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# OPPORTUNITIES AND CHALLENGES FOR SCALING UP GEOTHERMAL DEVELOPMENT IN LAC



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# OPPORTUNITIES AND CHALLENGES FOR SCALING UP GEOTHERMAL DEVELOPMENT IN LAC





San Jacinto-Tizate Geothermal Plant.  
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San Jacinto-Tizate Geothermal Plant.  
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# ACRONYMS AND ABBREVIATIONS

ADB	Asian Development Bank	EBRD	European Bank for Reconstruction and Development
AfD	Agence française de développement (French Agency for Development)	EHS	environmental, health and safety
Ar	argon	EIA	Environmental Impact Assessment
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (German Federal Ministry for Economic Cooperation and Development)	EIB	European Investment Bank
		ENAP	Empresa Nacional del Petróleo (National Petroleum Company)
		ENEE	Empresa Nacional de Energía Eléctrica (National Electric Energy Company)
CABEI	Central American Bank for Economic Integration	ENEL (NI)	Empresa Nicaragüense de Electricidad (Nicaraguan Electricity Company)
CAF	Corporacion Andina de Fomento–Banco de Desarrollo de América Latina (Andean Development Bank of Latin America)	ENEL (IT)	Enel Green Power
		ESAP	Environmental and Social Action Plan
CAPEX	capital expenditure	ESIA	Environmental and Social Impact Assessment
CCP	Cerro Colorado Power	ESMAP	Energy Sector Management Assistance Program
CDB	Caribbean Development Bank	ESMP	Environmental and Social Management Plan
CEL	Comisión Ejecutiva Hidroeléctrica del Río Lempa (Executive Hydroelectric Commission for the Lempa River)	ESMS	Environmental and Social Management System
CEPAL	Comisión Económica para América Latina (United Nations Economic Commission for Latin America and the Caribbean)	EU-LAIF	European Union Latin America Investment Facility
CFE	Comisión Federal de Electricidad (Federal Electricity Commission)	FI	Financial Intermediary
		FIT	feed-in tariff
CH <sub>4</sub>	methane	GCF	Green Climate Fund
CIF	Clean Investment Fund	GDF	Geothermal Development Facility
CO <sub>2</sub>	carbon dioxide	GDN	Geotérmica del Norte (Geothermal of the North)
CTF	Clean Technology Fund	GDP	gross domestic product
DFID	Department for International Development	GEEREF	Global Energy Efficiency and Renewable Energy Fund
DGDC	Dominica Geothermal Development Company	GEF	Global Environment Facility

GEOLAC	Geothermal Congress of Latin America	LCOE	levelized cost of energy
		MW	megawatts
GGDP	Global Geothermal Development Plan	N <sub>2</sub>	nitrogen
GHG	greenhouse gases	NH <sub>3</sub>	ammonia
GIZ	German Center for International Cooperation	NOx	nitrogen oxide
		NDF	Nordic Development Fund
GoCD	Government of the Commonwealth of Dominica	NCGs	non-condensable gases
		OHS	Occupational Health and Safety
GoM	Government of Mexico	O&M	operations and maintenance
GoN	Government of Nicaragua	PMA	Pitons Management Area
GoSL	Government of St. Lucia	PPA	power purchase agreement
GW	gigawatt	PPIAF	Public-Private Infrastructure Advisory Facility
H <sub>2</sub>	hydrogen		
H <sub>2</sub> S	hydrogen sulfide	PPP	public private partnership
Hg	Mercury	PS	Performance Standard
ICE	Instituto Costarricense de Electricidad (Costa Rican Institute of Electricity)	PTC	production tax credit
		RAP	Resettlement Action Plan
IDA	International Development Association	RPS	Renewable Portfolio Standard
		SAGS	steam-above-ground system
IDB	Inter-American Development Bank	SEP	Stakeholder Engagement Plan
IFC	International Finance Corporation	SIDS	Small Island Developing States
IFI	International Financial Institution	SO <sub>2</sub>	sulfur dioxide
INDE	Instituto Nacional de Electricidad (National Electricity Institute)	SREP	Scaling Up Renewable Energy Program
		SSA	steam sales agreement
IPP	independent power producer	TKB	Development Bank of Turkey
ITC	investment tax credit	TKSB	Türkiye Sınai Kalkınma Bankası (Industrial Development Bank of Turkey)
JICA	Japan International Cooperation Agency		
KenGen	Kenya Electricity Generating Company	UN	United Nations
		US	United States
KfW	Kreditanstalt für Wiederaufbau (German Development Bank)	UNU-GTP	United Nations University Geothermal Training Program
LAC	Latin America and Caribbean region		

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Please note that the findings, interpretations, and conclusions expressed in this report are entirely those of the authors and should not be attributed in any manner to the World Bank, its affiliated organizations, members of its Board of Executive Directors, or the countries they represent.



San Jacinto-Tizate Geothermal Plant.  
Photo courtesy of Polaris Energy Nicaragua S.A.

# EXECUTIVE SUMMARY

**M**any countries in the Latin America and Caribbean region (LAC) are endowed with world-class geothermal resources. There are 25 countries and territories in LAC with estimated geothermal resource potential, but only eight have installed geothermal power capacity. Fifteen percent or less of LAC's estimated geothermal resource potential is currently exploited to produce power. The majority of LAC's geothermal resources remain untapped, not only in the more advanced Central America and Mexico region but also in the Caribbean and in South America. If further explored and developed in a sustainable fashion, these resources could provide a significant share of the base-load power needs of the region at a competitive cost, resulting in direct economic and environmental benefits to many LAC countries. Various large and small geothermal developers are keen to enter or to expand their presence in LAC. There is also strong support for geothermal development from governments in the region and from the international development partner community that has been providing both concessional financing and technical assistance.

**While there are a number of barriers that slow the growth of the geothermal sector in LAC, there also are significant opportunities to address such barriers and to scale up development.** This report gives an overview of the physical, economic, financial, market, regulatory, environmental, and social obstacles that have hampered geothermal development globally and in LAC. It also provides examples of international

and regional experiences and best practices that have proved useful in overcoming these challenges. The report is a decision-maker's guide to assessing these key barriers and opportunities for expansion of geothermal development in LAC. It showcases an array of measures from around the world that clients in LAC can customize for application in their own domestic markets. Specifically, this report explores:

- Key elements that influence the investment decisions of geothermal developers in LAC;
- Approaches to mitigating resource risk that may be suitable for LAC and experience using these approaches around the world;
- Mobilizing finance for geothermal development and the different types of investors and financing sources available;
- Key policy, legal, and regulatory considerations that are necessary to support geothermal development; and
- Ways in which environmental and social considerations can be incorporated into geothermal developments to ensure that these investments will be sustainable over time.

**The intention of this study is to address key cross-cutting sector and regional issues in LAC and explore global solutions to these types of issues.** An in-depth, country-by-country geothermal analysis for LAC was beyond the scope of the proposed work. The key opportunities and challenges addressed in the report were identified through engagement with LAC policy-makers, utilities, and developers, and the

potential solutions and approaches outlined draw primarily from global experience. As regional experiences and approaches are more well-known by LAC policy makers and stakeholders, the countries engaged were most interested to learn from global experiences outside LAC. These approaches could later be adapted by LAC countries to meet their own country-specific needs, with further assistance from the World Bank and from other development partners supporting geothermal development in the region if needed.

### Electricity and Geothermal Sector Context

**The geothermal sector has a key role to play in power-sector development, which is essential to sustaining economic growth, reducing poverty, and increasing shared prosperity in LAC.**<sup>1</sup> The primary energy sector challenge in LAC is to meet growing demand for electricity while diversifying the energy generation mix. Meeting growing demand will require the addition of a significant amount of new generation capacity.<sup>2</sup> Given the often high and volatile oil prices the region has faced, there is considerable need for greater diversification of the region's generation matrixes with renewables. The region has a sizable opportunity to develop reliable, lower-cost power generation alternatives, such as geothermal, as a means to improve affordability, enhance competitiveness, and promote growth and poverty alleviation.

**Over the past decade, there has been rapid integration of renewable energy technologies in the LAC region.** Wind and biomass are two renewable energy technologies that have expanded the most quickly. More recently, there has also been increased adoption of and interest in the integration of both grid-connected and decentralized

solar power, given the significant drop in the prices of these technologies. In contrast, geothermal sector expansion has occurred at a much slower pace. The relatively lower risks, rapid deployment times, and lower investment requirements of both wind and solar have made these technologies increasingly attractive to both private sector and public players. Between 2006 and 2015, over 26 gigawatts (GW) of non-hydro renewable energy were deployed in the region, of which geothermal comprised only a small fraction.<sup>3</sup>

**The growth of intermittent renewables on the grid will require that regulators develop solutions to manage the increased variability and uncertainty of electricity generation.** Currently, combining these technologies with options like battery storage is more expensive than using conventional power generation technologies like geothermal, natural gas, coal, and oil. However, the rapid fall in the prices of renewable technologies such as solar and the continued evolution of storage, which is expected to become much more affordable over the next decade, may constrain future expansion of geothermal.

**There is significant estimated geothermal potential in the tectonically active LAC countries located along the Pacific Rim of Central and South America and in the Eastern Caribbean.** Geothermal can play an important part in diversifying the power generation mix in the LAC region. It is a reliable and clean source of energy that, unlike many other renewable technologies, can provide 24/7, base-load power. Geothermal power generation technologies are mature and have been used for decades around the world, including in LAC. In many LAC countries, geothermal provides opportunities to reduce the cost of electricity by shifting away from heavy

<sup>1</sup> LAC's gross domestic product (GDP) grew at an average rate of about three percent per year between 1970 and 2016. (World Bank 2018a).

<sup>2</sup> Electricity demand in LAC also has grown by about three percent per year on average since 1970 and is projected to more than double by 2030 under modest GDP growth assumptions. (World Bank 2018a).

<sup>3</sup> International Renewable Energy Agency. 2016.

reliance on petroleum-based fuels for power generation. Once developed, geothermal can supply electricity at a steady price, making consumers less vulnerable to oil price volatilities. As an indigenous resource, geothermal also can enhance energy security. Furthermore, compared with fossil fuel alternatives, geothermal is a clean energy source that can reduce the emission of greenhouse gases (GHG) and other pollutants considerably.

**Despite significant resource potential, the expansion of geothermal generation capacity in LAC over the past few decades was quite limited compared to that seen in the Asian and African regions.** There is an estimated 11 GW to 55 GW<sup>4</sup> of geothermal resources in LAC with the potential to be used for power generation, but the region's current installed geothermal capacity is only 1.67 GW. LAC has a significant opportunity to exploit this potential, if enabling conditions to facilitate geothermal investments are developed and if solutions that have been demonstrated to work elsewhere are adopted to overcome the key challenges that the region faces. Chapter 1 provides more details about the history and opportunities for geothermal development in LAC.

### Attracting Geothermal Developers – Key Investment Considerations

**The key factors that drive geothermal investment decisions in LAC are varied.** The World Bank conducted a series of in-depth interviews with private geothermal developers that are active in LAC to understand the key factors they assess before investing in geothermal projects. The most important investment considerations they highlighted were related to: i) geothermal resource conditions and risk, ii) the policy, legal, and regulatory framework, iii) institutional and local capacity to oversee and develop geothermal capacity, and iv) financial considerations.

**Geothermal resource conditions, as well as resource risks, are among the principal factors that influence investment decisions.** Developers interviewed indicated that their decision to invest is driven first by the quality and the estimated potential of the geothermal resource in a particular country and field. However, even if the resource potential is attractive, this often can be overshadowed by the inherent geothermal resource risk. Due to high resource risks, the significant, up-front investment capital requirements in the initial stage of geothermal development has been a leading factor in the slow pace of geothermal development throughout LAC and globally, dissuading investors from entering the market.

**Policy, legal, and regulatory frameworks for geothermal investments, as well as the underlying electricity market conditions in LAC, are also key factors that developers consider.** Developers often desire public support in the form of feed-in tariffs (FIT) and other fiscal incentives; contractual risk mitigation measures, such as partial risk guarantees or investment stabilization agreements; longer concession periods; and efficient permitting and licensing processes. Electricity market conditions and the cost competitiveness of geothermal power production is also a key factor for many developers. For example, the small market size in many Caribbean nations, such as Dominica and St. Kitts and Nevis, has discouraged geothermal investment in those countries, in spite of large estimated resources.

**Developers also considered the institutional capacity of governments and the limited local technical capacity and services to facilitate geothermal development.** Development decisions became more challenging when LAC governments had low awareness of the advantages and benefits of geothermal development for power

<sup>4</sup> The wide range of estimates for the region is due to the fact that most of this potential has not been confirmed by drilling.

generation. Experience suggested that this lack of awareness was often accompanied by limited government capacity to select qualified developers and to promote and oversee geothermal development. Availability of local drilling equipment and technical expertise are also key factors for developers. The limited market for geothermal drilling services in LAC, where such services are available in only a few countries, means that expertise and equipment often must be imported from other regions, which increases costs and mobilization time.

**Financial considerations such as access to risk capital and loans, as well as the availability of public support, also influenced investment decisions.** Some developers, particularly smaller ones, indicated that access to finance is a significant barrier, especially for the high-risk early stages of geothermal development. This was less of a challenge for more established developers,<sup>5</sup> which have larger balance sheets and a more global presence, but these developers are highly selective about the geothermal fields that they invest in. Developers interviewed indicated that public sector support to help mitigate early stage risks (through grants or cost-sharing instruments) would facilitate private investment. Chapter 2 describes in detail the key factors that the interviewed private geothermal developers consider when investing in LAC.

**Expanding Geothermal Development in LAC**  
**Based on discussions with LAC policymakers, utilities, and developers, the cross-cutting challenges affecting most countries in the region were identified.** These included: i) addressing geothermal resource risks; ii) mobilizing financing for geothermal development; iii) policy, legal, and regulatory reforms to improve the investment climate; and iv) environmental and

social considerations. Given that LAC stakeholders are interested in learning from experiences outside the region and that many of these same challenges affect geothermal developments around the world, this study primarily focuses on demonstrated global solutions. Some regional experience is also highlighted where lessons can be drawn from these experiences.

### **Geothermal Resource Risk**

**One of the biggest challenges to geothermal development globally—including in LAC—is the high resource risk in the early stages of geothermal development.** Until surface level reconnaissance and exploration drilling are carried out and an industry standard feasibility assessment<sup>6</sup> is completed, the viability of a given geothermal project remains uncertain. These risks can be a significant deterrent for investors and make it particularly challenging to raise the risk capital required to undertake exploration drilling. Resource risk is particularly significant in the LAC region, since most of the remaining unexploited resources are located in greenfield development areas where there is little information about the size and quality of the geothermal resources. It is important for LAC countries to address the issue of geothermal resource risks if they want to unlock their potential and expand geothermal capacity.

**This report presents several global approaches to facilitating geothermal resource risk mitigation that LAC countries could consider adopting.** Two principle approaches are explored: (i) government being the total geothermal project developer, and (ii) cost-shared drilling to mobilize private investment. The cost-shared drilling approaches presented have taken two main forms. In the first, the government undertakes the exploration drilling and then offers the field development to the private sector. Under the

<sup>5</sup> Such as Ormat, Energy Development Corporation, or ENEL Green Power (ENEL IT).

<sup>6</sup> Such an assessment should confirm proven steam supply of 50 percent to enable the raising of financing.

second cost-sharing approach, the government awards the rights for all stages of geothermal development to the private sector, but also provides financial support to help mitigate risks. In these types of cost-sharing approaches, developers and investors with more risk appetite (such as the government or specialized developers) undertake the upstream stages of development (drilling stages) to mitigate risks. Later, the private sector, using more conventional financing, undertakes the downstream phases (steam power plant development and operations and maintenance). These types of cost-sharing and joint-venture approaches are common in the oil and gas industries and there is emerging experience in LAC applying similar approaches to spur geothermal development.

**Other types of support to incentivize development have been used in different countries, with more varied results.** These include geothermal resource risk insurance, early stage fiscal incentives, and other measures. Several key lessons from an analysis of the different approaches are that: (i) public support is central to geothermal development, especially for reducing risks; (ii) well-targeted public support can leverage private participation; and (iii) approaches to scaling up geothermal should be customized to country-specific circumstances. Chapter 3 provides more details about geothermal resource risks and global and regional measures to address these hurdles.

### **Mobilizing Financing for Geothermal Development**

**Over the next decade, it is estimated that LAC will require an estimated US\$2.4 billion to US\$3.1 billion to finance the development of about 776 megawatts (MW) of geothermal power generation capacity.** Central America is planning to develop over 50 percent of this geothermal capacity in eleven fields, in both greenfield and brownfield developments. However, with only two fields expected to be built, geothermal development in South America

is projected to remain fairly stagnant due to less competitive market conditions. These include lower electricity prices and greater competition with other power generation options. In contrast, the Caribbean is ramping up its geothermal capacity, with new six fields and a total of 195 MW planned for development. Given the significant untapped geothermal resource potential throughout all parts of LAC, there is an opportunity to expand geothermal capacity well beyond the amount planned, if key obstacles can be overcome and more financing secured.

Mobilizing the projected funding requirements to finance geothermal development will be challenging. Since the 1990s, the LAC geothermal sector has attracted less than US\$1 billion of private investment. There is a significant gap between the amount of funding required to undertake the planned geothermal investments and the amount of private geothermal investment that has been attracted to LAC over the past three decades. Furthermore, the amount of geothermal development planned over the next decade is small compared to the region's total estimated geothermal potential, which, if exploited, would require significantly more investment. This study highlights some of the funding sources available in the LAC region, in particular those that have been used in the past or that are being used currently to finance geothermal development. Mobilizing the funding required to scale up geothermal development in LAC will require the combined efforts of both the public and private sector and support from the international development community. Chapter 4 explains the estimated investment needed to scale up geothermal capacity in LAC and the different financing sources available to the region.

### **Policy, Legal, and Regulatory Reforms to Enhance the Investment Climate**

**To expand geothermal development in LAC, establishment of a national strategic policy and deployment of legislative and regulatory tools to overcome barriers are essential.** Only about

half of LAC countries with estimated geothermal resource potential (or installed capacity) have a geothermal-specific law in force; even fewer have passed geothermal regulations. However, the lack of geothermal-specific laws or regulations does not mean that a country's geothermal resources are ungoverned, unregulated, or undeveloped. Geothermal resources are governed instead under energy, mining, mineral, or other types of legislation. However, the relationship between the different laws and regulations that impact geothermal development can be extremely complex and can cause uncertainty that can dissuade potential investors. Countries that have streamlined and facilitated geothermal development have put into place a legal regime that reconciles divergent and often competing laws.

**Successful development of geothermal resources requires a predictable and stable policy framework and legal regime.** At the same time, these need to be flexible to incorporate potential future modifications needed to facilitate investment and to reflect technological changes. The policy framework and legal regime are the primary tools needed by policymakers to shape and promote a country's geothermal development and consist of: i) the national geothermal energy strategy; ii) the laws that define, promote, or preserve resource exploration and utilization; and iii) the regulations that encourage, license, and ensure the safety and sustainability of geothermal development. The framework determines how geothermal development will maximize its potential benefits for the country. Policy, law, and regulations also determine the national investment climate and the likelihood of success or failure for a country's geothermal development.

**To effectively govern the sector, it is also imperative to ensure that adequate institutional and local capacity exists to execute these laws and regulations.** To facilitate institutional capacity, a government focused on developing geothermal capacity could appoint a lead agency and ensure that the agency has the legislative mandate to

manage its responsibilities. Other governmental actions consistent with building national institutional capacity include: ensuring that these institutions have sufficient capacity to handle the permitting and monitoring functions; ensuring adequate awareness and inter-institutional coordination; providing sufficient domestic training; and having access to external expert advisory services where needed.

**One of the most important areas in which institutional capacity may need to be strengthened is the screening and evaluation of potential companies applying for geothermal concessions.** Such screening and evaluation would help ensure that only qualified developers with the technical and financial capacity to develop the country's geothermal resources are awarded exploration and production licenses. Screening and evaluation would help diminish the risk of the awarding of concessions to speculators who have no intention of advancing field development. Stipulations in geothermal laws, regulations, and concession agreements can help by including shorter terms for concession periods, minimum developer qualifications, and physical and financial investment requirements to maintain the concession. Chapter 5 provides an overview of existing geothermal laws and regulations in LAC and legislative good practices based on global and regional experience.

### **Environmental and Social Considerations to Facilitate Geothermal Development**

**Environmental and social considerations are other key factors that impact the ability of geothermal developers to raise financing.** While geothermal is an environmentally friendly renewable energy technology, there are still various considerations that must be considered during the investment and operational stages to ensure that developments are undertaken in a safe and sustainable manner. Important considerations are: ensuring adequate measures are adopted for the treatment of drilling fluids; proper effluent and waste disposal; the following of industry

standard drilling practices and occupational safety measures; good practices for land acquisition; and addressing how construction-related matters are resolved. Most international financiers now require that projects meet international standards such as Equator Principles,<sup>7</sup> making safeguard compliance an integral part of a project's bankability. Insufficient safeguard practices on even one project could set back the entire sector development in a given country, as it raises concerns among project-affected communities and citizens at large. Therefore, it is essential that geothermal developments in the LAC region follow good safeguard practices and for authorities to both facilitate progress and ensure compliance. Chapter 6 describes the environmental and social risk mitigation tools commonly used for geothermal projects and offers examples of their application around the world.

### The Way Forward

**Governments and developers in LAC have made progress in advancing the region's geothermal resource development, but there is still much work to be done and many challenges to overcome.** Attracting qualified developers, mitigating resource risk, mobilizing finance, developing a sound policy and regulatory framework, and mitigating environmental and social risks are key challenges that hinder the region from reaching its full potential. Global experience from developed and developing countries can inform LAC's efforts to develop its geothermal resources, and these approaches can be customized to fit the specific circumstances of countries in the region. This report evaluates how the above geothermal challenges have been addressed successfully in

different countries and identifies measures and interventions that can be applied in the LAC region.

### **Various development partners are involved in the geothermal sphere in the LAC region, assisting with both reforms and investments.**

Through grants and loans, the World Bank Group stands out as the largest multilateral development bank financier of geothermal energy projects worldwide, with a long track-record of global experience. Both within the region and globally, the World Bank Group has developed knowledge products to inform policymakers and other stakeholders about ways to develop and finance geothermal resources; has provided technical assistance and advisory services for policymakers, utilities, and developers to help advance geothermal investment (including regionally in Chile, Nicaragua, Dominica, St. Lucia, Mexico, and El Salvador); and is financing different stages of geothermal development in many countries so that these nations may take advantage of the benefits from this clean renewable energy resource. The extensive experience and convening power of the World Bank Group also has placed it in a strategic position for donor coordination and outreach at the global and regional level, including through the Global Geothermal Development Plan Roundtables and the Geothermal Congress of Latin America (GEOLAC) events. In collaboration with other development partners and stakeholders, the World Bank Group is committed to supporting LAC countries with further investment, technical assistance, and analysis to facilitate the scale up of geothermal power capacity so that countries in the region can benefit from the affordable, reliable, and clean energy it can produce.

<sup>7</sup> "Equator Principles" is a risk management framework adopted by financial institutions, for determining, assessing, and managing environmental and social risk in project finance. <http://equator-principles.com>.



Saint Lucia Soufriere Geothermal Field.  
Photo courtesy of Gerry Hutterer, Geothermal energy expert, Geothermal Management Company, Inc.

# CHAPTER 1: GEOTHERMAL HISTORY AND OPPORTUNITIES IN LAC

**I**n LAC, there is significant estimated geothermal potential in countries located along the tectonically active Pacific Rim of Central and South America and in the Eastern Caribbean. Broad estimates indicate that LAC's geothermal potential for power generation could range from 11 GW to 55 GW.<sup>8</sup> The wide range of estimates is primarily because much of the geothermal potential in LAC is yet to be explored and validated by drilling.<sup>9</sup> Information for Mexico and Central America may have a greater degree of accuracy, since considerable drilling has taken place and several power plants are in operation there. Given the nascent state of sector development in the Caribbean and South America, broad estimates for these areas are more speculative.

**Only a small amount of this vast potential is being exploited for power generation.** Current installed geothermal capacity in the LAC region is only 1,669 MW, which represents less than one percent of the electricity matrix of the overall region.<sup>10</sup> Most installed geothermal capacity in LAC is concentrated in Central America and Mexico (1,602 MW). Small developments are present in Chile (48 MW) and in the Caribbean (Guadeloupe, 15 MW). There is evidence that there is considerable untapped geothermal potential in Mexico and Central America, as well as

the Andean and Caribbean sub-regions. Opportunity exists to expand the utilization of geothermal in LAC as an integral part of achieving a more diversified generation mix.

**The development of geothermal in the LAC region can be discussed in the context of three geographically distinct sub-regions: Mexico and Central America, the Caribbean, and South America.** The distinct sub-regional market differences have played—and will continue to play—an important role in the development of the geothermal sector. The sections below provide an overview of the history of geothermal development in the LAC countries in each sub-region that have successfully installed power generation capacity. There are also several countries, particularly in the Caribbean and in the Andean region, that have undertaken initial surface level studies and some drilling that has not yet resulted in installed capacity. These countries are not covered in as much detail in this chapter.

## Mexico and Central America

**Mexico and Central American countries have led geothermal development in the LAC region.** Since the first commercial geothermal plant was installed in Mexico in the early 1970s, over 1,600

<sup>8</sup> These are World Bank estimates, based on expert review of currently available studies that estimate geothermal potential of countries in the region.

<sup>9</sup> Geothermal power generation capacity can be estimated at a high degree of probability only after sufficient drilling has been completed.

<sup>10</sup> Tissot 2012.

**TABLE 1.1 Mexico and Central America's Installed Geothermal Capacity and Share of Electricity Production**

Country	Geothermal installed capacity (MW)	Geothermal share of total electricity generation (percent)
Mexico	957	2.3
Costa Rica	207	12.5
El Salvador	204	26
Guatemala	49	2.5
Honduras	35	3 (estimated)
Nicaragua	150	15

Source: World Bank.

<sup>a</sup> World Bank calculations, based on data released by each country and on regional electricity market statistics for 2016 issued by CEPAL 2016.

MW of geothermal capacity has been installed throughout the Mexico and Central American sub-region. While the majority of this capacity has been developed by Mexico (60 percent) countries such as Nicaragua, El Salvador, and Costa Rica also have established geothermal energy as a critical piece of their electricity supply (Table 2.1). In fact, geothermal energy now accounts for approximately 7.5 percent of Central America's total electricity generation,<sup>11</sup> with several studies indicating that there is an opportunity for the percentage to be vastly increased.<sup>12</sup> The estimated geothermal potential in the Mexico and Central America sub-region is likely to range between 5,600 MW and 6,900 MW,<sup>13</sup> of which less than 30 percent has been exploited thus far for power production.

## Mexico

**Mexico is among the world's largest geothermal producers, with nearly 1,000 MW of installed capacity.**<sup>14</sup> Historically, the electricity sector in the country has been managed and developed by

the government through its state-owned utility, Comisión Federal de Electricidad (CFE). Electric power generation, transmission, and distribution activities were exclusive government-driven activities until recent legislative changes.<sup>15</sup> In 2014, the government of Mexico (GoM) introduced legislation aimed at deregulating the electricity sector, which opened the door for the private sector to acquire geothermal concessions and to sell electricity in the national market. Among other changes, geothermal developers and power producers are now able to participate in electricity auctions, establish bilateral contracts with private and public-sector entities, and sell electricity to the wholesale market.<sup>16</sup> In 2015, Grupo Dragón, a privately-owned domestic geothermal developer, launched the first privately developed geothermal power plant in the country (25 MW). While to date this plant is still the only privately-owned geothermal facility in Mexico, the GoM has approved 22 exploration permits<sup>17</sup> to various developers, including CFE, Grupo Dragón, Grupo ENAL, Mexxus RG, and Storengie.<sup>18</sup>

<sup>11</sup> Dolezal et al. 2013; ESMAP 2013b.

<sup>12</sup> ESMAP 2012.

<sup>13</sup> Based on geothermal expert review of estimates of geothermal resource potential for electricity generation in these countries generated by different authors, and judgement of "most likely value."

<sup>14</sup> Richter 2018a.

<sup>15</sup> Government of Mexico (gobierno de México), "Geothermal Energy Law" (Ley de Energía Geotermica) (2014.)

<sup>16</sup> Flores-Espino et al. 2017.

<sup>17</sup> Flores-Espino et al. 2017.

<sup>18</sup> CFE, which has priority over geothermal exploration rights and permits, has 13 exploration permits.

**However, little new geothermal capacity has been installed in Mexico in recent years, with most of the capacity installed in the middle of the 20th century.** For example, CFE won a concession for 14 geothermal fields in January 2017 but has faced challenges in raising the financing to develop them. Thirteen of the fields concessioned to CFE are greenfields (undeveloped), the most challenging type of geothermal field for which to secure financing. The World Bank and the GoM plan to work together to address some of these challenges to expanding the country's geothermal power production. The technical assistance planned will focus on five key areas: (i) an assessment of the regulatory framework; (ii) a screening of geothermal fields; (iii) a review of geothermal development approaches; (iv) a review of financing options; and (v) the design of a proposed financing structure for field development.

**The GoM is committed to supporting renewable energy and geothermal sector development.**

This commitment has included setting renewable energy targets (35 percent of the energy mix by 2024), passing geothermal-specific legislation (2014 Geothermal Energy Act), and establishing resource risk mitigation facilities to boost the sector. If public support to the sector remains constant in the upcoming years, plans call for geothermal capacity in the country to expand by as much as 900 MW by 2029.<sup>19</sup> Given the complexities of geothermal development, this will be challenging, since meeting this target would require doubling the amount of geothermal capacity installed in Mexico since the 1980s. Nonetheless, the country has an estimated geothermal resource potential between 2,000 MW and 2,500 MW. Thus, there is significant scope for Mexico to scale up its geothermal capacity as a means to diversify its electricity matrix and displace a portion of Mexico's fossil fuel generation, which

is dominated by natural gas (approximately 50 percent of generation).

### **Costa Rica**

**Historically, the electricity sector in Costa Rica has been run by public utilities.** Since the regulatory reforms of the 1990s, private power producers have been able to participate in the power generation sub-sector in a limited way (capped at 30 percent of the country's total generation).<sup>20</sup> Through Instituto Costarricense de Electricidad (ICE), the government of Costa Rica has developed the entire 207 MW of the country's installed geothermal capacity. While the majority of the country's geothermal capacity was developed in the 1990s, ICE has continued to plan and build additional power geothermal power plants. ICE recently finalized the construction of a 35 MW power plant in Las Pailas, and plans to bring online an additional 165 MW in geothermal capacity over the next seven years (an additional 55 MW unit at Las Pailas power plant by 2019, and two 55 MW units at the Borinquen geothermal field by 2024).

**Costa Rica generates over 90 percent of its electricity through renewable energy sources.** With demand for electricity expected to continue to increase on a year-by-year basis, the government plans to bring online over 3,400 MW in additional generation capacity by 2035.<sup>21</sup> While wind and hydro are the two largest sources of electricity, geothermal provides around 12 percent to 13 percent of the country's electricity supply, as seen in Table 3.1. The estimated geothermal resource potential is likely to be around 900 MW to 1,000 MW.

**Costa Rica is seeking to expand its geothermal capacity, as part of coping with increasing hydrological variability and the risk of drought,**

<sup>19</sup> Flores-Espino et al. 2017.

<sup>20</sup> Monge et al. 2016.

