For wells that are insured, detailed drilling, logging and testing results are provided by the developer to the insurer. A well remediation program is typically provided in advance and followed through by the developer if the initial result of the well test does not meet the specified minimum well productivity. Well testing is witnessed and certified by a qualified independent consultant. After drilling of the insured wells has been completed, the testing results are analyzed to determine whether or not an insurance payout is warranted.

Through a geothermal risk insurance scheme, the developer is able to shift part or all of the drilling risk onto the insurer, while the developer pays the cost of the premium. The insurer may decide to create pools with other geothermal projects to spread the risk of losses among geothermal developments with different risk levels. As noted above, this is the current trend in well productivity insurance; however, there is little experience and success in scaling-up with this portfolio approach in geothermal projects to date.

2.4 Early-Stage Fiscal Incentives

Fiscal incentives that reduce the cost of exploration are not specific geothermal risk mitigation mechanisms, but it can have a catalytic impact on mobilizing risk capital towards drilling, akin to a partial cost shared scheme. Several countries have implemented modest fiscal incentives that support geothermal projects at the exploration and early drilling stages. These incentives include exemption from certain taxes and import duties, reducing the overall amount of risk capital required to undertake exploration and confirmation drilling. This mechanism provides a modest incentive by reducing a developer's exposure to potential losses that may result from unsuccessful exploration drilling outcomes. Fiscal incentives are more appropriate as a complementary policy that can enhance the impact of a more specifically designed geothermal resource risk mitigation scheme.

Several countries have such incentives, formulated in various ways, such as a reduction in taxable income (Indonesia), 100% tax deduction of investment in renewables (Mexico), exemption of taxes on the importation of machinery for geothermal development (Indonesia and The Philippines), and exemption of all taxes (except income tax) for geothermal project developers (The Philippines and Nicaragua) .

These incentives are implemented through legislation as a redesign of the fiscal architecture in a country. Their application typically does not require significant up-front public financial support, although some fiscal revenues may be lost. Tax credits (such as the Investment Tax Credit and the Production Tax Credit in the United States) have helped many geothermal developments, and are likely to have had some impact on the pace of development, but this impact is difficult to isolate and quantify.

Given that fiscal incentives are generally part of the overall tax policy, the government generally does not undertake a specific analysis of a project for which the incentive is available. Management and oversight requirements are dictated by the legislation that creates each incentive, but are typically modest since it is usually a part of an overall fiscal architecture. The requirements and methods for accessing early fiscal incentives vary by country, and require a sound understanding of the relevant tax policies and code in order to access the benefits and comply with associated obligations.

As support for renewable energy, governments have offered and underwritten various tax breaks in the hope of receiving more tax revenue later from profitable geothermal projects. The government holds some risk if the project is not developed due to potential foregone tax revenues that are not recovered. However, typically, fiscal incentives are applied on the margin to catalyze investments in geothermal and other renewable energy, while a majority of the risk of resources and project failure are still held by the developer under such a scheme.

2.5 Other Factors Influencing the Acceptance and Mitigation of Geothermal Risk

Alternative schemes and complimentary strategies to indirectly mitigate risk and incentivize investment in geothermal development have also been implemented. These include:

- Renewable Portfolio Standards (RPS), which include a mandated target percentage of renewable power in the energy portfolio of a country, state, or utility company.
- Feed-In Tariff (FIT), which sets the minimum prices for renewable energy.
- Loan Guarantees for geothermal projects.
- Tax credits, such as the Investment Tax Credits (ITC) at the start of power generation, or Production Tax Credits (PTC) for operating geothermal projects.
- Development of associated infrastructure (roads and transmission lines), another way to facilitate geothermal development, particularly in remote areas.

Although not all of these approaches are specific "resource risk mitigation" strategies, they enhance the overall feasibility of an investment, which can attract private investments in geothermal development. The resulting higher returns developers can make from a project compensates for some of the risks being taken, making geothermal development a more attractive investment opportunity. The increased profit potential can ease the burden of project financing and help advance development.

The Investment Tax Credit (ITC) approach is available in the United States and provides a tax credit of 10-30% of the capital investment costs in a geothermal project. The ITC is paid out at the completion of plant construction. This kind of tax incentive basically increases the ratio of (after-tax) revenue to (after-tax) expenses in a project.

The Production Tax Credit (PTC) is also available in the United States, and 2009 financial stimulus legislation included a mechanism for an up-front ITC cash grant in lieu of the PTC, providing benefit to companies with limited tax liabilities once a project becomes operational. The PTC is paid throughout the production lifetime of an operating project, at the rate of $0.02/kWh.

