Energy Under the Andes:
Benefits, Barriers to Development, and Relevant Policy Alternatives for Chile's Untapped Geothermal Resources

by

Andrew Reed

B.S. Business Administration, B.A. Spanish, University of Pittsburgh, 2006

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This thesis was presented

by

Andrew Reed

It was defended on

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and approved by

Marcela González, PhD, Assistant Professor

Sera Linardi, PhD, Assistant Professor

Thesis Advisor: Ilia Murtazashvili, PhD, Assistant Professor

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Andrew R. Reed

Chile is home to 10% of the world's volcanoes and, according to many scientists and energy experts, is a prime location for geothermal energy development. Yet, to date, Chile has no geothermal plant in production. Despite extremely high energy prices and energy shortages in the country, very little has been done to exploit one of Chile's most promising energy resources. Through a series of over 30 interviews with government officials, geothermal industry experts, community leaders, and university professors, I will clarify the advantages of geothermal energy in Chile, as well as the barriers to development and the potential policy solutions to diminish those barriers. The most critical barriers identified in this study are: (1) high cost and risk of initial investments, (2) lack direction on energy development and institutional support on the part of the government, and (3) vague elements of the legal and regulatory framework.

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PREFACE

A special thanks to my wonderful thesis committee and the incredibly helpful faculty and staff of CEGA at the Universidad de Chile.

1.0 INTRODUCTION

Chile has one of faster growing economies in the world. The Central Bank of Chile has noted GDP growth of 6.3% in 2011, 5.5% in 2012 and anticipated growth of 4.5 to 5.0% in 2013.[1] As a result of this growth, Chile had the highest GDP (PPP) per capita in 2011 in Latin America at USD $17,310 – well ahead of other Latin American economic centers like Brazil and Mexico.[2] Despite this economic success, Chile will likely be able to continue to realize such growth only if it is able to overcome a significant hurdle: serious energy supply constraints. High energy costs and slow energy project development in response to tight supply and increasing demand have recently forced Chilean citizens and industries to pay some of the highest energy prices in the Latin America. In fact, Chile had energy prices that exceeded averages among other OECD member nations by 61% in early 2013.[3] Evidence collected by various international and governmental agencies suggests that Chile will face serious (and perhaps debilitating) energy shortages and price increases by 2020 unless the nation finds ways to stabilize and secure its energy supply.[4] While the current situation may seem bleak, Chile has not exploited all of its domestic sources of energy - including those, like geothermal, that have proven cost competitive in some other markets. Development of these domestic sources could alleviate some of supply

[1] "2012 Quarterly Economic Indicators." Central Bank of Chile. Web. 2012.
[2] GDP, PPP (Current International $), World Bank. 2013. Web.
[3] Woods, Randall. 2013. "Chile Seeks Developed Status, Meets Soaring Energy Costs". Bloomberg.com. 15 Jan 2013.
[4] "An Unexpected Setback." The Economist. 1 Jun 2012. Web. 17 Apr 2013.