<sup>21</sup> IDB 2014a.

**which could become more severe due to climate change.** Costa Rica is heavily dependent on hydro-power to meet its electricity demand. While hydro-power is an environmentally friendly technology that provides low-cost electricity, it makes the country highly vulnerable to drought and climate change. Exploiting more of the country's domestic geothermal resources can mitigate the need to install more fossil fuel-based generation to meet base-load power demand. Given the country's goals to meet its energy needs using renewable resources and to enhance energy security, the expansion of geothermal capacity is an opportunity to help achieve these development objectives.

### **El Salvador**

**As was the case in many Latin American countries, El Salvador's electricity sector was significantly reformed during the 1990s.** The legal changes permitted the participation of the private sector throughout the generation and distribution sub-sectors. There are over 13 power generators currently operating in the country, including Duke Energy, which bought several thermal plants from the state utility company, Comisión Ejecutiva Hidroeléctrica del Río Lempa (CEL), in 1999.<sup>22</sup>

**Historically, geothermal development was led by CEL, which brought over 200 MW of capacity online.**<sup>23</sup> However, with the introduction of power sector reforms in the mid-1990s, CEL was broken up into several companies, including a geothermal developer initially called GESAL, then renamed LaGeo. In 2002, ENEL(IT), a large geothermal developer from Italy, acquired a minority stake in LaGeo and was integrated as a strategic partner, helping to develop an additional 44 MW in geothermal capacity between 2002 and 2007.<sup>24</sup> Following ENEL(IT)'s recent disinvestment in LaGeo, the government of El Salvador, which now

fully controls the company, continues to have a key role in geothermal development. The government has also played a role by enacting geothermal-specific legislation and setting ambitious geothermal capacity targets (40 percent of energy mix by 2019),<sup>25</sup> and through development of 80 MW in the San Vicente and Chinameca fields.

**Renewable energy comprises nearly 55 percent<sup>26</sup> of the country's 1,700 MW of installed electricity capacity.** Geothermal energy is one of the main sources of electricity in the country, producing about 25 percent of the country's electricity supply. The estimated geothermal resource is around 500 MW to 700 MW. Exploiting this estimated potential will be essential to meeting the country's ambitious geothermal capacity targets.

**The World Bank is currently providing technical assistance to support the Government of El Salvador in developing a portion of the country's untapped geothermal potential.** In particular, it is helping the Government of El Salvador execute due diligence and a gap analysis on the proposed Chinameca and San Vicente geothermal projects. The analysis will encompass technical, economic and financial, and safeguard aspects that are commonly assessed by the geothermal industry at the project feasibility stage. The technical assistance will also provide an action plan to address identified gaps, including recommendations and guidance to help the state geothermal company, LaGeo, bring existing assessments in line with industry standards to facilitate financing for further development of the Chinameca and San Vicente fields.

### **Guatemala**

**Deregulated since the 1990s, the Guatemalan electricity sector is comprised of both public and private actors that work throughout the**

<sup>22</sup> United States Department of State 2011; CNE 2016.

<sup>23</sup> Bertani 2015.

<sup>24</sup> ENEL(IT) has recently sold its minority stake in LaGeo for US\$280 million. Bloomberg News 2014.

<sup>25</sup> Richter 2016.

<sup>26</sup> CEPAL 2016.

**generation, transmission, and distribution sub-sectors.** The public sector continues to have presence in the electricity sector through the Instituto Nacional de Electricidad (INDE, the country's public utility company), which currently generates around 14 percent of the country's electricity supply.<sup>27</sup>

**The government has been a critical promoter of geothermal development in the country through INDE.** Since the early 1970s, INDE has conducted several studies that helped identify five high potential geothermal fields in the country.<sup>28</sup> The 2013–2027 energy policy framework set a target of 80 percent of the country's energy generation coming from renewable sources by 2027.<sup>29</sup> With 4,200 MW in installed capacity, Guatemala generates the majority of its electricity through thermal and hydroelectric sources, with only about six percent<sup>30</sup> of its electricity supply provided by geothermal, solar, and wind plants.

**Guatemala has 49 MW in installed geothermal capacity, which produces only about 2.5 percent of the country's total electricity supply.** The country has two plants currently in operation. These were built and are operated by local subsidiaries of Ormat, a large international developer and equipment manufacturer in the geothermal sector.<sup>31</sup> Guatemala's estimated geothermal resource potential is around 900 MW to 1,000 MW. Similar to other countries in the sub-region, Guatemala is looking to further expand its geothermal capacity to help meet its renewable energy targets.

## Honduras

**The power sector in Honduras has been dominated by state-owned utility Empresa Nacional**

**de Energía Eléctrica (ENEE).** ENEE is responsible for all transmission and distribution in the country. ENEE also generated about 15 percent of the total electricity produced in 2016.<sup>32</sup> In recent years, the electricity sector in Honduras was significantly reformed and strengthened through the creation of an Electric Power Regulatory Commission (Comisión Reguladora de Energía Eléctrica) and by enabling further private participation in the generation, transmission, and distribution sub-sectors.

**The geothermal sector has gained significant traction in the last year with the installation of the country's first geothermal plant at Platanares.**

The station, with a capacity of 35 MW, has been developed and will be operated by Ormat through a 15-year, build-own-operate contract with the local energy company ELCOSA.<sup>33</sup> The project has been financed, in part, through a US\$135 million loan from the Overseas Private Investment Corporation. Nevertheless, geothermal still only comprises around 1.5 percent of the country's total installed capacity of approximately 2,400 MW. Honduras has an estimated of 100 MW to 150 MW of likely geothermal energy potential. While the geothermal potential in Honduras may be low compared to other Central American countries, the country is actively seeking to diversify its electricity generation matrix by developing more geothermal.

## Nicaragua

**Although renewable energy accounts for about half of Nicaragua's power generation, the country still uses a significant amount of fuel oil and diesel to meet the country's electricity demand.** With demand for electricity expected to continue to increase in the coming years, the

<sup>27</sup> Ortega and Briz 2017.

<sup>28</sup> Manzo 2005.

<sup>29</sup> Ministry of Energy and Mines (Ministerio de Energía y Minas) 2013.

<sup>30</sup> CEPAL 2016.

<sup>31</sup> Bertani, *Geothermal Power Generation in the World, 2010–2014 Update Report*.

<sup>32</sup> Climatescope, "Honduras" (New York: Bloomberg New Energy Finance, 2017).

<sup>33</sup> Ormat Technologies, Inc., 2016.

government of Nicaragua (GoN) plans to add over 1,000 MW in renewable energy capacity by 2027.<sup>34</sup> This would allow the country both to diversify its energy matrix and to reduce its reliance on imported oil, especially in a future context of potentially increasing oil prices. The generation and distribution sub-sectors in Nicaragua are open to private-sector participation and the transmission segment is owned and operated by the state-owned company ENATREL.

**Nicaragua has over 150 MW of installed geothermal capacity, representing about 15 percent of the country's energy supply.** Since the 1970s, the GoN has played a key role in the sector by enacting geothermal-specific legislation (Law 443),<sup>35</sup> providing government funding for geothermal exploration (surface studies, exploration drilling, and preparation of a national geothermal master plan), and setting ambitious renewable energy plans (currently 73 percent of the energy mix by 2030). The development of the geothermal sector has become a cornerstone of the government's focus on reducing both the country's electricity tariffs and the country's dependence on imported fuels for electricity generation.

**Nicaragua's geothermal development was initially public sector-led but has since transitioned to a mixed public-private, cost-sharing development approach.** The first geothermal capacity was installed in the Momotombo field back in the 1980s, and the field has a total installed capacity of 77.5 MW, although much lower net capacity. The geothermal facility continues to be owned by the Empresa Nicaragüense de Electricidad (ENEL(NI)). In 2012, the geothermal developer Polaris completed the construction of a 72 MW power plant with financial support from the International Financial Corporation (IFC), as well as other financial institutions. The GoN, together with the Japan International Cooperation Agency (JICA) and the

Inter-American Development Bank (IDB), is seeking to confirm geothermal resources in two other areas (Mombacho and Consignina), by conducting surface studies and undertaking initial exploration drilling. Cerro Colorado Power (a subsidiary of Polaris) and the GoN (through the ENEL(NI)) have been working to develop the Casita San Cristobal geothermal field with World Bank financial support, using a public-private partnership (PPP) arrangement. While no new geothermal power plants have been commissioned or built since San Jacinto, the country has Central America's largest estimated geothermal potential, exceeding 1,000 MW.

**Mexico and Central America is the most advanced sub-region in LAC in terms of installed geothermal capacity and experience.** Geothermal is present in most of the sub-region's electricity markets, with the exception of Panama, and is a critical generation technology that is actively supported by many Central American governments and utilities. The existing resource risk mitigation measures, high electricity prices in this sub-region, and the region's focus on further integrating renewable energy technologies will continue to propel the growth of the geothermal energy sector in Mexico and Central America.

## The Caribbean

**The Caribbean sub-region has had little geothermal development, with only one plant currently in operation.** The limited size of the Caribbean markets, limited geothermal technical expertise in the region, the high up-front costs in relation to borrowing capacity, and the risks of developing geothermal energy—since almost all fields in the sub-region are still greenfields—have all constrained the sector's growth. Nevertheless, a combination of other factors in the Caribbean, including high electricity prices, significant estimated geothermal resources, and strong

<sup>34</sup> CIF 2015.

<sup>35</sup> Bloomberg New Energy Finance 2017a.

**TABLE 1.2: Caribbean’s Installed Geothermal Capacity and Share of Electricity Production**

Island	Installed MW capacity	Geothermal as percent of total electricity generation
Guadeloupe	15	approximately five percent

Source: World Bank.

government support, present an opportunity to facilitate geothermal growth in the sub-region. Governments in the sub-region have recognized the need to integrate renewable energy into their country’s energy mix to limit the economic impact of both oil price volatility and climate change. However, thus far Guadeloupe, an overseas territory of France, is the only island where geothermal capacity has been installed (Table 1.2).

### Guadeloupe

**With nearly 500 MW in installed capacity, Guadeloupe’s electricity sector is one of the largest in the Caribbean.** Guadeloupe’s electricity sector is characterized by the presence of a large state utility company (which manages the majority of the island’s generation, distribution, and transmission assets) and the importation of high volumes of oil-based fuels for electricity generation. Thermal generation accounts for over 80 percent of island’s installed capacity, with renewable energy providing the remainder. Guadeloupe has an estimated geothermal resource potential in excess of 40 MW.<sup>36</sup> While only a portion of Guadeloupe’s geothermal potential has been developed (15 MW), the island’s first geothermal plant dates back to 1986. In recent years, developers have demonstrated a renewed interest in the island’s geothermal market. In 2016, Ormat acquired a majority stake in the island’s 15 MW geothermal power plant.<sup>37</sup>

### Other Caribbean Islands

**Various other Caribbean islands, such as Dominica, St. Lucia, St. Vincent and the**

**Grenadines, and St. Kitts and Nevis, also are working to develop their geothermal resources.**

Dominica is the most advanced of these islands, as it has already completed production drilling and has a fully designed project for the construction of a seven MW geothermal power plant and above-ground infrastructure. It has also conducted an analysis to ascertain the viability of further expanding geothermal capacity for electricity exports. The Government of Dominica is in the process of securing financing from the World Bank and other financial institutions for the construction of the geothermal power plant, with plans to later expand the field capacity by installing a larger geothermal power plant to export power to neighboring islands. The World Bank is also supporting the government of St. Lucia with early surface level studies and an Environmental and Social Impact Assessment (ESIA) to develop its first geothermal field. In the future, the World Bank also plans to provide financing for initial exploration drilling intended to confirm the resource capacity to operate a 15 MW to 30 MW power plant. Several other multilateral development partners and regional banks such as the Caribbean Development Bank (CDB), IDB, the UK’s Department for International Development, the French Agency for Development (Agence française de développement (AFD)), and the governments of New Zealand and Iceland, have been supporting other islands to advance geothermal development.

**The Caribbean sub-region has an estimated geothermal potential of over 900 MW.<sup>38</sup> Developing even a portion of this capacity**

<sup>36</sup> World Bank 2013.

<sup>37</sup> Ormat Technologies, Inc. 2016.

<sup>38</sup> World Bank 2013.

**provides an opportunity to transform the electricity matrixes of these islands and lessen their extremely high dependence on oil for power generation.** The presence of strong government and development partner support can facilitate further development of geothermal resources in the sub-region. High electricity prices in the sub-region and government support in the form of risk capital and financing for the geothermal sector are key ingredients to scaling up development. Governments in the sub-region have become increasingly aware of the role that geothermal energy could play in: (i) decreasing the reliance on imported fossil fuels for electricity generation; (ii) protecting the sub-region's economy from the effects of climate change; and (iii) ensuring predictable<sup>39</sup> and cost-competitive electricity prices<sup>40</sup> for consumers.

## South America

**Geothermal development in South America is still in its nascent stage, with only one geothermal plant currently in operation.** While the sub-region has significant estimated potential for geothermal energy, the majority of these resources are in remote areas in the Andean mountain range. As a result, the economics of each potential field will vary significantly, with fields located in high altitude areas that may be over a hundred kilometers away from the transmission grid. These factors, along with region's historical reliance on hydro resources and fossil fuels along with its highly competitive electricity markets (given the low prices offered by natural gas and hydro), have all played a key role in constraining geothermal development in this sub-region.

**However, with an estimated potential of over 4,000 MW<sup>41</sup> and several potential fields identified in most Andean countries, the geothermal sector could become a critical piece of the sub-region's energy mix.**<sup>42</sup> In 2017, Geotérmica del Norte (GDN)—a joint venture between Enel Green Power (ENEL IT) and the public oil company, Empresa Nacional del Petróleo (ENAP)—started operating the region's only geothermal power plant, located in Chile (Table 1.3). Other Andean countries also are considering how to capitalize on their geothermal resources, but only a few countries in this sub-region have passed geothermal-specific legislation (for example, Chile and Peru). Surface level studies to identify geothermal potential in different fields are available for Argentina, Bolivia, Chile, Colombia, Ecuador, Peru, and Venezuela. Argentina and Bolivia also have conducted exploration drilling in their most promising geothermal sites, and Bolivia is preparing for the installation of a 100 MW power plant at the Sol de Mañana geothermal field.<sup>43</sup> In addition, countries such as Chile, Peru, and Argentina are exploring ways to enhance the competitiveness of geothermal in the context of their current electricity markets, which are dominated by an abundance of lower cost energy sources.

## Chile

**In the early 1980s, Chile was one of first countries in the region to privatize its electricity sector. As a result, there are many private-sector players operating in the generation, transmission, and distribution sub-sectors.** With an installed capacity of nearly 20,000 MW, Chile's electricity sector is the third largest in the region. Despite its size, the sector faces various challenges. First, Chile has among the highest electricity prices in the sub-region. Secondly, the

<sup>39</sup> Between 2002 and 2012, electricity prices in the region increased nearly 80 percent.

<sup>40</sup> There are several factors that will need to be addressed in order to reduce the high electricity prices in the sub-region, including sub-optimal generation infrastructure, isolated grids, and limited technical expertise. (IMF 2016).

<sup>41</sup> Bona and Coviello (2016) provide an in-depth analysis of 37 geothermal sites that the authors believe have enough information to be classified as promising fields for commercial development.

<sup>42</sup> Bona and Coviello 2016.

<sup>43</sup> Bolivia conducted surface level studies in the 1970s and drilled several wells between 1988 and 1992. (Camacho 2014).

**TABLE 1.3: South America’s Installed Geothermal Capacity and Share of Electricity Production**

Country	Installed MW capacity	Geothermal as percent of total electricity generation
Chile	48	< one percent (estimate)

Source: World Bank.

country imports over 70 percent of its total primary energy supply, exposing the sector to potential external price shocks.

**Chile has one of the largest estimated geothermal resource potentials in LAC, with a likely potential of about 2,000 MW to 3,000 MW.**

Until recently, Chile was believed to be an ideal market for geothermal development, given the presence of significant geothermal resource potential, a competitive electricity sector with multiple potential buyers, and strong energy sector legislation. In fact, the Geothermal Energy Law in 2000 triggered a significant surge in concession applications and awards. However, while the government has awarded more than 80 exploration concessions and twelve exploitation concessions in the last decade, the great majority of these fields have not undergone any

major exploration drilling. The only field that has become operational since that time is Cerro Pabellón (48 MW), operated by GDN.

**The traditional government policy in Chile has been to approach the country’s energy planning through energy neutral methods, not benefiting one energy technology over another.**

While such an approach has worked well for the growth of both intermittent renewable energy and fossil-based generation, geothermal energy faces a unique set of circumstances that require special consideration. In order to tap into the country’s geothermal potential, the government is exploring ways to promote the sector’s development and to address the obstacles recently raised by private geothermal developers in Chile, including (i) difficulty competing in electricity tenders that are dominated by solar and wind

### BOX 1.1

#### Chile Geothermal Roundtable Discussions

As part of the World Bank geothermal technical assistance program, a Geothermal Roundtable was set up as a joint public-private exercise aimed at: analyzing the status of geothermal energy in Chile; identifying existing projects, their development perspectives, and corresponding challenges; assessing the country’s geothermal potential and estimating the costs to develop it; and analyzing the systemic impact that the integration of geothermal energy may have on the interconnected electrical system.

The Geothermal Roundtable brought together more than 35 entities of the geothermal industry in Chile, including public institutions, academia, sector organizations and associations, private developers, and other industry players. A total of 13 workshops took place, starting in December 2016 and finishing in December 2017. A total of 648 levelized cost of electricity scenarios and 216 capital expenditure (CAPEX) scenarios for geothermal projects were analyzed, and a total of 12 energy matrices were modeled. A final report with conclusions and recommendations from the Geothermal Roundtable is being prepared, and is intended as a first step in a process that will continue with further analysis under the technical assistance provided by the World Bank.

offers, (ii) financial liabilities imposed by the concessions, and (iii) a lack of transmission lines near geothermal fields.

**To identify and help address the main barriers, the World Bank is aiding the Ministry of Energy of Chile in facilitating the development of the geothermal sector in the country.** This technical assistance aims to improve the policy framework and strengthen management capabilities for mobilizing investments in geothermal energy and to enhance market conditions for promoting sustainable development of the sector.

**The geothermal sector in South America will continue to face significant challenges without additional government support.** The competitive nature of the sub-region's electricity markets, the strong growth of other non-hydro renewable technologies like solar and wind, and the limited amount of geothermal risk mitigation measures have inhibited deployment of geothermal in the sub-region. However, with countries like Bolivia making significant progress toward deploying geothermal resources and other countries recognizing the need for a more diversified set of renewable energy technologies, there is an opportunity to address the key challenges in the sub-region and further develop the geothermal sector.

## Conclusions

**The LAC region has a long history of developing and exploiting its geothermal resources for power production, with much of the initial reconnaissance and surface level studies and drilling activities dating back to the 1970s and 1980s.** As estimates for LAC's geothermal potential run between 11 GW and 55 GW (Table 1.4), even exploitation at the lower end of the range provides significant opportunity for scaling up geothermal capacity in the region. Nevertheless, geothermal energy development in LAC thus far has been uneven, with Central America and Mexico accounting for 96 percent of installed geothermal capacity.

**The unique regulatory, market, and resources conditions of each sub-region in LAC helps explain the asymmetrical evolution of the region's geothermal sector.** Central America has been most successful in promoting the growth of geothermal energy; however, there were certain conditions—including high electricity prices, larger markets, and more easily accessible fields—that contributed to the early integration of geothermal into the electrical grid. For example, the high cost of imported fossil fuels for electricity generation not only incentivized policymakers to identify alternatives for electricity generation, but also made geothermal more economically competitive with oil and gas power generation.

**The drivers behind the low levels of geothermal development in the Caribbean and South American sub-regions vary significantly.** While the Caribbean faces many challenges similar to those in Central America, the Caribbean's extremely small markets create a particularly difficult environment for geothermal development. For example, low electricity demand requires smaller geothermal generation plants (the only one that is currently operational has a capacity of 15 MW). This constrains the ability of many geothermal developers to enter the Caribbean, since some developers have minimum project requirements that start at around 30 MW. In South America, the competitive nature of the sub-region's large electricity markets, which have access to large hydropower resources and low-cost fossil fuels, is one of many factors that have contributed to the slow uptake of geothermal energy in this sub-region. Given the better prices and lower risks offered by both fossil fuels and other renewable energy technologies, policymakers and private-sector entities have chosen not to aggressively pursue geothermal energy in this sub-region. Clearly, there is no one-size-fits-all approach to unlocking the growth of the geothermal sector in LAC. There are many nuances to each sub-region and country to take into consideration when developing potential solutions.

**TABLE 1.4: Estimated Geothermal Resource Potential in LAC Region**

Sub-region	Country/Territory	Installed geothermal capacity (MW)	Estimated potential (MW)				Most likely sub-region total	Sources
			Minimum	Maximum	Most likely	Most likely		
<b>Mexico and Central America</b>	Mexico	957	1,900	3,250	2,000–2,500	5,640–6,900	8, 18, 21, 22	
	Guatemala	49	800	4,000	900–1000		1, 2, 4, 5, 6, 17, 18, 20	
	Honduras	35	100	500	100–150		1, 2, 4, 5, 6, 17, 20	
	El Salvador	204	400	1,450	500–700		1, 2, 3, 4, 5, 6, 17, 18, 20	
	Nicaragua	150	300	4,000	1,200–1,500		1, 2, 4, 5, 6, 17, 18, 20, 23	
	Costa Rica	207	400	3,500	900–1,000		1, 2, 4, 5, 6, 17, 18, 20	
	Panama	—	25	230	40–50		1, 6, 17, 20	
	Colombia	—	700	1,370	600–800	4,250–7,000	1, 9	
	Venezuela	—	370	480	250–400		1, 9, 16	
	Ecuador	—	420	8,000	450–600		1, 9, 13, 14	
<b>South America</b>	Peru	—	600	2,860	650–1,000		1, 9, 15	
	Bolivia	—	510	1,260	500–600		1, 9	
	Chile	48	780	16,000	2,000–3,000		1, 9, 10, 11, 12	
	Argentina	—	490	1,010	500–600		1, 9	
	Dominica	—	240	680	500+	925+	1, 19	
	Grenada	—	180	360	30+		1, 19	
	Montserrat	—	130	280	100+		1, 19	
	St. Kitts and Nevis	—	450	590	25+		1, 19	
	St. Lucia	—	110	260	75+		1, 19	
	<b>Caribbean</b>							

*(continued on next page)*

TABLE 1.4: Estimated Geothermal Resource Potential in LAC Region (continued)

Sub-region	Country/Territory	Installed geothermal capacity (MW)	Estimated potential (MW)			Most likely sub-region total	Sources
			Minimum	Maximum	Most likely		
Caribbean	St. Vincent and the Grenadines	—	150	420	75+	925+	1, 19
	Cuba	—	10	30	30		1
	Dominican Republic	—	10	50	50		1
	Saba	—	500	1,000	no data		1
	Guadeloupe	15	500	1,500	40+		1, 7, 18, 19
Martinique	—	500	1,500	—		1	
<b>Total LAC region</b>		<b>1,665</b>	<b>10,575</b>	<b>54,580</b>			

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## CHAPTER 2: ATTRACTING AND SELECTING QUALIFIED PRIVATE DEVELOPERS

**D**espite the considerable geothermal potential for power generation in the LAC region, actual development has been limited. A key challenge, both in the LAC region and globally, is attracting qualified geothermal developers to invest in the exploitation of geothermal resources. The technical and financial qualifications of the geothermal developers in the region have varied. While there are some well planned developments that have been successful, in other instances poor practices and deviation from industry standards by developers have led to undesirable impacts. Poor practices that have occurred in the LAC region in the past include well blowouts, poor well targeting, excessive drilling, and inadequate disposal of spent fluids. Inadequate financial vetting of potential developers has led to instances in which less qualified developers are awarded concessions to geothermal fields with high potential, only for development to stall due to a lack of funding. In other instances, the concession agreements did not provide sufficient incentives to invest in exploration, since subsequent development rights were opaque. More qualified developers have limited interest in investing in relatively nascent or small markets, which may exacerbate the situation in some countries by limiting the pool of developers and choice.

**It is vital that LAC countries that seek private geothermal investments establish the right**

**conditions and enabling frameworks that will attract qualified developers.** This will include implementing a process whereby potential developers are carefully screened for their financial and technical qualifications prior to selection. LAC countries need to lay a sound legal and regulatory foundation to enable private developers to enter agreements that provide sufficient incentives for them to successfully advance through the multiple stages of geothermal development, including power plant commissioning. There are also other key conditions that developers, particularly private ones, consider before deciding to invest in a particular country and geothermal field.

**The World Bank contacted a diverse group of 12 private geothermal developers with experience investing in geothermal fields to identify some of the key conditions they seek before deciding to undertake a geothermal investment in LAC.** This chapter discusses the findings from phone interviews that were conducted with the seven developers<sup>44</sup> who responded to this request. In general, the developers interviewed had either a global investment focus or a regional and country-specific investment strategy. The interviews conducted covered the following four key areas: i) geothermal resource conditions and risk; ii) the policy, legal, and regulatory framework; iii) institutional and local capacity to oversee and develop geothermal capacity; and financial considerations.

<sup>44</sup> EDC Chile, EDC Peru, Ormat, Polaris, Reykjavik Geothermal, Geotermia Andina, Orka Energy, and Energía Andina.

The sections in this chapter present the primary considerations mentioned by the developers in each of these areas and the perceived barriers they encounter when investing in geothermal in the region.

### **Geothermal Resource Conditions and Risk**

**All geothermal developers said that the geothermal resource condition is one of the main factors to consider before investing in a specific country and field.** The condition of the resource includes such considerations as: the estimated geothermal resource potential in a country or field; the perceived geothermal resource risks; the amount of information available on the geothermal resource quantity and quality; and the stage of development of the geothermal field.

**Geothermal resource potential.** All developers indicated that their motivation to invest in the LAC region has been driven largely by the quality of the geothermal resources found in Mexico and Central America, and by the large, untapped geothermal energy potential inferred in other countries in the region such as Chile. A geothermal field's estimated capacity to produce power and estimated project size is a key consideration that influences geothermal developers' investment decisions, particularly for larger, more established developers that typically only consider bigger projects.

**Geothermal resource risks.** Most of the geothermal resources available in the region in recent years are located in greenfields. The risk profile for geothermal projects is unique in that the actual existence and availability of the resource can only be verified through exploration and appraisal drilling, which is expensive and may not result in conclusive evidence about the geothermal potential or the feasibility of a project. Geothermal investors must put a significant amount of capital (typically their own equity) at risk, without any guarantee that the geothermal resources will be suitable for

producing electricity. Many developers have faced significant challenges and have been unsuccessful in developing new geothermal power plants in the region, even when using their own capital and experts. Developers thus consider geothermal resource risk, especially during the exploration stage, as a major barrier to overcome. Chapter 3 of this study looks at geothermal resource risks and global approaches to this challenge in greater detail.

**Limited resource information.** Developers identified another investment barrier as the lack of adequate data that would allow them to perform a resource assessment early in the exploration phase. Developers considered that a repository of government-funded geothermal data and industry benchmarking (such as those in the United States, Kenya, and Indonesia) would provide developers and investors a framework for investment evaluation and would help to reduce the risk inherent in the early stages of geothermal development. Developers indicated that access to this information would help simplify early stage exploration and minimize risk, which could increase investor confidence and stimulate more investment in geothermal fields. The developers said that data sharing could also lead to other benefits, such as enabling researchers to enter geothermal fields that have not been developed and to innovate and test new technologies.

**Stage of geothermal development.** Some developers mentioned that they are more likely to pursue geothermal investments that are advanced in their development phase and infrastructure. Smaller geothermal developers tended to enter a geothermal development at the early reconnaissance and exploration drilling stage and then either sell their investment or partner with a larger developer or utility for the later stages. The larger, more established geothermal developers indicated that they have the capacity and are willing to enter into a project at any stage of the geothermal project life cycle, so long as they are

able to take majority ownership and control. A recent market sounding of geothermal developers<sup>45</sup> undertaken by the World Bank Group for Nicaragua showed that the developers interviewed expect prior surface level studies and at least some drilling to have been completed before investing in a field. Thus, the stage of development of a geothermal field is usually an important factor in developers' investment decisions.

**Ease of access to geothermal development.** For geothermal concessions located at high altitudes and in remote areas far from demand centers (as in most projects in Chile and the Andean region), developers said that the remoteness of some resources and the associated problems accessing drilling services and the electrical grid (such as local logistics and climatic conditions) are barriers to development. Not only does access to geothermal resources become more difficult, but the cost of the total investment also increases, amplifying the financial risk. With developers usually responsible for connecting geothermal facilities to the main transmission line, any steps a government can take to ensure construction of the necessary transmission lines and access infrastructure are viewed as very positive. Developers suggested that such infrastructure might be built by cost-sharing the additional investment in transmission between the developer and the government, or by the government recognizing the developer's contribution to this infrastructure as an additional investment cost and allowing developers to recover such costs through a temporary surcharge on the power purchase agreement (PPA) price paid by the off-taker.

### **Policy, Legal, and Regulatory Framework**

**All developers mentioned that the policy, legal, and regulatory framework in a given LAC country influences their decision to invest.**

Developers take into consideration whether there are renewable energy and/or geothermal policies and legislation in place and whether there is a supportive contractual environment. Important considerations include PPAs designed to facilitate geothermal development; the tariff offered; the fiscal incentives for geothermal; whether energy tenders enable geothermal participation; if there are realistic concession time periods (given the greater complexity of developing geothermal projects, especially greenfield ones); and whether permitting processes are streamlined.

**Renewable energy policies.** One factor that has influenced geothermal developers' decisions to invest in a particular country is that country's commitment to expanding or upholding its renewable energy targets. All developers indicated that a country's renewable energy targets provide an important signal on whether to pursue geothermal energy investments. Commitment can be seen through executive branch actions, supporting legislation, and creation of a legal environment that offers realistic opportunities for the private sector to enter a power generation market. Developers like government commitments to include geothermal energy in their national plans and goals for obtaining electricity from renewable energy sources.

**Renewable energy price and fiscal incentives.** When it comes to project economics, the developers believe that fossil fuel subsidies, in general, create disadvantages for renewable energy and that FITs for geothermal energy would be a strong incentive to spur development. Regarding fiscal incentives and tax breaks, developers said that exemptions from import duties, value added taxes, or income tax for a period following the start of project operations would help facilitate geothermal development. Some developers noted that when they approached large companies in

<sup>45</sup> US Geothermal, Ormat, EDC Chile and Peru, GeothermEx, Mighty River, Enel Green Power (a subsidiary of Enel Group), and LaGeo.

the mining sector to enter into energy contracts, these companies (particularly those in the Andean region of South America) were not interested in purchasing geothermal power. The mining companies did not want to worry about transmission line interconnections and the time required to commission a geothermal project.<sup>46</sup> They continue to source energy from diesel-based power generators, even when doing so is more expensive.<sup>47</sup> Some developers suggested that if governments were to provide tax incentives to these potential large off-takers in exchange for purchasing some amount of renewable base-load power, such incentives could enable geothermal developers to make these investments.

**Contractual risk mitigation measures.** The “pure-play” developers<sup>48</sup> that pursue geothermal investments in low and middle-income LAC countries where there is no prior experience with independent power producers (IPP) remarked that perceived regulatory and counter-party risks<sup>49</sup> affect strategic and financial investors’ interests and their decisions to invest in these countries. Pure-play developers recognize that multilateral development banks can provide instruments, such as partial risk guarantees, to mitigate some of these risks, but strategic and financial investors also want project-specific commitments, such as investment stabilization or similar agreements between foreign investors and the host government.

