ESMAP
Energy Sector Management Assistance Program

HANDBOOK ON PLANNING AND FINANCING GEOTHERMAL POWER GENERATION

MAIN FINDINGS AND RECOMMENDATIONS

ESMAP MISSION

The Energy Sector Management Assistance Program (ESMAP) is a global knowledge and technical assistance program administered by the World Bank. It provides analytical and advisory services to low- and middle-income countries to increase their know-how and institutional capacity to achieve environmentally sustainable energy solutions for poverty reduction and economic growth. ESMAP is funded by Australia, Austria, Denmark, Finland, France, Germany, Iceland, Lithuania, the Netherlands, Norway, Sweden, and the United Kingdom, as well as the World Bank..

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Energy Sector Management Assistance Program | The World Bank

MAIN FINDINGS AND RECOMMENDATIONS

Although the use of geothermal steam for electricity production began in the early 20th century, geothermal still only represents 0.3 percent of the world's total power generation. As of 2011, about 11 GW of geothermal power capacity has been built around the world, most of it in the last three decades.

Geothermal's relatively small current contribution belies its significant potential. In many areas of the world exploitable geothermal resources are far greater than current utilization, and geothermal generation has an important role to play in many countries' future energy mix. Geothermal resources have been identified in nearly 90 countries and more than 70 countries have already had some experience utilizing geothermal energy. It has been estimated that nearly 40 countries worldwide possess geothermal potential that could, from a purely technical perspective, satisfy their entire electricity demand.

Currently, electricity from geothermal energy is produced in 24 countries. The United States and the Philippines have the largest installed capacity, about 3,000 MW and 1,900 MW, respectively. Iceland and El Salvador generate as much as 25 percent of their electric power from geothermal resources. While geothermal energy potentially has a number of uses, including direct heating, this book focuses specifically on developing geothermal sources to generate electricity.

BENEFITS OF GEOTHERMAL ENERGY. Geothermal energy has many attractive qualities stemming from its renewable and fossil-fuel free nature, as well as an ability to provide stable and reliable base-load power at relatively low cost. Today, geothermal generation based on hydrothermal resources (i.e., underground sources of extractible hot fluids

Geothermal Power | Installed Capacity Worldwide

COUNTRY	CAPACITY (INSTALLED MW)
USA	3,098
Philippines	1,904
Indonesia	1,197
Mexico	958
Italy	843
New Zealand	762
Iceland	575
Japan	535
El Salvador	204
Kenya	202
Costa Rica	166
Turkey	91
Nicaragua	88
Russia	82
Papua New Guinea	56
Guatemala	52
China	24
France	16
Germany	7
Ethiopia	7
Austria	1
Australia	1

or steam) is a mature technology so technology risks can be considered low. For medium-sized plants (+/- 50MW), levelized costs of generation are typically between US$ 0.04 to 0.10 per kWh, offering the potential for an economically attractive power operation. Development of a domestic renewable energy resource provides an opportunity to diversify sources of electricity supply and to reduce the risk of future price rises due to increasing fuel prices.

ENVIRONMENT AND SOCIAL CONSIDERATIONS. From a global environmental perspective, the benefits from geothermal energy development are beyond dispute. CO_2 emissions from geothermal power generation, while not always zero, are far lower than those produced by power generation based on burning fossil fuels. Local environmental impacts from geothermal power replacing the use of fossil fuels also tend to be positive on balance—due largely to avoided impacts of fuel combustion on air quality and avoided hazards of fuel transportation and handling. Of course, like any infrastructure development, geothermal power has its own social and environmental impacts and risks that have to be managed, and the affected groups must be consulted throughout project preparation and development. The impacts from a geothermal power development project are usually highly localized; few if any of them are irreversible; and in most cases mitigation measures can be readily implemented.