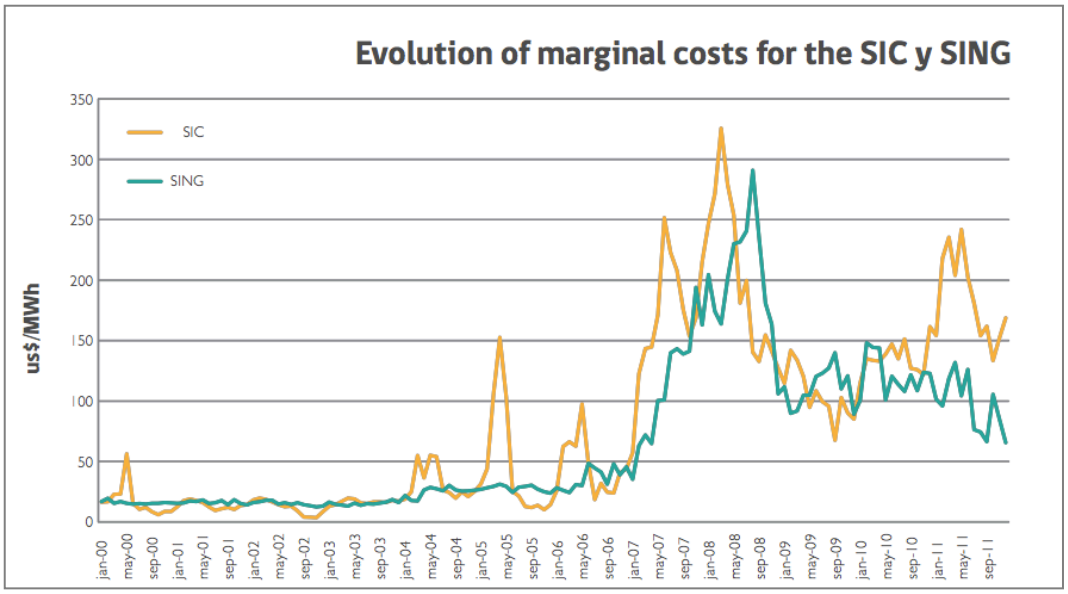
constraints. Through a series of interviews and interactions with key actors in the Chilean geothermal sector, I will clarify how key actors in the energy sector perceive the advantages of geothermal energy in Chile, as well as barriers to development and potential policy solutions to diminish those barriers. I will also compare how these perceptions may be similar or different across actors in an attempt to shed light on how feasible policy solutions for certain barriers may be. Some of the most critical barriers to geothermal development identified in this study are: (1) high cost and risk for investors, (2) lack of government direction and institutional support on the part of the government, and (3) vague elements of the legal and regulatory framework.

2.0 BACKGROUND

Because Chile has very few indigenous sources of energy, the country must rely on imported fossil fuels for energy production. The energy sector faced serious stress in 2007 and 2008 when Chile's main supplier of natural gas, Argentina, experienced a colder than normal winter. Needing a greater supply of natural gas to heat the homes of its own citizens, Argentina severely reduced supply to Chile. Diesel oil, although quite expensive, was the only available alternative to meet the unexpected shortages in supply in natural gas. Diesel oil was readily available and could be substituted for natural gas in thermoelectric plants that no longer had a supply arriving from Argentina. In the same period as the natural gas shortage, drought in Chile decreased energy output from many of the domestic hydroelectric facilities – which supplied roughly half of the energy supply at the time.[5] In its most recent annual report, the board chairman of Chilean energy company Colbún S.A., noted "the Chilean power sector…has faced a complex situation which has prevented it from regaining balance between supply and demand." As a result, energy shortages and high, volatile energy prices have been present since 2007 in Chile's two major grid systems, the Central Interconnected System (SIC) and the Norte Grande Interconnected System (SING).

[5] Government of Chile. National Energy Strategy 2012-2030. Government of Chile, 2012. PDF File.