To investors, this type of legal arrangement or host government contract is important, both to

protect their assets and entitlements and to ensure stability in the governing regulations. If the electricity off-taker is a public utility that governs all of a project’s revenues, the pure-play developers indicated that a host government guarantee, designed to ensure that the government-owned utility makes timely payments, is essential to cover counter-party risk and to make the PPA bankable. These developers also suggested that multilateral development banks could provide host government officials with capacity building on project contract issues to facilitate financial closure for projects.

**Energy auctions.** Latin America has seen an increase in the use of energy auctions to encourage development and construction of renewable energy projects. This has allowed wind and solar companies, in particular, to bid and win many tenders to produce energy at prices with which geothermal projects often cannot compete. Developers said that the structure of these auctions does not take into consideration geothermal projects’ ability to provide firm (non-intermittent) power that can help meet base-load demand. Undertaking a feasibility study for a geothermal project to confirm resources and provide investors greater certainty costs significantly more than a feasibility study for a wind or solar project.<sup>50</sup> Furthermore, completing feasibility studies for solar or wind power usually takes around one year, whereas an industry level geothermal feasibility study could take three years or more.

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<sup>46</sup> In some cases, mining companies have facilities co-located with geothermal resources and are attractive prospects for developing geothermal energy. However, for mining companies, the timing of geothermal energy delivery is a major risk and they are often reluctant to enter into long term PPAs, which geothermal financing requires.

<sup>47</sup> The intermittent nature of renewable energy and the lack of economical energy storage options limit the extent to which mining companies can rely entirely on wind and solar for their power needs. However, because the potential cost savings are too great to ignore, in recent years mining companies have started to buy solar or wind generated power during the day, supplementing this with diesel generated power at night.

<sup>48</sup> A pure-play developer is a developer that focuses more on geothermal resource development than on power plant operation.

<sup>49</sup> Counter-party risk is the risk to each party in a PPA contract that the counterparty will not live up to its contractual obligations.

<sup>50</sup> A geothermal feasibility study would typically require that at least two to three wells be drilled, which can cost anywhere from US\$2 million to US\$8 million each. An average investment of US\$1 million to US\$2 million is needed to prepare a detailed feasibility study for a solar or wind project.

If a government wishes to promote geothermal development, developers felt that government auctions should consider the differences in renewable energy sources and not award tenders based only on the lowest cost. Geothermal projects are not well suited to compete in auctions that do not distinguish between base-load and intermittent load technologies. Geothermal developers recognize that competitive auctions ensure value for money to electricity consumers but feel that governments could run separate auctions for renewable energy sources that can provide base-load power to help ensure long-term electricity system reliability.

**Power purchase agreements.** Given resource uncertainty, geothermal developers indicated that their participation in an energy auction likely would require the use of preliminary exploration data in order to be able to bid an electricity power purchase price for an estimated amount of power generation capacity. Bidding with such unknowns is a substantial economic risk for geothermal projects, as the auction price and capacity typically feed into the fixed PPA price that results from the auction.

One developer recommended that a potential solution would be for governments to grant a conditional PPA to a geothermal company at the project pre-feasibility stage, which first would be verified by a competent third party. This arrangement could send a positive signal to potential investors by creating a potential off-taker and showing that some level of certainty exists for the quantity of electricity that a given geothermal project could produce. Under such a conditional PPA arrangement, once an industry level feasibility study is completed that defines the project's production capacity level, a definitive electricity purchase price could be set that falls between the minimum and maximum price range initially stated in the conditional PPA.

Another developer mentioned that it is more difficult for private geothermal developers entering

at later stages of development to guarantee the production level of a geothermal plant over the 20-year lifetime of a PPA agreement, if the developer was not involved in developing and modeling the resource from the beginning. Some developers prefer to undertake the exploration drilling and feasibility analysis themselves, even without public support, to ensure that these activities meet industry standards.

**Concession period and environmental and social considerations.** Another factor that developers consider before investing is the length of the geothermal concession to explore and develop the resource. Governments in the region generally want a shorter concession period, especially for exploration concessions and to maintain greater control over the resource. Developers seek longer exploration terms to ensure that there is adequate time to confirm the viability of the geothermal resource. A balance needs to be struck between governments and developers to achieve the shared goal of developing geothermal resources and producing power. For example, several developers indicated that the two-year period for exploration concessions in Chile is insufficient for concessions that are located in areas that require negotiation or mediation processes with local communities or lengthier environmental impact studies. Developers noted that building trust with communities is essential for the success of a project and this takes time. However, this is not the case for all exploration concessions, particularly for countries with geographic, environmental, and social challenges that are not so complex and where exploration activities can be completed more quickly.

**Permitting and licensing process.** In addition to concession awards and contracts, additional land, environmental, water, and other permits and licenses are often required before starting geothermal exploration and exploitation activities. These may come from central governments, environmental and water authorities, or local and municipal governments, as well as land holders.

Developers noted that overly bureaucratic processes for obtaining the necessary licenses and permits can cause delays, add to geothermal project costs, and possibly discourage investment.<sup>51</sup> Streamlining or consolidating these processes could help speed-up the pace of geothermal development.

Chapter 5 of this study provides more detail about key policy, legal, and regulatory conditions that are important to facilitate geothermal development.

### **Institutional and Local Capacity to Oversee and Develop Geothermal Capacity**

**Institutional and local capacity also influence most developers' investment decisions.** "Capacity" includes government institutions awareness of and ability to oversee the geothermal sector; the capabilities of government employees to evaluate the qualifications of developers seeking concessions; geothermal technical capacity within the country; and the availability and type of geothermal development equipment available, often within the country as a whole.

**Limited awareness and capacity.** Many developers mentioned that there is a lack of technical knowledge and information about geothermal resources and the advantages of environmentally benign geothermal base-load power in governments of countries with untapped geothermal potential.<sup>52</sup> They also believe that a lack of local expertise in geothermal regulation and promotion causes delays in obtaining and granting concessions. Developers hold that more geothermal expertise within governments would not only help to elevate the profile of geothermal energy, but also increase consideration of it in future resource planning and energy diversification efforts. The developers stated that education, capacity building,

and information are needed in the public, private, and social sectors for successful development and management of geothermal energy.

**Selecting qualified developers.** The large, more established geothermal developers noted that, in some countries, geothermal concessions are not being developed because they were granted to firms that do not have the capacity to develop geothermal projects themselves. They believe many speculators have entered the concession award process with the intention of later selling their rights or investments to larger developers, and that these speculators impede geothermal development. By allowing speculation that makes concessions more expensive for experienced developers, some governments inadvertently have increased the cost of development. This situation also can lead to geothermal concessions remaining undeveloped for many years, if experienced developers with the capacity to develop the fields are unwilling to pay the speculative prices required to acquire the concession. Developers recommend that government institutions undertake a detailed evaluation of private developers to ensure that they are technically and financially qualified to receive a concession and to ultimately develop the geothermal resources. In some instances, the capacity of government officials may need to be strengthened to ensure that they can adequately perform this role.

**Drilling costs and technical expertise.** The lack of local drilling rigs, services, and trained crews in many LAC countries drives drilling costs higher, undermining the cost competitiveness of geothermal power facilities and hindering geothermal exploration. Developers mentioned that drilling companies are less likely to keep drilling rigs on a permanent basis in a country where the critical mass of drilling business is small. Developers that

<sup>51</sup> Such delays also add to project costs for other types of renewable and non-renewable energy investment projects.

<sup>52</sup> A regulatory framework specific for geothermal is also lacking in most of these countries. In Latin America, only Mexico, Nicaragua, Chile, and Peru have geothermal laws.

operate in countries where there are several geothermal concession areas believe that industry and governments should coordinate the development of projects in similar concession areas to create a pool of drilling equipment and trained geothermal expertise that can be drawn upon.

## Financial Considerations

**Many developers said that financial considerations influence their investment decisions.** Some of the financial considerations mentioned include the availability of public support, risk mitigation measures, and perceived financial risks, which are considered a challenge for developers investing in the early phases of geothermal development.

**Access to finance.** For smaller pure-play geothermal developers, which are common in the LAC region, access to finance is a particular challenge. These developers indicated that they normally would seek funding from venture capitalists or industry investors to conduct the initial exploration drilling phases. However, some developers mentioned that in recent years this type of risk capital has become very difficult to raise. In a typical scenario, smaller developers in the post-exploration stages of development would approach more established geothermal developers or utilities to help them complete and finance the production drilling, steamfield development, and power plant construction stages. However, the costs and risks associated with the exploration phase makes finding early stage financing a significant challenge for smaller developers. Larger, more established, integrated geothermal developers do not see access to finance as a major challenge. These developers typically have the ability to finance and assume the exploration risk but are more selective about the geothermal fields in which they invest.

**Public support and risk mitigation.** Some developers indicated that the public sector's mitigation of the risks involved with geothermal exploration by undertaking drilling activities and confirming the resource is positive and helpful. Developers mentioned that cost-shared exploration drilling, support for expanding transmission infrastructure, and creation of a space for geothermal power in electricity auctions are all important factors. They view grants or cost-shared investment for early stage geothermal development as the most effective means of public support.

**Financial and resource risk.** Various developers indicated that geothermal resource risk outweighs other risks such as regulatory or country risk in financiers' decision to invest in a particular project.<sup>53</sup> These developers would be more likely to extend finance to pursue brownfield geothermal investments (that is, geothermal fields already producing power) and to accept political risk in a particular country. This would be more attractive to them than investing in a geothermal greenfield where resource risk is higher, even if it is a more stable country. The time to first cash flows is also an important factor in their investment decision process and the reason why some developers prefer fields at a more advanced stage of development. Early cash flow is even more relevant today, one developer indicated, because most financial backers have become interested in earlier, more secure, and steady dividend payment streams.

Chapter 4 discusses in-depth investment needs, the challenges in mobilizing financing for geothermal development in LAC, and the funding sources available.

## Conclusions

**A geothermal developers' decision to invest in LAC is influenced by a number of factors.** First,

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<sup>53</sup> Geothermal resource risk refers to drilling success and sustainability of resource exploitation, whereas political risk is the risk that an investment's returns could suffer as a result of political changes or instability in a country.

it is largely driven by the quality of the geothermal resources encountered in the region, the estimated resource potential, and the level of existing information on geothermal fields. Countries' renewable energy and geothermal policies and legislations also provide an important signal for the developers' investment decisions. Despite their interest and investments made to date, most developers have faced challenges in developing and expanding geothermal capacity in the region,

particularly in greenfield sites. Developers identified four principal areas that they consider crucial when deciding to invest: i) geothermal resource conditions and risk; ii) the policy, legal, and regulatory framework and whether it supports geothermal development; iii) institutional and local capacity in the geothermal sector; and vi) financial considerations. These key considerations are summarized in Table 2.1 below.

**TABLE 2.1: Key Factors for Attracting Qualified Geothermal Developers in LAC**

Key considerations	Company 1	Company 2	Company 3	Company 4	Company 5	Company 6	Company 7
<b>Geothermal resource conditions and risk</b>							
Geothermal resource potential		✓	✓	✓		✓	
Geothermal resource risks	✓	✓	✓	✓	✓	✓	✓
Limited resource information	✓	✓	✓	✓	✓	✓	✓
Stage of geothermal development		✓				✓	
Ease of access to geothermal resource	✓		✓	✓			✓
<b>Policy, legal, and regulatory framework</b>							
Renewable energy policies/plans	✓	✓	✓	✓	✓	✓	✓
Renewable energy price and fiscal incentives	✓	✓	✓	✓	✓	✓	✓
Contractual risk mitigation measures	✓	✓			✓	✓	
Energy auctions	✓		✓	✓	✓		✓
Power purchase agreements	✓	✓		✓			
Concession period	✓		✓	✓			✓
Environmental/social considerations			✓				✓
Permitting and licensing process			✓	✓			✓
<b>Institutional and local capacity</b>							
Limited awareness and capacity	✓	✓	✓	✓	✓		✓
Selecting qualified developers		✓	✓	✓	✓		✓
Drilling costs and technical expertise	✓	✓	✓		✓	✓	✓
<b>Financial considerations</b>							
Access to finance	✓	✓				✓	✓
Public support and risk mitigation	✓	✓	✓		✓	✓	✓
Financial and resource risk	✓	✓	✓	✓	✓	✓	✓

Source: World Bank.

# CHAPTER 3: GEOTHERMAL RESOURCE RISKS AND OPTIONS FOR MITIGATION

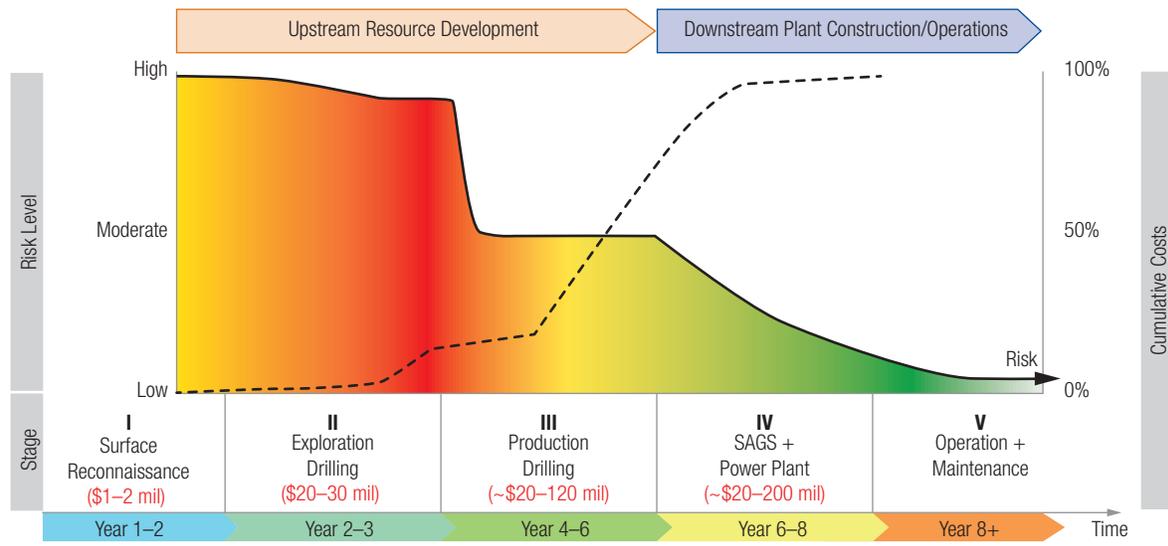
(This Chapter is an updated extract from two recent World Bank publications)<sup>54</sup>

## The Key Challenge

Geothermal power is typically developed in a series of stages so that risks are progressively reduced as the resource capacity and the investment costs become more predictable. However, advancing through these stages can require significant investment, depending on the scale

of development. Furthermore, completing the stages before a geothermal power plant can be commissioned for operation takes years. Figure 3.1 illustrates the key stages in developing geothermal resources for power generation, the associated risk, and cost profiles, along with typical costs and time duration.<sup>55</sup>

FIGURE 3.1: Overview of the Typical Geothermal Development Process



Source: Adapted from ESMAP 2012.

Note: Illustrative CAPEX costs in US\$, million are typical for development of 10 MW to 100 MW power plant.

<sup>a</sup> Operations and maintenance (O&M) cost is not shown in the figure. Using reported reference values for fixed and variable O&M cost for geothermal power plants (ESMAP 2012) the estimated O&M cost for a 10 MW to 100 MW power plant is about US\$0.5 million and US\$5 million per year.

<sup>54</sup> This chapter is an extract from two recent World Bank publications on this topic: 1) Subir K. Sanyal et al., *Comparative Analysis of Approaches to Geothermal Resource Risk Mitigation: A Global Survey*, ESMAP Knowledge Series; 024/16. (Washington, DC: World Bank Group, 2016.); and 2) Roberto La Rocca, Peter Johannsen, Laura Berman, and Migara Jayawardena, *Mobilizing Risk Capital to Unlock the Global Potential of Geothermal Power*, Live Wire; 2017/71. (Washington, DC: World Bank, 2017).

<sup>55</sup> For more information on geothermal development stages and technology, see ESMAP Geothermal Handbook: [https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/FINAL\\_Geothermal%20Handbook\\_TR002-12\\_Reduced.pdf](https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/FINAL_Geothermal%20Handbook_TR002-12_Reduced.pdf).

**While a variety of factors contribute to the slow pace of geothermal development around the world, one of the most widely recognized and unique obstacles is the high resource risk during the early stages of the geothermal development process.** During the surface reconnaissance and exploration drilling stages there is considerable uncertainty regarding resource flow capacity and temperature. Given the limited amount of available information in these stages, developers cannot predict whether a geothermal project will result in commercially productive wells that will sustain generation long enough for the project to be commercially viable. There is also uncertainty regarding the overall cost to extract the geothermal fluids and to inject the heat-depleted brine to replenish the reservoir. Uncertainty is reduced after drilling and testing confirms geothermal resource availability, but this is only achieved after exploration drilling is completed. Only then can a feasibility<sup>56</sup> assessment be carried out to determine the “bankability” of the project and whether to invest in subsequent stages of development. This also makes raising the initial risk capital for geothermal exploration challenging for developers, especially those in the private sector. This “resource risk” is a common barrier to advancing geothermal development globally.

### Approaches to Geothermal Resource Risk Mitigation

**A number of approaches to geothermal development have been applied around the world with varying degrees of success.** Public support, either by itself or in collaboration with the private sector, has played a major role in the expansion of geothermal energy. While there is no one-size-fits-all solution, worldwide, very few geothermal developments have advanced without some form of government or development partner support.

The most common geothermal development approaches applied successfully within LAC and other regions are described below.

### Public Sector as the Total Geothermal Project Developer

**Globally, the public sector has been a major developer of geothermal resources.** As shown in Table 3.1, either the government or quasi-government agencies have undertaken the full scope of geothermal project development for about a third, or over 3.9 GW, of the installed geothermal capacity around the world. In all of these geothermal fields, public sector financing was used for every stage of geothermal development, as shown in Figure 3.2.

**In countries where developers were backstopped financially by the government and in which there was technical capability, geothermal has been successfully expanded by the public sector.**

In the LAC region, this was the case for Costa Rica, El Salvador (both for the initial greenfield development and again in recent years), Nicaragua (for the Momotombo geothermal field), Guadeloupe, and Mexico (for all but one geothermal development). Public sector led geothermal development in LAC has resulted in the bulk of geothermal capacity installed in the region, 1,362 MW in ten different geothermal fields.

**Many countries outside LAC also undertook full public sector geothermal development.** This has included the Philippines (for the initial greenfields developed), New Zealand, and Iceland, all of which are among the top ten geothermal countries worldwide, based on the amount of installed capacity.

**However, in countries where governments could not continue this high level of investment,**

<sup>56</sup> The decision whether to proceed or not is typically made on the basis of results from a feasibility assessment based on proven steam supply of 50 percent (technical, financial, and economic) as well as on an environmental and social impact assessment (safeguards).

**TABLE 3.1: Government-Led Development of Geothermal Generation Capacity (2017)**

Country	Number of fields supported	Installed capacity (MW)
Costa Rica	2	177
El Salvador	2	149
Nicaragua	1	70
Mexico	4	1030
Guadeloupe	1	15
Indonesia	5	547
Philippines	5	608
New Zealand	2	220
Iceland	6	664
Turkey	1	15
Ethiopia	1	8
Kenya	2	488
<b>Total</b>	<b>32</b>	<b>3,991</b>

Source: Using World Bank/ESMAP updated data, table from Subir K. Sanyal et al., *Comparative Analysis*.

**FIGURE 3.2: Development Stages in Public Sector as Total Geothermal Project Developer**

Stage of development	I Surface reconnaissance	II Exploratory/ test drilling	III Production drilling	IV SAGS and power plant	V Operation and maintenance
Financing	Public funding	Public funding	Public funding	Public funding	
Developer	Public sector	Public sector	Public sector	Public sector	Public sector

Source: World Bank.

**geothermal expansion sometimes slowed or stalled.** Lessons learned from global experience show that when the public sector takes the lead in geothermal development, it is essential to have well-coordinated policies, clear mandates, sufficient multi-year financing, access to equipment, and technical capacity.

### **Cost-Shared Drilling to Mobilize Private Geothermal Investment**

Many governments who want to develop geothermal may be unable to do so due to lack of technical capability, financing capacity, or interest in undertaking full development of the geothermal sector. In these cases, the government may look to attracting the private sector.

However, as mentioned previously, the private sector can find it challenging to mobilize the necessary risk capital and funding, especially for early drilling activities. Given this situation, in recent years governments have sought ways to mitigate enough risks to attract qualified geothermal developers to invest.

### **Risk mitigation to attract the private sector is usually achieved through two broad approaches:**

a) the public-sector funding surface reconnaissance and early stage drilling activities, before offering a more “de-risked” project to the private sector for development; or b) the government provides development rights to a private developer, along with support through a financial scheme to shift some

**TABLE 3.2: Estimated Geothermal Generation Capacity Resulting from Cost-Sharing Schemes (2017)**

Country	Number of fields supported	Resulting installed capacity (MW)
Costa Rica	1	30
Chile	1	48
El Salvador	1	44
Guatemala	2	52
Mexico	1	25
Nicaragua	1	72
Indonesia	1	60
Philippines	5	1,260*
New Zealand	6	547
United States	6	150*
Turkey	5	309*
Japan	15	534*
Kenya	1	100
<b>Total</b>	<b>45</b>	<b>3,231</b>

Source: Updated version, using World Bank/ESMAP data, of table from Subir K. Sanyal et al., *Comparative Analysis*.  
 Note: \* Estimated capacity.

risk for early stage exploration drilling away from the private developer. Under both approaches, described in the following sections, the goal is to complete an exploration program and confirm resources, after which the private developer is in a better position to mobilize financing and undertake the remaining stages of development until the power plant is commissioned.

As shown in Table 3.2, these types of approaches have been used by many countries and have led to the development of over three GW of geothermal capacity worldwide. In the LAC region, these types of cost-sharing approaches

have been applied in Costa Rica, Chile, El Salvador, Guatemala, and Nicaragua and successfully led to the installation of 198 MW of installed capacity in six different geothermal fields.

**Public-Sector led Exploratory Drilling**

Under this cost-sharing approach, to mitigate risk the public sector retains the development rights to the geothermal field throughout exploration drilling, with the remaining stages of development offered to the private sector after resource confirmation. This scheme (depicted in Figure 3.3 below) utilizes public resources and

**FIGURE 3.3: Development Stages in Public-Sector led Exploratory Drilling**

Stage of development	I Surface reconnaissance	II Exploratory/ test drilling	III Production drilling	IV SAGS and power plant	V Operation and maintenance
Financing	Public funding	Public funding	Private funding	Private funding	
Developer	Public sector	Public sector	Private sector	Private sector	Private sector

Source: World Bank.

technical capacity (either in-house or contracted from the public sector), to undertake surface reconnaissance (Stage I) and exploration drilling (Stage II) to confirm the geothermal resource, in line with industry standards. This helps de-risk the project for subsequent investors. Following resource confirmation, the government then transfers the development rights to a private developer, through either a negotiated agreement or a competitive process.<sup>57</sup>

**Since the public sector is responsible for geothermal development Stages I and II (see Figure 3.3), the selected private developer takes over the project at a time of far greater investment certainty.** The reduced exposure can attract more qualified developers that are willing and capable of mobilizing larger amounts of financing to complete production drilling (Stage III), to construct the steam-above-ground system (SAGS) and power plant (Stage IV), and to continue with plant O&M (Stage V). Under this scheme, the public sector bears all of the risk during initial surface reconnaissance and exploration. The public sector entities that carry out the exploration drilling should have sufficient risk capital to finance a robust drilling plan and the technical capability to carry out the plan consistent with industry standards (or to contract recognized firms that have this expertise) in order to instill confidence and attract subsequent private developers. It is equally important that the selected private developer be qualified and capable of undertaking the remaining development stages and commissioning the power plant in a timely manner and in line with industry standards.

In the LAC region, countries in which governments undertake early stage reconnaissance and drilling activities before offering projects to private developers have included:

- Nicaragua, where publicly funded exploration and initial production drilling proved the geothermal resources at the San Jacinto-Tizate field before the development rights were awarded to a private developer that undertook the remaining production drilling, well field expansion, and construction of the power plant and associated facilities.
- Guatemala, where government drilling reduced risk and was a successful catalyst that encouraged private participation in geothermal development at Zunil and Amatitlan.

**As there is still considerable risk after exploration, particularly during steamfield development, in some cases the public sector has undertaken all upstream development (Stages I, II, and III), before offering only construction and operation of the power plant to the private sector.** There are also instances, such as the Momotombo geothermal field in Nicaragua, in which the public sector has undertaken all upstream geothermal development and maintained ownership but transferred the geothermal power plant and steamfield operations and maintenance to a selected private company. In other instances, including in Costa Rica, the Philippines, and Indonesia, the public sector continued to operate the upstream field and then sold the steam to a private power producer. Global experiences for schemes that split the geothermal steam production and power generation have been mixed, however, and the steam sales model has not always worked well. The main disadvantage of the steam sales model is the inability of the power producer to manage the reservoir and control the steam supply. This leaves the power producers exposed to resource risk that is out of their control while at the same time remaining obligated to supply power under the PPA.

**While there are many successful global examples of using this approach, there are also a few**

<sup>57</sup> Given the small size of the geothermal sector globally, attracting a significant level of qualified competition may be challenging, especially in small and nascent markets where the investment climate is weak.

**drawbacks.** First, public sector led exploration ties up a relatively large amount of public resources. It also leverages limited private investment and very little of the technical know-how of private developers. However, under a few public sector-led drilling scenarios, the government can sometimes recover its investment. This can be done either through lower tariffs given the reduced risks, or through compensation from the selected private developer when the exploitation concession is awarded.

**Cost-Shared Exploratory Drilling**

**An alternate approach is government use of financial mechanisms to mitigate risk to attract subsequent private investment.** As depicted in Figure 3.4 below, under this scheme the field development rights are granted by the government to a qualified private developer from the start. Since private developers are often challenged in raising risk capital, the public sector can provide part of the funding to cover surface reconnaissance and exploration drilling (Stages I and II). This approach lowers the investor’s potential losses and costs by reducing the amount of risk capital the private developer needs to raise. At the same time, this cost-sharing strategy reduces the risks and potential losses that would need to be absorbed by the public sector if the project does not advance, compared to the public sector solo undertaking of these activities.

**This approach offers an opportunity for the public sector to rely on private sector expertise and, if desired, remain at arms-length from the**

**investment.** This can be especially useful when the government has limited sector experience and the private sector has expertise but finds it difficult to raise the necessary funding. In this cost-shared drilling scheme, if the results of exploration are favorable and the project is determined to be “bankable,” the private sector usually develops the subsequent stages (Stages III and IV) alone, and then operates and maintains the facility (Stage V).

**There are several examples of cost-shared, risk mitigation schemes in which governments have established financial mechanisms that provide financing directly to the private sector to help mitigate early stage geothermal resource risks.** Japan and the United States have successfully implemented cost-shared exploration schemes to catalyze private sector geothermal exploration investments, which has led to substantial follow-on development (see Figure 3.5). In various instances over the past few decades, Japanese developers benefited from a scheme that included a cost-share of up to 50 percent for exploration wells and a 20 percent cost-share on production and injection wells. This cost-sharing brought about the installation of most of the 536 MW of geothermal power capacity operating in Japan today. In the United States, developers were able to confirm productive conditions at several fields under this approach, which were later developed for a total of about 150 MW of geothermal capacity.

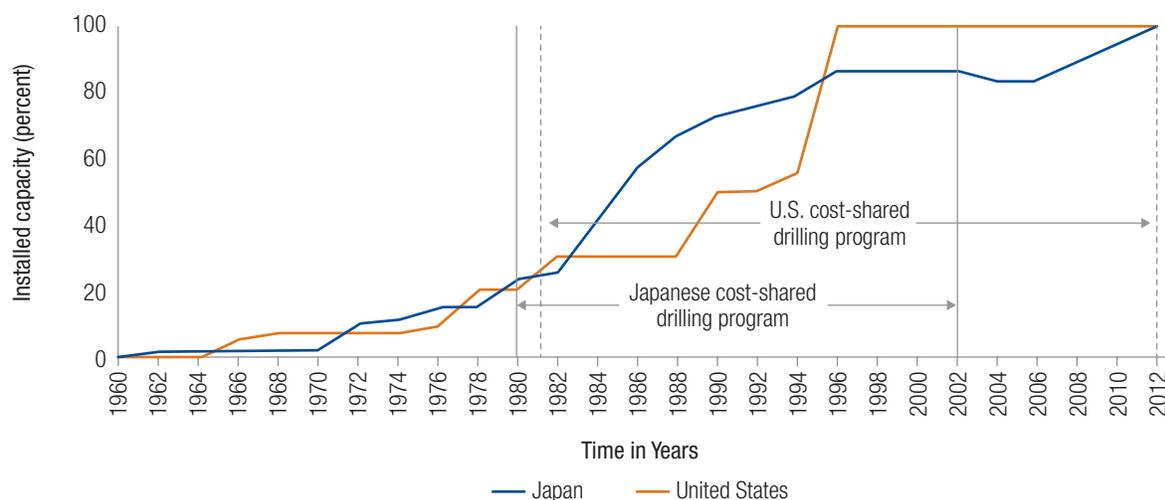
**In both Japan and the U.S., the national geological survey initially identified the most**

**FIGURE 3.4: Development Stages in Cost-Shared Exploratory Drilling**

	I	II	III	IV	V
Stage of development	Surface reconnaissance	Exploratory/ test drilling	Production drilling	SAGS and power plant	Operation and maintenance
Financing	Public funding	Public funding	Private funding	Private funding	
Developer	Private sector	Private sector	Private sector	Private sector	Private sector

Source: World Bank.

**FIGURE 3.5: Evolution of Geothermal Power Generation Capacity in the United States and Japan**



Source: Sanyal et al. 2106.

**promising fields that would be eligible for cost-shared drilling, but the subsequent 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. Figure 3.5 illustrates the noticeable expansion in geothermal capacity several years after establishing such programs, as the initial investment cost-sharing enabled projects to move forward. This figure also highlights how expansion slowed down soon after these government-sponsored programs closed, indicating the importance of having consistent and long-term strategic policies to support geothermal development. Currently, the World Bank is supporting similar cost-shared exploration efforts in countries such as Nicaragua and Turkey. The German development bank Kreditanstalt für Wiederaufbau (KfW) has also set up a similar Geothermal Risk Mitigation Facility in East Africa and, most recently, in the LAC region (which is described further in Chapter 4).

### Geothermal Resource Risk Insurance

**Geothermal resource risk insurance schemes are designed to insure the productivity of a well or a portfolio of wells.** This productivity can be

stated in terms of megawatt capacity or a combination of flow rate and enthalpy. After initial 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. 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, current thinking regarding geothermal insurance is to cover the aggregate output of a group of wells.

**While insurance schemes offer a fully private sector solution and appear attractive, exploration drilling insurance schemes in geothermal have, to date, seen limited application (a few tens of MWs).** Some countries have attempted to apply this method (most notably Germany) with modest success. Driven in part by its high FIT for geothermal power, Germany succeeded in implementing this type of insurance product.

