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Comparative Analysis of Approaches to Geothermal Resource Risk Mitigation

A Global Survey

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The authors of the *Comparative Analysis of Approaches to Geothermal Resource Risk Mitigation: A Global Survey* are:

- **Subir K. Sanyal** (coopsanyal@gmail.com) is the former President of GeothermEx
- **Ann Robertson-Tait** (Ann1@slb.com) is the Business Development Manager and a Senior Geologist at GeothermEx
- **Migara S. Jayawardena** (mjayawardena@worldbank.org) is a Senior Energy Specialist in the Energy and Extractives Global Practice at the World Bank
- **Gerry Huttrer** (ghuttrer@colorado.net) is a geologist consultant for the Energy and Extractives Global Practice at the World Bank
- **Laura Berman** (lberman@worldbankgroup.org) is an Energy Specialist in the Energy and Extractives Global Practice at the World Bank

EXECUTIVE SUMMARY

Geothermal presents an opportunity for many countries to diversify their power generation mix in a sustainable way. It is a clean energy source that can reliably produce baseload power on a 24/7 basis. It also provides sizable global and local environmental benefits when developed properly. Geothermal can often be a less costly option than utilizing fossil fuels when its environmental benefits are considered; and it helps stabilize the cost of electricity supply since it is not subject to the volatility of international commodity prices during operations. For many countries where it is indigenous, geothermal can enhance energy security as well.

Despite over 100 years of development and an estimated global potential of 70 to 80 GW, only about 15 percent of the known reserves are presently exploited and producing electricity.

While there are many reasons, in various countries, for the slow pace of geothermal development, one widely recognized and unique obstacle that is globally applicable is the high resource risk during the early stages of the multi-stage geothermal development process. The real or perceived uncertainty regarding the steam resource capacity during the early stages of geothermal field development makes it very difficult to mobilize the required risk capital, especially through the private sector, for the exploration drilling required to confirm the size, temperature, pressure, chemistry, and potential production rate of the resource.

Addressing this challenge is even more relevant given that the majority of sites suitable for development around the world are green fields (*i.e.*, new fields), where the resource risks are often perceived to be especially high. A common theme that is apparent when reviewing global experience is that successful scale-up of geothermal development has benefited from some form of government facilitated support. While such support can come in many forms that can improve the overall profitability of geothermal projects, there are some schemes that specifically incentivize mobilization of risk capital into geothermal exploration drilling. The approaches that have been implemented in various countries to scale-up geothermal development through public support include the following:

- Over 3.5 GW of global installed geothermal capacity has been developed through the public sector, by government or government-backed entities. In some of these cases, the public sector takes on the full resource and other project risks by acting as the total project developer, covering all of the multi-stage development process, and continuing on to operate the power plant.

- Arrangements for cost-shared drilling between the government and private sector can also leverage public resources to mobilize private funds. This could primarily be undertaken in two ways: (i) government-led exploration and resource confirmation is conducted before the development rights are transferred to the private sector to complete and operate the now reduced-risk project, and (ii) the private sector is responsible for developing all stages of a geothermal project, but the government shares the cost of the high risk exploration stage to shift some of the risks away from the developer. In each case, governments take on some or all of the exploration risks in order to catalyze private funding for the larger portion of the development. It is estimated that over 3 GW of geothermal capacity has been catalyzed through different types of cost-sharing risk mitigation schemes.

- Geothermal resource risk insurance seeks to pool exploration risks across a portfolio of development projects by insuring the productivity of a well prior to drilling, where some or all of the losses would be covered if certain pre-specified goals are not achieved. To date, only a few tens of megawatts of installed capacity have been developed through this mechanism primarily due to the fact that geothermal, being a globally small sector, provides limited opportunities to widely pool risks. Also, the high degree of uncertainty during the exploration stage drilling makes the insurance premiums high and thus often unaffordable for developers.

- Fiscal incentives are not specific risk mitigation mechanisms, but when they are available, they reduce the up-front cost of geothermal exploration. They have the effect of transferring some of the early-stage risks as they reduce the amount of risk capital that needs to be mobilized, thus lowering a developer's exposure to potential losses should a project not advance further.

Which is the best approach? To make this determination, it is important to carefully consider the specific circumstances in a given country and its national geothermal development goals. The evidence indicates that some of the risk mitigation schemes described above have made significant contributions to the scale-up of geothermal. However, other important considerations in any given country could include the strategic objectives of the geothermal and power sector, scale and timeframe for development, available domestic technical capacity, ability to administer and oversee the schemes, financial impact and affordability of the approach, and other stakeholder considerations. The **annex** to this report provides a framework through which different approaches to geothermal resource risk mitigation can be screened in order to determine their suitability.

While resource risk mitigation schemes can be critical for kick-starting and scaling-up geothermal development programs, they are not substitutes for addressing various other challenges and risks faced by those investing in geothermal in a specific country. These factors that can undermine the investment climate, depending on the circumstances of a given country, could include inadequate policies to support the development of the sector, the high up-front costs to develop the steam field and the power plant, the availability of transmission access to geothermal sites, a lack of basic infrastructure required to provide easy access to these areas, limited availability of technical expertise, and the overall country risk perceived by investors. The implementation of any resource risk mitigation scheme should be in coordination with addressing these other important investment considerations, should they exist, as any or all of them can impact the success of the geothermal development programs.

The report concludes with a number of illustrative cases of countries that have implemented various resource risk mitigation schemes and other types of support to promote geothermal development. They include examples in select countries with significant geothermal development such as Japan, Kenya, Nicaragua, the Philippines, Turkey, and the United States; and also several nations that have had significant public sector support for geothermal development but have had little or no geothermal power production to date such as Australia, Chile, and Argentina. While the success rate in mobilizing risk capital towards geothermal exploration and scaling-up geothermal capacity has varied from country to country, the experience provides rich lessons about the applicability of various risk mitigation schemes.