The very attractive FITs offered for geothermal energy in countries such as Germany are typically calculated on the basis of development costs. Because Germany's geothermal resources are often deep and difficult to develop, the price that has been mandated for geothermal power is accordingly high. RPS programs are essentially a mandate for a state, region or utility district to have a specific percentage of renewable power sources. These have led to higher price offers for renewable power in order to mobilize investments to meet obligations. The resulting improvement in the overall long-terms returns for developers have helped promote investments in geothermal.

These various schemes shift some risk away from the developer, through a reduction in initial capital investment (in the case of the ITC) and a higher effective return (in the case of the PTC, RPS or FIT). Basically, they provide an incentive for the developer to accept higher risks because of higher returns; but do not eliminate the downside risk should the project not advance after exploration drilling if it is determined to be unfeasible. Since most of these incentives are output-based, the projects must be operational and producing electricity to benefit from them. It may not necessarily help mobilize risk capital for exploration since, if a project were to stall at any of the development stages, the developer would bear the loss and therefore would not benefit from these incentives.

3. IMPACT OF RISK MITIGATION STRATEGIES ON GEOTHERMAL GROWTH

To illustrate how different risk mitigation strategies have worked to date, the various forms of such support in several countries have been reviewed, including select countries with significant geothermal development (Japan, Kenya, Nicaragua, The Philippines, Turkey and the United States) and those that have had significant support for geothermal development but have little or no geothermal power production to date (Australia, Chile, and Argentina). Risk mitigation strategies have had different results in different countries. For example, nearly AU$300 million (approximately US$263 million) was invested for geothermal development in Australia, including AU$50 million (approximately US$44 million) earmarked for drilling activities, which led to a number of wells being drilled, despite the fact that overall prospects for geothermal development in the country are limited due to resource characteristics (deep, low permeability) and transmission infrastructure (the best resources are far from the nearest grid access point). Similarly, there has been government and private investment in Chile beginning in the late 1960s, but no geothermal power production to date. Like Australia, the geothermal resources in Chile are remote, but the Chilean government, international investors, and IPPs are still determined to develop a successful geothermal market. The Clean Technology Fund (CTF), one of the Global Climate Investment Funds, through the World Bank Group and the Inter-American Development Bank, is assisting the Government of Chile in this regard; it has allocated $53 million to be channeled through the two multi-lateral development banks to support activities that have the potential to mobilize private investments in geothermal development in Chile.

In **Japan**, development began in the early 1970s with a major period of growth from 1975 to 1995 (see Figure 2 below). This was the period when cost-shared drilling was successfully used to stimulate geothermal projects. Subsequently, government policy changed and the cost-shared drilling programs were eliminated because geothermal was thought to be a mature technology that did not require government support. The result was that no new geothermal developments were undertaken in Japan for almost twenty years, where the installed geothermal capacity remained at 536 MW. More recently, the Fukushima earthquake and subsequent closure of nuclear power plants in Japan have renewed government interest and support to the geothermal industry. As part of its efforts to diversify its energy portfolio, the government passed legislation in 2012 that included attractive FITs for renewable power. The tariff for geothermal projects that generate less than 15 MW is ¥42/kWh ($0.40/kWh), and ¥27.3/kWh ($0.36 kWh) for projects of 15 MW or more. In addition, there has been some easing of restrictions about developing geothermal resources in and around Japan's national parks. These changes and an abundance of geothermal resources may drive the Japanese geothermal market further in the coming years.

Kenya is a reasonably successful example of the government taking on all or part of the role as the developer through various public sector entities. Development by the state power generator began in the early 1970s, then stalled for the first few years due to the slow pace, and at times, the lack of funding. Increased interest from a variety of development partners and the introduction of IPPs (including one geothermal IPP at the Olkaria field) into the geothermal market spurred some growth of geothermal power development in this country. Additional growth is anticipated with a combination of the recently formed state-owned Geothermal Development Company (GDC) due to efforts to mitigate resource risks and the participation of private-sector geothermal IPPs. Some Kenyan projects have successfully applied to the Africa GRMF for cost-shared drilling support. In this sense, the Kenyan example demonstrates how geothermal development can be driven by a combination of:

- early risk mitigation schemes through full and/or partial government funding;
- guaranteed power price (or steam price in the case where GDC sells steam to an IPP); different development schemes (all government; all IPP; initial exploration and possibly drilling by government, followed by resource concessioning to and development by IPPs; Public-Private Partnerships); and,

- a significantly important coordinated program in Kenya to develop transmission infrastructure to bring power to market from remote fields.