**There are several reasons that geothermal resource risk insurance schemes have not been widely used.** The primary reasons for the limited use are that geothermal development is a small sector globally, and insurance companies have been unable to amass an appropriate scale for such coverage to be efficient (that is, a sufficiently large portfolio to spread the risk); and the typically high premiums (due to the significant uncertainty during the exploration stage) may not be affordable to some developers. Additionally, the actuarial process of preparing an insurance scheme can be complex and time consuming. To date, such schemes have not proven effective in helping to scale up geothermal during the higher risk exploration stage. However, there may be some suitable opportunities for drilling insurance to be used at the production drilling stage to advance development of steam fields.

**Because of these complexities, two attempts at using a geothermal insurance scheme in Turkey and in Mexico have fallen through.** It is worth noting that in countries where there is little information about the resource characteristics of different geothermal fields, other approaches to reducing resource risks may be more effective.

**Other Types of Complementary Support**  
**Countries have also used an array of complementary tools and strategies that indirectly mitigate risk and incentivize investment in geothermal development.** 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;
- FITs, which sets the minimum prices for renewable energy and mandates off-takers to purchase renewable energy at these set prices;
- Loan guarantees for geothermal projects, including government full faith and credit guarantees, as well as partial risk guarantees and letters of support;

- Geothermal fiscal incentives that support geothermal projects at the exploration and early drilling stages, including exemption from certain taxes and import duties;
- Renewable Energy tax credits, such as the Investment Tax Credits (ITC) at the start of power generation, or Production Tax Credits (PTC) for operating geothermal projects; and
- Development of associated infrastructure (roads and transmission lines), which 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 and can help attract private investment to the sector.** The resulting higher returns that developers can make from a project compensate for some of the risks, making geothermal development a more attractive investment opportunity. This increased potential to make profits can ease the burden of project financing and help advance development.

**Several countries have implemented fiscal incentives for geothermal in different ways.** Some of the forms used include: waiving duties on the import of geothermal equipment and income tax breaks for the first years of geothermal operations (Nicaragua, Ethiopia, and Kenya); tax exemptions or reductions in taxable income (Indonesia); 100 percent tax deduction on investment on renewable power (Mexico); exemption of taxes on machinery imported for geothermal development (Indonesia and the Philippines); and exemption of all taxes, except income tax, for geothermal project developers (the Philippines). These incentives are implemented through legislation and their application typically does not require significant up-front public financial support, although some fiscal revenues may be lost. Tax credits (such as the ITC and the PTC in the United States) have helped many geothermal developments and are likely to have had some impact on the pace of development, but this is difficult to quantify.

**Other tools that have facilitated geothermal development are FITs.** For instance, 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 and this has helped attract investors into the sector.

**Similarly, RPS programs—essentially a mandate for a state, region, or utility district to have a specific percentage of renewable power sources—have also been useful.** These have led to higher price offers for renewable power in order to mobilize sufficient investments to meet these obligations. The resulting improvement in the overall long-term returns for developers have helped promote investments in geothermal.

**While these different schemes can help incentivize renewable energy and geothermal investments, it is unlikely that any of them in a vacuum will be sufficient to catalyze significant geothermal investment in LAC.** Their implementation—in combination with targeted geothermal resource risk mitigation approaches and other policy, regulatory, and financing strategies—will be key to stimulating successful geothermal development in the region.

### Emerging Approaches in LAC

**The existing geothermal power facilities operating in the LAC region have been developed by a combination of fully public efforts and cost-shared approaches between the public and private sector.** As seen in other parts of the world, typically the early stages of geothermal development—especially surface reconnaissance, exploration drilling, and sometimes even production drilling—have been undertaken by public sector entities, such as CFE in Mexico and ICE in Costa Rica. In other cases, they have been developed by way of PPPs such as Enel Green Power and ENAP in Chile. There are also various

examples in the region in which the private sector further develops the steam field and constructs and operates the power plant, such as Polaris Energy Nicaragua S.A and Grupo Dragón at Domo San Pedro geothermal field in Mexico.

**The World Bank is currently working with governments, utilities, and geothermal developers in several LAC countries to customize geothermal resource risk mitigation approaches and to help finance the implementation of such approaches.** While many of these World Bank supported projects build on the risk mitigation approaches discussed earlier, they also have unique considerations: (i) the state of geothermal development in each country; (ii) the nature of the field; and (iii) local technical capacities. However, as the emerging approaches in Dominica, Nicaragua, and St Lucia described below have not yet begun implementation, it is too soon to draw lessons learned from these approaches.

#### Dominica

**Over the past decade, Dominica has been trying to develop its geothermal resources as a means to lower and stabilize the costs of electricity in the country.** Dominica faces some of the highest electricity prices in all of LAC, given its heavy reliance on diesel for power generation. While the country has some hydropower capacity installed, further diversification of the country's energy matrix through the exploitation of the country's large estimated geothermal resource potential has been a top priority for the government. Geothermal development in Dominica has been conducted thus far under a public-led drilling approach, which is facilitating subsequent development by the private sector. Early geothermal surface level work and exploration studies were done by the government, with support from various development partners and agencies.

**The Wotten-Waven field in the Roseau Valley has a theoretical capacity of up to 100 MW, the largest in the Caribbean region.** The early reconnaissance and surface level studies at the

Wotten-Waven field were conducted as part of a European Cooperation Programme in 2008, in partnership with several other regional and international agencies. Afterwards, the government, through its Ministry of Public Works, Energy, and Ports, invested about US\$10 million (financed by an AFD loan) to conduct additional surface studies and exploration drilling in 2011–2012. This initial exploration drilling work identified the presence, with a 50 percent probability, of a geothermal resource able to support approximately 65 MW of power generation capacity. While the government of the Commonwealth of Dominica (GoCD) has consistently sought to attract a private developer to further develop the field, it has been so far unsuccessful due to the risks associated with geothermal development, especially for a small country and an untested market like Dominica. The country thus decided to revert to using a public sector-led development approach. From 2013–2014, the government undertook production drilling and confirmed the availability of sufficient steam at the wellhead to develop a seven MW plant. During this time, the World Bank provided technical assistance to GoCD, through an ESMAP/Small Islands States (SIDS)-DOCK grant. This assistance was to support review of the drilling results, identify key gaps in the baseline environmental and social work, and recommend actions to address any gaps to ensure that the geothermal field was developed in line with industry and international standards.

**With the field’s geothermal resources now proven, the GoCD is now planning to construct a seven MW geothermal power plant through a PPP approach, with support from the World Bank, DFID, and the government of New Zealand.** This small geothermal power plant will feed domestic demand, as well as confirm the production capability of the steamfield, which is a prerequisite to further expanding the

Wotten-Waven field. A private enterprise, called the Dominica Geothermal Development Company (DGDC), was established to own and operate the geothermal power plant. The DGDC is staffed by a combination of local and international personnel, and technical assistance is being provided by the government of Zealand to support its operationalization. The technical support provided by development partners has been key in supporting the GoDC and DGDC to advance development of the Wotten-Waven field. The financing needed to construct the small geothermal power plant is being provided by the GoDC IDA, the Clean Technology Fund (CTF), DFID, SIDS-DOCK, and the government of New Zealand. This financing will then be on-lent by the GoCD to DGDC on the same terms as the financing is received, to help bring down the cost of geothermal power production (compared to the cost if commercial financing were used) so that the country can benefit from more affordable power. The expectation is that once the small power plant is commissioned and the operational viability of the field proven, this will help attract private investors. Depending on resource availability, a large geothermal power plant with a capacity of around 40 MW to 100 MW could be developed for electricity exports to Guadeloupe and/or Martinique through undersea cables. This larger, more complex investment will require partnering with the private sector, but it is still too early to determine under what approach it would be developed. Dominica is an example of a cost-shared drilling approach that was initially publicly led, but that is expected to mobilize significantly more private geothermal investment.

### **St. Lucia**

**The government of St. Lucia (GoSL) has also prioritized the development of geothermal resources to help diversify the country’s energy mix.**<sup>58</sup> St. Lucia faces many of the same challenges

<sup>58</sup> GoSL has established renewable energy targets of 35 percent by 2035 and 50 percent by 2050. Project Information Document/Integrated Safeguards Data Sheet (PID/ISDS), World Bank, May 2017.

encountered by other Caribbean islands, including high electricity prices, reliance on imported diesel fuels, and a small electricity market. Geothermal surface level studies conducted thus far have been public sector led. However, once the public sector mitigates early stage geothermal risks—including through the upcoming World Bank supported exploratory drilling—the intention is to attract a qualified private developer to take on the production drilling and power plant construction phases and to then operate the plant. St. Lucia has a long history of working to develop its geothermal resources. The Sulphur Springs area has traditionally been considered the most promising area and has been studied since 1951 through reconnaissance studies funded by the United Nations and drilling in the 1970s and 1980s. However, this work did not confirm the commercial viability of using the geothermal resources to produce power. Furthermore, as the location of the initial areas were within the Pitons Management Area (PMA), a UNESCO-designated World Heritage Site, this further stalled development.

**In recent years, GoSL, with the help of the World Bank and other donors, has contracted several additional surface level studies to further assess the viability of the country’s geothermal resources.** From 2014 to 2016, the government also received technical assistance from the World Bank to develop a geothermal roadmap for identifying, exploring, and exploiting the geothermal resources for electricity generation. This included early surface level studies, which lead to a comprehensive pre-feasibility study and an ESIA for the next stage of exploration drilling. The findings from these surface exploration studies suggest the possible existence of a geothermal reservoir, just outside of the PMA area, that had not been identified by previous studies.

**The government now plans to implement an exploration drilling program using public resources to finance the drilling of three to five deep exploration wells.** This project aims to assess the quality of the geothermal resources in

the areas where the recently completed surface studies suggested the existence of a geothermal reservoir. The government’s Department of Sustainable Development will implement the project and will establish a dedicated geothermal implementation team. The government also plans to contract an external exploration management consultant to enhance its capacity to implement and oversee the drilling program. The government and development partners such as the World Bank, CTF, SIDS-DOCK, and DFID, among others, plan to finance this US\$22.5 million project. Under the project’s most recent design, technical assistance will also be provided to the government for support in selecting and contracting a private developer to carry out the subsequent phases of geothermal development, if commercially viable. Thus, St. Lucia plans to use a public sector-led exploration drilling approach to mitigate risk, and after will offer the remaining stages of development to the private sector.

## **Nicaragua**

**There is considerable potential for Nicaragua to use geothermal to diversify its generation mix and lower and stabilize energy costs.** Nicaragua has the highest geothermal resource potential in Central America, but less than 10 percent is used for power production. While geothermal power plants in the Momotombo and San Jacinto-Tizate fields are operational, it has been difficult for the country to expand its geothermal capacity. Like many countries, a major obstacle to geothermal development in Nicaragua is resource risk. This resource risk makes it difficult to secure the funding required to confirm the geothermal resource potential in Nicaragua’s 10 remaining greenfields.

**The GoN is looking to expand its geothermal power capacity to reduce and stabilize the overall cost of the country’s power supply by diversifying away from fuel oil.** To facilitate geothermal development, over the past four years, the World Bank has provided the GoN with technical assistance, including: conducting a

geothermal sector diagnostic, screening, and prioritization of Nicaragua’s undeveloped geothermal fields; assessing of global approaches to geothermal resource risk mitigation; conducting a market sounding with geothermal developers to ascertain their interest in investing in Nicaragua; and supporting a geothermal resource risk mitigation investment project. Based on a screening and prioritization of fields in Nicaragua’s Geothermal Master Plan by the GoN and the World Bank, the Volcán Casita San Cristobal geothermal field (Casita field) was identified as the most promising geothermal prospect in the country.

**Advances in Casita field development have largely been due to the efforts of and funding from Cerro Colorado Power (CCP), a private company that was awarded the concession for development of the Casita San Cristobal geothermal field by the GoN.** Between 2009 and 2011, surface studies (geological, geophysical, and geochemical) were completed, an access road and drilling platform was constructed, and a slim/core hole was drilled that identified the availability of a high temperature steam resource. Despite this positive outcome, the remaining resource risks in the field have prevented the project from advancing further, as CCP has been challenged to raise the

risk capital necessary to complete the exploratory drilling activities and confirm the resources.

**The GoN has decided to support geothermal resource risk mitigation in the Casita field to enable field development to move forward so that the country can benefit from the lower cost power that could be produced.** The GoN, utilizing a US\$45 million International Development Association (IDA) credit from the World Bank, plans to finance a three-to-five-well exploration drilling program, industry standard feasibility study, and the accompanying environmental and social safeguard implementation work. The GoN would provide this funding to the state-owned utility ENEL(NI), which will invest in the aforementioned exploration activities and in exchange receive shareholding in CCP. If the commercial viability of the geothermal resources for power generation is confirmed, it will likely enable CCP to raise significantly more finance from private and multilateral development banks to undertake production drilling and the construction of the SAGS and an initial 25 MW to 35 MW power plant. This is the first time that a PPP approach to geothermal development will be used in Nicaragua. However, similar approaches in which state-owned enterprises or PPPs do upstream field development

**TABLE 3.3: Emerging Geothermal Development Approaches in LAC**

Geothermal Development Approach	Stage of Development/ Financing					
	Surface reconnaissance	Exploratory drilling	Production drilling	SAGS and power plant	Operation and maintenance	Financers
<b>Dominica</b> (Wotten-Waven field)	Public sector (GoCD)	Public sector (GoCD)	Public sector (GoCD)	Cost-shared (GDC, with public financing)	Private sector- GDC (proposed)	IDA, CTF, DFID, SIDS-DOCK, government of New Zealand, GoCD
<b>St. Lucia</b> (Fond St. Jacques, Belle Plaine, Mondesir- Saltibus fields)	Public sector (GoSL)	Public sector (GoSL)	Private (proposed)	Private (proposed)	Private (proposed)	IDA, CTF, SIDS- DOCK, ESMAP, DFID, GoSL
<b>Nicaragua</b> (Casita San Cristobal field)	Private sector (CCP)	Cost-shared (ENEL/CCP)	Private sector- CCP (proposed)	Private sector- CCP (proposed)	Private sector-CCP (proposed)	IDA, ENEL(NI), CCP

Source: World Bank, various.

and then private sector entities conduct the downstream activities are common in the oil and gas industries. Thus, a PPP variation of the cost-shared drilling approach mentioned earlier in this chapter would be applied to this project.

**Some overall lessons that have emerged from these new geothermal approaches are:** (i) recognition that the risks associated with the initial stages of geothermal development are one of the leading factors that slows down geothermal field development; (ii) concessional finance is key to both funding early drilling activities, but also to lowering the cost of a geothermal project and the electricity produced; and (iii) technical support from development partners is critical, given the limited geothermal expertise in the LAC region, especially in countries that are developing geothermal for the first time. A summary of the geothermal development approach used in each of these countries by development stage is depicted in Table 3.3 above.

## Conclusions

The following key lessons have emerged through the comparative analysis of global and regional approaches to geothermal resource risk mitigation:

- **Public support is central to geothermal development, especially for reducing project risks.** Very few geothermal resources worldwide, including in LAC, have been developed without some form of public intervention, either through investments or by regulatory means. Public support is especially important for reducing resource risks, as seen in a number of countries in the LAC region. Early investment by governments in surface reconnaissance and exploration drilling has been a critical catalyst in advancing geothermal development.
- **Well-targeted public support can leverage private participation.** In instances in which

the private sector is willing to take on some of the burden of geothermal development, targeted public investments can be catalytic for later harnessing private investment. Full or partial investments by governments through the mobilization of risk capital for exploration drilling can significantly de-risk geothermal operations and help attract private investment for the remaining stages of development. This has been the case in various LAC countries, and is also essential for advancing the new geothermal developments in Dominica, St. Lucia, and Nicaragua.

- **Approaches to scaling up geothermal should be customized and commensurate to country-specific circumstances.** While resource risk mitigation can be catalytic in unlocking the potential for commercial development in geothermal fields, this alone cannot guarantee successful installation of geothermal generation capacity. In some instances, the exploration drilling and feasibility study may determine that a project is not commercially viable. In cases in which a viable resource is confirmed, there may be a need to address other country, market, and sector related barriers that impede projects, and to launch additional financial incentives and mechanisms. Thus, a comprehensive approach to geothermal development is needed in order to most effectively scale up geothermal development in LAC and globally.

A more detailed comparison of the different geothermal resource risk mitigation schemes presented in this chapter and the key features of each scheme can be found in the World Bank/ESMAP full report *Comparative Analysis of Approaches to Geothermal Resource Risk Mitigation: A Global Survey*, which can be accessed at: <https://openknowledge.worldbank.org/handle/10986/24277>.



San Jacinto-Tizate Geothermal Plant.  
Photo courtesy of Polaris Energy Nicaragua S.A.

# CHAPTER 4: MOBILIZING FINANCING FOR GEOTHERMAL DEVELOPMENT

## Power and Geothermal Investment Landscape to Date

**The unique characteristics of geothermal development may help to explain the relatively low levels of private investment in the global sector.**

While often grouped together with other renewable energy technologies,<sup>59</sup> geothermal energy is in fact very different from many renewables, not only in terms of its uses (base-load power), but also in terms of its economics and financing. Extracting geothermal energy is a capital-intensive activity, with the first phase alone (resource confirmation) requiring investments in excess of US\$20 million to US\$30 million over two to three years.<sup>60</sup> At the same time, the early stages of geothermal development have a relatively high-risk profile (only 60 percent probability of success).<sup>61</sup> Unlike other energy extractive resources, geothermal steam cannot be transported far. It is usually converted into electricity close to where the resource is extracted and sold to a local off-taker at prices consistent with the average cost of electricity within a country. This means a relatively low cap on potential

investment returns, which, coupled with the high-risk profile of geothermal investments, makes it difficult for investors to justify financing projects.<sup>62</sup> Thus, even though developing geothermal requires similar “wild-cat” approaches as the oil and gas industry, the economic drivers are very different. Not surprisingly, there are only a small number of investors and companies with the necessary capital and risk tolerance to embark on a geothermal project. In fact, just 20 companies control over 70 percent of global geothermal electricity production worldwide.<sup>63</sup> There is also a limited number of financial institutions willing to back these investments.

**Private investment flows into the geothermal sector in the LAC region have been influenced by each country’s electricity market, geothermal resource conditions, and investment climate.**

Factors such as the relative price of other competing technologies, local legislation, market size, local utility credit risk, and the topography and accessibility of the location of the geothermal resource all play a key role in determining the

<sup>59</sup> Author conversations with several developers in the LAC region.

<sup>60</sup> Illustrative costs in US\$ million are typical for development of a 10 MW to 100 MW power plant, based on data presented in ESMAP 2012a.

<sup>61</sup> The success rate averaged over the first five wells drilled was 59 percent, based on global database of wells in geothermal fields which together supply power to 71 percent of the world’s installed geothermal electricity generating capacity. IFC 2013.

<sup>62</sup> The topography and accessibility of a particular geothermal field may have significant cost implications. For instance, in South America, many of the geothermal fields are located in remote areas of the Andean mountain range, which increases the cost of developing the fields. As a result, the average cost per megawatt of developing a geothermal field in South America is above \$US6 million, significantly over the \$US4 million to US\$5 million per megawatt that it costs to develop a field in Central America.

<sup>63</sup> World Energy Council 2016.

relative attractiveness of investing in a country's geothermal sector. In the LAC region, the stark differences among the electricity markets, and the political, regulatory, and country conditions of the Central America and Mexico, the Caribbean, and South America sub-regions have also influenced the amount of private investment in the geothermal sector.

**The Central America and Mexico sub-region has received the vast majority of private geothermal investment in LAC. From 1993 through 2017, there was over US\$1 billion of private investment in the geothermal sector in this sub-region.** Private investment has contributed to the development of about 564 MW (36 percent) of geothermal capacity in the Central America and Mexico sub-region. In contrast, the public sector has financed about 64 percent of the total geothermal capacity installed in this sub-region (that is, 1,038 MW). A number of factors have facilitated this geothermal investment, including the larger size of electricity markets in this sub-region compared to the Caribbean. However, with the exception of Mexico, most markets are still small to medium size by regional standards, and political instability and violence have impacted the investment climate in some countries. Nevertheless, given the large estimated resource potential and existing knowledge about the resource characteristics in many fields, there is both public and private sector interest in further geothermal development. Governments in this sub-region have had long-standing interest in developing their geothermal resources to limit exposure to oil and diesel price volatility. There has also been active geothermal investment and operations in the region for decades, so there is more local capacity and awareness about the geothermal sector than in other sub-regions.

**The very limited amount of geothermal capacity installed in the Caribbean sub-region has been publicly financed.** In Guadeloupe, the 15 MW of installed capacity was developed by the public

sector, with France absorbing the geothermal development risk of its overseas territory. Most of the geothermal fields being developed in the Caribbean rely heavily on government and development partner financing. While high electricity prices provide a strong incentive for geothermal development in this sub-region, the high capital cost of geothermal investments, small market size, and limited borrowing capacity of many Caribbean governments have led utilities and potential developers to limit investment. However, there is still significant interest by the public sector in developing and exploiting the geothermal resources in this sub-region given the potential to help lower and stabilize electricity prices.

**The South America sub-region has attracted a limited amount of private investment to the geothermal sector.** Chile is still the only country in this sub-region with any installed geothermal capacity, with approximately US\$320 million of private investment used to develop the 48 MW Cerro Pabellón geothermal power facility. The South America sub-region is attractive to investors because of larger-size electricity markets and significant estimated geothermal resource potential. However, lower electricity prices and significant competition from other electricity generation technologies, less geothermal resource knowledge from actual drilling, difficult terrain complicating access to the resources, and less local experience and capacity make South America a less attractive sub-region for geothermal investors. Geothermal has been at a significant disadvantage compared with large hydro, fossil-based fuels, and even non-conventional renewables like small hydro solar and wind, making it difficult for geothermal development to gain traction and interest from investors. Out of the eight geothermal plants that have come online since 1993 in LAC, Cerro Pabellón was the only one located in South America.

**While the amount of geothermal development and investment has varied in each sub-region of LAC, lack of financing is one common factor across all sub-regions.** Private geothermal

**TABLE 4.1: Private Sector Investment in the Power and Geothermal Sectors in LAC, 1993–2017**

Countries	Power sector (US\$ million)	Geothermal sector (US\$ million)
Costa Rica	1,600	70
Chile	—	320
El Salvador	1,300	46
Guatemala	3,930	104
Honduras	2,600	180
Mexico	15,900	160
Nicaragua	1,200	451
<b>Total</b>	<b>26,530</b>	<b>1,331</b>

Source: PPIAF database.

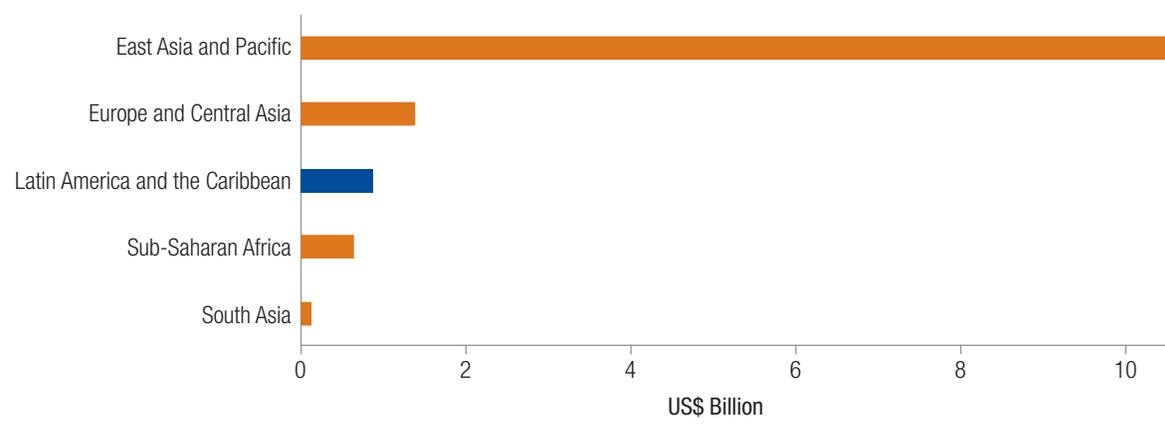
Note: The PPIAF database does not include information for Chile and Guadeloupe on the amount of private investment that has been mobilized in the power sector.

investment represented only five percent of total private investment in the power sector in LAC from 1993 to 2017 (Table 4.1). While mobilizing funds for exploration drilling may be the largest barrier, developers continue to face challenges in finding finance even after the resource has been proven and the viability of the project confirmed. Given the risk profile of geothermal development, companies often need to raise capital on a stage-by-stage basis, which can create significant project delays and increase costs.

**Private Investment in LAC’s geothermal sector has also been moderate compared to other**

**regions of the world.** LAC’s private investment in the geothermal sector represents only six percent of total private geothermal investment globally from 1993 to 2017. As seen in Figure 4.1, the LAC region’s private geothermal investment was dwarfed by that of the East Asia and the Pacific region, where total private investment (US\$10.5 billion) was 15 times greater than in LAC. Private geothermal investment in LAC during this time period was more comparable to that seen in the Europe and Central Asia and Sub-Saharan Africa regions. Overall, the LAC region ranks third among all regions in the amount of private geothermal investment

**FIGURE 4.1: Private Geothermal Investment by Region, 1993–2017 (US\$ Billion)**



Source: World Bank.

attracted from 1993 to 2017. However, as LAC’s estimated geothermal resource potential could range from 11 GW to 55 GW, the region has an opportunity to significantly scale up investment in this sector.

### Looking at the Horizon: Investment Needs in the Geothermal Sector

#### Future Investment Needs to Enable Geothermal Development in LAC

During the next 10 years, the LAC region will require an estimated US\$2.4 billion to US\$3.1 billion to finance the cost of developing about 776 MW of geothermal power generation capacity.<sup>64</sup> This level of investment encompasses the cost of fully developing all stages of the 19 geothermal fields that LAC countries plan to develop in this period (Table 4.2). An estimated US\$240 million to US\$330 million<sup>65</sup> will be needed just to cover the riskier exploration stage costs and confirm the resource in these geothermal fields, which is typically the most difficult funding to raise. Since 1993, LAC’s private sector investment into the geothermal sector has averaged only US\$54 million per year from 1993 to

2017. Thus, raising the level of funding required to develop LAC’s planned geothermal capacity expansion will be challenging. Mobilizing the finance required to develop LAC’s entire 11 GW to 55 GW of estimated potential would present an even greater challenge.

#### Central America and Mexico

The Central America and Mexico sub-region has over 400 MW of geothermal developments planned for the next ten years. Given that this is the sub-region with, by far, the most advanced geothermal sector, many of the sector’s investors and companies have experience in this market. This may help mobilize the necessary US\$1.7 billion to US\$2.2 billion that will be required to develop the region’s planned geothermal projects. However, developing this capacity will also likely require support from the public sector and international financial institutions, given the low levels of private geothermal investment historically seen in LAC. Table 4.3 provides a summary of the geothermal investments planned for the Central America and Mexico sub-region that are likely to be initiated over the next decade.

TABLE 4.2: Planned Geothermal Developments in the LAC Region

	Central America and Mexico	Caribbean (OECS)	South America	Total
Number of fields with planned investments	10	7	2	19
Planned capacity additions (MW)	448	195	133	776
Estimated exploration costs (US\$, million)	180 to 270	60 to 90	<i>Financing already secured</i>	240 <sup>a</sup> to 330 <sup>b</sup>
Estimated total development cost (US\$, billion)	1.7 to 2.2	0.72 to 0.92	<i>Financing already secured</i>	2.4 <sup>c</sup> to 3.1 <sup>d</sup>

<sup>a</sup> This figure includes an estimated exploration cost of US\$25 million per field. However, adjustments have been made for fields for which developers have already secured the funding to finance the exploration stage.

<sup>b</sup> This figure includes an estimated exploration cost of US\$30 million per field. However, adjustments have been made for fields for which developers have already secured the funding to finance the exploration stage.

<sup>c</sup> This figure includes an estimated cost of US\$3.9 million per megawatt installed.

<sup>d</sup> This figure includes an estimated cost of US\$5.0 million per megawatt installed.

<sup>64</sup> These calculations assume a total development cost ranging from US\$3.8 million to US\$5 million per MW installed. Estimations are based on those used in ESMAP Geothermal Handbook, World Bank, 2012. Adjustments have been made to these assumptions for the fields for which the financing has already been secured.

<sup>65</sup> These figures assume an estimated exploration cost of US\$25 million to US\$30 million per field. However, adjustments have been made where developers have already secured the funding to finance the explorations stage of a particular field.

**TABLE 4.3: Planned Geothermal Projects in Central America and Mexico Region (Next 10 Years)**

Country	Number of fields	Estimated capacity (MW)	Estimated investment required (US\$) <sup>a</sup>
Costa Rica	3 fields (Borinquen field units I and II, Las Pailas units III and V, and Backpressure unit) <sup>b</sup>	163.5	US\$640 million to US\$820 million
El Salvador	2 fields (Chinameca and San Vicente)	80.0	US\$312 million to US\$400 million
Guatemala	1 field (El Ceibillo) <sup>c</sup>	25.0	US\$97.5 million to US\$125 million
Mexico	1 field (Nayarit field, Ceboruco unit)	25.0	US\$117 million to US\$150 million
Nicaragua	3 fields (Casita San Cristobal field, <sup>d</sup> Volcán Cosiguina field <sup>e</sup> and San Jacinto expansion) <sup>f</sup>	149.0	US\$561.1 to US\$715 million <sup>g</sup>
Total	10 fields	447.5	US\$1.7 billion to US\$2.2 billion

<sup>a</sup> Cost estimations are based on those used in ESMAP 2012a.

<sup>b</sup> GEA 2016.

<sup>c</sup> US Geothermal (recently acquired by ORMAT), recently received a US\$3.4 million grant from the Geothermal Development Facility for Latin America to aid the development of three production wells. (Richter 2017; and GEA 2016.

<sup>d</sup> World Bank 2017a.

<sup>e</sup> IDB 2016.

<sup>f</sup> GEA 2016.

<sup>g</sup> This particular figure assumes zero exploration costs, since the IDB and the government of Nicaragua already have developed a resource risk mitigation project aimed at validating the presence of commercial levels of geothermal energy in the Cosiguina field. (IDB 2016).

### Caribbean

**The Caribbean has around 195 MW in planned geothermal developments that would require the mobilization of over US\$700 million in financing** (Table 4.4). While there is currently

only one plant that has been developed in Guadeloupe, many islands in the Caribbean (such as Dominica, St. Lucia, and St. Kitts and Nevis) are actively looking to develop their geothermal resources, having already conducted various

**TABLE 4.4: Planned Geothermal Projects in Caribbean Region (Next 10 Years)**

Country	Number of fields	Estimated capacity (MW)	Estimated investment required (US\$ million) <sup>a</sup>
Dominica	1 field (Wotten-Waven field) <sup>b</sup>	40	136 to 170
Grenada	1 field (Mount St. Catherine) field) <sup>c</sup>	30	117 to 150
Guadeloupe	1 field (Bouillante 3 field, expansion unit) <sup>d</sup>	30	97 to 120
Montserrat	1 field (Cork Hill field) <sup>e</sup>	5	19.5 to 25
St. Kitts and Nevis	1 field	45 <sup>f</sup>	175.5 to 225
St. Vincent and the Grenadines	1 field	15 <sup>g</sup>	58.5 to 75
St. Lucia	1 field (Soufriere) <sup>h</sup>	30	117 to 150
Total	7 fields	195	720 to 915

<sup>a</sup> Assuming completion of project if exploration and drillings are successful and consistent with estimations.