Figure 1. Change in Marginal Energy Costs



Source: Government of Chile, Ministry of Energy, CDEC-SIC and CDEC-SING

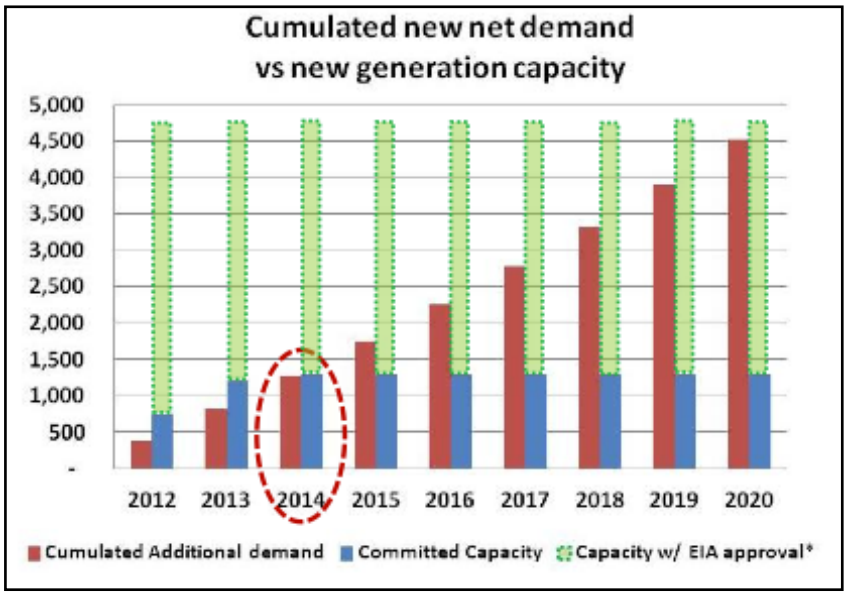
Further compounding Chile's energy problem is the lack of new energy projects under construction. Several new power generation projects that were meant to meet incremental growth in demand have faced major delays and/or have been completely stopped due to public opposition or judicial intervention. In fact, it is projected that only 30% of the 11,000 MW of additional installed capacity planned by the National Energy Commission (CNE) in 2006 will be available by the commission's original deadline of 2015. [6] In 2014, Chile reaches a critical juncture in capacity vs. demand. Without more planned projects reaching the point of development, the energy problem may soon become and energy crisis.

This lack of new projects under construction in the pipeline means that Chile will likely have to depend on very expensive diesel imports in the near term to fuel existing facilities. Colbún's 2011 Annual Report warns that generation companies will likely need to rely 'high-

[6] Colbún S.A. Annual Report 2011. Colbún S.A., 2011. PDF File.

cost diesel oil' for a 'greater than reasonable fraction of power generation'.[7] According to Bloomberg New Energy Finance (BNEF), diesel energy remains one of the most expensive options in Chile's energy mix.

Figure 2. Demand vs. Capacity in Electricity Generation, SIC and SING



Source: GDF Suez

High and overly variable energy prices could severely hinder the country's export economy by increasing the cost of goods produced, particularly in Chile's very large mining sector. Some private companies – particularly those in the mining sector – have been forced to stray from their core businesses to develop in their own energy projects to ensure supply.[8] High energy prices are beginning to introduce a feeling of uncertainty among Chilean businesses and citizens. Rising energy costs are particularly worrisome due to the impact of currency

[7] Colbún S.A. Annual Report 2011. Colbún S.A., 2011. PDF File.
[8] Urenda, Juan Carlos. "The Chilean Mining Sector." Office of the Mining Commission. Santiago, Chile. 11 Mar. 2013. Invited Speaker.

appreciation on the competitiveness of exports, which accounted for 35% of Chile's GDP in 2010.[9] Over time, Chile may become increasingly less competitive on the world market if the government cannot partner with the energy sector to correct escalating prices and supply bottlenecks. The situation has lead former president Ricardo Lagos to comment, "Now, our energy policy isn't very clear, which makes it difficult for some to make investments with Chile."

A crucial industry to consider is the mining industry. Chile is the world's largest producer of copper. In 2012, mining and mining-related services accounted for 40% of Chile's GDP and 35% of all energy usage in Chile.[10] In the near term, Chile's continued growth and development hinge on the stability and growth of the mining sector. In Chile, energy accounts for roughly 15% of costs in mining. Chile has the second highest energy prices of any major copper-producing nation in the world. Only in the Democratic Republic of the Congo does it cost more to power a copper mining operation.[11] Fortunately for Chilean mining companies, global copper prices have been very high in recent years (See Table 1), helping to insulate these firms from some of the burden of high energy costs in the years after energy prices spiked in 2007. However, the Chilean copper industry could very easily face lean years if copper prices take a different trajectory, as current *costs* for producing one pound of copper in Chile ($1.60/lb) are nearly the identical to the *price* per pound of copper on the world market in 2005 ($1.67/lb).

[9] Bradley, Ruth. "Chile: Start with Challenges" *Latin Trade* July/August 2011, 54-58.
[10] Martinez, Pablo. "GDF Suez in Chile." Austral Offices. Santiago, Chile. 11 Mar. 2013. Invited Speaker.
[11] Urenda, Juan Carlos. "The Chilean Mining Sector." Office of the Mining Commission. Santiago, Chile. 11 Mar. 2013. Invited Speaker.