BARRIERS TO DEVELOPMENT. Given such advantages, the question must be asked why the use of geothermal power is not more widespread than it is. The main barriers to greater utilization of geothermal energy for power generation are related to risk and financing. Like most other renewable energy technologies, the financing profile for geothermal indicates a high up-front cost and relatively lower operating costs compared to conventional thermal power generation projects. The high upfront capital requirement (a mid-range estimate is close to US$ 4 million per MW), combined with relatively long lead time before returns on the investment result in a high sensitivity to financing costs. In addition, unlike wind or solar, or even hydropower, a significant portion of the upfront investment is required to determine the resource viability; the level of uncertainty can be high. Obtaining the financing required to overcome this geological exploration risk (or resource risk) is often considered the greatest challenge.

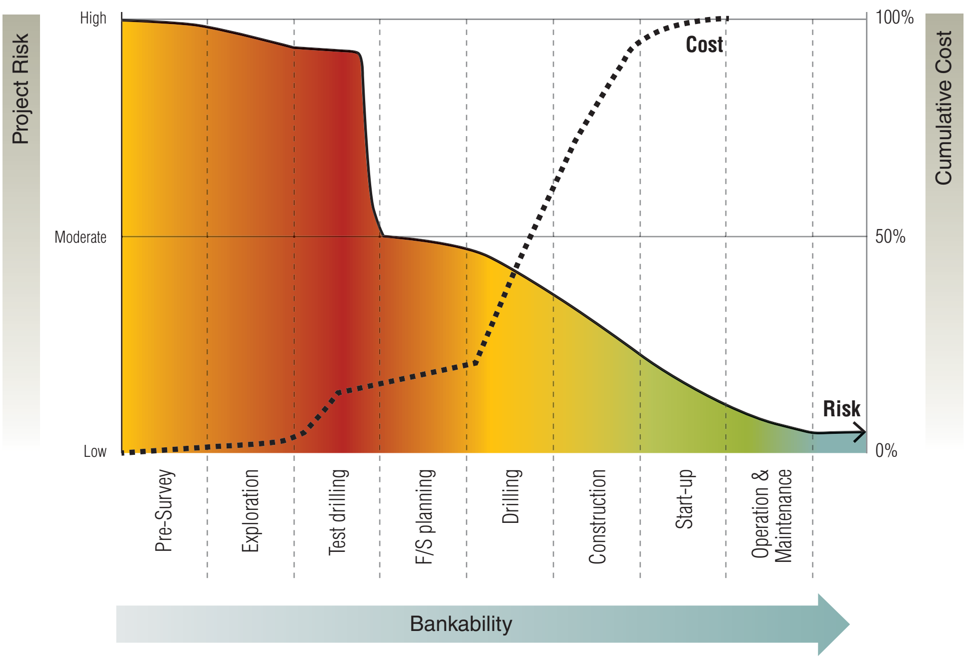
Ultimately, the high upfront risks can make geothermal projects, especially in their early phases, less attractive for investors. Furthermore, while land/space resources are generally less of a constraint for geothermal power in achieving the needed scale than for most other power generation technologies, the maximum capacity of the plant is ultimately limited by the heat production capacity of the reservoir. Even the renewable nature of geothermal energy is not unconditional, as the capacity of a reservoir to replenish itself can be compromised by unsustainably high withdrawal rates or by failure to re-inject geothermal fluids.

PHASES IN GEOTHERMAL DEVELOPMENT. To better understand the nature of the risks that are specific to geothermal, it is helpful to consider the project cost and risk profile through the various stages of project development.

A geothermal power project can be divided into a series of development phases before the actual operation and maintenance phase commences: preliminary survey; exploration; test drilling; project review and planning; field development/full-scale drilling; construction; and start-up and commissioning. A full-size geothermal development project typically takes from 5 to 10 years to complete. Due to its long project development cycle, geothermal power is not a quick fix for any country's power supply problems, but should rather be part of a long-term electricity generation strategy.

In a risk analysis of geothermal projects, many risks are found to be essentially the same as in any grid-connected power generation project—such as completion/delay risk, off-take risk, market demand/price risk, operational risk, and regulatory risk. The elevated level of financing risk due to high upfront cost is common for most other renewable energy technologies. The diagram illustrates a key feature that distinguishes geothermal from other power generation technologies. Test drilling, which can account for up to 15 percent of the overall capital cost, is required at a point in project development when the risk of non-viability is still high.