The global experience highlighted in this report is helping policy makers make informed decisions regarding the most suitable approaches for geothermal development, in particular for geothermal resource risk mitigation. The World Bank is helping a number of countries apply the findings documented in the report to address geothermal resource risks, including in Chile, Nicaragua, Dominica, Saint Lucia, Armenia, Kenya, Ethiopia, Tanzania, Djibouti, Turkey, and Indonesia.

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[1] 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 (i.e., countries in the "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 to 80 gigawatts (GW) based on currently commercial technologies.[2] However, only about 12 GW of this total potential is being exploited today, and many substantial geothermal prospects are still waiting to be developed.

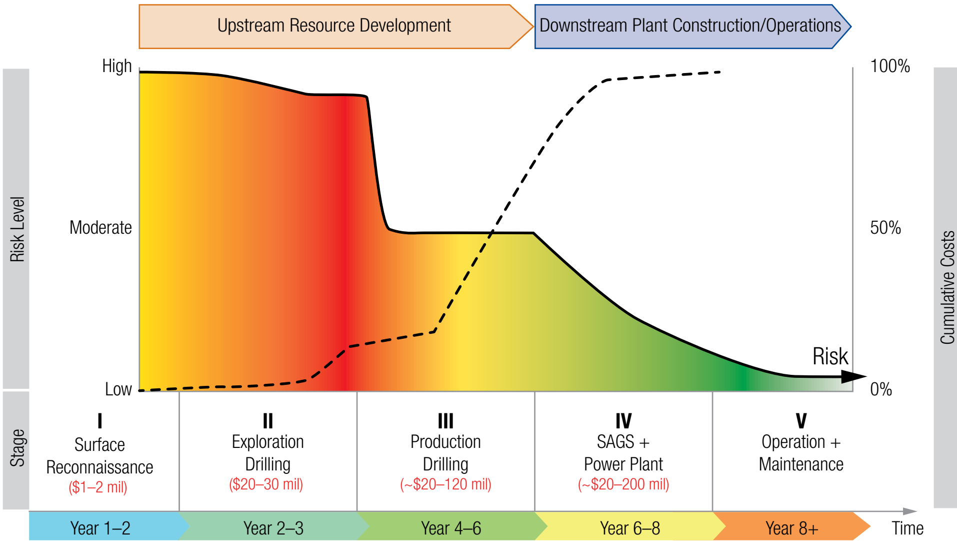
Geothermal power development faces a combination of challenges that can include inadequate policies to support the development of the sector, the high up-front cost of developing the steam field and the power plant, the availability of transmission access from load centers to geothermal sites, a lack of basic infrastructure to access 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 two to three years. Before operations can commence, another three to five 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 (i) the need for significant up-front capital investment long before revenue is earned from electricity sales and (ii) 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, namely, 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 reinjected the heat-depleted brine to replenish the reservoir. This uncertainty is considerably reduced after drilling and testing have confirmed the resource availability (following the completion of Stage II), which in turn allows the financial feasibility of proceeding with investment in subsequent development stages (Stages III and IV) to be ascertained.

A typical exploration campaign and initial test drilling program of 3 to 5 geothermal wells carries a cost ranging from $20 to 30 million. While modest in comparison to the total

Figure 1 | A Conceptual Representation of Risks and Costs during the Different Stages of a Geothermal Development



Source: Adapted from Geothermal Handbook (ESMAP 2012).

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 this 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.

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 incentivize the development of 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. The work was undertaken to assist World Bank client countries 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 APPROACHES

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). 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 typically do not sufficiently incentivize investment in exploration drilling and confirmation of geothermal resources.

A number of countries have taken more targeted action through specific schemes to address resource risks and mobilize investments towards exploration drilling and resource confirmation. These approaches have been primarily through the separation of the development responsibilities and financing burden at different stages of the geothermal development cycle between the public and private sectors. It has led to the geothermal resource risks being shifted towards the party that is better placed to handle it in a given country, resulting in the advancement, and often a scale-up, of geothermal development. Herein the focus is on four[3] types of approaches that have been used in various countries to mitigate geothermal resource risk:

1. **Government**, taking on the full resource and other project risks by acting as the total project developer (exploring, discovering, building and operating the project), through state-owned enterprises or other government-backed entities

2. **Cost-shared drilling** for mobilizing private development where some or all of the risk of drilling to develop the steam field is shifted to the public sector

3. **Geothermal resource risk insurance** that looks to pool exploration risks across a portfolio of development

4. **Early-stage fiscal incentives** (exemption from duties, tax credits, etc.) that lower the financial exposure developers would face during exploration drilling

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

- the key features of the approach;
- the pros and cons of the scheme;
- the operational/management oversight requirements for implementing the scheme;
- where the scheme has been applied internationally;

- the impacts of the scheme on the pace and/or amount of development of geothermal power generation capacity; and
- the financial impact on stakeholders.

A summary framework for comparing these key aspects of the four geothermal resource risk mitigation approaches is included in the Annex.

3. GOVERNMENT AS TOTAL GEOTHERMAL PROJECT DEVELOPER

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: (i) complete control at all stages of a geothermal project where private participation is limited; or (ii) 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, 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, the government has served as the total project developer in a significant number of geothermal developments around the world, leading to the development of more than 3.5 GW of geothermal power—about one-third of the current installed worldwide capacity. In all of the countries listed in Table 1, 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 simply may 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,

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**

Note: Data as of mid 2014.

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.

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 adequate 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 both the (upstream) resources and 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 government ultimately bears the 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.

4. 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 of 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 from resource risks.

- **Government-led exploration drilling to facilitate later private project development.** In this scenario, government agencies may carry out publicly funded surface reconnaissance and exploration drilling to reduce resource risk, thus facilitating the entrance of private companies to develop the remainder of the project (*i.e.*, through the development of the rest of the well field, as well as power plant construction and operation).