Table 1: Copper Prices, Copper Exports, and Total Exports in Chile, 2003-2011

	2003	2004	2005	2006	2007	2008	2009	2010	2011
Copper price (in US$/lb)	0.81	1.30	1.67	3.05	3.23	3.15	2.34	3.42	4.00
Copper exports (in US$ billion)	8.0	15.4	19.9	34.1	39.2	31.8	29.7	41.2	44.4
Total exports (in US$ billion)	**21.7**	**33.0**	**42.0**	**59.4**	**68.6**	**64.5**	**55.4**	**70.9**	**81.4**

Source: Central Bank of Chile

So, what can be done to improve energy security? The large-scale coal and hydroelectric projects proposed in recent years will likely not be the solution. These projects have proven very unpopular and , in some cases make the country's energy matrix even less sustainable. The answer to Chile's energy woes will likely be found in (1) increased usage of liquefied natural gas (LNG), (2) more strategic development of hydroelectric projects, and (3) a significant increase in investment in non-conventional renewable energy (NCRE). See Figure 3 Appendix for complete analysis of energy resource alternatives in Chile.

While a variety of NCRE resources may be considered for matrix expansion in the future, geothermal energy represents a particularly attractive choice (Again, see Appendix Figure 3 for review of energy options in Chile). Unlike hydropower, Geothermal would not be impacted by drought. Unlike fossil fuels, it would not be subject to fluctuations in international supply and prices. And, perhaps most importantly, unlike most other renewables, it can produce energy 24 hours per day, 7 days per week. The fact that geothermal energy can produce around the clock means that it is a base load energy resource. In other words, it is a *perfect* substitute for base load fossil fuels in energy generation. Therefore, it can be used to power large-scale industrial operations – like mining – that operate continuously. Geothermal represents a significant opportunity to meet some of the needed incremental growth in capacity and, at the same time,

achieve a greater amount of secure, domestic energy supply. Many countries, like Iceland,[12] the Philippines,[13] and New Zealand[14] have faced similar energy constraints and have turned to their geothermal resources to buttress a variable and unstable energy supply. For the remainder of this essay, I will consider opportunities related to geothermal energy, one of the most abundant and promising undeveloped NCRE energy resources in Chile.

[12] Mims, Christopher. "One Hot Island: Iceland's Renewable Geothermal Power." *Scientific American.* 20 Oct 2008.
[13] "Philippines Tap Energy from Earth's Core". Online Video Clip. *CNNMoney.* CNNMoney, 25 Feb 2013. Web. 14 Apr 2013.
[14] International Energy Agency. New Zealand 2010 Review. International Energy Agency, 2010. 65. PDF File.