<sup>b</sup> World Bank 2017a.

<sup>c</sup> GEA 2016.

<sup>d</sup> GEA 2016..

<sup>e</sup> The Montserrat geothermal power plant will provide from two MW to five MW. (Crawford 2016).

<sup>f</sup> NREL 2015.

<sup>g</sup> Richter 2018b.

<sup>h</sup> World Bank 2018b.

surface level studies and other preliminary activities. For instance, as mentioned previously, in Dominica the government is developing a seven MW plant that will serve the local market. Plans calls for a later expansion of capacity to between 40 MW to 100 MW to be able to export neighboring electricity to markets.<sup>66</sup>

### South America

**Most development financing has been secured for the estimated 133 MW in geothermal developments that South America has planned for the next decade** (Table 4.5). With countries such as Chile leading the way, the region’s resource potential seems strong, but there is still ample opportunity to include geothermal in the resource development plans of many other countries. Geothermal development in this sub-region has underperformed that of other LAC sub-regions due to various reasons, including low prices for fossil-based fuels, competitive markets, and lack of government interest in developing the resource. Recently, countries like Chile and Peru have been attempting to jump-start their geothermal sectors by developing legal frameworks and assigning concessions, among other actions. Chile has awarded more than 80 exploration concessions and nine exploitation concessions in the last decade, so the investment requirement in Chile could far surpass the US\$642 million that has been raised to develop the Laguna Colorada field in Bolivia and to expand the Cerro Pabellón field in Chile. However, there has been no exploration drilling in the majority of geothermal fields in

the sub-region with concessions. It is feasible that several additional geothermal projects could begin development in the South America sub-region over the next decade, in which case additional financing would be needed.

### Financing Geothermal Development

**Financing geothermal development is a complex endeavor.** Each stage of a geothermal project has a unique set of resource risks, capital demands, and operational challenges. Thus, financing is typically raised on a stage-by-stage basis from different types of investors and may utilize a range of financial structures. Given the high-risk profile and low return potential of geothermal relative to other extractive sectors, raising financing for geothermal is more difficult, and very different from raising financing for similar extractive businesses, let alone for other renewable technologies like wind and solar. Moreover, it is important for public sector actors and development institutions that are interested in promoting geothermal development to address not only the financing constraints at each stage, but also to help ensure that there is timely access to such resources. In a business where operational delays cost millions of dollars, access to capital when it is needed can make or break a project.

### Funding Sources in the LAC Region

Given the different risks and investment requirements for the various stages of geothermal development, the types of funding secured will include

**TABLE 4.5: Planned Geothermal Projects South America Region (Next 10 Years)**

Country	Number of fields	Estimated capacity (MW)	Estimated investment required (US\$ million)
Chile	1 (Cerro Pabellón expansion)	33	120 (already secured)
Bolivia	1 (Laguna Colorada)	100	552 (already secured)
Total	2	133	0 (funding already secured)

<sup>66</sup> World Bank 2017.

public financing, grants and loans from international financial institutions, private equity, and loans from commercial banks. Within the LAC region, commercial lenders generally have been reluctant to extend credit for the exploratory stages of geothermal development. There have also been few high-risk investors, such as private equity funds, with the risk appetite and capital required to fund geothermal projects. Consequently, most successful geothermal ventures in LAC have been funded with public and development partner financing, at least during the initial stages of development. Governments and other public-sector entities have been making significant efforts to mobilize concessional funding for geothermal development and to attract private investors, but far greater support will be needed to fill the geothermal investment gap in LAC.

### **Geothermal Developers**

**In the absence of external financiers with sufficient interest in geothermal investment, geothermal developers often have used their own resources to fund exploratory activities.** This may help slightly lower the rate of return required by investors for these stages of development, but it also locks up a substantial portion of a company's capital into a single project for several years.<sup>67</sup>

**Publicly-owned developers have been key drivers of geothermal development in the LAC region.** Developers like ICE, ENEL(NI), LaGeo, and CFE developed over 1,300 MW of geothermal capacity in LAC, using their own balance sheets, as well as obtaining funds from their government partners and international financial institutions. In addition, these developers have also conducted critical exploration and pre-feasibility studies that have incentivized private sector developers to participate in the geothermal sector.

**Some larger, more established private geothermal developers in the region that have very strong balance sheets, such as ORMAT and ENEL(IT), have fully financed all stages of geothermal development.** Given the capital requirements of geothermal projects, many large-scale developers take a portfolio approach to developing this resource and diversify their resource risk by investing in multiple fields in various locations, but the presence of this type of developer in LAC is limited.

**In contrast, the medium-sized private geothermal developers in the region tend to focus their financial resources in only one or two markets.** While these entities still have good balance sheets that they may be able to leverage to raise finance for each project, their resources and ability to explore various fields simultaneously are limited. In a few cases, these entities may conduct much of the groundwork to develop a particular field (securing concessions rights, development rights, conducting several studies, and proving the resource) and then attempt to sell the project to a larger company.

### **Government and Public Entities**

**Today, the public sector is the largest investor in the geothermal sector in the LAC region, having developed the majority of the 1.6 GW of installed capacity in the region** (Table 4.6).<sup>68</sup> These entities often use their own government revenues or borrowing capacity to acquire loans and grants from different international and bilateral entities to fund this development. The high level of public sector participation is not surprising, since the electricity sectors with the highest levels of geothermal development, Mexico and Central America, have been historically managed by public utilities. In addition, the high-risk nature and large capital requirements of

<sup>67</sup> Identifying and verifying the availability of geothermal resources can take an average of two to three years. In addition, drilling and completing the construction of the plant can extend for another three to five years.

<sup>68</sup> Yopez-García et al. 2010.

geothermal development have driven governments to take a leading role in the region's geothermal sector.

### **Private Equity**

**Developers sometimes seek private equity investors to help fund the initial stages of a geothermal development, since these investors generally have a higher risk appetite.** However, private equity investors require rates of return that are commensurate with a high level of risk, which may limit a geothermal company's ability to offer competitive prices in the local markets. In the LAC region, private equity investors have mostly stayed away from early stage geothermal ventures, and either invested at a later stage or opted to invest in other renewable energy technologies that are more certain.

**There are several well-funded and established private equity funds with renewable energy portfolios operating in the region.** Recently, the private equity funds that have shown appetite for early stage geothermal investments are those established with a blend of concessional financing from international donors. The ability of these blended finance programs to mobilize private investment in the geothermal sector has shown that geothermal developers are receptive to these financing instruments, particularly those that offer incentives compared to other financing options available in the region.

### **Commercial Banks**

**Commercial banks have ample experience in providing loans for extractive energy businesses.** However, given the high-risk nature of geothermal development, commercial banks typically only involve themselves during the late stages of a project—once resources have been proven, and a PPA has been secured. Experience in LAC has shown that some commercial banks only consider offering financing for plant construction once at least 50 percent of the geothermal fluid required to fulfill the plant generation capacity is already available.

**Over the past few years, there have been a few partnerships between international financial institutions and financial intermediaries to develop credit lines with tranches earmarked for clean energy projects, including geothermal.**

For instance, the IFC and the European Investment Bank (EIB) together have allocated US\$225 million to projects in which they have partnered with banks in the region to support climate change mitigation projects through framework loans. However, the mid-term reporting of those institutions seems to suggest that the level of geothermal projects accessing this financing is low, compared to other clean energy options. Nevertheless, the fact that such programs are being established is a step in the right direction.

### **Development Finance Institutions**

**Multilateral and bilateral development finance organizations have played a key role in promoting the development of geothermal in the LAC region thanks to their ability to mobilize finance and technical assistance.** These institutions have supported geothermal development through technical assistance grants, direct loans to governments, project finance to private developers, lines of credits to financial intermediaries that provide financing to geothermal developers, and other financial instruments like concessional loans.

The **World Bank Group** is the leading multilateral development bank providing geothermal development assistance globally. With over US\$2.3 billion mobilized in investment financing and technical assistance, the World Bank Group accounts for nearly 60 percent of the US\$3.8 billion invested by all multilateral development banks from 1978 to 2017. The World Bank is present in the region through its own investment financing operations, as well as through the multiple funds it manages. ESMAP leads the Global Geothermal Development Plan (GGDP), an initiative by multilateral and bilateral development organizations to mobilize new funds for initial investment phases of geothermal projects,

specifically exploration drilling. Overall, the GGDP has raised US\$235 million so far, of which US\$70 million has been allocated to support development of projects in the LAC region. The World Bank is providing technical assistance to the governments of Chile, Dominica, Nicaragua, El Salvador, and St. Lucia to advance development of geothermal resources and will soon start supporting Mexico. The World Bank is also working to secure a combination of concessional and traditional loans and grants and to leverage additional funding from other development organizations to help its clients finance several geothermal projects in LAC. This includes the US\$48.2 million Geothermal Risk Mitigation Project in Dominica, the US\$22.5 million Renewable Energy Sector Development Project in St. Lucia, and the US\$45 million Geothermal Resource Risk Mitigation Project in Nicaragua. All are currently under preparation and are expected to be approved in 2018 and early 2019.

The **IFC**, part of the World Bank Group, offers debt and equity financing to the geothermal sector, with structuring options and technical expertise on issues such as resource risk. The IFC currently participates in three active financing lines in LAC that geothermal companies may harness: a US\$130 million loan to Banco Galicia that includes one tranche to finance sustainable energy projects in Argentina; a US\$20 million contribution to a US\$160 million fund (the Central American Mezzanine Infrastructure Fund II), which seeks investments in equity, quasi-equity, and subordinated loans in renewables; and a 10-year senior debt package for up to US\$75 million to Banco Bice to support a pre-identified pipeline of renewable energy projects, including geothermal. The IFC also made a direct US\$60 million investment to help develop the San Jacinto power plant in Nicaragua. With 72 MW in installed capacity, the San Jacinto plant is now the second operational geothermal power plant in Nicaragua.

The **IDB** began financing geothermal power in 1985, and has since financed geothermal projects

in Costa Rica, El Salvador, Bolivia, Chile, Nicaragua, Mexico, and the Eastern Caribbean. Currently, the IDB has five geothermal projects in execution and one more in the pipeline, comprising more than US\$1.3 billion in financing, which includes IDB's ordinary capital and co-financing from other donors. In addition, the IDB has a US\$4 billion joint venture with JICA (Co-Financing for Renewable Energy and Energy Efficiency) to support renewables in the LAC region, which includes geothermal. Geothermal co-financed projects in this joint venture include a US\$200 million loan to Costa Rica for the construction of the Las Pailas II and Borinquen I geothermal power plants. With JICA, the IDB also started a US\$600 million fund to finance renewable energy projects in Central America and the Caribbean, including for geothermal power generation.

The **Caribbean Development Bank**, together with the IDB, established a Sustainable Energy Facility for the Eastern Caribbean (US\$71.5 million in loans and grants) in 2015 to support renewables development, including geothermal power. Part of this facility uses concessional financing from the CTF (US\$19 million) and a grant from the Global Environmental Facility (US\$3 million).

On the technical assistance side, there is also a Regional Geothermal Training Programme (US\$2.7 million) jointly financed by the **Nordic Development Fund** (NDF), IDB, and the government of El Salvador. Its objective is to develop a geothermal training program and facilitate the training activities in El Salvador to serve the LAC region.

**JICA** also has direct geothermal lending programs in the region to support resource development and construction of geothermal plants. JICA's support includes a concessional loan of US\$560 million in Costa Rica for the construction of several geothermal power plants in the Guanacaste Province and a concessional loan of US\$552 million to the government of Bolivia to finance the development of the Laguna Colorada field.

**The EIB** has an energy portfolio that includes activities to support the construction, extension, and rehabilitation of renewable energy power plants. For projects above US\$26 million, the EIB can either provide direct finance to project promoters or indirect finance through a government or other financial intermediaries. The EIB currently uses both mechanisms in the geothermal space in the LAC region. In Costa Rica, the EIB is financing the construction of a geothermal plant (Las Pailas II, US\$60 million). The EIB also partners with national and regional banks to support climate change mitigation projects through framework loans, such as its recently approved US\$150 million loan to Banco de Santander in Chile to increase finance options for renewable energy projects in the country.

In addition to its participation in multi-donor programs, the **German Center for International Cooperation (GIZ)** started a program to promote geothermal in Central America. With US\$6 million in financing, the initiative seeks to improve the investment climate and human resource capacity to facilitate the implementation of geothermal projects in the region through policy dialogue, knowledge dissemination, capacity building, and direct project development. The program is active in Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama.

**AFD** is only present in the region's geothermal space through its participation in multi-donor initiatives. In the past, AFD has also provided direct finance to geothermal projects (for example, a concessional, non-sovereign loan of about US\$10 million to finance exploratory drilling in Dominica in 2008–2012).

### **Multi-Donor Funds/Facilities**

**There are also several multi-donor funds and facilities that both governments and geothermal developers may access to help finance geothermal projects in the region.** International finance organizations and donor countries have developed a suite of tools that governments and private sector entities can use to expand both renewable energy and geothermal development in LAC and globally. These tools include cost-sharing drilling schemes, grants for surface level studies and pre-drilling work, and concessional loans, among other financing instruments. Some of the regional and global multi-donor facilities and funds that LAC countries may access to expand geothermal development include:

The **Geothermal Development Facility for Latin America (GDF)** is a multi-donor initiative to promote geothermal energy in the region by promoting both public and private investments.<sup>69</sup> It was established primarily by the German government, KfW, and the European Union, and in collaboration with other partners such as the World Bank, ESMAP, Development Bank of Latin America (CAF), Central American Bank for Economic Integration (CABEI), IDB, AfD, EIB, JICA, NDF, German Federal Institute for Geosciences and Natural Resources (BGR), and GIZ.<sup>70</sup> The initial capitalization was €50 million for risk hedging instruments, with an anticipated €700 million for credit lines to be pledged over time. The duration of the facility was established at 10 years.<sup>71</sup> The GDF will finance preparation, exploration drilling, production drilling, and construction through its financing lines. The surface exploration grants cover up to 40 percent of the cost of these activities to a maximum of

<sup>69</sup> GDF is managed by IDA Fund Management, which is a consortium of Interlink Capital Strategies, a management consulting firm, and Dewhurst Group, LLC, a geothermal exploration and development company with offices in Latin America.

<sup>70</sup> The grant providers are the German Federal Ministry for Economic Cooperation Development (BMZ) and the European Union through the Latin America Investment Facility (EU-LAIF), respectively, through KfW Development Bank. Further grants are foreseen by members of the Stakeholder Group and third donors. GDF Stakeholders are BMZ, EU-LAIF, KfW, CAF, CABEI, World Bank, ESMAP, IDB, AfD, EIB, JICA, NDF, BGR, and GIZ.

<sup>71</sup> Funds approved to date. When it was first launched in 2014, the facility was expected to provide at least US\$75 million in tailored risk mitigation instruments and US\$1 billion in tailored bridge and investment financing.

€0.6 million. For exploration drilling, financing covers up to 40 percent of the cost of exploration drilling of as many as three wells, to a maximum of €5.8 million. If exploration is successful, project developers commit to repay 80 percent of the funds received, which can be refinanced through bridge and investment financing lines provided by the different multilateral and bilateral development banks that are part of the facility. If the exploration results are unsuccessful, then there is no repayment by the developer. The facility allows up to one project per developer, per country, to be submitted during each application round for each type of instrument. Overall, the GDF seeks to facilitate at least 350 MW of geothermal generation capacity development in the LAC region.

To date, the **GDF** has undertaken one round of financing, providing US\$22 million in grants for drilling activities and surface studies in six countries (Colombia, Guatemala, Honduras, Bolivia, Ecuador, and Chile) for eight projects (four exploration drilling programs and four surface studies programs). If successful, the first round of GDF funding is expected to support the development of 285 MW of new geothermal capacity and leverage up to €1.6 billion in future investments. In December 2017, GDF called for expressions of interest for its second round of financing and received 16 applications for seven different LAC countries. The Call for Proposals stage will be completed in July 2018, and it is expected that GDF will select between six and eight new projects that could potentially add up to 600MW of additional generation capacity.

The **CTF** is a funding window of the CIF that promotes concessional lending, guarantees, and grants to both public and private entities globally. This multi-donor fund is being utilized by the World Bank, African Development Bank, Asian Development Bank (ADB), European Bank for Reconstruction and Development (EBRD), and the IDB to fund clean energy projects in a number of countries. It has US\$5.8 billion in resources,

with US\$3.8 billion already under implementation (including the US\$235 million funding for early stage geothermal exploration raised by the GGDP). The CTF invests in renewable energy and clean technology projects. In LAC, CTF funding has primary focus on Brazil, Chile, Colombia, Mexico, and Peru. There are several CTF funded geothermal operations under implementation in the LAC region—in Mexico, Colombia, Chile, and the previously mentioned sustainable energy fund for the Caribbean—that are being channeled to clients through the World Bank, IDB, and CDB. There are also several geothermal projects under preparation (in Dominica and St. Lucia) that would be co-financed with CTF funding extended through the World Bank.

Another comparable multi-donor effort is the **Scaling Up Renewable Energy in Low-Income Countries Program (SREP)**, a program to channel resources for renewable energy solutions in low-income countries through five multilateral development banks. The only LAC countries that qualify for the funds are Nicaragua, Honduras, and Haiti. Currently in the LAC region, SREP finances only one geothermal project, which is in Nicaragua. SREP resources are channeled through the IDB (US\$6.75 million in contingent recovery grant and US\$750,000 in grants), which is financing geothermal exploration in the Cosiguina field and transmission improvement. The SREP Investment Plan for Nicaragua also allocates an additional US\$15 million in concessional financing for geothermal development to be channeled through the World Bank.

The **Green Climate Fund (GCF)** that recently was set up by the 194 countries that joined the United Nations Framework Convention on Climate Change also seeks to promote low-emission technologies and climate resilient development by leveraging public investments to mobilize private finance. Current pledges to this fund exceed US\$10.3 billion. Funding applications to the GCF can be submitted directly to national and sub-national organizations, reducing the necessity of

using international intermediaries. Projects in Least Developed Countries and SIDS have preference. So far, only one geothermal project in the LAC region has been awarded with GCF funds, an US\$80 million package to fund the development of up to 60 MW of geothermal power plants in the Eastern Caribbean that is being managed by the CDB and IDB.

The **Global Environmental Facility (GEF)** is a multi-donor trust fund, supported by 39 donor

countries and administered by the World Bank, that provides countries with finance and technical assistance to meet international environmental conventions. One of its main programs in the LAC region that could be tapped by geothermal actors is the Multilateral Investment Fund-IDB PPP Platform for low carbon technology investment financing (US\$15 million). The current replenishment period (GEF-6, 2014–2018) received pledges of nearly US\$4.5 billion, and set aside special allocations to fund programs with the private sector.

## CHAPTER 5: POLICY, LEGAL, & REGULATORY REFORMS TO IMPROVE THE INVESTMENT CLIMATE

**P**olicies, laws, and regulations are key factors that influence geothermal developers' investment decisions worldwide.

A country may have abundant geothermal resources of developable, commercial quantity that can help meet the nation's energy demand, but global experience has shown that this source of stable and clean energy consistently remains underdeveloped when the country's policymakers do not first address the policy, legislative, and regulatory barriers that limit the development of geothermal energy production. A major barrier in geothermal development worldwide has been the lack of a comprehensive framework. Such a framework should: (i) put appropriate policy mechanisms in place to spur and maintain significant levels of growth in the private market; (ii) provide clear direction for geothermal energy development through the promulgation of laws and regulations; and (iii) address institutional constraints and build institutional structure to support geothermal development.

**Geothermal legal regimes in the LAC region are a patchwork quilt of differing legal approaches—some that support and some that inhibit geothermal resource development.** In an effort to encourage the use of geothermal energy, a number of jurisdictions in the region have enacted laws and promulgated regulations that specifically address geothermal resources as a discrete (*sui generis*) resource. There are thirteen LAC jurisdictions that have geothermal-specific legislation or regulations in place or in draft form, which means that only about half

of the countries and territories with estimated and installed geothermal potential in the region have geothermal-specific legislation in place. The term “geothermal-specific” refers to laws and regulations that are focused on reconciling and harmonizing conflicting rules that can stand in the way of expeditious development of national geothermal resources.

**Just because a country has not enacted a geothermal-specific law does not mean that its geothermal resources are undeveloped, ungoverned, or unregulated.** Only five of the eight jurisdictions in LAC with installed geothermal capacity have a geothermal-specific legislation in place. For example, Guadalupe, which has neither a geothermal-specific law nor regulation in effect, has still developed geothermal power generation capacity. El Salvador and Honduras also do not have geothermal-specific legislation in place despite having installed geothermal capacity. In LAC countries that do not have geothermal-specific laws, the laws that govern geothermal are based on dramatically divergent legal principles. Since geothermal resources are to some extent mineral commodities, some countries manage resources through mining or mineral laws (Bolivia and Argentina). Given that geothermal energy is a sustainable resource, energy and electricity laws have been applied (El Salvador, Guatemala, and Panama). Since geothermal fluids may impinge on groundwater reserves, laws governing underground drinking water may also factor into the governance of geothermal fluids in most LAC countries. In some

nations, LAC resources are also governed in part by common law (in common-law countries such as Dominica, Grenada, and Montserrat) or by French civil law (St. Lucia and Martinique). To further complicate the governance of geothermal resource development, the awarding of electric concessions is often governed independently of geothermal resource legislation. Electricity generating concessions and the right to sell to the grid are crucial to successful geothermal development, since governmental geothermal policies in the LAC region generally focus on power generation, rather than on secondary uses such as agriculture or geothermal heating and cooling.

**Successful geothermal resource development requires the harmonizing of multiple rules at every level of government.** In some LAC countries, environmental protection statutes have been enacted without considering the unique characteristics of geothermal resources. At the local level, zoning regulations and building permits may apply that do not necessarily allow for the realities of geothermal drilling and generation. In some LAC countries, private landowners may own the land and the resources, in other countries private landowners may own the land but not the resources.

**Consistent with the overall trend in LAC, the geothermal sector has also been trying to encourage more private sector investment, as illustrated by the actions of countries like Mexico, Chile, and Argentina.** For example, for many years, the GoM funded geothermal green-field development. However, as Mexico has shifted to a policy allowing private sector development, it enacted a geothermal-specific law and promulgated a geothermal-specific regulation, as well as complementary environmental protection laws to provide greater clarity and certainty to investors.

**The interplay of laws and regulations that impact geothermal development in LAC is extraordinarily complex.** Geothermal

development runs the gambit from drilling for the heat of the earth and extracting geothermal fluids from below its surface, to generating electricity on the surface directly above the resource. Dozens of rules, regulations, licenses, and laws are at play—and since many were originally designed without geothermal resource development in mind, they are often applied in ways contradictory to efficient development of the resource. Countries throughout the region are therefore crafting laws designed to reconcile such legal impediments to geothermal development, as well as to facilitate private sector investment in generating electricity from this green, sustainable, indigenous resource.

**Policymakers in LAC should consider incorporating a number of critical elements into their policy and legislative framework to effectively govern development and operation of the geothermal sector.** This chapter addresses the framework in which geothermal resource policymakers operate, and explores best practices from global and regional experience for establishing a national strategic policy and deploying legislative and regulatory tools to overcome geothermal policy hurdles. These approaches can be adapted for application in LAC countries to facilitate expanding the region's geothermal capacity.

## Establishing a National Strategic Policy Framework

### Articulating National Goals in a National Strategic Policy

The importance of a clearly stated national strategic policy on geothermal resource development cannot be overstated. Historically, when a country fails to establish meaningful policy goals, geothermal development flounders (such as in Chile, Eritrea, and Indonesia after the Asian crisis). Without clearly articulated strategic goals, the architecture of the implementing laws and regulations may well lead to suboptimal outcomes. For example, it may be counterproductive to promote the development of atomic energy,

hydropower, and geothermal resources without first harmonizing the interrelation of these sources in the energy mix. From the perspective of any potential investor in the geothermal energy sector—be it private sector investor, lender, or public sector donor—the direction, predictability, and stability established by the policy framework determines the investment climate.

### Identification of Strategic Elements

One of the first steps required to develop a national policy framework is the identification of strategic elements. In formulating a national energy policy, the policymaker’s task is first to identify broad national goals such as rural electrification, lower energy costs, and carbon footprint reduction; secondly, to analyze to what extent these goals may compete; and, finally, to focus on how these competing goals may be harmonized in a context of domestic political and economic priorities. Since national goals often compete with one another, the policymaker’s priority is harmonizing these competing goals with domestic political priorities. For example, it is environmentally sound to reduce carbon footprints both by preserving forest land and by promoting clean, geothermal energy. However, in Indonesia, estimates suggest as much as three-quarters of the country’s geothermal resources are under what is known as “Protected and Conservation Forests.” Since the 1999 Forestry Law of Indonesia precluded the development of “mining activity” in the forests and since geothermal resources were until 2016 governed by the mining law, the national government needed to reconcile the legitimate goals of geothermal development and forestry conservation—a process that took almost a decade and a half.

The check list set forth in Table 5.1 is intended to serve as an aid to the policymaker to ensure that most relevant strategic issues are considered.

### Identify Potential Hurdles to Achieving National Geothermal Goals

A meaningful strategic policy includes an analysis of the hurdles or impediments that have

frustrated strategic policies in other nations and that are likely to have a domestic impact. In this analysis, the policymaker identifies risks and hurdles and initiates measures to overcome them.

Among the hurdles that have been identified in various legal regimes are:

- Constitutional barriers;
- Unreliable resource information;
- Inability to finance a PPA or SSA;
- Lack of local technical capacity;
- Underdeveloped human resource capacity;
- Currency not convertible;
- Unwarranted favoritism for domestic developers;
- Unpredictable electrical supply and demand market;
- Resources not commensurate with predictable national need;
- Inadequate infrastructure;
- Externalities not factored in to evaluations of cost;
- Ownership conflicts; and
- Gaps in legislative and regulatory framework.

### Adapt Best Practices to Local Circumstances

Identifying best practices from other countries for overcoming barriers is a useful starting point, but the country-specific context must also be considered. Policy tools used in one country could be difficult to replicate with the same results in another country. The best approach for a policymaker is to adapt international best practices and solutions to a nation’s unique environment, resources, and politics.

### Inventory of the National Energy Profile

Sound policy and effective laws and regulations for implementing a national geothermal policy regime should be formulated in the context of an accurate and up-to-date inventory of real-world country conditions. When formulating policy and setting forth geothermal laws, a prudent policymaker may:

**TABLE 5.1: A Policymaker’s Checklist to Use in Formulating a National Geothermal Strategy**

Issue	Strategic considerations
Identify reason(s) to promote geothermal development	Describe and prioritize strategic geothermal resource development objectives. For example: <ul style="list-style-type: none"> <li>• Reduce cost of electricity to rate payer</li> <li>• Rural electrification</li> <li>• Diversify energy mix (reduce dependence on fossil fuels and hydropower)</li> <li>• Meet environmental clean-fuels goal—reduce carbon footprint</li> <li>• Use domestic fuel sources (reduce dependence on imported fuels)</li> <li>• Develop direct uses</li> </ul>
Obtain best investment in geothermal development	Establish speed of development required to meet goals. Determine concessionary measures and incentives to meet all goals in time targeted: that is, the expenditure of government funds or the creation of incentives to ensure that the grid is augmented by new geothermal energy in the prescribed time.
Obtain best financing for geothermal development	Determine the relative roles of donors, private sector investors, public sector and private sector lending institutions, and governments at all levels. Most geothermal development by the private sector is project financed, meaning that the developer collateralizes the income stream from a PPA or Steam Sales Agreement (SSA) to obtain a loan. Will the central government issue guarantees or letters of comfort if the off-taker is parastatal or government-owned?
Allocate costs between public and private sectors	Determine the requisite mix of public and private sector investment that is politically as well as financially feasible. Evaluate the appropriate balance between the roles of the public and private sector with respect to developing the infrastructure and in controlling or owning the geothermal resource below both public and private lands.
Allocate responsibilities among national & local governments	Evaluate the relative roles of the central government, regional and local governments, and private persons in owning and leasing geothermal resources. Determine the appropriate jurisdiction to award the rights to develop geothermal resources, both for electrical use and direct use. Will all licenses in a single geothermal resources area be issued by the same jurisdiction?
Allocate development benefits among the stakeholders	Determine the allocation of benefits among the stakeholders: <ul style="list-style-type: none"> <li>• Will the public good be better served by a lowered cost of electricity or repayment in the form of royalties or taxes (or some mix of the approaches)?</li> <li>• How will the national government recover the cost of preparatory development work and regulatory oversight expenses?</li> <li>• How will local jurisdictions participate in economic development in their area?</li> <li>• How will private landowners be compensated?</li> <li>• What is the appropriate formula for determining private sector investor return on investment and loan repayments?</li> </ul>
Allocate development between electricity and direct use	Determine how to prioritize allocation of resources between generation and direct uses. Will a generation concession also grant the concession holder the right to develop direct uses or will direct uses be subject to separate concessions (issued by whom)?
Determine who bears the cost of market access	Who provides transmission? In an unbundled market, does the generator or the transmission authority bear the cost of transmission, and how is this cost factored into the evaluation of geothermal as a least-cost energy source? Can an IPP sell (distribute) directly to an end customer or only to a monopoly distribution company? Will a consumer be allowed to self-generate?
Identify and resolve other significant national issues	Will rural electrification be promoted? Is this a goal that will be subsidized? How significant a factor is employment of nationals in the development equation?

Source: World Bank.

- Identify geothermal sites and determine what statutes, policies, entities, or persons control the rights to access and to develop those sites.
- Inventory and reconcile all existing laws and regulations that may affect geothermal development.

- Identify all national and local government institutions that may issue any authorization that in some way controls geothermal development, including secondary authorizations such as building permits issued by local jurisdictions.

### Identification of the Stakeholders and Their Respective Roles.

Identification of all governmental and non-governmental stakeholders and their potential role in promoting or impeding geothermal development is a critical part of executing a successful strategy. Early inclusion of decision makers, influencers of public opinion, and power brokers may help build consensus and prevent last minute and unanticipated obstructions from arising.

### Legislative Best Practices

The national strategic policy articulates national goals, but legislation is needed to articulate and apply these goals. A clear understanding and acceptance of the government’s policy goals is essential to implement the legislation needed to reach those goals. Furthermore, the drafters of the legislation must be able to identify and set the objectives (or tactics) that are best suited to achieving those goals in an expeditious and effective manner.

The legislation developed should seek to institute these goals and remove any identified specific barriers. When development of geothermal resources for the production of base-load power has been identified as a national priority, and investment in that development by the private sector is desired, the drafters of geothermal legislation should strive to remove any identifiable legal barriers to investment in geothermal technologies. Laws striving to achieve such ends can provide a basic structure for the ownership and financing of sustainable geothermal resources and set forth incentives to encourage investment by competent developers.

The most effective legislation meshes market supply and demand, resource potential, and

institutional capacity with the tactics or strategy that might best ensure that policy goals are reached in an effective and timely manner. The following sections explore the implementation tools available to policymakers and the best practices for legislation derived from the experiences of many countries.