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 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 40 percent for exploration wells, and a 20 percent cost-share on production and injection wells. This cost-sharing hastened the installation of most of the 536 megawatts (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 a fund[4] set up with the support of international development partners to cost-share 40 percent of the first one or two wells in a field (see Box 1).

Box 1 I Geothermal Risk Mitigation Funds – Examples of Cost-Sharing Schemes from Africa and Latin America

Developed by KfW and hosted by the African Union Commission, the Geothermal Risk Mitigation Funds (GRMF) is the first multi-donor scheme to specifically support geothermal risk mitigation in Africa. The facility provides qualified public and private developers with (i) grants for surface studies, and (ii) cost-sharing for exploration drilling. Regarding the second, qualified developers can receive up to 40 percent of the cost of up to 2 exploration wells, plus 20 percent of the cost of related infrastructure. In the case of a successful exploration and subsequent field development, project developers can receive an additional 30 percent of the pre-determined cost of exploration wells as a "premium." Developers can apply once per year for grant funding from the GRMF and their applications are evaluated against a set of stringent, pre-determined financial and technical criteria. Four projects in Kenya and Ethiopia which received grant funding during the first Call for Proposals in December 2012 are currently in the exploration stage. It has shown that funding can be mobilized for geothermal exploration by leveraging cost shared support from the public sector. Given a successful first Call for Proposals, a second round was carried out at the end of 2014.

The Geothermal Development Facility (GDF) for Latin America follows a similar approach and is the first multi-donor scheme to support geothermal energy in Latin America. Developed on the basis of the experiences with the GRMF by KfW in cooperation with a variety of other donors and financiers, including the World Bank, it is foreseen to include: (i) a Risk Mitigation Fund to support early exploration drilling stage; (ii) Investment Financing Windows to provide tailored financing for subsequent investments during the crucial production drilling and construction stages; and (iii) a Technical Assistance Forum to coordinate existing and planned technical assistance programs of participating donors and financiers. The key element in the GDF for LCR will be a Contingency Grant that qualified public and private developers will be able to access, which would cover 40 percent of the cost of up to 3 exploration wells (up to a pre-determined maximum). In case of an unsuccessful exploration well, the Contingency Grant would be converted into a full grant with no further financial obligation for the project developer. For successful exploration wells, 80 percent of the Contingency Grant would be returned to the Risk Mitigation Fund, thus becoming available to other qualifying projects. To avoid placing undue burden on the equity position of developers during later stages of project development, the GDF will also offer re-financing of repayments as part of larger financing packages through the Investment Financing Windows of the GDF for LCR. The GDF for LCR was formally launched at the end of 2014.

- A similar facility[5] is being considered by multiple development partners, including the World Bank, to catalyze geothermal development in the Latin America region (see Box 1).

- Australia implemented a scheme similar to the one in Japan, and cost-shared grants mobilized private efforts to undertake exploration drilling. Unlike Japan, the funds were directed toward "enhanced geothermal systems" 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 percent 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: (i) enhanced geothermal systems is not a commercially proven technique; and (ii) many of the potential geothermal areas in Australia are remote, requiring considerable transmission infrastructure that further undermines the financial feasibility of geothermal operations.

- A cost-shared exploration scheme is presently being prepared for demonstration in Nicaragua with the support of the World Bank.

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 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 scheme 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 it would be reduced, some programs have extended the cost sharing to subsequent drilling of production and injection wells required for a project. 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 through public resources by reducing the developer's exposure to potential losses. It also reduces the required amount of additional 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 speed up development by catalyzing private participation in the sector.

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 of all of the costs incurred by the government for exploration drilling have been recovered through different mechanisms of offering risk-reduced prospects to the private sector for development.

There are several cases in which government action(s) 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 resources was proven with primarily publicly funded exploration by a mixed ownership company[6] before the development rights were relinquished to a private developer for undertaking production drilling, well field expansion, and construction of the power plant and associate facilities.

- 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.

There are similar efforts that are underway in Djibouti, Ethiopia, and Dominica, with the support of the World Bank and other development partners.

When a government undertakes full early-stage geothermal exploration drilling, it injects risk capital into the market that may not otherwise be available. However, following the resource confirmation, private market conditions should be sufficient to provide 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.

The government-led exploration drilling scheme is effective under similar conditions to that of the cost-shared drilling approach. It works best when: (i) the government has clearly defined goals and the intention to mobilize private sector expertise and financing; and (ii) 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 considerations:

- the government must have sufficient capability to undertake 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.

OTHER APPROACHES 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 tries to 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 the larger pool of IPPs. However, since the government entity that develops the well field often continues to oversee upstream operations 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:

1. 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 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.

2. 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 private-public partnership (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.

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, the Philippines, and more recently in New Zealand, 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. Although later divestiture has mobilized private expertise and capital, these developers can face challenges similar to other private developers in mobilizing future risk capital.

Box 2 | Transfer from Public to Private Ownership through Divestiture of Geothermal Development Entities: Examples in the Philippines and El Salvador

In some cases, the government has taken on the role of full-scale geothermal developer for a period of time, later divesting all or part of a formed geothermal development entity. For example, in the Philippines, a specific entity—Energy Development Corporation (EDC)—was formed by the Philippine National Oil Company with a mandate to explore, develop, produce, generate and market indigenous energy sources, including geothermal energy. In 2007, after developing geothermal installed capacity of more than 1,100 MW, EDC was privatized and now operates as publicly traded company with significant geothermal operations in the Philippines and interests in projects in several other countries including in the LCR region.

El Salvador's geothermal development was initially the responsibility of the state electric utility Comisión Hidroelèctrica del Rio Lempa (CEL), which set up a specific geothermal unit (initially called GESAL, later LaGeo) to develop and operate the nation's geothermal resources. LaGeo currently operates about 200 MW of geothermal power capacity at two fields. After a public tender in 2001, the renewable subsidiary of the Italian utility (Enel Green Power) purchased 9 percent of LaGeo in 2002, and gradually increased its share to 36 percent, with the Government of El Salvador holding the remaining shares. After years of operation under this arrangements, LaGeo later reverted back to full Government control following Enel Green Power's sale of its ownership share.