Geothermal Project Risk and Cumulative Investment Cost



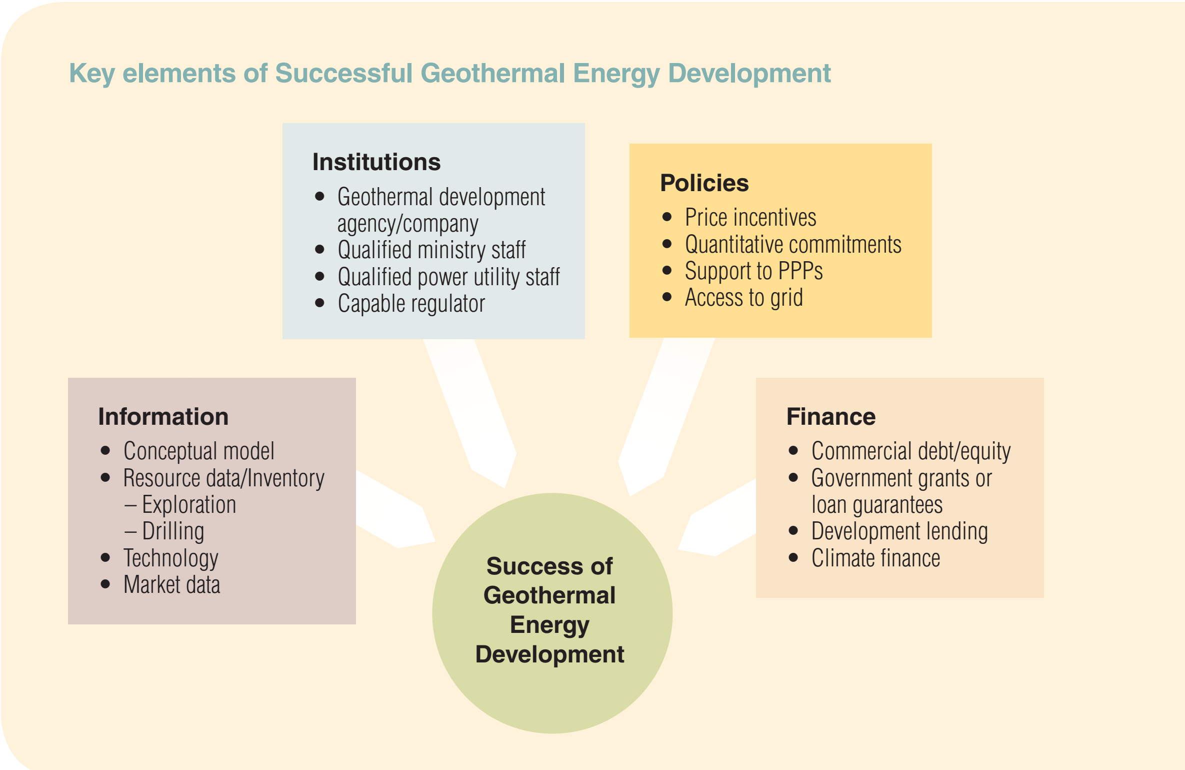
The resource risk (or exploration risk) reflects the difficulty of estimating the resource capacity of a geothermal field and the costs associated with its development. Oversizing the power plant is a risk closely related to resource risk, but it acquires additional significance for two reasons. First, oversizing the plant magnifies the resource risk by concentrating investment resources in a given location—as opposed to spreading it out by building smaller plants in several geologically independent fields. The second reason is related to sustainability of the geothermal operation. Excessive plant capacity can lead to unsustainable extraction rates resulting in pressure drops or even reservoir depletion.

The upstream/exploration phases, and especially the test-drilling phase, can be considered the riskiest parts of geothermal project development. The test drilling phase is much more capital intensive than all the previous phases, while still fraught with uncertainty. Significant investment is required before knowing whether the geothermal resource has enough potential to recover the costs.