3.0 THE STATUS OF NCRE IN CHILE AND THE CASE OF GEOTHERMAL

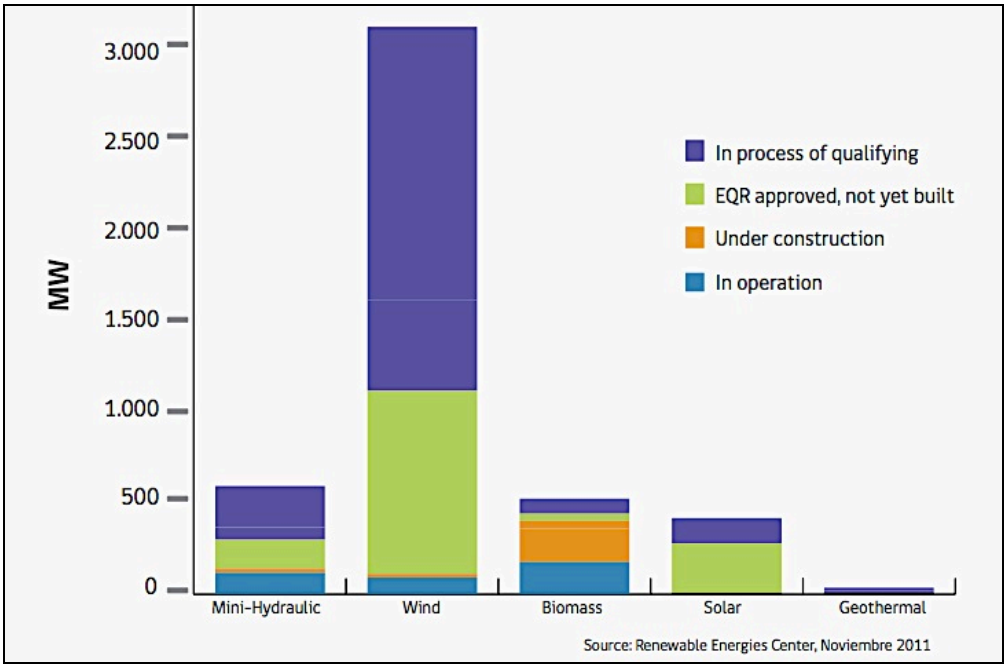
In April of 2008, the government of Chile passed the Law for the Development of Non-Conventional Renewable Energy (NCRE). This law requires electric companies to demonstrate that a specific percentage of energy produced is generated from NCRE sources. As of 2010, the law required that 5% of energy was generated from NCRE sources. This required 5% will incrementally climb to 10% by 2024.[15] In 2012, the government released an updated national energy strategy. In this report, the Piñera administration dubbed the 10% level 'inadequate' because only 3% of energy was being produced from renewables at the time of the February 2012 publication. The strategy noted, "Our objective for the future composition of the matrix is to accelerate the incorporation of NCRE sources…" The report called for 20% of all energy to be derived from NCRE sources by 2020 as part of an effort to make the matrix "ever-cleaner, more diverse and safer". However, after over a year of debate, this strategy for NCRE has yet to become law.

Despite the slow but somewhat promising growth of NCRE in Chile, there are still vast amounts of renewable resources not being utilized or developed. Geothermal energy is a prime example of an underdeveloped source. Of the 743.12 MW of non-conventional renewable energy

[15] International Energy Agency. Chile Energy Policy Review. International Energy Agency, 2009. 167. PDF File.

in production in Chile as of June 2012, there was not a single mega-watt being produced from a geothermal plant.[16] See Figure 3 below for 2011 NCRE development data.

Figure 3: Status of Renewable Energy Development in Chile, 2011



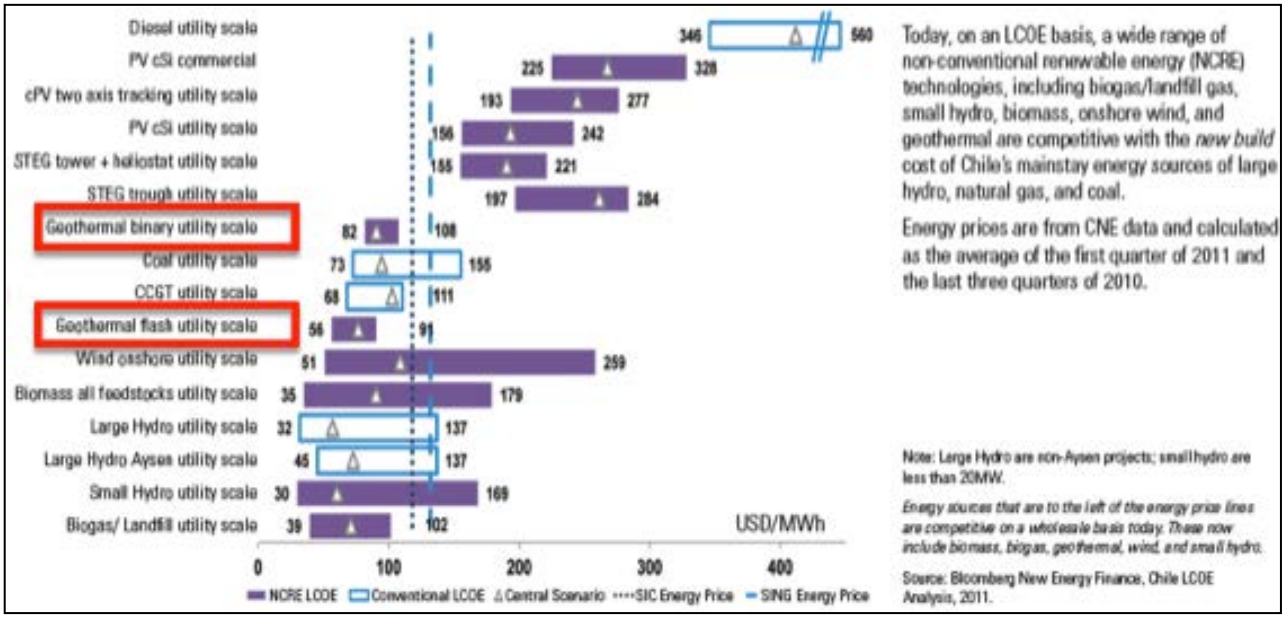
Source: Center for Renewable Energy, Chilean Government