In countries that have used these various cost-sharing mechanisms, the estimated geothermal capacity catalyzed as a result is summarized in Table 2. As can be seen, approximately 3 GW of geothermal power has been developed as a result of the cost-sharing and similar risk mitigation mechanisms described above.

Table 2: 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**

Note: * Estimated capacity. Data as of mid 2014.

5. GEOTHERMAL RESOURCE RISK INSURANCE

Geothermal risk insurance is designed to insure the productivity of a well, which can be stated in terms of megawatt 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 by the developer to secure the policy. Although the drilling process itself can also be insured, here 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 both 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: (i) globally, geothermal development is a 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 (ii) 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 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 the field's 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 FITs in Germany) have been needed to create a market for this type of insurance product.

To date, a few tens of megawatts 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 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 even 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 makes 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.

6. 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 reduction in taxable income (Indonesia), 100 percent tax deduction of investment on renewable power (Mexico), exemption of taxes on the importation of machinery for geothermal development (Indonesia, the Philippines), and exemption of all taxes, except income tax, for geothermal project developers (the Philippines).

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 held by the developer under such a scheme.

7. OTHER FACTORS INFLUENCING THE ACCEPTANCE AND MITIGATION OF GEOTHERMAL RISK

Alternative schemes and complimentary strategies to promote renewable energy and indirectly mitigate risk and incentivize investment in geothermal development have also been implemented. Some of these include:

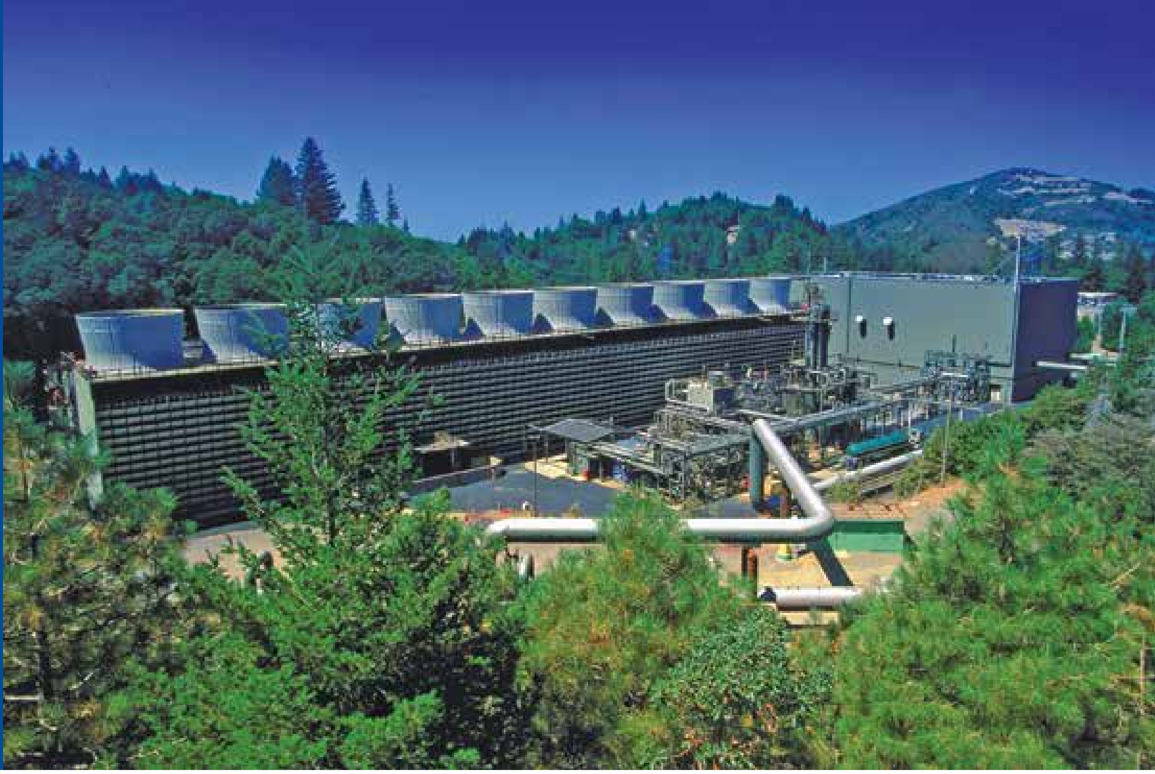
- **Renewable portfolio standards (RPS)**, which include a mandated target percentage of renewable power in the energy portfolio of a country, state, or utility company
- **Feed-in tariff** (FIT), which sets the minimum prices for renewable energy and mandates offtake
- **Loan guarantees** for geothermal 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) is another way to facilitate geothermal development, particularly in remote areas

Although not all of these approaches are specific "resource risk mitigation" schemes, they enhance the overall viability of an investment that can attract private investments in geothermal development. The resulting higher returns developers can make from a project compensates for some of the risks, 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 to 30 percent of the capital investment costs in a geothermal project. The ITC is paid out once at the completion of power 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-term 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 does 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.