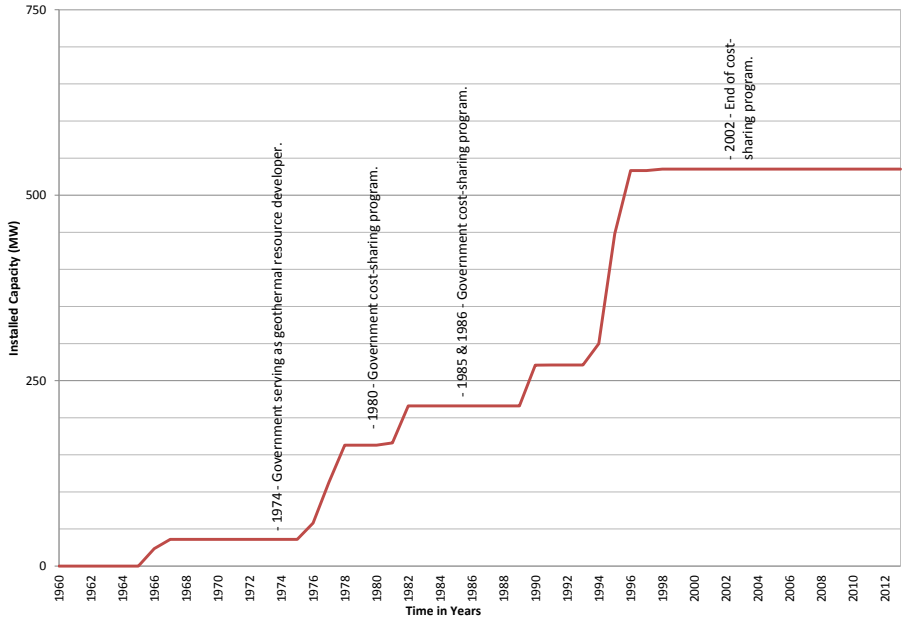

Figure 2: Installed Geothermal Power Capacity vs. Time in Japan

Nicaragua's early geothermal development has followed a similar development to Kenya, with the government as the sole developer in the early drilling stages. However, Nicaragua did not have a dedicated governmental geothermal entity, and an exploration license was not granted to an IPP until the early 2000s. Development stalled during the 1990s but has picked up recently due to interest from some IPPs and development banks. The Government of Nicaragua is also working with the World Bank to design and implement a cost-shared resource risk mitigation scheme using concessional development partner financial assistance.

In **The Philippines**, the state-owned Commission on Volcanology initiated studies on geothermal energy in 1962 and in 1967 succeeded in lighting the first light bulb with geothermal power. In 1976, Philippine National Oil Company (PNOC) set up a dedicated geothermal subsidiary (Energy Development Corporation, or EDC) that proceeded to explore, discover and develop many geothermal resources on several islands. Simultaneously, the state invited an international oil company (Union Oil Company) to conduct geothermal exploration and resource development in the country. Union Oil Company then created Philippine Geothermal, Inc. (PGI) to undertake these activities. In the 1970s, EDC installed a few small wellhead power generators. By 1979, PGI had developed two large fields, while the state-owned National Power Corporation (NPC) built several large power plants and started selling geothermal electricity to consumers. As illustrated in Figure 3 below, these activities led to a rapid development of geothermal power between 1979 and 1983, when NPC installed the first large power plant to be supplied by steam from a field developed by PNOC.

The most promising fields were developed during this period, after which the pace of development slowed down for nearly a decade. In 1992, a Department of Energy was created in the country, and became involved in the geothermal industry. Between 1992 and 1995, there was major growth in the country's geothermal power capacity because of new fields developed by PNOC and plants installed by NPC. In 1995, the state signed several Build-Own-Transfer (BOT) power contracts with private power developers, for which steam resources were to be supplied by EDC. Between 1995 and 1999, EDC's field development activities and the BOT plant constructions led to a major spurt in the installed capacity of the country. As EDC matured as a company and was able to access capital markets, it was divested with the assistance of the World Bank Group and in 2001 became a private geothermal operator. Since then EDC has begun to expand globally, including in Latin America. At present, a new wave of geothermal power development is underway in The Philippines, with the state no longer actively involved. In many ways the history of The Philippines case presents an excellent example of a balance between private and public partnership that helped rapidly scale-up geothermal development.