The balancing of probabilities of success against the costs of a failure to reach the best expected outcome can be handled by formal techniques, such as the use of a decision tree. The potential project developer is essentially faced with one of three choices: go ahead immediately with production drilling and risk project failure; undertake test drilling at a certain cost but possibly reduce the risk of project failure through the knowledge gained; or, decide that the prospect is not sufficiently attractive to make it worthwhile risking money even for testing. The technique allows analyzing and adopting choices that maximize the expected value of geothermal development by applying probabilities to various project outcomes. Monte Carlo simulation is another probabilistic technique that can be applied for a more detailed analysis of the collective impact of many variables.

KEY ELEMENTS OF SUCCESSFUL GEOTHERMAL DEVELOPMENT. The existence of exploitable geothermal potential in the country, while essential, is only a prerequisite for a successful geothermal development effort. There are four key elements supporting such an effort: availability of sufficiently accurate geothermal resource data and other relevant information; effective and dedicated institutions; supportive policies and regulations; and access of the project developer to suitable financing.

INFORMATION. Information is the first key element supporting the development of a geothermal project or program. The country government has an important role to play in making geothermal resource information available to potential developers and investors. At a minimum, the government should keep public records on such geothermal attributes as seismic data (events, fractures, etc.) and deep drilling data (temperature, pressure, faults, permeability). A reliable conceptual model of the entire underlying geothermal system (or, at a mini-



mum, the field/reservoir under development) should be available. Information on groundwater resources is also essential as groundwater should not be contaminated with geothermal reservoir fluids and, among other uses, is a potential source of cooling water for the power plants.

INSTITUTIONS. The second key element is the strength of institutions and their structural organization with respect to geothermal energy development. A legal framework for geothermal resource use—starting with the definition of property rights—is needed to provide a foundation for institutions. While the right of ownership to the resource generally rests with the state, various forms of private sector participation in the exploration, development, and exploitation of the resource have evolved in many countries.

Geothermal exploration and exploitation rights in particular areas are granted by governments or regulators by means of concessions, leases, licenses, and agreements. Granting of these rights should be based on the following three principles: a clear legal and regulatory framework; well-defined institutional responsibilities; and transparent, competitive, and non-discriminatory procedures, including adequate measures for controlling speculative practices.

Countries that are successful in geothermal power development have a number of factors in common: a core/dedicated national geothermal exploration and development organization capable of handling large-scale infrastructure projects consistent with international and industry standards; a committed and adequately staffed ministry or similar department of government in charge of the energy sector whose functions include explicit planning for geothermal energy development; an adequately staffed and committed national power utility; and a capable regulator (especially, in the context of a liberalized electricity market) whose functions include the enforcement of the country's renewable energy policies and balancing the interests of generators and consumers.

The core agency in charge of geothermal exploration and development can be a government agency or, more often, a state-owned company with the requisite industrial capabilities. Examples are: the Geothermal Development Company (GDC) of Kenya, and Pertamina Geothermal Energy Corporation (PGE) in Indonesia, the Energy Development Corporation (PNOC EDC) in the Philippines, and the integrated state power company (CFE) in Mexico. The latter two examples suggest that the company in charge of geothermal exploration may not necessarily have geothermal energy as its sole focus or the word "geothermal" in its name. In all cases, the core agency/company is a vehicle through which the government of a country attempting to scale up its geothermal power takes an active role in absorbing a significant portion of the exploration/resource risk of geothermal development.

SUPPORTIVE POLICIES. The third key element of successful geothermal energy development is the presence of supportive policies for attracting private investors. Governments around the world use a wide range of policy and regulatory instruments to support the deployment of renewable electricity. Most renewable energy sources receive public support in several different forms. Countries with strong renewable energy development agendas have introduced either feed-in tariffs (FITs) or quota obligations, such as renewable portfolio standards (RPSs), as their core policy.