8. IMPACT OF RISK MITIGATION STRATEGIES ON GEOTHERMAL EXPANSION: ILLUSTRATIVE CASES

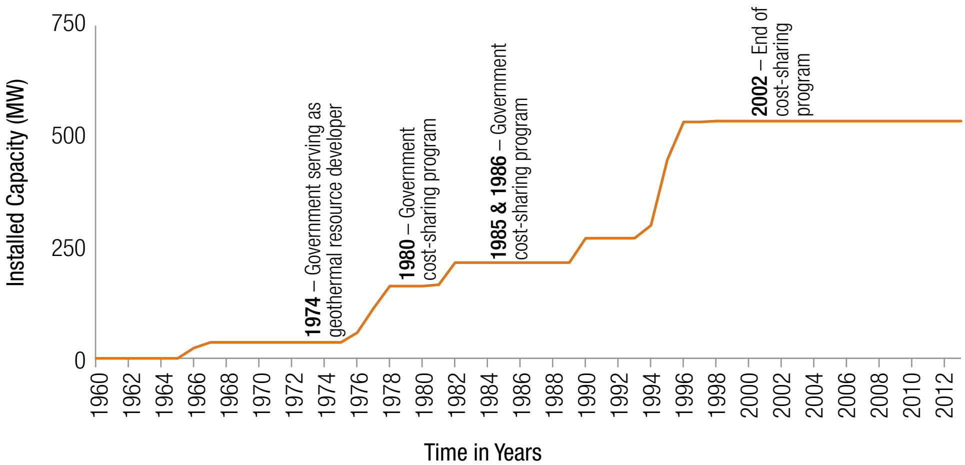
To illustrate how different risk mitigation strategies have worked to date, the various forms of such support in several countries have been reviewed, including select countries with significant geothermal development (Japan, Kenya, Nicaragua, the Philippines, Turkey and the United States) and those 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 very limited because of natural 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, 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.[7]

In **Japan**, development began in the early 1970s with a major period of growth from 1975 to 1995 (see Figure 2). 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 20 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 which is making efforts to mitigate resource risks and private 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 factors:

Figure 2 | Installed Geothermal Power Capacity over Time in Japan



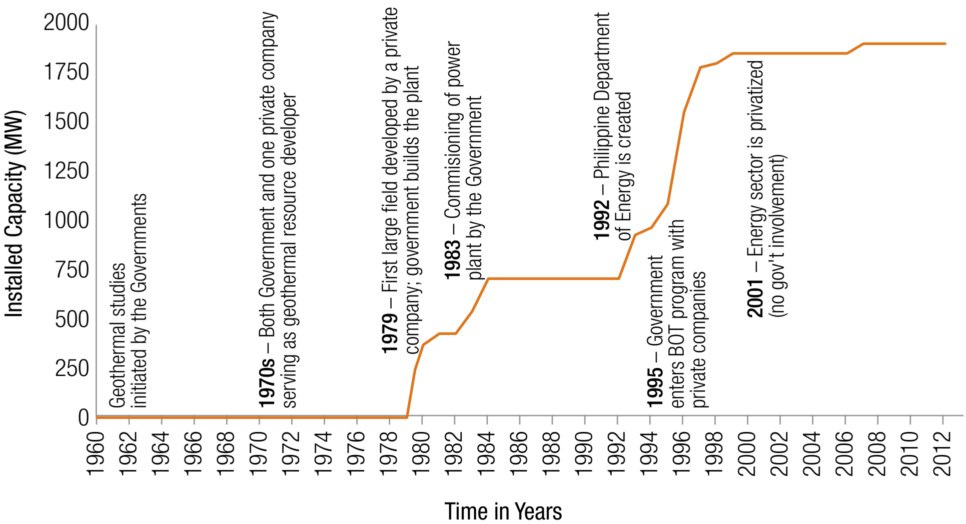
- early risk mitigation schemes through full and/or partial government funding;
  - guaranteed power price (or steam price in the case where GDC sells steam to an IPP); different development schemes (e.g., all government; all IPP; initial exploration and possibly drilling by government, followed by resource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

Nicaragua's early geothermal development has followed a similar development as 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 presently working with the World Bank to design and implement a cost-shared resource risk mitigation scheme through development financing 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 developed two large fields, while the state-owned National Power Corporation (NPC) built several large power plants and started selling geothermal electricity to consumers. These activities led to a rapid development of geothermal power between 1979 and 1983, as illustrated in Figure 3, when NPC installed the first large power plant to be supplied with steam derived 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

Figure 3 | Installed Geothermal Capacity vs. Time in the Philippines



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 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 geothermal in 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, particularly 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 partnerships 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 decentralize 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 as indicated in Table 3, 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.

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

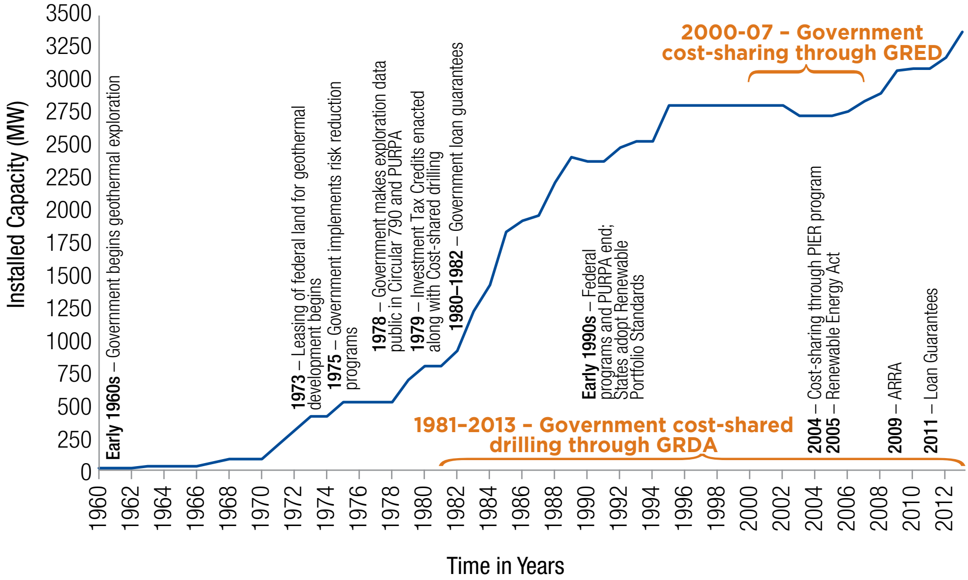
Table 3 | Geothermal Projects under Development in Turkey

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*

Note: * MTA exploration well nearby (but not within the project area). Data as of October 2014.