### Governance Tools

Legislation is the preferred tool used to achieve the predictability and stability in national-level policy that is conducive to a favorable geothermal investment climate. This may involve:

- **Legislative vehicles.** In many countries, the laws governing geothermal resources (such as the mining law of Indonesia, the spa law of Japan, and the water laws of numerous U.S. states) were enacted without contemplating the possibility that geothermal resources would be involved. Treating resources as unique and complex as geothermal energy resources as “water” or as a “mineral” usually leads to legal confusion and unpredictable results. It is essential that a law designed to encourage the development of natural resources reflect the science and engineering needed to develop geothermal resources.
- **International precedent.** As with policy, the legislative practices in countries that develop geothermal resources are instructive, but wholesale transfer of the geothermal laws of one country to another is generally not practical. Just as geothermal resources, electricity markets, and the geography of each country may differ, similarly the legal, institutional, and cultural regimes differ. These variances must be factored into legislation in each jurisdiction.

Internationally, geothermal energy is explicitly addressed in various legislative vehicles:

- Specific legislation on geothermal energy (Nicaragua, Kenya, the state of California in the U.S., and United States federal law),

- Mining/mineral law (Argentina, Germany, and Philippines),
- Water law (the state of Idaho in the U.S.),
- Energy or electricity law (El Salvador, Guatemala, and Panama),
- Other legislation (such as Japan’s spa law or South Australia’s petroleum law), and
- Multiple laws (water, as well as sui generis specific legislation on geothermal energy, as in Iceland).

An analysis of the pros and cons of each of these approaches when drafting national legislation to meet national policy goals is essential to produce a sound result. Based on global experience, a discussion of some of the most critical elements to cover in legislature used to govern geothermal sector development and operation follows.

***Address All Potential Uses and Applications of Geothermal Resources***

Ideally, a geothermal law should address all present and potential applications of the geothermal resources, both for electricity and for direct use. The law should properly address the known, anticipate the obvious, and build in some mechanism for course correction when the unanticipated occurs.

***Address Geothermal Resource Ownership***

It is essential to clarify ownership of a country’s geothermal resources. National law may be ambiguous as to whether and to what extent geothermal resources are owned by the state or are part of the surface or mineral estate. Such uncertainty must be clarified and resolved for development to occur.

***Address Transparency When Awarding Exploration, Drilling, and Exploitation Grants***

Defining the award process for geothermal development and usage rights is also key. When the private sector is engaged in the development process, best practice is to provide a clear and transparent process for the granting of permits, licenses, and concessions. If geothermal resource

areas are to be auctioned, a transparent process that ensures maximum participation of technically and financially qualified geothermal development firms is also important.

***Incorporate “Use-Or-Lose” Policy***

It is also important to specify the time period in which geothermal resource development or use must occur or the rights to these resources are lost. Best practice for granting any natural resource concession includes incorporation of a “use-or-lose” policy encapsulated in a law, license, or concession that defines time limits for the various stages of geothermal development. If not met, these provisions mandate the return of the resources to government control. Such policy may include incremental mechanisms or milestones that will prevent geothermal resource areas from being held by speculators or under-funded developers without meaningful development.

***Provide for Sustainability***

Legislation should guide use of geothermal in a sustainable way or ensure that sustainability is the duty of the concession holder. Ensuring that the steam field is maintained at a “sustainable condition” is key to long-term electricity production. Sustainability, in this instance, means long-term electricity production. Ideally sustainability is the policy goal, but it may not be a realistic legislative option because the sustainable production capacity of geothermal systems is unknown beforehand.

***Provide for Reclamation***

Legislation should anticipate the steps to be taken when geothermal resources are no longer sustainable, or when the economics of development result in a developer withdrawing from a development area. It should define how the geothermal resource area is to be returned to its original condition.

***Address Coexistence of the Classes of Uses of Geothermal Resources***

In a defined, discrete geothermal resource area, in which a variety of uses may be made of the same

geothermal resource, two approaches have been undertaken: “prioritization” and “monopoly.”

- **Prioritization** means that, within a discrete geothermal resources area, multiple concessions, licenses, and permits may be issued to multiple parties. For example, one concession may be for electricity production and another may be for a spa; however, laws and regulations prioritize the uses to which geothermal resources may be put.
- **Monopoly** within a discrete geothermal resources area means that all concessions, licenses, and the ability to sub-license are awarded exclusively to the winning bidder for the electricity concession. In other words, one party receives a monopoly.

#### **Ensure that Requisite Rights of Use are Incorporated in a Geothermal Resources Concession**

There are rights that are prerequisite to geothermal development, rights that are implied or secondary, and other rights that incentivize the private sector, but are not prerequisite. These rights should be incorporated into any concession or omitted only after due consideration. The following sections address prerequisite, implied, and incentive rights.

#### **Prerequisite rights**

Geothermal resource concessions must provide the concessionaire with the rights to enter the geothermal resources area for the purpose of generating and transmitting electrical power from geothermal resources. The prerequisite rights that a concessionaire must have on a geothermal resource site are threefold and include:

1. **The right to access and develop the site**, meaning the right to occupy and use land. A concessionaire who secures the rights to geothermal resources also needs to secure the right to enter and exit the surface land overlying the geothermal resource in order to situate drilling wells and generation

facilities. These rights must be reconciled with the legal rights of the surface owners, whether on public or private lands.

2. **The right to use the energy resource** means the right to extract, take, use, and apply geothermal resources on or under any land that is the subject of a geothermal resources concession. Any questions regarding the title to the geothermal resources will need to be resolved and the owners’ relative geothermal, mineral, water, and surface rights will need to be addressed.
3. **The right to sell electricity** simply means the right to generate, transmit, and sell electricity. Before beginning a project, geothermal energy developers need to be confident that they can make a return on their investment. The developers need rules to ensure that they will be able to sell the electricity they produce at a reasonable price.

#### **Implied (secondary) rights**

The explicit right to access and develop the site implies several indirect (secondary) rights. The following are examples of indirect rights from multiple geothermal laws:

- Transmit, use, supply, and sell electricity;
- Erect, construct, and maintain temporary housing and buildings for the concessionaire’s own use and for use by the employees of the concessionaire;
- Erect, construct, and maintain the plant and buildings;
- Erect, construct, provide, and use such works, machinery, and appliances as may be necessary for the purpose of generating electricity and in connection with the reclamation, utilization, and reinjection of geothermal fluids, including water;
- Utilize spent fluids exiting from a power plant for non-electrical purposes;
- Construct and maintain roads and other means of communications and conveniences; and
- Reclaim and utilize any geothermal by-products.

### ***Incentivization rights***

When national policy seeks to encourage private sector investment, a variety of legislated incentives may be authorized, such as a tax holiday, repatriation of income in the form of hard currency, and facilitation of work visas for foreign workers, among other possible incentives.

### ***Establish How Surface and Sub-Surface Land is to be Awarded***

In many countries, access on state-owned lands is provided by concession grants, but in others the private sector developer will need to negotiate and to reach agreements with private property owners. The open issue is whether and to what extent the government assists the developer in gaining such access, especially over private lands. In the event that a private property owner suddenly inflates the price of the land because, for example, it is changing from an agricultural farm to a geothermal production site or if the land owner simply refuses to grant access to the land, most governments have the ability to step in and moderate the price of the property.

One name for this step-in right is “eminent domain”, which means the right of a government to take private property for public use, with payment of compensation. Certain geothermal-specific laws in Latin America (Nicaragua, Peru, and Mexico) imply that the concessionaire will reach agreement with landowners, but geothermal activity is deemed to be “used by the public” under the law, a designation that gives the government considerable reserve power to step in.

The step-in power of the government is generally a strong tool for the developer in negotiation with private landowners, who understands that not reaching a reasonable agreement with the geothermal developer means forced access under

compensation defined by legal terms (such as cadastral values, frequently not aligned with market conditions). Whether this step-in right is used is a political decision.

### ***Reconcile the Rights of Multiple Concessionaires Who May Be Tapping into the Same Reservoir***

More than one person may have concessional rights to a single geothermal field or resource. While sole ownership is not necessary, a clear understanding of state ownership rights and processes could reduce this potential barrier to development, which complicates project financing as well as utilization rights and issuance of concessions. An extreme example is when a geothermal field extends across a national border, as is the case with the Tufiño-Chiles prospect that lies across the border between Colombia and Ecuador.<sup>72</sup> The majority of international geothermal legislation that considers the issue of multiple concessionaires tapping into the same resource relies on the concept of sustainable exploitation of the resource as a unitized operation. The terms “unitized operations” or “unitization” refers to reservoir-wide development and the concept that development and production of geothermal resources will be under coordinated management. The objective of unitization is to coordinate the development and operation of an entire producing reservoir so that exploration, drilling, and production can proceed in the most efficient and economical manner and that avoids overexploitation and depletion of the field due to multiple users.

### ***Follow Best Practices in Establishing the Length of Time a Geothermal Resource Concession May Be Held***

The length of time granted for a geothermal resource concession must, of necessity, account for the time required to explore for a commercial quality resource, to drill and to establish a steam

<sup>72</sup> In this case, the governments of Colombia and Ecuador have signed a bilateral agreement on the development of the resource. (Haraldsson 2012).

field, to construct a generating facility, and to connect with the transmission network. All of these activities should occur within the timeframe authorized in one or multiple government authorizations and must occur within the regulatory framework of the host country. Time to obtain the equity and debt financing must be factored in. Recalling that the majority of geothermal generating facilities are project financed, this additional period of time must be sufficient to allow repayment of debts. In addition, after commercialization of the resource, there must be a period of time built-in for cost recovery.

- ***Timeframe of the concession.*** Preparatory work (from reconnaissance and exploration to resource confirmation) generally lasts from two to five years and an exploration concession is often used during this period. In various countries, the exploration concession period can be extended. The time frame for an initial exploitation concession typically ranges from 20 years to 35 years.<sup>73</sup> Five to 20-year renewal periods have been used. For example, the new Indonesian geothermal law provides that the maximum exploration period (including the period for a feasibility study) is five years, which can be extended twice for one year each time. The maximum term of a geothermal exploitation license in Indonesia is 37 years, and extensions can be granted for a maximum of 20 years for each extension.
- ***Timeframe for generation and exploitation.*** When a generation license that is separate from a steam production license is required for geothermal operations, alignment between the timeframes for electricity generation and resource exploitation will be needed to avoid legal gaps. For example, at the request of geothermal developers, the length

of geothermal exploitation concessions in Nicaragua has been increased from 25 years to 30 years to align the resource exploitation concession and generation licenses. This extra time allotment avoids situations in which a geothermal operator might be committed to continue delivery of energy to the grid after the operator's resource exploitation right has expired.

#### ***Address definitions in the legislation***

Definitions are the heart of any legislative or regulatory document. By addressing fundamentals, legal ambiguities may be addressed, and downstream legal conflicts may be avoided. There are a number of essential definitions that are required in any law addressing geothermal resources, and they may determine whether a specific legal regime succeeds. The most fundamental definitions are those for “geothermal resources” and “geothermal resources area.”

### **Best Legislative Practices Designed to Facilitate Private/Public Sector Development**

#### ***Facilitating Private-Sector Investment***

If the government determines that geothermal resources will be developed by the private sector, with the private party either serving as an IPP or participating in a PPP, the private sector developers must secure two fundamental legal rights as a pre-condition to obtaining financing:

- The exclusive right to explore for geothermal resources in a defined geothermal resources area and to extract the geothermal resources in that area; and
- The right to generate and sell electricity to a legitimate buyer.

<sup>73</sup> To illustrate the typical exploitation concession period granted in various countries includes 20 years (Romania), 25 years (Poland), 30 years (Italy, Kenya, France, Slovakia, Nicaragua, Peru, and Mexico), 32 years (Nevis, Dominica), 35 years (Bulgaria), and 37 years (Indonesia).

### **Ensure a Financeable PPA**

Lack of a bankable PPA has been a major impediment to geothermal development worldwide. A bankable PPA or SSA are essentially long-term agreements, signed with a creditworthy off-taker, that enables repayment of debt by providing an adequate and predictable revenue stream. Loan financing requires an off-take agreement by a solvent buyer—usually in the form of either a PPA or an SSA. The creditworthiness of the off-taker is key to obtaining finance, and government guarantees are often required for projects in which state-owned enterprises are parties. The government should thus consider actions to ensure bankable PPAs and SSAs.

### **Establish Institutional Capacity**

To ensure institutional capacity, a government focused on developing geothermal capacity on any large scale should appoint a lead agency and ensure that the agency has the legislative mandate to manage its responsibilities. Other governmental actions that can be taken include:

- Expedite all steps of the geothermal process, from tender through authorization to electricity production. Delays in the development process add to the cost of electricity generated—a cost which is usually paid by end users.
- Minimize the number of agencies and institutions involved in regulation and issuing government authorizations, or create a single agency to manage geothermal development.
- Provide the lead agency with the capacity and authority to design appropriate policies, negotiate agreements, and monitor and facilitate investor activities.
- Explore whether creation of a geothermal development state-owned enterprise to produce steam and/or to generate electricity will advance national policy goals.
- Establish a legislative basis for PPPs, if such does not exist and is warranted.
- Provide domestically trained personnel with the expertise to effectively implement and

monitor exploration, drilling, and exploitation activities.

- Determine whether third-party transaction advisory services are desirable to augment the domestic cadre.
- Avoid inherent conflict of interest by ensuring that the agency promoting development is not the agency regulating it.
- Organize the internal operations of the responsible government entity to ensure that the ministry, department, or agency responsible for geothermal resource development can perform its promotional or compliance function.
- Ensure that there is inter-institutional coordination, so government entities talk to each other on a regular basis.

### **Institutionalize Fiscal and Non-Fiscal Incentives**

Policymakers should consider institutionalizing fiscal and non-fiscal incentives designed to allow the country to be competitive with other countries in attracting geothermal investment.

### **Balance Competing National Interests**

Ensure that there is a balance between the developer's needs, the legal rights that government must grant the developer to fill those needs, and the accompanying legal duties that the government should impose on the developer. Competing interests that often need to be reconciled include:

- The need to ensure that national resources are held for the benefit of the people and are not exploited without adequate compensation against the need to ensure that the electricity charges to the end user consumer (the general public) are both low and stable.
- The need to ensure a bankable project that allows the project to proceed through mobilizing private finance, for both the exploration and exploitation stages against the need to comply with government objectives to reduce returns to minimize electricity prices.
- The need for additional electricity generation capacity against the need for responsible

protection of the environment, local communities, and landholders' rights.

### Regulatory Best Practices

**The general purpose of regulatory regimes globally is to detail the steps required to implement the policy goals and objectives set forth in laws.**

After identifying goals through the national energy policy and then establishing them through legislation, policymakers must articulate in regulations the best way to ensure the execution of those goals. Regulatory rules should be successfully communicated both within the government and to the stakeholder community and enforced in a consistent manner.

### Inventory Regulatory Tools

The principal regulatory tools that the government may use to enforce the national policies and legislation are government authorizations and penalties if infractions occur. Such authorizations will vary from country to country and may be issued in various ways, such as licenses, permits, clearances, company incorporation documents, environmental impact assessments, contracts (such as PPAs and SSAs), or other measures that require investors, developers, or government agencies to prepare documents and receive a government clearance before the applicant can proceed. For example, such documents include land-related clearances, which usually must be obtained from local governments, or sometimes from regional and national governments. Almost every investor has to acquire land and construction rights as a pre-condition to constructing a power plant. In smaller markets where there may be only one or two geothermal projects, the policymakers may also self-regulate or regulate by contract. The larger and more sophisticated markets (such as the United States) typically use a larger number of regulations.

### Best Practices in Regulatory Regimes

Various best practices from regulatory regimes in different jurisdictions that LAC countries may consider include:

- **Establish objective criteria.** Establish objective criteria for granting government authorizations for surface reconnaissance, exploration drilling, production drilling, power plant construction, and the different phases of geothermal development and operations.
- **Institute a rational concession system for investors to proceed from one development phase to the next.** Rights for exploration and exploitation of geothermal resources may be awarded to private developers through a single or multiple stage concession system. The single concession system grants a developer an all-in-one right for the complete geothermal exploration-development-exploitation process. The multiple stage concession system generally separates the exploration and exploitation phases. In both the single and multiple stage systems, exploration and exploitation are regulated as milestones or phases of a legal and administrative permission procedure. The major difference between single and multiple stage concessions is that in a single stage concession the concessionaire proceeds automatically from one stage to another, unless it fails to perform according to the terms of the concession. In a multiple stage concession, the concessionaire proceeds to a subsequent stage only if it can show that it has achieved the specific milestone(s) set in regulations. The difference is subtle but significant, as it shifts the burden of proof to the developer in multiple phase systems.

To illustrate, in Mexico, Nicaragua, Peru, and Chile, where geothermal-specific laws have been enacted, a multiple step concession system is applied. Single concession systems are more commonly used where geothermal is regulated within other energy or mineral resource laws. Worldwide, both single (for example, in Indonesia) and multiple (for example, in British Columbia, Indonesia, Italy, Kenya, and some states in Australia) concession systems are linked to geothermal-specific regulations. The multiple concession system is more common than the single one.

### **Safeguard Against Speculation**

In any geothermal concession system, the government, as both policymaker and owner of the geothermal resource, can use regulatory mechanisms to prevent speculation in geothermal resource areas by introducing specific safeguards:

- To prevent non-productive developers freezing out other, potentially productive developers;
- To ensure optimization of resource exploitation, applying industry standard procedures and development schemes; and
- To provide sufficient legal certainty that a concessionaire that invests in development will have a right to obtain permission to produce electricity if a commercial geothermal well field is developed.

### **Establish a Rational Fee Structure**

Fees tied to the acreage of a geothermal resource concession site may be used by the government to enforce a use-or-lose policy. Fees may be used to fund government regulation of a project, but if such fees are too large, they can increase the cost of electricity to the end user.

### **Establish Bonding Requirements**

Bonds tied to abandonment of drilling sites may be used to assure reclamation of a geothermal resource area. Bonds may also be linked to well safety.

### **Establish Model Negotiating Documents**

Model documents such as licenses, concessions, PPAs, and pre-drafted and government-approved negotiating language (such as *force majeure*) may expedite the development process.

### **Institute Legitimate Regulatory Purposes, but Avoid Bottlenecks for Development**

The process of applying for regulatory authorizations can present bottlenecks to faster development; however, regulatory licensing processes have proven necessary to take advantage of the safeguards that are established in such regulations. At the same

time, it is good practice for regulators to try to avoid micromanagement of an undeveloped resource.

### **Avoid Burdening Projects with Expenses**

Ideally, regulatory compliance avoids future expenses that might arise due to noncompliance, which might make projects ultimately very expensive or lead to a developer or other entity effectively being barred from undertaking further development.

### **Draft Regulations to Follow Real-World Scientific, Engineering, Financial, and Operational Practices**

Most geothermal concession systems incorporate the science, engineering, technology, and financing issues inherent in geothermal resource development into their regulatory licensing scheme. Table 5.2 illustrates how these concepts are utilized in the government approval processes, although other steps also may be included.

### **Draft Regulations to Include Developer Requirements**

Most countries that have advanced geothermal programs have promulgated legal and regulatory systems requiring that prospective concessionaires seeking a geothermal concession first must prove that they possess the technical and financial capabilities to develop the resources. When a concession is tendered, and a bidder previously has obtained a concession—either in another location in the host country or in another country—it is also common to require a recommendation letter from the governing authority on the bidder's performance. This helps to ensure that the developer's profile and experience is adequate for successful development.

### **Determine How to Ensure Local Participation**

In many countries, a foreign bidder must bid as an incorporated local subsidiary. Often a specified percentage of the subsidiary's ownership must be held by citizens of the jurisdiction, thus making the likelihood of foreign bidders who are successful more politically palatable.

**TABLE 5.2: Phases of Geothermal Project Development and Regulation**

Phase of development	Description	Regulatory purpose
Surface reconnaissance	Consists of observing surface geological features and commonly taking geochemical samples from surface manifestations (for example, hot springs or fumaroles).	Allows access for observations and sampling and sets forth the requirements to be met before a developer is granted exploration and drilling rights.
Exploratory drilling	Consists of minimum land disturbance, including geoscientific exploration; geological, geochemical and geophysical surveys; and drilling shallow temperature gradient wells. <sup>a</sup>	Allows conducting of surface investigations and shallow drilling. In general, exploration permits are issued for exploration that does not disturb the land. Establishes criteria for proceeding to drilling and steam field development. <sup>b</sup>
Production drilling	Consists of exploration and appraisal drilling (slim holes and full-size deep wells) to confirm existence and characteristics of geothermal resources that can be used to generate electricity.	Allows drilling operations and provides requirements precedent to the stages leading to electricity production.
SAGS and power plant construction	Consists of development of steamfields by drilling of production and reinjection wells, installation of the steam gathering system, and construction of the geothermal generation facility.	Allows the development of steam field and generating facilities. Steam field production may be provided to an unrelated party that generates electricity.
Operations and maintenance	Consists of the commercial operation and exploitation of the geothermal field and generation of electricity.	Allows generation of electricity (may include transmission and distribution). In most countries, the authority to generate electricity is by statute and not tied to resource development (necessary in geothermal development).

Source: World Bank.

<sup>a</sup> Some governments license developers to drill full-size, deep wells during the exploration stage. If deep wells are permitted in the exploration stage, the license needs to address reclamation needs, should such drilling does not produce commercially usable resources.

<sup>b</sup> Many geothermal laws in Latin America include an “exploration concession” phase (meaning surface exploration and exploratory drilling up to resource confirmation).

### **Ensure a Developer Can Comply with Technical Requirements**

Ensuring potential geothermal developers have adequate technical capacity is paramount to successful development. This could include demonstration of experience developing geothermal or power projects in the past or provision of information on the technical qualifications of the developer in the bid documents for a concession or license, among other requirements. In a tendered concession, bidders also could be required to submit a work program that covers the plan and schedule for exploration and exploitation.

### **Ensure That a Prospective Developer Provides Proof of Financial Capability**

If governments wish to secure qualified geothermal developers, another critical provision is to require proof of financial capacity, in order

to avoid speculation and the possibility that geothermal field development might be stalled due to insufficient funding.

### **Risk Allocation and Mitigation in the Context of Policy, Laws, and Regulations**

Historically, development of natural resources by the private sector in any country has been directly correlated to the degree of institutional stability and the predictability of the country’s policy, legislative, regulatory, and judicial framework. The degree of stability and predictability may collectively be labeled “legal risk.” Legal risk contains two primary sub-components: “stability risks” and “predictability risks.” From the perspective of a potential investor in the geothermal energy sector, the direction, predictability, and stability established by the national policy framework determines the investment climate and the likelihood of success for geothermal development. Mitigation

of these risk factors is critical in instituting a national legal regime designed to develop domestic geothermal resources.

## Conclusions

**As LAC policymakers assess the key areas of reforms needed to scale up geothermal development, a first step is to establish a strategic policy that sets forth the objectives of the geothermal and power sector.** A national policy will, of necessity, identify the scale and timeframe for development, the available domestic technical capacity, the parties responsible for administration and oversight of development, and the financial implications, as well as other national stakeholder considerations. Once a national policy comes into being, the tools available to implement the policy and overcome obstacles that policymakers have identified include legislation, regulations, and government approvals (permits, licenses, and concessions). In deploying these tools to implement the national geothermal framework, policymakers can draw on global experience and proven best practices to establish a legal regime that is most likely to promote successfully geothermal development for power generation.

**The global experience highlighted in this chapter is designed to assist policymakers in making informed decisions regarding the most suitable policies and policy implementation approaches for geothermal development in their own countries.** A policymaker shaping a geothermal resource development strategy can undertake a four-step analysis:

1. State the goal for geothermal development;
2. Identify potentially competing national goals;
3. Harmonize and prioritize goals; and
4. Establish the mechanisms to best implement the national goal for geothermal development.

**In each of these steps, the policymaker may draw on strategic decisions that have**

**international precedent in other legal regimes and adapt these precedents to domestic circumstances.** When a government makes a strategic decision to leverage private investments to free up its own economic resources, the legal regime will need to address the challenges faced by private developers in mobilizing future risk capital. Legislation implementing the national policy will need to encourage developers, while simultaneously ensuring resource sustainability, environmental integrity, and low-cost electricity prices to the consumer—in all cases a delicate balancing act. Likewise, when government or government-backed entities develop or operate geothermal facilities and when government or government-owned entities pair with a private entity to form a PPP, the legal regime needs to be tailored to mitigate risk.

**To move geothermal energy development forward, policymakers will need to strive to reduce legal and regulatory ambiguity and to demonstrate strong political will to overcome institutional constraints.** Policymakers may need to reevaluate the laws and regulations governing geothermal development domestically—particularly those related to impacts on and engagement of local communities, government participation in financing or guaranteeing projects, and the concession system. The timeline and requirements for obtaining the requisite permits, licenses, and concessions, including the requirements and timing for environmental impact studies, also need to be examined. The policymaker who is determined to promote the development of domestic geothermal resources should strive to develop a legal regime that is both predictable and stable.

**In sum, successful geothermal resource development can be facilitated by the predictability and stability established by the policy framework and the legal regime.** Policy, law, and regulations determine the national investment climate, and thus influence the likelihood of success of national geothermal development.

## CHAPTER 6: ENVIRONMENTAL AND SOCIAL SAFEGUARDS

**E**nvironmental and social risk management is a critical element of successful geothermal development, starting from the earliest stages of planning and continuing through exploration, construction, operation, and decommissioning. All geothermal projects present environmental and social impacts and risks of varying intensity and magnitude. The degree of these impacts and risks depends on the location and terrain, the nature of the geothermal resource, and land use and ownership, as well as the population in the area of the geothermal field. With adequate assessment, planning, monitoring, and timely, information-based decision-making, the impacts and risks can be managed effectively.

**This chapter discusses the range of environmental and social risks and impacts in developing geothermal energy for power production and ways to mitigate these through design and application of international best practices, as well as through adherence to the safeguard standards and policies of International Financial Institutions (IFIs).**<sup>74</sup> Environmental and social impacts and risks should be identified and addressed from the earliest stages of geothermal development and international best practice measures should be adopted during all stages. This can be done, in large part, through compliance with international standards and policies.

Because international financing is needed for most geothermal development, if a project does not follow international best practices and standards from the outset, it may be ineligible for international financing altogether or later may have to invest in costly mitigation to become eligible, delaying development of the project and increasing the project cost.

**Both globally and in LAC, some governments have adopted international standards and mitigation requirements, while others have not.** This has been done in different ways for different countries, through such methods as: including requirements for geothermal developments in a country's national environmental laws and regulations; passing specific geothermal legislation that includes environmental, social, and health and safety standards or requirements; and, in some smaller countries where there is less capacity, through the use of contracts or self-regulation by the developers. Only a few LAC countries with geothermal potential or installed capacity have environmental laws that specifically address geothermal aspects. Costa Rica, Honduras, Mexico, and Grenada have environmental laws that mention the geothermal sector, but most of the remaining countries deal with geothermal in the same way as any other large infrastructure project. Regardless of national and local requirements, however, both public and private sector supporters

<sup>74</sup> An IFI is a financial institution that has been established by more than one country, and hence is subject to international law (for instance, World Bank, IFC, the Multilateral Investment Guarantee Agency, IDB, EIB, and so on).

of geothermal development should become familiar with associated environmental and social impacts and risks. International best practices should be incorporated in planning and operation from the outset to avoid mistakes, mitigate impacts successfully and in a timely manner, and minimize delays, thereby reaping the benefits of international experience and funding. Moreover, it is equally important to have an effective monitoring program in place to be able to maintain standards.

**The most common environmental impacts and risks of geothermal development fall into the following categories:** physical environment (that is, water, air, and soil); ecology and biodiversity; physical and visual landscape; worker health and safety; cultural heritage; and cumulative impacts. Social impacts and risks are generally related to land ownership and use; community health and

safety; economic and social disruption; and social vulnerability and exclusion. Local opposition, which can significantly delay projects, may be precipitated by either environmental or social impacts and risks.

**International best practices in geothermal development and other energy investments are articulated in different documents, primarily developed by IFIs, including the World Bank Group.** Private financial institutions have also developed similar principles. The most recognized principles and guidance for environmental and social risk assessment and management are listed in Table 6.1 below:

The most widely accepted practices that are typically applied are the Equator Principles and the IFC/World Bank Performance Standards which are explained in more detail below.

**TABLE 6.1: Recognized Principles and Guidance on Environmental and Social Impacts and Risks**

	<b>International environmental/ social standards and guidance</b>	<b>Links with additional information</b>
1	The Equator Principles	<a href="http://www.equator-principles.com">http://www.equator-principles.com</a>
2	IFC Performance Standards	<a href="http://www.ifc.org/performancestandards">www.ifc.org/performancestandards</a>
3	World Bank Group Safeguard Policies <sup>a</sup>	<a href="http://www.worldbank.org/en/programs/environmental-and-social-policies-for-projects/brief/environmental-and-social-safeguards-policies">http://www.worldbank.org/en/programs/environmental-and-social-policies-for-projects/brief/environmental-and-social-safeguards-policies</a>
4	World Bank Group OP 4.03	<a href="https://policies.worldbank.org/sites/ppf3/PPFDocuments/090224b0822f7442.pdf">https://policies.worldbank.org/sites/ppf3/PPFDocuments/090224b0822f7442.pdf</a>
5	World Bank Group Environmental, Health, and Safety (EHS) Guidelines	<a href="http://www.ifc.org/ehsguidelines">www.ifc.org/ehsguidelines</a>
6	IFC/World Bank Environmental, Health and Safety Guidelines for Geothermal Power Generation	<a href="http://www.ifc.org/wps/wcm/connect/329e1c80488557dabe1cfe6a6515bb18/Final%2B-%2BGeothermal%2BPower%2BGeneration.pdf?MOD=AJPERES&amp;id=132316197516">http://www.ifc.org/wps/wcm/connect/329e1c80488557dabe1cfe6a6515bb18/Final%2B-%2BGeothermal%2BPower%2BGeneration.pdf?MOD=AJPERES&amp;id=132316197516</a>
7	IFC/World Bank Environmental, Health and Safety Guidelines for Electric Power Transmission and Distribution	<a href="http://www.ifc.org/wps/wcm/connect/66b56e00488657eeb36af36a6515bb18/Final%2B-%2BElectric%2BTransmission%2BAnd%2BDistribution.pdf?MOD=AJPERES&amp;id=1323162154847">http://www.ifc.org/wps/wcm/connect/66b56e00488657eeb36af36a6515bb18/Final%2B-%2BElectric%2BTransmission%2BAnd%2BDistribution.pdf?MOD=AJPERES&amp;id=1323162154847</a>
8	Core conventions and instruments of the International Labor Organization and the United Nations	<a href="http://www.un.org/documents/instruments/docs_en.asp">http://www.un.org/documents/instruments/docs_en.asp</a>
9	Convention on Biological Diversity	<a href="https://www.cbd.int/intro/">https://www.cbd.int/intro/</a>
10	Good international industry practice	<a href="http://www.ifc.org/ehsguidelines">www.ifc.org/ehsguidelines</a>

Source: World Bank.

<sup>a</sup> In 2016, the World Bank adopted a new Environmental and Social Framework, which is being more fully developed for roll-out. See <http://www.worldbank.org/en/news/feature/2016/08/05/the-new-environmental-and-social-framework>.

**Equator Principles.** The Equator Principles Association is a voluntary association of 91 financial institutions in 37 countries. The association describes the principles as “a financial industry benchmark for determining, assessing, and managing environmental and social impacts and risks in projects.” A brief review of the principles demonstrates an analytical and action framework that basically parallels the IFIs in approach, with a strong emphasis on transparency and accountability. The ten Equator Principles address:

1. Review and Categorization;
2. Environmental and Social Assessment;
3. Applicable Environmental and Social Standards;
4. Environmental and Social Management System (ESMS) and Equator Principles Action Plan;
5. Stakeholder Engagement;
6. Grievance Mechanism;
7. Independent Review;
8. Covenants (in financing documentation);
9. Independent Monitoring and Reporting; and
10. Reporting and Transparency.