Geothermal power stands out as a special case among renewable energy sources, and the scope of application of such policy instruments needs to be carefully considered in the specific context of the country at hand. Attention should be given to approaches that facilitate financing for the test drilling phase, as this is the key to reducing the risk to a level that becomes more attractive for private financing. Policies that support improved returns during the operating phase, such as FITs and RPSs, are generally less effective at overcoming the exploration risk hurdle, especially in countries lacking a track record in geothermal development. There are only a few examples of FIT schemes being applied to geothermal power, with most of the examples found in continental Europe.

Outside of Europe, Africa and Asia have seen budding interest in using FITs for geothermal, but the efforts have resulted in policies setting a ceiling price instead of a FIT in some cases (e.g., Indonesia).

Government support to public-private partnerships (PPPs) involving build-operate-transfer (BOT) or similar contracts may be a logical policy choice for countries seeking a more limited commitment to geothermal power development, such as a particular milestone in a country's power system expansion plan or even an individual project. The BOT model used in the Philippines and the Mexican PPP model demonstrate the effectiveness of the approach.

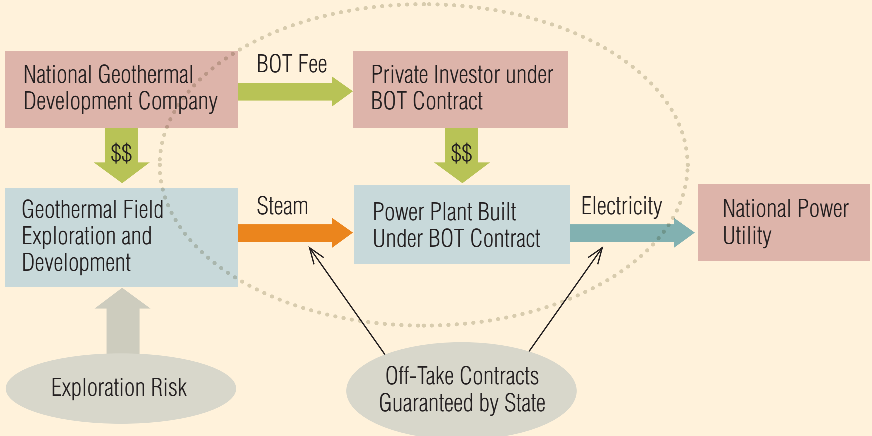
After proving the commercial viability of its geothermal sector through a series of successful PPP contracts with the government taking the exploration/resource risk, the country may wish to progress to models that allocate more of this risk to the private developer. Three basic options can be considered: inviting proposals from private companies to develop new geothermal sites through concessions or PPPs in which exploration/resource risk is taken by the private investor/developer; introducing attractive off-take prices through a FIT policy (or setting quantitative targets through RPS), while phasing out public support in the upstream phases; and privatization of the national geothermal development company and its assets including operating geothermal power plants. The last option, however, needs to come with explicit commitments by the investor to further geothermal development, including in greenfield areas.

FINANCE. The fourth key element of successful geothermal energy development is financing. Scaling up geothermal power development requires active participation of both the public and private sectors. Reliance solely on commercial capital for geothermal development is rarely viable even in developed country markets. In developing countries, where the challenges involved in attracting private capital to geothermal projects are often greater, the commitment of the public sector—including the country government, international donors, and financial institutions—is an essential element of success in mobilizing capital.

The respective roles of the public and private sector in mobilizing finance for geothermal development depend on particular circumstances of the country, including the government's fiscal situation, its preference for the level of private sector participation, the desired level of vertical integration of the geothermal development market, and other factors.

If private sector financing of geothermal projects is envisaged, the costs of capital need to be carefully considered as the financiers may require a high premium for the risks involved. This is true for both debt and equity capital, and the role of the latter needs to be especially emphasized. While debt financing typically covers the greater part of the capital requirements (commonly 60 to

The Philippine BOT Model: Private Investor Insulated from Exploration Risk and Off-Take Risk



Source | Authors based on Dolor 2006.

70 percent of the total project cost), lenders usually require that a significant amount of equity be invested in the project as well. Private equity investors, however, are likely to require relatively high rates of return on their invested capital. Required return on equity of 20 to 30 percent per year is not unusual, due to risks noted earlier.