Policies Act (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 4, 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 United States, 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 illustrates the development of geothermal in the United States over time highlighting policy and other interventions of significance.

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



Box 3 | Geothermal Resource Risk Mitigation is a Challenge in Smaller Economies

In many smaller economies (particularly small islands), small-scale geothermal can be a lower cost power generation option since many have high cost of supply and limited available alternatives. Limited capacity and experience often compel them to depend on private sector-led development. The challenge of geothermal resource risk is compounded by the typically nascent state of the sector and limited market size, making it particularly difficult to attract qualified private developers. While cost-sharing mechanisms can help reduce risk and mobilize private risk capital, such upfront outlays can be sizable in relative terms for many small economies and unaffordable. This poses a significant challenge for geothermal development in small economies since they need to minimize multiple risks in order to attract qualified developers, but may lack the capacity and resources for undertaking such activities.

The Government of the Commonwealth of Dominica was facing a similar dilemma when they wanted to develop the Wotten Waven/Laudat geothermal field in the Roseau Valley. Geothermal was expected to reduce the high cost of electricity, which was in excess of US$0.40/kWh due to the heavy reliance on high cost diesel. The government approached a number of development partners for assistance, including the French Development Agency (AFD) and the European Union, which provided initial grants for geothermal exploration. This enabled the government to make an initial investment of about $10 million. In addition to funding support, the development partners (including the World Bank Group and the Clinton Climate Initiative) also provide technical assistance to ensure the project's compliance with international industry standards. As a result, the government was able to confirm the resource capacity, increasing market confidence and attracting a qualified developer to enter an initial agreement to develop the geothermal resources under a public-private partnership (PPP) arrangement.

The Government of Saint Lucia is currently exploring similar options with the assistance of the World Bank Group and other development partners to develop the geothermal resources in the Soufrière area.

Djibouti in North Africa faced a similar situation. It was in search of lower cost power generation options, with the potential at Fialé Caldera within the Lake Assal region presenting a useful option to explore. Its nascent industry made it a challenge to attract private developers; while limited experience and funding capacity within the government made private participation an imperative, if the country were to develop its geothermal resources. A number of development partners, including the World Bank, African Development Bank and AFD, pooled resources totaling over $31 million to assist the Government of Djibouti carry out exploration drilling and confirm the commercial viability of exploiting the geothermal resources in the area for power generation. The intention is to enhance market confidence through resource confirmation and seek private participation for a substantially lower risk project. The resource confirmation with public and international support is currently under implementation.

9. 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 to 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, the 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. More recently there are efforts underway to utilize international development funds to buy down these premiums to make the scheme attractive to developers. 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.

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 lead to successful execution throughout the multiple stages of development in a geothermal project. 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 minimize 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 for developers to assume 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 a geothermal risk mitigation approach that has proven to be successful internationally and can be customized to suit local conditions.

Box 4 I Global Geothermal Development Plan led by the World Bank

The Global Geothermal Development Plan (GGDP) is an initiative led by the World Bank's Energy Sector Management Assistance Program (ESMAP), which aims to scale-up the development of geothermal energy by addressing resource risks through sustained international partnerships. A key feature of the GGDP is an effort to mobilize substantial new concessional funding for the high risk and capital intensive upstream phases of geothermal development (including exploration drilling) in order to catalyze investment in all other stages of the geothermal value chain in low- and middle-income countries. The GGDP efforts have led to the allocation of $235 million in funding to date from the Clean Technology Fund, which are being mobilized through various risk mitigation modalities towards programs and projects that, in particular, facilitate private sector engagement in geothermal development. The large scale funding towards upstream risk mitigation is also being complemented with an additional $7 million from ESMAP, to help identify suitable projects and prepare them according to industry and international standards. These and other lessons on good practices in geothermal development are also being widely disseminated through South-South exchanges between developing countries as well as during the annual GGDP Roundtable event. Geothermal development countries throughout the world that are receiving GGDP assistance to advance development of the sector include: Latin America & Caribbean (Chile, Nicaragua, Dominica, and Saint Lucia), East Asia & Pacific (Indonesia), Africa (Kenya, Ethiopia, Tanzania, and Djibouti), and Europe and Central Asia (Armenia and Turkey).

Annex: Summary Framework for Comparing Geothermal Risk Mitigation Schemes

Type of Risk Mitigation Approach	Government as Developer	Cost-Shared Drilling	Resource Risk Insurance	Early Stage Fiscal Incentives
Key features of the approach	Government or government- supported agencies explore and develop the geothermal resource throughout the full development cycle including power plant	Government supported drilling leads to reduced risks catalyzing private capital towards geothermal development, primarily through several mechanisms: • Exploration drilling that is cost-shared between the public and private sectors • Government-led exploration drilling (typically first few wells and testing) to facilitate later private project development *(in a small number of cases, publicly developed geothermal assets where risks have been reduced, have been later privatized)*	Insurance to hedge against the risk of lower than expected well productivity (based on generation capacity or a combination of flow rate and enthalpy), helping developers mobilize risk capital for exploration drilling and resource confirmation	Exemption from taxes and import duties (and other fiscal impositions) related to exploration drilling (such as drilling equipment and materials), reducing the overall amount of risk capital required to undertake exploration drilling and resource confirmation
Countries where it has been applied	Costa Rica, El Salvador, Nicaragua, Mexico, France, Indonesia, the Philippines, New Zealand, Iceland, Turkey, Ethiopia and Kenya	Costa Rica, El Salvador, Guatemala, Nicaragua, Indonesia, the Philippines, New Zealand, United States, Turkey, Japan, Kenya and Australia	France and Germany to date; efforts are underway to implement this kind of insurance in Turkey, Kenya and the United States	United States, Mexico, Turkey, the Philippines and Indonesia
Pros	• Mobilizes large-scale financing from public sources supported by governments who are able to afford financial outlays • Backstops resource risks through the strength of a government balance sheet (*i.e.*, treasury)	• Catalyzes private investment in geothermal development and utilizes private expertise • Increases liquidity and availability of risk capital for exploration drilling • Reduces developer's exposure to financial risk for exploration drilling and helps leverage private equity/debt for subsequent work • Requires less public funding in comparison to government undertaking full development	• Insurance cover reduces developer's risk of drilling failure • Helps mobilize equity capital by reducing exposure to financial losses during exploration drilling and resource confirmation • Reduced burden on government since insurance is typically provided by specialized private entities (unless governments consider subsidy provision to buy-down cost of insurance premium)	• Lowers overall investment costs for exploration stage by decreasing the amount of early stage risk capital required • No requirement for up-front public financial support