Turkey's early geothermal development was also solely conducted by the government, with resource administration divided between the national government (for research and power generation) and provincial governments (for district heating and geothermal development for direct use purposes). Geothermal power was developed at a slow pace until 2005, when the state mining entity and geological survey (MTA) published its inventory of Turkish geothermal waters and the government amended its laws to de-centralize power production. The Renewable Energy Law and other related laws were implemented, including a mandated FIT, leading to an increase in geothermal power production starting in 2008. The fields that had been explored to varying degrees, and in many cases where MTA undertook some initial drilling, were among the first to be developed by the private sector, largely because MTA's early work had the effect of mitigating some of the resource risk. The geothermal sector is continuing to grow, with many new geothermal projects in Turkey now under development almost entirely by the private sector, in fields that were explored to varying degrees by MTA.

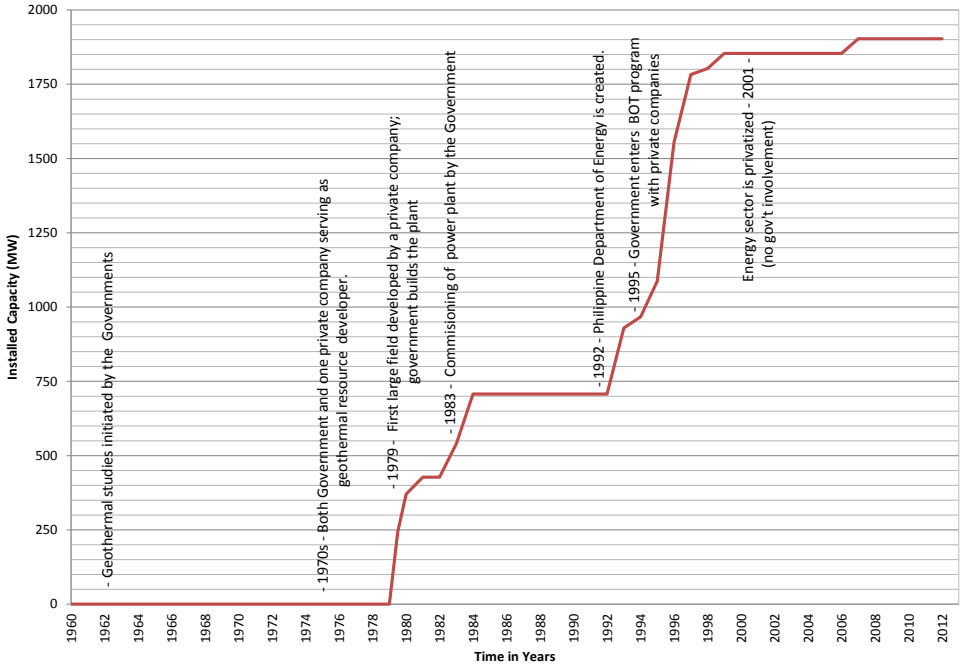

Figure 3: Installed Geothermal Power Capacity vs. Time in The Philippines

The **United States** has a complex history of geothermal development. The government participated in resource development in the late 1960s with research and early drilling conducted by Federal and State agencies, and by independent parties. By the 1970s, several laws had been put in place (most importantly, the Public Utility Regulatory Policies Act, or "PURPA") and sufficient knowledge had been developed regarding geothermal resources to spur a geothermal boom from 1980 to the late 1990s. As shown in Figure 7, the United States has had various forms of government cost-sharing and tax incentives, but has kept the majority of the development and capital investment directly with the private sector. In combination, policy decisions (PURPA and RPS in certain states), some direct government support (in the form of cost-shared drilling) and a favorable tax climate have led to geothermal growth in the United States. While cost-shared drilling has been helpful throughout the history of geothermal development in the US, it is important to note that PURPA was a major motivator for geothermal development through the early 1990s. Since then, tax credits in place since the 1990s have made taking early stage geothermal risk worthwhile for some IPPs, with some continued support from cost-shared drilling. A new round of cost-shared drilling (using slim holes to prove certain resources, including those with no surface expression) is under consideration at present. Figure 4 below illustrates the development of geothermal in the United States over time highlighting policy and other interventions of significance.