In addition, from an equity investor's perspective, risk factors include risks associated with the financing structure (leverage). For example, return on equity is sensitive to changes in the terms of debt financing, such as interest rate, maturity period, grace period (if applicable), and the debt-equity ratio.

One of the options to bring return on equity above the threshold rate required by the private investor is for the government (or international donors) to grant-finance a portion of the costs of the initial project development, including exploratory drilling. Such investment cost sharing in the early stages of the project can increase the private investor's estimated return on equity to a level that is sufficiently attractive, without resorting to the option for the government to subsidize and/or raise the tariff for the consumers.

In international experience, many different development and financing models have been utilized for geothermal power development. Even within a single country, various models have been adopted, either consecutively or at the same time. The financing structures and the corresponding risk allocations can vary widely. However, a review of models reveals some common patterns.

MODELS OF GEOTHERMAL POWER DEVELOPMENT. The upstream phases of geothermal project development tend to rely heavily on public sector investments, while private developers tend to enter the project at more mature phases. The project development cycle (and sometimes the broader geothermal market structure) may be vertically integrated or separated (unbundled) into different phases of the supply chain. In an unbundled structure, more than one public entity and/or more than one private developer may be involved in the same project at various stages.

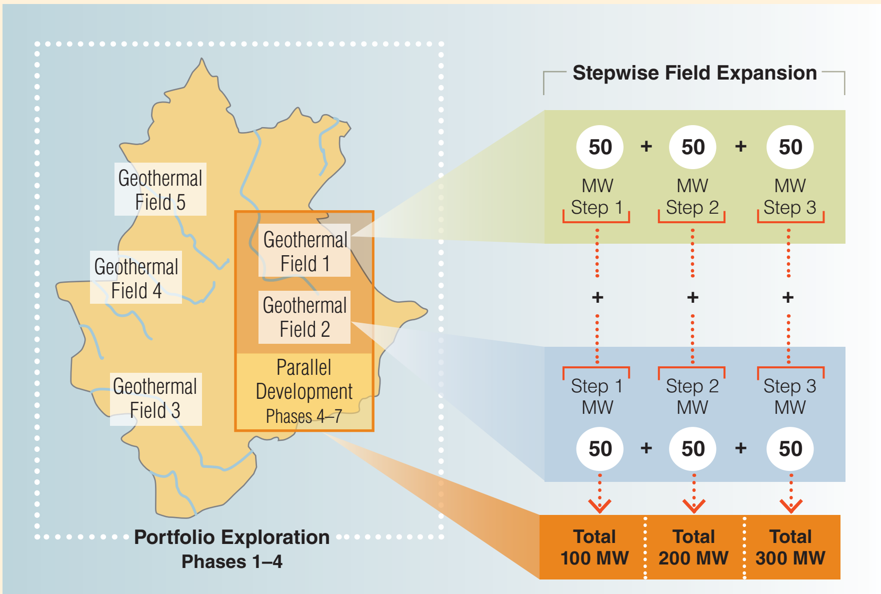
Eight different models of geothermal power development are identified in this Handbook. On one extreme is a model where a single national entity implements the full sequence of phases of a geothermal power project. This is financed by the national government, in conjunction with any grants from donors and loans from international lenders. In this model, risk is borne almost entirely by the government, either directly or through sovereign guarantees of loans. The burden on the public finances is reduced only by revenues earned from sale of electricity and by donor grants if available. This model has been utilized in several countries, including Kenya, Ethiopia, and Costa Rica.

On the other extreme is a model exemplified by the case of a fully private development led by an international oil company in a recently launched 100 MW project in the Philippines. The company has agreed to fund the project using hydrocarbon revenue and assumes the full risk from exploration to power generation. Similar private developments can be found, for example, in Australia and Italy.

In between these extremes, there is a broad spectrum of additional models to be found. Sometimes, more than one state-owned company or more than one arm of government is involved in the provision of funds for geothermal development, while the private sector role is limited (e.g., Iceland, Indonesia, and Mexico). In other cases, PPP structures are utilized where the private participant plays an active role (e.g., El Salvador, Japan, Turkey, new development in Kenya and Indonesia, and the former model in the Philippines based on BOT contracts).