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Annex: Summary Framework for Comparing Geothermal Risk Mitigation Schemes *(continued)*

Type of Risk Mitigation Approach	Government as Developer	Cost-Shared Drilling	Resource Risk Insurance	Early Stage Fiscal Incentives
Cons	• Some governments may not be able to afford large scale investment in geothermal due to financial capacity and/or investment trade-offs related to the use of public funds • Some countries may not have public sector agencies with the necessary skills/capacity to undertake geothermal development • Mobilizing financing for geothermal development may be cumbersome due to government bureaucracy • Multiple government agencies may create conflicts that cause delays or cancellation of efforts	• Some projects will not be viable for full scale development despite public funding outlays • Requires up-front public funding that is not necessarily recoverable, possibly leading to a perception of cost-sharing support as a subsidy to the private sector (although it may be possible that some funding could be recovered in a scheme that requires successful projects to repay the government's cost-share)	• High insurance premiums make scheme unattractive for private developers • Does not create direct liquidity in the market for risk capital. • Increases required overall upfront investment since developer must raise funds to cover exploration drilling and insurance premium • Challenging to commercially underwrite substantial uncertainty (losses) in a relatively small global pool of potentially covered geothermal exploration and confirmation wells. (lack of reliable actuarial information) • Complex to design, implement and monitor • Limited number of private insurers offering coverage	• Depending on scale of existing fiscal imposition, may have only a limited impact on overall project costs • May require alteration to overall national fiscal architecture and its implementation in order to apply
Number of fields and installed capacity (MW) developed as a result of risk mitigation scheme (as of Nov 2013)	Costa Rica: 177 MW (2 fields) El Salvador: 149 MW (2 fields) Nicaragua: 70 MW (1 field) Mexico: 980 MW (4 fields) France: 15 MW (1 field) Indonesia: 417 MW (5 fields) Philippines: 608 MW (5 fields) New Zealand: 220 MW (2 fields) Iceland: 664 MW (6 fields) Turkey: 15 MW (1 field) Ethiopia: 8 MW (1 field) Kenya: 180 MW (1 field)	Costa Rica: 30 MW (1 field) El Savador: 44 MW (1 field) Guatemala: 52 MW (2 fields) Nicaragua: 70 MW (1 field) Indonesia: 60 MW (1 field) Philippines: 1,260 MW* (3 fields) New Zealand: 547 MW (6 fields) United States: 150 MW* (6 fields) Turkey: 215 MW* (5 fields) Japan: 534 MW* (15 fields) Kenya: 100 MW (1 field) East Africa: 5 projects approved for cost-shared drilling * MW capacity is estimated	To date, a few fields in Germany (for power or combined heat and power) and France (for heat). The overall generation capacity for the German projects is <20 MW in aggregate	This has helped many geothermal developments, but by itself cannot be cited as the driver for any geothermal power project

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Annex: Summary Framework for Comparing Geothermal Risk Mitigation Schemes (*continued*)

Type of Risk Mitigation Approach	Government as Developer	Cost-Shared Drilling	Resource Risk Insurance	Early Stage Fiscal Incentives
Impact on the pace of geothermal power production	Where governments were committed and capable to support state agencies that had capacity to undertake expansion, it accelerated geothermal growth. When government were less capable of fully supporting the pertinent state agencies, development slowed or stalled	Served as a significant catalyst for all current geothermal power generation in Japan Less impact in the United States (commensurate with lower funding for this scheme)	Insurance may have helped accelerate the pace of geothermal power development in Germany but the high FIT has played a major role in geothermal development	Limited impact on pace, serves more as a compliment to enhance other modalitlies of geothermal development
Operational/ management requirements (How fields are chosen, evaluated, monitored, and how projects are administered)	Fields are typically chosen based on overall development plans for energy sector in country. Oversight is generally carried out by a designated government agency. Project implementation is often by a designated state-owned enterprise with sufficient qualifications. It is common for these various government agencies to strengthen their own capacity by contracting external "third party" specialists and consultants	In both the US and Japan, fields were initially identified by preliminary exploration by the government, some were then chosen for development by private companies The government or its consultants review drilling plans and evaluate the results for internal and external reporting In the Japanese cost-sharing program, disclosure of data was not required. In the US programs, there is a requirement for public reporting and disclosure of most data gained during cost-shared drilling	Once a field is chosen by the developer, there are many requirements to obtain the insurance. The project goes through a rigorous due diligence process to first qualify for insurance. All permits, licenses, approvals, documentation of access, etc., and all exploration and drilling plans and data must be provided For the insured wells, detailed drilling, logging and testing results are provided to the insurer. A well remediation program must be specified in advance (and followed by the developer) if the initial result is not promising. Well testing must be witnessed and certified by a qualified independent consultant. After the insured drilling has been completed, third parties (lender consultants) review the results to determine whether or not a full or partial payout is warranted	Fields are chosen by the developer The government may or may not review the resource and development plans at this time. Management and oversight of these incentives are typically dictated in the legislations that create such incentives The requirements and methods for accessing early fiscal incentives will vary widely depending on country and its' fiscal mechanisms

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Annex: Summary Framework for Comparing Geothermal Risk Mitigation Schemes *(continued)*