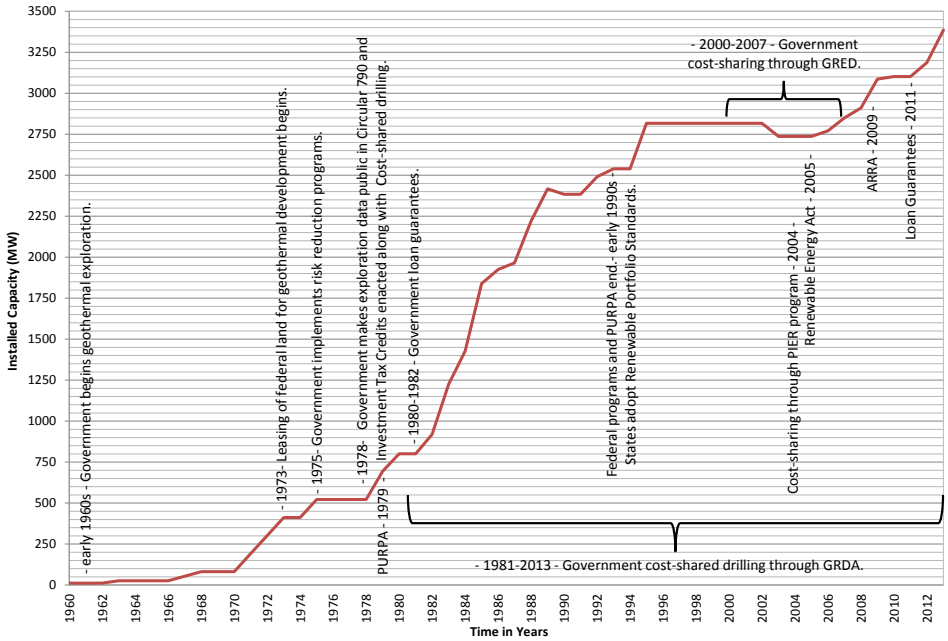

Figure 4: Installed Geothermal Power Capacity vs. Time in the United States

4. CONCLUSIONS

Resource risk is a major barrier to geothermal development worldwide because it can stall geothermal development in its initial stages. The high risks that are typically perceived when exploring a new geothermal field make it difficult to mobilize the required risk capital for funding early drilling. For this reason, a large number of geothermal developments have been undertaken by government or government-supported entities including national oil companies and state-owned enterprises. When qualified entities and sufficient capacity exists in a country, geothermal development has expanded, as in the case of Mexico and The Philippines. However, many governments have neither the financial capacity nor adequate technical expertise to undertake large-scale expansion of geothermal resources. In such cases, various ways of attracting private capital and expertise are used to develop geothermal resources for the benefit of the country.

Since it is difficult for private investors to mobilize risk capital during the uncertain early stages of geothermal development, governments have taken action to reduce the risks taken on by geothermal developers and/or otherwise incentivize developers to invest in geothermal exploration. Cost-sharing of resource risks between the public and private sectors has enabled risk capital and private expertise to be mobilized towards geothermal drilling. Cost sharing is a win-win situation in that it reduces the burden on public finances while catalyzing geothermal development by the private sector. It is also relatively straight forward to implement, monitor and manage.

Although it can also help attract risk capital to geothermal projects, experience with geothermal well productivity insurance schemes is limited, and the results have been mixed. While an insurance scheme does not require explicit government support, the high uncertainty at the exploration stage and the relatively small pool of available projects has made it difficult to diversify geothermal resource risks through a market mechanism without the imposition of high insurance premiums. There are recent efforts underway to utilize international development funds to buy down these premiums to make the scheme attractive to developers; however, exploration wells will always carry a high risk. The result is a lack of subscribers to insurance schemes, as was the case in the United States. On the other hand, high FITs for high cost geothermal projects (particularly in Germany) played an important role in facilitating the acceptance of the high premiums and participation in the insurance scheme. It has led to a modest expansion in geothermal development, but it is yet to be seen if such a scheme can actually help scale-up geothermal power, especially in developing countries.

More generally, geothermal well productivity insurance may be a more appropriate resource risk mitigation strategy during: 1) the confirmation drilling stage, after the discovery well and perhaps a second successful well have been drilled; and 2) the development drilling stage.

Risk mitigation schemes, while critically important for tackling a major barrier to getting a geothermal development initiated, may not be sufficient, if implemented in isolation, to result in successful completion of the multiple stages of geothermal project development. For this reason, it is important that any specific risk mitigation instrument is applied in coordination with other incentives that enhance the overall investment climate for geothermal development. For example, tax incentives (especially those that reduce the early stage exploration costs and limit the developers' exposure) can reduce risk and mobilize risk capital for early geothermal drilling. Even output-based incentives such as lower taxes and favorable prices can enhance the overall viability of the project, which can serve as an incentive that attracts developers to take on early stage risks. Therefore, nations that want to scale-up development of geothermal resources for power generation should carefully consider the specific conditions that exist in their country, including the power sector needs and challenges, the level of geothermal expertise, financial and human resource capacity, and other factors to select an internationally proven and successful geothermal risk mitigation approach that can be customized to suit local conditions.

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