RISK MANAGEMENT THROUGH A PORTFOLIO APPROACH. Whether the project is public or privately led, exposure to resource risk should be carefully managed. Exposure can be limited based on risk diversification principles long employed by extractive industries such as oil and gas. To the extent possible, a portfolio of moderately sized projects should be undertaken in parallel rather than implementing large projects in sequence. Countries with extensive inventories of identified geothermal fields are well placed to benefit from the application of a portfolio approach to test drilling. The country's geothermal development company could, for example, have an investment portfolio consisting of multiple

Parallel Development of Two or More Geothermal Fields Reduces Resource Risks



projects to develop geologically independent geothermal fields and construct the first, moderately sized geothermal power plant in each (or some) of them. It is generally recommended that each geothermal project should utilize initially only a portion of its respective geothermal reservoir's production capacity to maximize the returns on information from operations. Subsequently, additional plant capacity may be added so the degree of utilization of each field's productive capacity will increase gradually over time.

To summarize the point on resource risk management, a strategy minimizing resource risk exposure could consist of the following approaches: portfolio exploration, in which the country explores and evaluates multiple geothermal fields, thereby increasing the probability of finding at least one viable site and reducing the chance of overlooking significant development opportunities; parallel development of the fields selected from the portfolio to reduce time and costs; and incremental/stepwise expansion, reducing the risk of reservoir depletion and pressure drops by developing a geothermal power project in cautiously sized steps, determined by reservoir data.

A stronger role for institutional investors in supporting geothermal development could be achieved through increasing involvement of private insurance companies. The availability of large portfolios of geothermal projects offers fertile ground for insurance schemes, since risk management through diversification is the foundation of the insurance industry. To reduce the cost of coverage, such schemes will have to initially rely upon public sources of subsidized capital (including grants from governments, donors, or climate finance).

DEVELOPMENT ASSISTANCE. Official development assistance available from the multilateral and bilateral development banks, as well as climate finance facilities, have a key role to play in supporting geothermal energy development. The concessional nature of capital supplied by climate finance vehicles, coupled with the involvement of major international development organizations, creates unique opportunities for leveraging capital from various sources to support low-carbon investments.

Considerable efforts and resources in recent years have been devoted to attempts at setting up funds using concessional financing to mitigate geothermal resource risk. Two significant programs supporting the development of such funds have been undertaken under the auspices of the World Bank. In both cases, the Global Environment Facility (GEF) has been the main source of concessional capital. The experience from designing and operating geothermal funds in Europe and Central Asia, as well as the more recent experience in Africa, has helped the international community learn some valuable lessons and develop a better understanding of the available options for the future.

Key principles underlying the design of a successful global or regional facility to support geothermal development have emerged from this experience. The facility needs to be well staffed and professionally managed. It needs to have a critical mass of concessional capital sufficient to leverage co-financing from the market at large—including private sector debt and equity. The greatest impact from concessional financing on the bankability of a typical mid-size geothermal power project can be expected when such financing is directed to the test drilling phase of project development. Success during the test drilling phase is the key to bridging the crucial gap between the early start-up phases that are unlikely to attract debt financing and the more mature phases of the project when the financiers begin to see the project as increasingly bankable. The geographic scope of the project portfolio should cover an area containing well established and highly promising geothermal reservoirs, principally those suitable for electricity generation. The area should also be sufficiently wide to allow for a diverse portfolio of geothermal project locations to reduce the concentration of resource risk. Finally, the operational procedures of the facility should include incentives to apply prudent investment risk management principles and techniques.

Possible designs for a donor-supported geothermal development facility include: a direct capital subsidy/grant facility; a loan (on-lending) facility; and a risk guarantee/insurance facility. The choice of the design depends on particular circumstances of the country/region and donor agencies involved. In principle, any of these designs can reduce private investors' risk and thus reduce the risk premium for the return on equity and the overall cost of capital, opening up new opportunities for attracting investments to scale up geothermal power.

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