**IFC/World Bank Performance Standards.** There are eight IFC/World Bank Performance Standards (PS) that were developed largely based on the Equator Principles. The first standard (PS1) defines the ESIA framework. It identifies and assesses the nature and magnitude of a spectrum of environmental and social impacts and risks, including those referred to in the other seven PSs, which elaborate objectives and procedures to assess and manage different topics. The other PSs are used to strengthen the analytical and mitigation content of the ESIA and their value is reflected in the ESIA or operational documents, such as Emergency Preparedness and Management Plans. All PSs relevant to an investment either provide the framework for addressing respective issues in the ESIA or, in the case of Resettlement and Indigenous Peoples, identify specialized studies and management frameworks and action plans that must be prepared with the participation of affected peoples, in addition to

the ESIA. These Performance Standards are almost universally accepted by other IFIs, such as the Inter-American Investment Corporation of the IAD, ADB, EBRD, and EIB. More details about the IFC and World Bank’s eight Performance Standards and the objectives of each one can be found in Annex 3.

The following sections provide information on how the PSs are applied in practice for geothermal projects.

### **Environmental and Social Impacts and Risks in Geothermal Development**

**Like other infrastructure projects, the range of environmental and social impacts and risks associated with geothermal energy development are well defined and thus relatively easy to anticipate.** However, specific impacts and risks and their scale vary from one site to another, and some risks emerge only as the geothermal resource is explored and the final design is completed. Many of the impacts and risks can be mitigated by decisions related to siting and design. The iterative process of geothermal development offers opportunities to introduce mitigation at appropriate times and include additional mitigation measures, as needed, as geothermal development progresses and site-specific impacts and risks are identified. This section discusses the principal environmental and social impacts and risks and highlights the different stages of geothermal development at which these impacts and risks might occur.

**The relative importance of different risks depends not only on a particular investment, but also on the presence or anticipated development of additional geothermal investments in the area.** Any risk assessment must take into consideration the cumulative risks of existing, new, and anticipated geothermal investments. The most obvious cumulative impacts are on water demand, air quality, environmental degradation, and livelihood assets.

## **Environmental Impacts and Risks**

**Geothermal environmental risks and impacts may be grouped into seven principal categories, which are described below.**

**Land and habitat loss.** Many new developments occur in fairly remote areas with volcanic characteristics, yet can take place in areas that are already in use and populated. The implications of remoteness include: (1) small local populations, (2) the need for promoting access by constructing new or improved roads leading to and around the site, and (3) an increased likelihood of being either near or within critical habitats or protected areas. Despite having a limited footprint, a new facility can disrupt local use and livelihood patterns that are dependent on crop or animal production—especially when the land is used by indigenous peoples. In some areas, local concerns about perceived risks (not always real or founded) that geothermal development may cause landslides, seismicity, and disturbances from natural hydrothermal manifestations, may lead to resistance to geothermal development in local populations.

**Water risks.** This category includes water use and quality. Well drilling, stimulation, and testing require surface and underground water that could pick up dissolved minerals and can pollute surface and ground waters if not managed carefully. Similarly, water used to clean the facilities may add contaminants, and leaks from breaks in well casings can contaminate groundwater. Surface and underground water requirements vary at different stages of development and operation, from drilling to managing the geothermal resource and cooling. The relative abundance of nearby water sources and the amount of competition for their use determines the level of risk.

**Solid discharges and waste.** Drilling muds are generally recycled and reused, but the cuttings can contain hazardous materials such as sulfides, arsenic, mercury, nickel, and other heavy metals,

which can leak into the environment if not managed and disposed of properly. Holding ponds constitute a public hazard if not protected from unauthorized access.

**Gas emissions.** The principal non-condensable gases (NCG) encountered in geothermal development are carbon dioxide (CO<sub>2</sub>) and hydrogen sulfide (H<sub>2</sub>S). In some cases, mercury (Hg) can be present in low, but significant, amounts in the NCG. NCG are released at well sites in site development and afterwards. During operation, the NCG is carried with the steam from the well, passes through the steam turbine, where the water vapor is condensed, and is released through venting. NCGs can be captured and treated for commercial purposes or injected back into the sub-surface, but injection of NCGs is not a common practice. H<sub>2</sub>S, in particular, has an obnoxious smell even at low concentrations and poses a health hazard if concentrations are high. Some jurisdictions require that H<sub>2</sub>S and Hg be removed from the geothermal NCG through chemical treatment. See Box 6.1 for more details.

**Dust and noise.** Noise pollution from geothermal is especially prominent during well drilling, stimulation, and testing phases and during construction of the powerhouse and related facilities. The operation of the transformer, power house, and cooling towers add noise to the environment, depending on design. Construction machinery and trucks for the facilities also increase noise and dust in the project area.

**Occupational health and safety.** Employees at geothermal drilling and operation facilities face various occupational risks to their safety, ranging from well blowouts to pipeline failure and seismicity issues and impacts. Some of the impacts and risks can be mitigated by having a robust regulatory framework that includes health and safety standards or requirements (for example, one that requires geothermal companies to put in place and adopt standard industrial safety

## BOX 6.1

### Geothermal Gas Emissions

Gases are naturally present in all geothermal fluids. CO<sub>2</sub> is usually the most abundant geothermal gas, with the second most common geothermal gas being hydrogen sulfide (H<sub>2</sub>S). Other gases that typically are found are nitrogen (N<sub>2</sub>), hydrogen (H<sub>2</sub>), methane (CH<sub>4</sub>), ammonia (NH<sub>3</sub>) and argon (Ar). A host of other gases may occur in trace concentrations, including mercury (Hg). The most environmentally sensitive gases in geothermal fluids are H<sub>2</sub>S and the GHGs CO<sub>2</sub> and CH<sub>4</sub>. Harmful levels of Hg emissions have been observed in only a very few systems. The range of the environmental effects of these gases is very different: the effects of the GHG emission are global, whereas the effects of H<sub>2</sub>S and Hg (if present) are much more localized. Both CO<sub>2</sub> and H<sub>2</sub>S represent potential hazards for workers in power plants. H<sub>2</sub>S can cause death at moderate concentrations. Around geothermal power plants the concentrations of this gas are low, but this gas has an obnoxious odor and a detrimental effect on electronic equipment. In rare cases, GHG emissions from geothermal power plants can be much higher, on par with coal fired power plants. Unusually high GHG emissions occur where carbonate rocks are present in the geothermal reservoirs, which is a rare occurrence.

The geothermal gas present in geothermal fluids is typically emitted into the atmosphere at geothermal power plants. Technologies for capturing the geothermal gas or removing certain gases from the gas stream are commercially available. If there is a market for the gas, such as in Turkey, where geothermal CO<sub>2</sub> is captured and purified to beverage grade, gas capture facilities can be commercially viable. In California and Italy, installation of facilities for H<sub>2</sub>S removal is mandatory. In Iceland, the amount of H<sub>2</sub>S that can be emitted is curtailed to prevent atmospheric concentrations of the gas from exceeding a threshold level in inhabited areas near power plants. A range of technologies for the removal of H<sub>2</sub>S from geothermal gas are commercially available. For more details, see ESMAP Report “Greenhouse Gases from Geothermal Power Production” at <http://hdl.handle.net/10986/24691>.

practices in the field). Other risks that are specific to geothermal, such as the risk of encountering toxic fumes in a closed area, can be addressed by requiring companies to adopt standard industrial health and safety practices, such as management plans to mitigate this risk that include emergency response measures.

### Social Impacts and Risks

**Geothermal development can impose impacts and risks on the population in the immediate area and sometimes well beyond.** This may cause local opposition due to real as well as perceived risks, which can significantly affect the viability and schedule of an investment.

Consequently, it is important to anticipate and manage social impacts and risks from the outset. This section addresses five types of real and perceived social impacts and risks.

**Livelihood and ecosystem services.** Land acquisition or loss of access to land due to geothermal development can impact the livelihoods and everyday lives of local people. Regardless of whether the land is owned by individuals, communities, or even the state, if people are dependent on it for livelihoods or resources that they use consistently, the loss can be difficult to overcome, even if the users are compensated by relocation, cash, or land swaps. The severity of

the risk varies, with vulnerable and indigenous peoples<sup>75</sup> most at risk.

**Disruption.** Drilling, testing, construction, operation, and decommissioning can disrupt family and community life with increased traffic, influx of labor, and damage to assets and resources. This can have consequences for health and safety, as well as peace of mind.

**Conflict.** New facilities and investments, including land purchases, bring new opportunities to communities, but also disruptions and competition over access to employment, commercial opportunities, and ownership of new resources. Such changes can renew long-standing kinship or clan conflicts or create new ones based on gender, generation, or other factors.

**Cultural heritage.** New geothermal developments can take place in or near sites that are protected or prized for cultural significance or aesthetic aspects, threatening or compromising the physical or visual status of the site. Nationally or internationally recognized cultural assets generate much interest, but even sites of local importance require special attention.

**Apprehension and opposition.** In addition to the social impacts and risks caused by the objective factors described above, geothermal investments can cause local people to be apprehensive or suspicious, based on real information about poorly-managed developments in other areas, rumors, misunderstandings, or fear of the unknown. Such apprehension can generate local opposition, which may be nurtured and amplified by external interests.

### **Impacts and Risks by Development Phases**

**The types of impacts and risks and their relative intensity vary at different phases of geothermal development, according to the characteristics of both the site and the investment.**<sup>76</sup>

Table 6.2 shows the environmental and social impacts and risks that may appear and those that are most prevalent at each geothermal development phase. The most risks and impacts are present starting at the exploration phase, which includes drilling of exploratory wells, and they intensify during the resource development phase, when major production and injection well are drilled, and the resource is stimulated and tested. If the field has been developed properly, many of the potential environmental risks decline during power plant development. They may reappear during operations, when old wells deplete, and new ones are drilled. Social risks remain and may intensify and diversify if they are not anticipated and managed well from the outset. Consequently, the timing of risk assessment and mitigation is critical.

**Virtually all geothermal environmental and social impacts and risks can be minimized or mitigated with timely and adequate assessment, including monitoring, and by the adoption of international best practices.** Timing is essential because new information about the geothermal resource is generated in each stage of development, and some mitigation decisions may have to wait for specific information. For example, the amount and type of NCG emissions become evident from well drilling and testing. Mitigation approaches are developed once the composition of the gases is understood, but other mitigation

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<sup>75</sup> In PS7, the term “indigenous peoples” is used in a generic sense to refer to a distinct social and cultural group possessing the following characteristics in varying degrees: i) self-identification as members of a distinct indigenous cultural group and recognition of this identity by others; ii) collective attachment to geographically distinct habitats or ancestral territories in the project area and to the natural resources in these habitats and territories; iii) customary cultural, economic, social, or political institutions that are separate from those of the mainstream society or culture; or iv) a distinct language or dialect, often different from the official language or languages of the country or region in which they reside.

<sup>76</sup> This point highlights the importance of conducting serious and thorough environmental and social assessments as early as possible to ensure proper analysis of the situation and clarification and adoption of appropriate design and mitigation measures.

**TABLE 6.2: Environmental and Social Impacts and Risks by Development Phases**

Impact or Risk	Exploratory drilling	Production drilling	SAGS and power plant	Operation and maintenance
Land acquisition	X	XX	XX	
Land and resource access	X	XX	XX	
Surface pollution	X	XX	X	X
Sub-surface pollution	X	XX		X
Surface/groundwater extractions and use	X	XX	X	XX
Solid discharges—muds, drilling fluids, cuttings	X	XX		X
Solid waste	X	X	XX	XX
H <sub>2</sub> S emissions	X	XX		XX
CO <sub>2</sub> emissions	X	XX		X
Other emissions	X	X		X
Noise	X	XX	XX	X
Dust	X	XX	XX	
Occupational health/safety	X	XX	XX	X
Direct livelihood loss	X	XX	XX	
Indirect livelihood loss		XX	XX	
Indigenous vulnerability	XX	XX	XX	XX
Traffic	X	XX	XX	X
Labor influx	X	XX	XX	
Community asset vulnerability	X	XX	XX	
Conflict over investment, location	X	XX	XX	
Conflict over opportunities		XX	XX	
Physical cultural resource impacts	X	XX	XX	
Visual impacts	X	XX	XX	XX
Tourism effects		XX	XX	X
Rumors, fears	XX	XX	X	
Organized opposition	XX	XX	XX	X

Source: World Bank.

Notes: X = low impact and risk; XX = high impact and risk, without mitigation.

measures need not be delayed. For instance, procedures to manage solid emissions to avoid surface and sub-surface pollution are relatively simple and straightforward. The mineral composition of the cuttings and buds that result from the initial slim-hole drilling can be used to forecast the mineral composition of the production wells and to specify measures.

**On the social side, well-informed neighbors are good neighbors. Any geothermal development should start with a serious stakeholder engagement plan to initiate two-way communication between developers and the local population.** If successful, the engagement process will allay fears and misunderstandings and bring out local concerns, priorities, and expectations that can

inform project siting decisions. For example, project siting can be designed to minimize the physical and visual impact of facilities and services such as roads and power lines. Land requirements, which may not be known in early stages of the investment, will emerge as detailed decisions are made regarding the location of drilling platforms, above-ground pipes, the power house, and related facilities. To prepare project staff, owners, and other land users for eventual negotiations and acquisition, the project should develop and disseminate a land acquisition and compensation framework by the time exploratory wells are drilled, if not before. These and other issues will be discussed in more detail in the section on risk assessment.

### **Impact and Risk Mitigation**

**As indicated previously, most environmental and social impacts and risks of geothermal development can be adequately mitigated.** This can be done through a combination of judicious planning and the use of geothermal industry best practices. The information derived from the ESIA, actions included in the Environmental and Social Mitigation Plan (ESMP), a proactive stakeholder engagement program, and other necessary plans and compliance documents are also important. Some countries have a robust legal framework that assists with managing geothermal risks and impacts, and the extent to which the laws and regulations fully cover geothermal development vary from one country to another. In some countries, there are general laws that apply to all infrastructure investments; in others, a more specific regulatory regime will govern the geothermal sector. However, the laws and regulations in many countries do not cover the full spectrum of issues that are addressed in the international environmental and social standards. Investors often need to carry out Environmental Impact Assessments (EIAs), ESIA, land acquisition, and some construction activities before international funding is secured. If international funding is involved, the IFIs and Equator Principle members will insist that these standards are met, which

generally entails carrying out retrospective due diligence and implementing remedial measures to meet the standards. Annex 3 illustrates how to manage many of the geothermal risks and impacts mentioned previously, either through compliance with international standards or through the domestic legal framework.

### **Environmental and Social Risk Assessment and Management**

**The predominant international standard mechanism used to identify and manage environmental and social impacts and risks is the ESIA.**

The developer sponsors the ESIA, but it is generally carried out by an independent party with appropriate expertise. Most countries require only an EIA be prepared for infrastructure investments. A more in-depth ESIA usually meets national requirements, but the scope and breadth of the ESIA is wider and deeper than most national EIA requirements. In particular, an ESIA also identifies the extent and complexity of potential social impacts and the socio-economic characteristics of people in the project area. It comprises the normal contents required by a national EIA, in addition to four additional components that have gained traction over the last two decades through the convergence of the policy requirements of various international agencies: i) ESMP, ii) Stakeholder Engagement Plan (SEP), iii) grievance mechanism, and iv) community health and safety plan. If the ESIA is carried out to supplement or update a previous EIA/ESIA, it will include an Environmental and Social Action Plan (ESAP) that assesses the content and implementation of previous efforts taken to identify deficiencies and to plan actions to bring the process up to international standards. Finally, standalone land acquisition and resettlement documents and/or an indigenous peoples' development framework or plan may also be required, as appropriate.

**As geothermal development is carried out in stages, ESIA preparation is normally an**

**iterative process.** This means that the level of detail in the initial ESIA during the exploration phase may be limited—focused on drilling and access. The second stage would be carried out after there is more understanding about the geothermal resource and the conceptual outlines of the full project. At this point, a full-blown ESIA would result, establishing baselines, addressing cumulative impacts, and focusing on mitigation and monitoring. As project parameters further evolve, supplemental ESIA's would be undertaken to address the impacts of new drilling platforms, above-ground structures, and other changes that are made. The next section focuses on three critical components of a full ESIA for geothermal development—the ESIA Report, the ESMP, and the SEP—in addition to the standalone safeguards documents that may be required.

### ESIA Components

**ESIA report.** ESIA's prepared according to international standards usually have similar tables of contents.<sup>77</sup> However, the actual detailed contents of an ESIA varies considerably, according to the type of investment and the specific physical and institutional context in which it is carried out. Each investment needs a tailored ESIA, the expected content of which is described in the ESIA's terms of reference. The content is subsequently developed further through the initial consultation and scoping session in the target area, which is the first field exercise of a higher risk (Category A)<sup>78</sup> investment, which is often the category into which geothermal projects fall. Following the preparation of a draft report, the

ESIA team conducts a second consultation in the target area to discuss findings and recommendations, and to solicit feedback from people in the affected area. The framework for the consultation rounds is clarified in the SEP and the results of the feedback consultation are reported in the final document.

**There is a wide range of information that feeds into the ESIA, including geothermal-specific information that is collected and assessed as part of the process.** After the scoping exercise, a multi-disciplinary team undertakes the field work for the ESIA. The work articulates the baseline situation, including local characteristics, anticipated impacts, institutional responsibilities, information on the local population and economy, and so on. In addition, field work should focus on issues specific to geothermal development. The main topics that should be covered in an internationally accepted ESIA for a geothermal investment can be found in Annex 3.<sup>79</sup>

**ESMP.** ESIA's establish a detailed implementation framework to address environmental and social impacts and risks. The ESMP<sup>80</sup> is a simple, clear matrix that distills the critical elements of the ESIA into a detailed action plan. It lists all required actions, including both one-time and periodic monitoring, and a timetable for execution. The plan assigns responsibility for each action, from monitoring to remediation, and estimates the resources needed to implement that action. Finally, the ESMP sets requirements for oversight, reporting, and information dissemination to

<sup>77</sup> Outlines are readily available. See IFC Guidance Note 1, pages 39 and 40 for a cursory outline. This document is perhaps the most useful reference for the preparation and execution of an ESIA. The Equator Principles also include a useful list of topics to be included in an ESIA.

<sup>78</sup> Category A projects are those likely to have significant adverse environmental impacts that are sensitive, diverse, or unprecedented. These impacts may affect an area broader than the sites or facilities subject to physical works.

<sup>79</sup> In addition to resources cited in the Introduction to this report, see also OPIC 2012; Landsvirkjun 2017; Kagel et al. 2007; Barclays Bank PLC, 2015; World Business Council for Sustainable Development 2005); and Idaho National Laboratory 2006.

<sup>80</sup> Not to be confused with an ESMS, which is the Equator Principles' reference to a corporate system; the Asian Development Bank's policy statement required of private sector borrowers; or the proposed Environmental and Social Commitment Plan that the World Bank will introduce in its new Environmental and Social Framework. These documents are institutional commitments, rather than specific project documents.

project and other authorities, as well as to affected populations.

**SEP.** If geothermal development is successful, the facility will ultimately be in the community for many years. An investor has a practical need to develop good community relations at the beginning of the project and to maintain them to the end. All geothermal developments should establish an effective SEP from the earliest stages of site investigation and maintain it to the final stages of decommissioning. The SEP establishes the conceptual background for the identification

and application of performance standards to ensure that the disadvantaged, minorities, indigenous peoples, women, and older persons are engaged. It also includes mechanisms to measure implementation and effectiveness. As an example, see Box 6.2 on ways in which gender matters are can be addressed.

### **Standalone Safeguards Documents**

**There may also be a need for additional, standalone safeguards documentation if specific PS or safeguards policies are triggered.** If the geothermal project requires land acquisition or

#### **BOX 6.2**

##### **Incorporating Gender in Geothermal Projects**

There is growing recognition about the importance of gender equality for economic growth and poverty reduction. As part of its broader gender strategy, the World Bank is committed to addressing this in energy infrastructure development. Geothermal projects should be responsive to gender issues not only to promote equity, but also because of the risk of undermining project effectiveness, efficiency, and, ultimately, sustainability if the gender-differentiated impacts of projects are overlooked. The World Bank's Global Geothermal Development Plan, an initiative to scale up the use of geothermal power in 12 countries, includes a provision to identify and incorporate gender considerations across the geothermal value chain (exploration, siting, drilling, completion, and production).

ESMAP is taking the lead by researching the gender aspects of geothermal development and identifying actionable entry points for the incorporation of gender equality and social inclusion into geothermal projects. A first step in this process was the formulation of a Guidance Note on Gender and Geothermal to provide guidelines for World Bank staff, project developers, and investors on how to incorporate gender concerns into the preparation and implementation of geothermal projects. Inclusive approaches are highlighted that ensure that women's voices are heard and respected, that women can become agents of change within their communities, and that women's skills and knowledge are brought in to create better managed and more successful projects.

In a review of the Latin America geothermal portfolio, a common issue identified was how to create a gender balance in the project workforce, as well as create ancillary jobs for women. Mitigating actions that were identified include i) ensuring that women are encouraged to apply for on-site jobs and supported in their careers; ii) including gender-focused civil society organizations or government staff in the planning process to bring attention to the need for (and needs of) women in the workforce; and iii) training and employing women on the use of geothermal resources (for example, condensates for drip irrigation, mechanical power, or process heat) for income generation.

is situated in an area inhabited by indigenous peoples, PS5 and PS7 apply. If the project will adversely affect biodiversity, PS6 applies. Both IFIs and members of the Equator Principles Association will require borrowers to prepare standalone documents if specific PS's are triggered. The principal standalone safeguards documents that may be needed include:

**Land acquisition and livelihoods frameworks and plans (related to PS5).** The loss of land for infrastructure development can adversely affect people by restricting livelihood opportunities, even if the owners or users are compensated. If land is acquired through a market-based “willing buyer-willing seller” arrangement, in which either party can refuse to conclude the transaction, PS5 does not apply. In most countries, however, energy investments are considered to be of national interest, and thus land acquisition is subject to eminent domain, which may be triggered when the buyer and seller fail to reach agreement. In many countries, people who do not own the land they use are not compensated when they lose access to it. PS5 is designed to apply international standards to the land acquisition process. The objectives of the standard are to avoid or minimize land acquisition and resettlement impact if acquisition proves to be unavoidable. The standard is to compensate the loss at full replacement value and to restore livelihoods to pre-project levels or higher. The standard applies to all affected persons,<sup>81</sup> whether landowners or others, including squatters.

If the location and amount of needed land is not known, as is typically the case in geothermal development, the first step is to prepare a land acquisition and compensation framework that describes the steps in the land acquisition, decision-making, and negotiation processes; identifies types of affected persons; and clarifies

entitlements for compensation or additional support. If land acquisition is anticipated but not defined, the land acquisition and compensation framework guides operations related to land acquisition. A social audit also is conducted to assess prior land acquisition related to the project and to determine if the outcome is consistent with the objectives of the framework. If not, a mitigation plan should be developed and implemented. If relocation is required, a resettlement action plan is prepared to cover the entire process, from the census to alternative site selection, entitlement definition, livelihood restoration, and implementation monitoring and assessment. Given the limited footprint of geothermal development, as well as flexibility in siting facilities, projects usually do not require resettlement. Moreover, livelihood impacts may be minimal, especially if alternative land is available for purchase or swap.

**Biodiversity action plan/biodiversity management plan or offset (related to PS6).** In areas of high biodiversity value, the investor must develop a robust, long-term, biodiversity monitoring and evaluation program, with clearly defined objectives and mechanisms to assess outcomes. In particular, the plan should assess if the development leaves the biodiversity for which the area is noted in a better state than before the project was implemented (net gains). To protect and measure those values over time, the plan may require set-asides nearby or in other areas with similar biodiversity values and mechanisms. If a project is expected to have adverse effects on biodiversity or critical habitats, a biodiversity action plan, biodiversity management plan, or a critical habitat offset may be required before project development proceeds (IFC/World Bank PS6). Each of these activities requires significant investigation and preparation and significant expert inputs. Moreover, there may be little

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<sup>81</sup> Any person or persons, household, firms, or public or private institutions who, on account of a development project, would have their standard of living, livelihoods, or assets affected.

institutional support to oversee the studies, manage the plans, or decide and execute the offsets. This process can significantly delay projects and increase direct and indirect costs.

**Indigenous peoples plans (related to PS7).** A likely scenario in some LAC countries is that indigenous people will be affected by geothermal development. In such cases, the investor is expected to conduct systematic field investigations and extensive consultations to prepare a plan that ensures that adverse impact on indigenous peoples is avoided or minimized. The plan—which should be developed jointly, treating indigenous people with respect and dignity and giving them authority over the process—should enable indigenous communities to receive sustainable development benefits and opportunities from the project. The objectives and mechanisms are outlined in PS7 and Guidance Note 7. As indicated previously, the requirement for consultation and free, prior, and informed consent of indigenous peoples is unique to this PS and potentially a challenge to authorities and developers, since complying with the PS has serious implications for many aspects of the project, from site design to field operations. At the earliest exploratory phase, specialists should determine if there are indigenous peoples in the area and, if so, mobilize appropriate expertise and develop the knowledge and relationships that can result in a legitimate indigenous-peoples plan.

**Stakeholder engagement and grievances mechanisms.** Few countries have adopted systematic stakeholder engagement practices and associated transparent grievance procedures. Few private sector developers have adopted them, except perhaps those dependent on financing from IFIs and Equator Principles institutions. Consequently, these international standards are new to most agencies and firms developing geothermal energy and require institutional adjustments to be effective. If the ESIA process is the developer's first

introduction to the standards, and if development activities are already underway in the field, the first step in the SEP process may consist of beginning to completely re-align existing relationships with the surrounding population. It is also good practice to develop and institute grievance mechanisms, which are procedures to receive formal notification of local issues and to facilitate resolution of affected communities' concerns and grievances about the project's environmental, and social performance. The SEP and grievance mechanisms should be developed during ESIA preparation, in close consultation with project management, local residents, and affected persons.

### Legislative and Regulatory Management of Environmental and Social Impacts and Risks

**Many of the industrialized nations that are developing their geothermal resources have instituted multi-layered, domestic regulatory regimes to manage natural resources and to regulate pollution.** Such environmental regimes are generally designed to be consistent with international environmental governance systems (such as the Paris Climate Agreement). When a jurisdiction focuses on geothermal development, policymakers may need to re-think national environmental and public welfare development guidelines. Using a geothermal development filter, national public welfare and environmental rules can be re-oriented toward geothermal resource development goals. For example, the state of Colorado in the U.S. has robust environmental regulations, but after enacting a Geothermal Resources Act in 2003,<sup>82</sup> the state promulgated geothermal-specific rules designed to protect “public health, safety, welfare, and the environment, and preventing the waste of geothermal resources that may result from the construction and use of geothermal wells.”

<sup>82</sup> Colorado Department of Natural Resources 2004.

**On the other end of the continuum, some nations have limited regulatory regimes and capacity to govern environmental, social, and health and safety practices.** These countries, including the Caribbean island nations and some of the Latin America states, frequently do not have a robust legal and regulatory regime in place. Many smaller countries do not have sufficient human capacity or the financial wherewithal to manage a complex regulatory regime. Often policymakers in these countries create a legal, regulatory, and contractual environment that is self-regulating and that does not require the country to invest in creating a government-funded regulatory body. These policymakers place the burden of ensuring safety and protecting the environment on the private sector developer.

### **Creating a Geothermal Framework**

**The past century of geothermal energy development worldwide has taught lessons about the minimum government oversight needed to manage environmental, safety, and social risks.** Although not intended to be comprehensive, the following, brief checklist is a baseline for policymakers to consider.<sup>83</sup> Such guidelines, at a minimum, establish the general rules of operation as well as the standards for developing a geothermal field. When there is sufficient geologic and engineering data available from previous drilling operations—for example, as in Kenya, Turkey, and Indonesia, where a state parastatal has developed the field—guidelines may supplement more broadly applicable statutory and regulatory requirements. Standalone guidelines, drawing on global experience, also can be drafted to apply in a greenfield situation. The following guidelines highlight areas in which experience indicates that the state needs to exercise some regulatory oversight. These guidelines should be interpreted as being complementary to the

Equator Principles and IFC PSs discussed earlier in this chapter.

- **General rules** address the responsibilities of the well owner, operator, and constructor for maintaining the safety of geothermal wells, as well as the authority of the state to enter and inspect well and facilities, and enforce laws, regulations, and contracts. These general rules address vertical and directional drilling, as well as recovering geothermal resources from multiple reservoirs, especially if there are multiple users of a reservoir. The IFC Environmental and Health and Safety Guidelines for Geothermal Power Generation can inform regulations in countries in which few regulatory guidelines have been promulgated.
- **Governance rules providing for interagency coordination** generally include establishment of a coordinating council, an interagency organization that facilitates the coordination of physical, field-based services as well as the authorizations and permitting requirements provided to or by a country's state-owned enterprises and agencies that are stakeholders. Such an interagency group would not have super-administrative authority. Instead, it would have the authority to compel interagency dialogue, after which it would set forth evaluated alternatives to the decision maker for final resolution. These governance rules may include allocating agency participation in or responsibility for the preparation and monitoring of the ESIA and the SEP, a grievance mechanism, a community health and safety plan, and an ESMP.
- **Community interface guidelines** support a country's stakeholder state-owned enterprises and agencies and the private sector in coordinating early interactions with the

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<sup>83</sup> In addition to the adequacy of domestic human resources, other considerations include political and social traditions. For example, a country with a strong *laissez faire* economic tradition (such as Chile) may be more prone to favor private sector self-regulation.

community that hosts a geothermal project, a process critical to long-term success.

- **Minimum standards** for different types of wells establish standards for deep wells (equal to or over 750 meters) as compared to shallow wells. They also establish standards for geothermal fluid above and below 100° Celsius, since preventing high temperature well blowouts is a paramount safety concern. Moreover, these rules set minimum standards for reinjection wells. The use and operation of a geothermal reinjection well, especially at higher flow rates and pressures, has the potential to contaminate aquifers and ground water. Since the failure to inject may undermine field sustainability, it is prudent to establish guidelines for mandatory reinjection.
- **Independent engineering certification** of compliance with state-established standards and procedures by a state-recognized engineer ensures that resource development occurs in a manner that safeguards life, public health, safety, welfare, property, and the environment.
- **Restoration procedures**, such as well plugging, are important since unused or inoperable geothermal wells are potentially hazardous to public health, ground water resources, and the environment. Government enforcement of a well owner's responsibility to ensure that an unused geothermal well is properly plugged according to best practices has proven prudent. Likewise, returning unused well fields to pre-project condition may require a government mandate.

The ideal of a national holistic melding of policy, law, and regulation to integrate geothermal resource development and environmental and social considerations may be challenging for many reasons—including lack of national capacity. International practice has taught that there is value in governments exercising oversight by:

- Focusing on how existing laws and regulations may be recast to apply in a geothermal resource development environment;

- Drafting geothermal-specific rules that address the public health, safety, and welfare environment that is best monitored by the state; and
- Creating an intra-governmental body that encourages government agencies to work together to facilitate integration of geothermal energy development and environmental and public welfare tools in a coordinated manner, mindful of host communities near geothermal projects.