Type of Risk Mitigation Approach	Government as Developer	Cost-Shared Drilling	Resource Risk Insurance	Early Stage Fiscal Incentives
Risk holder and back-stopper	The government is the ultimate investor and holds all the risk in a majority of the cases. Development partner assistance in the form of grants may aid in some cases (Kenya and the Philippines) and share in the investment and risk, but loan support would require payback by government or government-backed entity. Where there is partial public ownership of government agencies (e.g., KenGen in Kenya, and LaGeo in El Salvador, the private sector holds a proportion of the risk. Some dedicated SOEs (e.g., Mighty River Power in New Zealand and Reykjavik Geothermal in Iceland) have government backing as a vehicle to promote technology export, even though they are expected to operate on a commercial basis	The government and private developer share the cost and risks of exploration and confirmation drilling. Costs borne by the government are low compared to the (full) investment by the developer, but the catalyzing impact on the project finances can be significant Repayment in case of a failed project has not been required to date in the schemes that have been implemented. Other mechanisms such as revolving funds replenished by payback for successful wells and projects, could be considered to some extent	The developer shifts part or all of the drilling risk to the insurer, depending on the extent of the coverage. The insurer may decide to create pools with other geothermal projects to spread its own risk. The limited scale of insurance schemes and lack of available actuarial data do not provide sufficient information to confirm the ability or capacity to pool such risks	As a support for renewable energy policy, 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 in foregone revenue especially if no project is developed following exploration drilling. The geothermal developer holds the majority of the risk

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Annex: Summary Framework for Comparing Geothermal Risk Mitigation Schemes (*continued*)

Type of Risk Mitigation Approach	Government as Developer	Cost-Shared Drilling	Resource Risk Insurance	Early Stage Fiscal Incentives
Overall Impact of Scheme	Has worked very well in countries that were committed and capable to support the geothermal development (e.g., Costa Rica, New Zealand, Iceland. the Philippines), it has been moderately successful in countries with significant geothermal resources but less consistent development strategies (e.g., El Salvador, Indonesia, Kenya), and not so well in smaller, less developed countries that may have more pressing needs for limited government funds (e.g., Ethiopia, Djibouti, Bolivia) Has spurred geothermal development in countries where real or perceived country risk is high In some cases, it has led to formation of profitable geothermal state-owned enterprises that were subsequently privatized (Philippines, New Zealand, and El Salvador)	Management of this scheme is relatively simple and straight forward, serving as a significant catalyst for private-sector geothermal development by increasing the availability of risk capital, particularly funds needed to reduce exposure to early-stage exploratory drilling/resource confirmation Costs to the government are significantly less than for Government as the full Developer, since far smaller proportion of the riskier part of the development is being supported A governments Cost-share portion could be recovered from the developer for successful projects, thus creating a limited scope for revolving exploratory drilling funds	Limited availability and difficult to obtain at an acceptable price for exploration well drilling, but may be available for select projects at later stages such as production drilling when there are still some degree of risks (albeit less than during exploration) Although the financial risk to developers is reduced, the overall development costs are increased by the price of the premiums. Developers who need it most may not qualify for coverage and/or their premium could be inaccessibly high Has a high level of operational and management requirements owing to the need for due diligence monitoring of the resource, drilling and remediation programs, as well as certification of well tests	Government reduces their tax revenue at the exploration stage in the hope that a profitable and taxable project will be stimulated and then developed Tax credits act as an early stage equity investment incentive by providing modest tax advantages Simple to implement and monitor, typically through existing fiscal architecture

ENDNOTES

[1] Geothermal technology can be flexible to load-follow based on power system requirements, but it is predominantly utilized as a base-load renewable generation option.

[2] The high level estimates are based on commercially proven technologies to extract fluids from the sub-surface and produce power. They do not include other resource extraction technologies such as Enhanced Geothermal Systems (EGS), which, if they were to become commercially feasible, could increase the overall global geothermal potential.

[3] The first four approaches are illustrated in Table 1. The fifth approach is for the full development cycle to be carried out by private developers, which has seen limited success in scaling-up, particularly in developing countries.

[4] Geothermal Risk Mitigation Facility (GRMF) for East Africa.

[5] Geothermal Development Facility (GDF) for Latin America, under preparation.

[6] Intergeoterm is a company formed in 1992 by the Government of Nicaragua, through the Instituto Nicaraguense de Energía (INE) and a consortium of Russian companies, where INE had approximately 71% participation.

[7] The Clean Technology Fund has allocated $53 million to be channeled through the two multi-lateral development banks to support activities that will be catalytic in mobilizing private investments in geothermal development in Chile.

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ACRONYMS AND ABBREVIATIONS

AFD	French Development Agency
BOT	Build-Operate-Transfer agreement
EDC	Energy development corporation
FIT	Feed-in tariff
GDC	Geothermal development company
GDF	Geothermal Development Facility
GGDP	Global Geothermal Development Plan
GRMF	Geothermal Risk Mitigation Funds
GW	Gigawatt
ICE	Instituto Costarricense de Electricidad (Costa Rica)
IPP	Independent power producer
ITC	Investment tax credits
KenGen	Kenya Electricity Generating Company
KfW	Kreditanstalt fur Wiederaufbau (German development bank)
LCR	Latin America and Caribbean (World Bank region)
MTA	General Directorate of Mineral Research & Exploration (Turkey)
MW	Megawatt
NPC	National Power Corporation (Philippines)
PGI	Philippine Geothermal, Inc.
PNOC	Philippine National Oil Company
PPP	Public-private partnership
PTC	Production tax credits
PURPA	Public Utility Regulatory Policies Act (United States)
RPS	Renewable Portfolio Standards

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Written by | Subir K. Sanyal, Ann Robertson-Tait, Migara S. Jayawardena, Gerry Huttrer, and Laura Berman

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Energy Sector Management Assistance Program

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Energy Sector Management
Assistance Program
The World Bank
1818 H Street, NW
Washington, DC 20433 USA
email: esmap@worldbank.org
web: www.esmap.org