### Environmental and Social Risk Management—Illustrative Cases

**This section illustrates how environmental and social impacts and risks have been managed in some existing and planned geothermal investments.** Five cases are described briefly to demonstrate how environmental and social issues may be identified and managed in the preparation and implementation of geothermal projects. The cases include projects both under preparation and implementation, focusing on actions taken to meet international standards, and one case that demonstrates a missed opportunity to apply and then comply with the standards.

#### Armenia—Geothermal Exploratory Drilling Project

A project that was prepared in Armenia in 2014–2015 is a good example of a typical geothermal exploration project financed by IFIs and shows how environmental and social impacts and risks were assessed and managed.

The project finances exploration infrastructure and exploratory well drilling in two stages. The first stage consists of building an access road, water pipeline, and small rig pads; the drilling of one or two slim wells; and provision of technical assistance to assess the drilling results. If the results are positive, the second stage includes construction of larger rig pads, water supply and production-size exploratory wells, as well as technical assistance for well testing and analysis, a feasibility study for the power plant, and transaction

advisory support. In a remote part of Armenia, the drilling site is a large, open, communal pasture used by three villages. The local economy is based on animal husbandry and has a high level of female-headed households, the result of out-migration. A traditional road reaches the area and needs to be upgraded before drilling can begin.

An ESIA was prepared for the drilling program that identified the potential adverse environmental impacts, including water extraction, generation of waste materials from drilling and earth works, and a small amount of hazardous waste and toxic emissions, all of which can be mitigated adequately. The ESIA also confirmed that the project area was community property, with some plots rented to individuals. Near the road were scattered private plots. The ESMP prepared included environmental and social monitoring and follow-up activities throughout the project life. A resettlement policy framework was also prepared, as the road alignment and location of project facilities was not known at appraisal. This document provides the institutional blueprint to access the land needed, outlining procedures, entitlements, and management.

See project link for more information: <http://projects.worldbank.org/P152039?lang=en>.

### **Turkey—Geothermal Development Program**

This project is an example of a financial vehicle to support private sector investment in geothermal development through financial intermediaries. The project was approved in November 2016 and is under implementation.

The Industrial Development Bank of Turkey (TKSB) and the Development Bank of Turkey (TKB), both of which have long-standing collaboration with the World Bank, are executing this project as financial intermediaries. The project has two components. Component I is a risk sharing mechanism for resource validation executed by TKB, and also provides technical assistance for capacity building. Component II

is a loan facility for resource development, executed by both TKB and TKSB. The objective is to stimulate private sector geothermal development by sharing the financial costs and risks of both exploration and resource validation and by providing long-term loans to develop the resource. Component II is available to borrowers who have reached the production drilling stage, with or without the support of Component I.

As financial intermediaries (FIs), the banks are responsible for ensuring that their clients comply with the environmental and social safeguard policies of the World Bank, as well as local policies. In practice, implementing banks often find it difficult to manage the compliance process, as their internal resources are limited, and points of leverage are restricted. TKB and TKSB have a proven record of success and extensive experience working with the World Bank. They also have undertaken major efforts to develop their internal environmental and social safeguard management capacity. This project was selected to highlight the quality of the project materials that the banks prepared to provide information and guidance to their prospective clients. Of note are the environmental and social management framework, with an executive summary; the resettlement policy framework for each component; and an environmental and social guidance note for geothermal power projects. With these documents in hand, as well as the IFC Performance Standards, TKB and TKSB clients will be in a strong position to understand international standards for environmental and social risk assessment and management and will be able to decide in advance if they can meet them.

The first two projects under each of the credit lines (one with TKB and another one with TKSB) were subject to ex-ante due diligence (including on safeguards) and a “no objection” from the World Bank. All Category A projects require a “no objection” from the World Bank. This serves as a mitigation measure, as it ensures that both FIs keep building their internal capacity (with

the World Bank's guidance) and it gives the World Bank a direct role in riskier projects.

For more information, see <http://projects.worldbank.org/P151739?lang=en>.

### **Nicaragua—Geothermal Resource Risk Mitigation Project**

This case demonstrates what may be required to fill gaps in an EIA prepared to meet both the national and international standards required to secure IFI financing.

The project will support the development of geothermal exploration drilling. Prior to World Bank engagement, the geothermal concessionaire already had carried out the reconnaissance and drilling of an initial slim-hole well. The first stage of the project is to be financed by the World Bank and consists of exploration drilling of three to five wells and preparation of a feasibility study and an ESIA that meets international and IFC/World Bank standards. If the resource is confirmed and other conditions are met, the second stage of the field development will include production and injection wells, and construction of the SAGS and power plant, which is expected to be financed by the private sector and other multilaterals. The site is located on the slopes of the Casitas Volcano, northwest of Managua, bordering and partially within the Casita San Cristobal Natural Reserve.

**Environment.** To meet local requirements, EIAs were carried out for both the exploration and exploitation phases. The environment permit was granted by the Government for the exploitation phase. A new ESIA was then prepared to meet IFC/World Bank Performance Standards and World Bank Safeguards Standards. The ESIA includes a substantive social assessment, a SEP, and an ESMP, as well as an ESAP that specifies actions to be taken to bring the ESIA and management practices in line with IFC/World Bank performance standards. The client is also preparing an ESMS to operationalize the environmental and social activities. Once the exploration drilling and feasibility

study is completed, another ESIA and ESMP will be prepared for the remaining stages, which will inform the client's decision to move forward.

**Land acquisition and livelihoods.** Current land requirements were secured through easement agreements with five landowners. The easements do not adversely affect local access to water or other resources, nor do they cause any physical or economic displacement. Nonetheless, a completion audit was carried out to ascertain if compensation for the easements complies with PS5. A few corrective actions were identified and included in the ESAP that is being implemented. To anticipate possible future land acquisition for the project, a resettlement policy framework was also prepared. This will be updated alongside the ESIA, if needed, should field development proceed to the production drilling and SAGS/power plant development stages.

For more information, see <http://projects.worldbank.org/P155197?lang=en>

### **Indonesia—Geothermal Clean Energy Investment Project**

This case from Indonesia illustrates how an ESIA can improve the overall project design.

The project supports the development of geothermal units in Bengkulu (140 MW) and North Sulawesi (40 MW) by Pertamina Geothermal Energy. In Bengkulu, production drilling already was underway for one power plant, to be constructed and operated by the energy utility (ADB funding). The project would develop the wells, above-ground system, and a second power plant, drawing on the same geothermal resource. In North Sulawesi, the project would fund production and injection wells, above-ground systems, and a power plant in the general vicinity of existing geothermal development. Both areas are populated, with economies based on coffee and rice production in Bengkulu and mixed agriculture in North Sulawesi. The population is clustered in villages, and the project requires land acquisition but no resettlement. In both places,

much of the access infrastructure is in place. A full ESIA was conducted in each area and, ultimately, a resettlement action plan, as well.

**Environment.** During the preparation of the ESIA, modeling of the results from some wells showed that the concentration of H<sub>2</sub>S could exceed tolerable levels in nearby communities and that the cumulative effects of two power plants would increase the likelihood of excessive emissions. This signaled the possible need to install scrubbers at the power plants to remove the H<sub>2</sub>S, and the ADB was contacted. They had not commissioned similar modeling but agreed that if further well tests obtained consistent results, scrubbers would be installed in the power plant they support. Subsequent tests indicated lower H<sub>2</sub>S concentrations and the decision regarding scrubber installation was postponed pending further developments, as it did not affect the design of the power plant. Meanwhile, the ESIA has been updated several times, as new drilling sites were identified and explored.

**Land acquisition and livelihoods.** Pertamina acquired land as needed through a “willing buyer-willing seller” process, negotiating collectively with owners of the target plots. The process will be repeated for each drilling platform and successive land requirements. Review of prior acquisitions revealed that owners were satisfied, as the compensation was above market prices and enabled them to purchase alternative land.<sup>84</sup> Over time, local land prices increased but the above market margin paid by Pertamina decreased and negotiations became more difficult. The willing buyer-willing seller approach continued and was confirmed by instances in which negotiations failed and the proposed site was substituted by another. As the project is of national interest, Pertamina can exercise eminent domain, but refuses to do so as it risks hurting relationships with the communities.

Because expropriation was possible, however, Pertamina prepared and disseminated a land acquisition and resettlement policy framework to guide the process according to international standards.

For more information, see <http://projects.worldbank.org/P113078?lang=en>.

### **Kenya—Electricity Expansion Project**

This final case illustrates how one aspect of the project can demonstrate international best practices in a challenging environment, while, at the same time, another aspect illustrates weaknesses that required special attention during implementation. The project demonstrates the value of ongoing supervision and monitoring and also highlights the importance of heeding lessons learned.

The project is part of a major electricity expansion program supported by several IFIs, including EBRD, EIB, AFD, JICA, and KfW. The World Bank financed components are 280 MW of geothermal capacity at Olkaria IV and I, with associated infrastructure; transmission lines and substations; slum electrification; and sector institutional development. The geothermal site is located within Hell’s Gate National Park in the Rift Valley, northwest of Nairobi. For health reasons, about 1,000 people were resettled, mostly Maasai pastoralists who were moved from a 4,200-hectare tract to a 1,700-hectare tract that was largely unsuitable for grazing.

**Environment.** The Hell’s Gate National Park was created after the first geothermal power facility was already installed. The land is characterized by rugged terrain, volcanic hills, valleys, gorges, boulders, and highly weather-altered rocks. Vegetation is mainly shrubs and short trees. Over 100 bird species can be found at the park, including notable populations of vultures that roost on the park’s high cliffs, and the park also contains many important amphibian species.

<sup>84</sup> Given current standards, this cursory review of past experience would not be an adequate substitute for a real social audit.

Various land animals are native, as well as over 100 bird species. Located nearby is Lake Naivasha, a well-known freshwater lake. The park and lake attract local and international tourism, education, and research activities. The Kenya Wildlife Service and the Kenya Electricity Generating Company (KenGen) have a memorandum of understanding that governs geothermal operations in the park. To minimize adverse impacts, studies were undertaken to establish animal migratory routes, breeding grounds, bird flying routes, tourist circuits, and protected plants and wildlife species, and facilities were adjusted accordingly. For example, steam pipelines on major animal routes were looped to enable easy animal movement and game proof fencing was installed to keep animals away from brine pools. Conservation operations maintain the unique scenic features and wildlife species within the park, and the geothermal plants have not altered its ecology significantly.

**Social safeguards.** The Maasai were resettled in August and September 2014. In July through September 2014, residents used the EBRD's complaint mechanism to express dissatisfaction with the plan and potential impacts. In October 2014, the World Bank Inspection Panel received complaints about resettlement. A joint investigation was undertaken in late March and early April 2015 and the Inspection Panel issued its report in July 2015. The residents claimed that they should have been treated as indigenous people according to the Bank's Indigenous Peoples Policy, under which they would have had much more active and inclusive involvement in decisions on the design, planning, and implementation of the resettlement program. Instead, they held that their inputs were not adequately sought, elders were sidelined, communications were ineffective and not in the local language, and essential documentation was not made

available in a timely manner and in an accessible language.

Residents claimed that some vulnerable people were excluded from resettlement benefits; the resettlement site was far from traditional areas and was unsuitable for grazing and inadequate for the population; land titles were not issued, as promised; housing design and materials were undesirable; and little attention was paid to livelihoods. In addition, the resettlement occurred as soon as houses were constructed but before the rest of the community infrastructure was completed. The Inspection Panel reviewed the complaints and determined that had the Maasai been treated as indigenous people, many of the issues would have been avoided. The lead international agency, the EIB, proposed an arbitration process that followed its complaint mechanism, with the World Bank as an observer. Mediation started in August 2015 and ended in May 2016. The results were presented to the community and the mediation agreement was signed by KenGen and the community a month later. Meanwhile, additional funding was made available to cover the costs of implementing the agreement.<sup>85</sup> The mediation agreement that followed the inspection panel investigation of the Kenya Electricity Expansion Project resulted in additional World Bank actions to alleviate harms suffered by affected residents. It also led to measures to improve identification of affected individuals who had been left out of the resettlement process, to improve the physical infrastructure of the resettlement site, and to support livelihood restoration. The lessons learned from this and other inspection panel cases on the importance of consultation, participation, and information have also been included in a recent inspection panel publication.<sup>86</sup>

For more information, see <http://projects.worldbank.org/P103037?lang=en>.

<sup>85</sup> A summary of the request is available at: <http://ewebapps.worldbank.org/apps/ip/Lists/CaseInformation/ViewPanelCase.aspx?ID=102&ContentTypeId=0x01009B45ABCD870B07438938BCBF4A34C2E3>.

<sup>86</sup> The Inspection Panel 2017.

## Conclusions

**Proper environmental and social risk management is an essential element for successful geothermal development and operations.** This chapter highlights two key points: i) geothermal development poses clear environmental and social risks, but these can be managed successfully through the timely application of sound design and mitigation principles; and ii) as international funding is usually required for geothermal development, this provides further rationale for adopting and adhering to international standards, from the earliest conceptual stages through to final development and decommissioning. The Equator Principles, IFC/World Bank Performance Standards, and IFC/World Bank EHS Guidelines constitute the core international standards that are acknowledged by international lenders in the public and private sectors.

**For effective management of social and environmental risks, good planning and timeliness are critical.** Most geothermal development

requires international financial support, which carries obligations to meet international standards on financial, technical, environmental, and social attributes of the investment. Developers have two options in this regard. First, to become familiar with the international standards and adopt them from the outset, or, second, to instead adhere to only local requirements at the start and face the prospect of needing to upgrade environmental and social investigations and practices later. The latter choice risks adding both additional cost and delays to the development timetable, as well as the possibility of additional costs for mitigation to reverse negative impacts already in place. Moreover, if the full ESIA is undertaken late in the geothermal development process, and if environmental and social concerns are not fully integrated in the ESIA and the ESMP, it is unlikely that project management will take ownership of the results or fully fund and implement the ESMP and associated plans. Serious, early attention to environmental and social issues can create the framework for harmonious geothermal development.



San Jacinto-Tizate Geothermal Plant.  
Photo courtesy of Polaris Energy Nicaragua S.A.

# ANNEXES

## ANNEX 1: LAC Countries with Geothermal Laws and Regulations

Table A1.1 below, which was developed from publicly available materials, identifies the LAC jurisdictions that have geothermal-specific legislation or regulations in place or in draft form.

**TABLE A1.1: Geothermal Laws and Regulations in LAC Countries with Geothermal Potential/Capacity**

Country	Geothermal law in force	Geothermal bill in draft	Geothermal regulation promulgated	Installed capacity (MW)
Costa Rica	✓		✓	207
El Salvador			✓	204
Guatemala	✓			49
Honduras				35
Mexico	✓		✓	957
Nicaragua	✓			150
Panama				
Cuba				
Dominica	✓		✓	
Dominican Republic				
Grenada		✓	✓	
Guadeloupe				15
Martinique				
Montserrat				
Saba				
St. Kitts and Nevis	✓ (Nevis)	✓	✓ (Nevis)	
St. Lucia	✓	✓		
St. Vincent and the Grenadines	✓		✓	
Argentina				
Bolivia				
Chile	✓			48
Colombia				
Ecuador	✓		✓	
Peru	✓			
Venezuela				

## ANNEX 2: World Bank Group Performance Standards

The World Bank's Performance Standards and the objectives of each of these standards are the following:

### PS1: Assessment and Management of Environmental and Social Impacts and Risks and Impacts

- Identify and evaluate environmental and social risks and impacts;
- Adopt a mitigation hierarchy to anticipate and avoid risks and impacts on workers, affected communities, and the environment; where impacts and risks remain, offset and compensate;
- Promote the use of environmental and social management systems;
- Establish plans for stakeholder engagement and community grievance mechanisms and ensure that relevant environmental and social information is disclosed and disseminated.

### PS2: Labor and Working Conditions

- Promote the fair treatment, non-discrimination, and equal opportunity of workers;
- Establish, maintain, and improve the worker-management relationship;
- Promote compliance with national employment and labor laws;
- Protect workers, including different vulnerable groups;
- Implement high standards of health and safety.

### PS3: Resource Efficiency and Pollution Prevention

- Avoid or minimize pollution from project activities;
- Promote more sustainable use of resources, including energy and water;
- Reduce projected-related GHG emissions.

### PS4: Community Health, Safety, and Security

- Anticipate and avoid adverse impacts on the affected communities, from both routine and non-routine circumstances, throughout the life of the project;

- Ensure that safeguarding of personnel and property is in accord with relevant human rights principles and in a manner that avoids or minimizes impacts and risks to affected communities.

### PS5: Land Acquisition and Involuntary Resettlement

- Avoid displacement; when unavoidable, minimize displacement by exploring alternative project designs;
- Avoid forced eviction;
- Anticipate and avoid adverse social and economic impacts from land acquisition or restrictions on land use; if unavoidable, minimize and compensate for loss of assets and ensure that resettlement activities are implemented with appropriate disclosure, consultation, and informed participation of those affected;
- Improve or restore the livelihoods and standards of living of displaced persons;
- Improve living conditions among physically displaced persons through provision of adequate housing with security of tenure at resettlement sites.

### PS6: Biodiversity Conservation and Sustainable Management of Living Resources

- Protect and conserve biodiversity;
- Maintain the benefits of ecosystem services;
- Promote the sustainable management of living natural resources by adopting practices that integrate conservation needs and development priorities.

### PS7: Indigenous Peoples

- Ensure the development process fosters respect for the human rights, dignity, aspirations, culture, and livelihoods of indigenous peoples;
- Anticipate and avoid adverse impacts on indigenous peoples; if unavoidable, minimize and compensate;
- Promote sustainable development benefits and opportunities for indigenous peoples;

- Establish and maintain an ongoing relationship based on informed consultation and participation;
- Ensure free, prior, and informed consent of indigenous peoples;
- Respect and preserve the culture of indigenous peoples.

**PS8: Cultural Heritage**

- Protect cultural heritage (paleontological, archaeological, living, and architectural)

from the adverse impacts of project activities and support its preservation;

- Promote the equitable sharing of benefits from the use of cultural heritage through informed consultation and participation;
- Implement chance-find procedures.

More information on the World Bank's Performance Standards can be found at the following website: [www.ifc.org/performance-standards](http://www.ifc.org/performance-standards).

## ANNEX 3: Environmental and Social Risk Mitigation Measures

**TABLE A3.1: Environmental and Social Risk Mitigation**

Impacts and risks	Examples of risk mitigation measures (including legal or regulatory)
Land acquisition	<p>Minimize land use by judicious site planning to avoid settlements, critical habitats, and high value and intensive land-use areas, and minimize new roads and interruption of population movements. Acquire land on a voluntary basis, avoiding eminent domain, based on a land acquisition and compensation framework that is well disseminated, and a resettlement action plan if relocation is involved (International Finance Corporation/World Bank Performance Standard 5--IFC PS5). If indigenous people are affected, prepare an Indigenous Peoples Plan based on free, prior, and informed consent of the affected people (IFC PS7). If critical habitats affected, prepare a biodiversity action/management plan (IFC PS6).</p> <p>Legal framework: Acquisition may be provided by grants of concessions on state-owned lands (by law, regulation, or contract) and on private land by negotiation or "eminent domain," the constitutional or legislated right of a government to take private property for public use with payment of compensation. Projects that need land acquisition and resettlement of communities to allow for project development typically include a resettlement action plan. Since the expenditure of funds will be required, plans are normally established by law. Plans outline actions for replacement of housing, infrastructure, services, and utilities and the restoration of livelihoods of displaced households.</p>
Land access	<p>Protect wells and facilities from unwarranted access by safety fencing and other barriers, following IFC/World Bank EHS Guidelines for Geothermal Power Generation.</p> <p>Legal framework: Ingress and egress for developers is usually dictated by law, but requires the issuance of permits, licenses, and concessions for specific geothermal resources. Best practice for granting of any natural resource concession includes incorporation of a "use-or-lose" policy encapsulated in law, license, or the concession that defines limits for the various stages of geothermal development areas.</p>
Surface pollution	<p>Test and monitor water resources periodically; adopt toxic and non-toxic waste disposal system that meets local and international industry standards, such as the IFC EHS Guidelines for Geothermal Power Generation.</p> <p>Legal framework: In most countries, environmental and natural resources law describe the network of treaties, statutes, regulations and common and customary laws relating to environmental pollution. Nationwide laws establish a legal and institutional framework for the management of the environment. A distinct set of regulatory regimes focuses on the management of specific natural resources, such as geothermal resources. Dismantling and restoration is usually assured by mandating bonding requirements.</p>
Sub-surface pollution	<p>Test and monitor groundwater periodically; adopt industry standard drilling operations—proper casings, drilling fluids, and drilling muds—to reduce the likelihood of polluting groundwater sources. Follow IFC/World Bank EHS Guidelines for Geothermal Power Generation.</p> <p>Legal framework: Covered by regulations under environmental and natural resources law and national (or provincial) water law.</p>
Extractions	<p>Measure water availability and use, and monitor resources periodically; follow water-use limits set by local or national authorities; adjust requirements for drilling, housing, and facility cooling to meet limits; recycle and reuse water to the maximum extent possible.</p> <p>Legal framework: Implementation of "field rules" as regulation or directive, establishing standards for drilling practices (for example, casing and cementing of cooler groundwater zone) and requisite government inspections.</p>
Solid discharges—muds or drilling fluids	<p>Adopt industry standards for waste disposal according to IFC/World Bank EHS General Guidelines and IFC EHS Guidelines for Geothermal Power Generation, using impervious storage tanks and settling ponds, reusing drilling fluid if feasible.</p> <p>Legal framework: Covered by regulations under environmental and natural resources law.</p>
Solid discharges—cuttings	<p>Adopt industry standards for waste disposal by disposing in boreholes or depositing on appropriate landfill sites, following IFC/World Bank EHS General Guidelines and IFC EHS Guidelines for Geothermal Power Generation.</p> <p>Legal framework: Covered by regulations under environmental and natural resources law.</p>

*(continued on next page)*

**TABLE A3.1: Environmental and Social Risk Mitigation** (continued)

Impacts and risks	Examples of risk mitigation measures (including legal or regulatory)
H <sub>2</sub> S emissions	<p>Conduct baseline air quality tests and set up sensors to monitor air quality periodically, concentrating on facilities and settlements. Well-test results establish the level of H<sub>2</sub>S risk anticipated. If IFC/World Bank EHS Guidelines are exceeded, removal technologies may be required in the power plant. Continuous monitoring should occur in all plants and drilling sites.</p> <p>Legal framework: Regulations under environmental and natural resources law establish requirement for monitoring the concentration of the acidic gases, H<sub>2</sub>S and CO<sub>2</sub>, in the ambient air to ensure concentrations do not go beyond the recommended limits for workplace exposure and for disposal into the atmosphere at specific points.</p>
CO <sub>2</sub> emissions	<p>The most common geothermal gas, CO<sub>2</sub> is usually released in the air. Measurements are taken at all drilling sites; sensors should be put in place in working areas and closed spaces. If there is high volume, CO<sub>2</sub> can be utilized in commercial operations, as in Turkey.</p> <p>Legal framework: Covered by regulations under environmental and natural resources law.</p>
Other emissions	<p>If mercury is significant, it may be removed chemically, but this is rare.</p> <p>Legal framework: Covered by regulations under environmental and natural resources law.</p>
Noise	<p>For residents, noise is mitigated most effectively by placing geothermal facilities away from settlements and habitations and minimizing nighttime activities. The most acute noise, well testing, can be reduced by using buffers. All industrial noises should meet IFC/World Bank EHS General Guidelines.</p> <p>Legal framework: Regulations establish acceptable the decibel range in excess of which energy dissipaters or silencers to mitigate noise are required.</p>
Dust	<p>Dust impacts can be mitigated by wetting exposed areas and graveling or paving roads; to reduce impact on residents, truck traffic should be restricted in the evening and nighttime.</p> <p>Legal framework: Covered by regulations under environmental and natural resources law.</p>
Occupational health and safety	<p>Employees should be given clear codes of conduct regarding health and safety, on and off the job; emergency preparedness and response plans should be developed and used to train employees. Living facilities and job sites should comply with IFC/World Bank EHS General Standards and IFC EHS Standards for Geothermal Power Generation, as well as IFC PS2. OHS incidents and accidents should be reported continuously and subject to periodic review.</p> <p>Legal framework: In common-law jurisdictions, employers have a common-law duty to take reasonable care of the safety of their employees. Statute law may impose other general duties and create government bodies with powers to regulate workplace safety issues; details vary from jurisdiction to jurisdiction.</p>
Direct livelihood loss	<p>Issue should be highlighted in the ESIA. Private and communal land lost to the project should be substituted, if possible, or compensated at replacement value. If land replacement is adopted, the amount and quality of replacement land should be assessed to ensure that it will yield similar results. The most adversely affected should be given priority for employment and other measures adopted to offset for losses through the development of a livelihood restoration plan or RAP (IFC PS5).</p>
Indirect livelihood loss	<p>Loss of livelihood due to the reduction of communal land or other resources should be anticipated through the ESIA and addressed in a livelihood restoration plan or RAP (IFC PS5).</p>
Indigenous vulnerability	<p>Indigenous people should be identified in the ESIA or early social assessment. The project should establish an ongoing relationship with indigenous people to ensure their informed consultation and participation, and they should participate in the preparation of an Indigenous Peoples Plan that is based on their “free, prior, and informed consent” (IFC PS7).</p> <p>Legal framework: Domestic laws that deal specifically with social regulations related to geothermal development can be based on IFC PS7 or World Bank OP 4.10 Indigenous Peoples.</p>
Traffic	<p>Anticipated traffic should be discussed, and rules set through the SEP to minimize disruption to communities and ensure safety.</p>

(continued on next page)

**TABLE A3.1: Environmental and Social Risk Mitigation** (continued)

Impacts and risks	Examples of risk mitigation measures (including legal or regulatory)
Labor influx	<p>Anticipated influx information disseminated and discussed through consultations, according to the SEP and assessed in the ESIA. Temporary workers subject to clear rules of conduct signed at hiring; infractions reported through grievance procedures.<sup>a</sup></p> <p>Legal framework: National investment laws that facilitate private sector investment generally allow foreign labor with geothermal expertise work visas for the project duration.</p>
Community asset vulnerability	<p>Siting of new facilities subject to consultation (SEP); access and use of community assets protected by rules of conduct. Compensation for reduced assets through a livelihood restoration plan (IFC PS5).</p> <p>Legal framework: Domestic laws that deal specifically with social regulations related to geothermal development can be based on IFC PS 5 or World Bank OP 4.12 Involuntary Resettlement.</p>
Conflict over investment, location	<p>Siting of new facilities and revision of facility sites subject to prior notification and open discussions (SEP), focusing on transparency and accountability.</p> <p>Legal framework: Establish “unitization” regulations so development and production of geothermal resources will be under coordinated management to avoid multiple users of the same field tapping into the resource and overexploiting and depleting it.</p>
Conflict over opportunities	<p>Employment and facility service opportunities subject to transparent procedures established through the SEP to minimize conflict and suspicion.</p>
Physical cultural resource impacts	<p>Cultural resources identified in ESIA, with provision to protect them, and “chance-find” requirements embedded in all contracts (IFC PS8).</p> <p>Legal framework: Covered by regulations under environmental and natural resources law, plus international agreements such as Convention Concerning the Protection of World Cultural and Natural Heritage that was adopted by the General Conference of UNESCO in 1972.</p>
Visual impacts	<p>Facility siting and design subject to transparent notification and consultation (SEP) and adjusted to avoid or minimize visual disturbances.</p> <p>Legal framework: Covered by regulations under environmental and natural resources law.</p>
Tourism effects	<p>ESIA identifies anticipated impacts and includes provisions in ESMP to mitigate and measure impacts, utilizing SEP as a dissemination and consultation mechanism.</p>
Rumors, fears	<p>SEP developed, disseminated, and discussed at earliest stages of project development. It identifies significant stakeholders, including affected persons, establishes ongoing mechanisms to assure transparency in decisions related to siting and changes to the facility, and sets a clear consultation and information sharing program, including the dissemination of information through national and local press and informal networks. If similar facilities are accessible, affected people should be transported to see them. The ESIA also identifies local issues and apprehensions and proposes steps to address them through consultation, experience sharing, or other means.</p>
Organized opposition	<p>The SEP and ESIA identify all stakeholder issues, organized and individual, and proposes mechanisms to engage opposition continually and openly, transparently responding to concerns and demonstrating an inclusive project approach, adjusting to reduce or resolve opposition issues.</p>

<sup>a</sup> The World Bank’s Environmental and Social Safeguards Advisory Team recently issued guidance on this issue, “Managing the Risks of Adverse Impacts on Communities from Temporary Project Induced Labor Influx” in December 2016.

## ANNEX 4: Environmental & Social Impact Assessment Topics for Geothermal projects

The following are the main topics that should be covered in an internationally accepted ESIA for a geothermal investment:

- Air emissions including H<sub>2</sub>S, Hg and, to a certain extent, CO<sub>2</sub> (present in the steam), during the drilling stages as well as from power plant operation;
- Effluents, including drilling fluids and cuttings associated with exploration, development, and operational activities and dust emissions;
- Spent geothermal fluids associated with rejection water from steam separators during drilling and operational phases;
- Water consumption and extraction associated with the geothermal power generation activities, well drilling (exploration and production phase), and provision of make-up water in cooling systems;
- Emergency preparedness and response for all phases, including the risk of well blowouts, pipeline failures, and exposure to excessive levels of H<sub>2</sub>S;
- Local ecology and biodiversity, land use, landscape characteristics, and potential impacts;
- Proximity to recognized habitats (protected or not), anticipated impacts, and existing restrictions;
- Assessment of proposed or actual location of facilities relative to population, human activities, recreation, or cultural heritage;
- Construction impacts, especially roads, pipelines, and site preparation;
- Associated facilities, such as transmission lines and substations;
- Community health and safety impacts (including infrastructure safety, noise, water resources, and traffic), primarily during development phases, but can also be significant during operations;
- Labor requirements and labor sourcing, including anticipated labor influx, living facilities, health services, and management of labor population on and off the job, including such issues as poaching risks;<sup>88</sup>
- Occupational health and safety of the workers with respect to geothermal gases, confined spaces, potential impacts from unrelated seismic activities, heat, noise, and blowout risks, during all phases of project development, as well as disaster planning activities;
- Stakeholder participation and consultation with affected communities and wider interested parties to gather information about the baseline conditions in the area and to communicate project intentions to the community, while ensuring that communications do not limit participation based on gender or age;
- Social aspects, including population, socio-economic status, livelihood choices, employment, ethnic and social composition, vulnerability, local administration and informal authority, landowning and land use, social services, gender, cultural heritage, indigenous peoples, and local opposition, organized or not;
- Plans and procedures to protect workers and those involved in the project (according to International Labour Organization conventions and UN conventions) and to reduce negative impacts on local populations;
- The establishment of an approach to land acquisition and compensation, including resettlement planning, if necessary;
- Analysis of alternatives; and,
- The assessment of cumulative impacts that are likely to result from the proposed project if expansion of the facility is planned, additional projects are anticipated, or other geothermal facilities are in the area of influence of the project.

<sup>87</sup> World Bank, “Managing the Risks of Adverse Impacts on Communities from Temporary Project Induced Labor Influx” (Washington DC: World Bank Environmental and Social Safeguards Advisory Team, 2016.)



San Jacinto-Tizate Geothermal Plant.  
Photo courtesy of Polaris Energy Nicaragua S.A.

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