The Ministry of Energy speculates that two geothermal plants will likely come online by 2015, each with a capacity of less than 100MW.[17] However, recent comment by the general manager for one of these projects indicated a timeline the completion of his project will likely occur after 2015.[18] Regardless, these two plants represent only a small fraction of the amount of geothermal power that could be produced in Chile. The International Energy Agency notes that the country exhibits much potential for generating geothermal energy, as Chile is home to 10%

[16] Centro de Energías Renovables. "Proyectos ERNC en Operación". Centro de Energías Renovables. June 2012. Web. 22 Aug 2012.
[17] Espinosa, Carolina. Personal Interview. 26 July 2012.
[18] Trenkle, Rüdiger. "Central Geotérmica Curacautín" Offices of the Center for Geothermal Excellence of the Andes at La Universidad de Chile. Santiago, Chile. 4 Apr. 2013. Guest Speaker.

of the world's volcanoes. The National Petroleum Company of Chile, ENAP, estimates that the country has the potential to produce 3,350MW of geothermal energy[19], a significant percentage of the nearly 8,000MW of additional capacity the government predicts will be needed by 2020.[20]

Figure 4: Chile LCOE Analysis, 2011



Source: Bloomberg New Energy Finance

Geothermal energy is not only abundant, but also cost competitive. The In 2011, the International Energy Agency reported, "New plant generation in some countries can be highly competitive…at USD 50/MWh and 80/MWh". With its wealth of resources, Chile can likely produce at similar costs. A 2011 Bloomberg New Energy Finance analysis of levelized cost of energy (LCOE) in the Chilean market finds geothermal to be one most cost competitive NCRE sources *and* one of the more cost competitive resources of any type. Only onshore wind,

[19] International Energy Agency. Chile Energy Policy Review. International Energy Agency, 2009. 163. PDF File.
[20] Government of Chile. National Energy Strategy 2012-2030. Government of Chile, 2012. PDF File.

biomass, biogas, and certain types of hydroelectric resources supersede geothermal LCOE. See Figure 4 for LCOE analysis.

Obviously, some energy development companies recognize the potential for a larger, stronger geothermal sector in Chile and have established operations in the market (See Appendix Table 4 for review of active geothermal development companies in Chile). In fact, a tender for 20 geothermal concessions (a government permit for exploration in a given area) in April of 2012 brought nearly USD $250 million of promised investment from both domestic and international companies.[21] As of July 2012, 76 concessions have been granted for geothermal exploration and 6 concessions granted for exploitation. An additional 83 concessions for exploration have been requested, but have yet to be approved by the government (See Appendix for list of geothermal concessions by company in Chile as of July 2012).[22] Despite all of this activity, the fact remains that development of the geothermal sector in Chile lags far behind its potential. Interest in geothermal energy among some of the biggest, most influential companies in the Chilean energy generation market remains relatively tepid (See Appendix Figure 5 for review of Chile's largest energy generation companies). A 2010 initiative that included Colbún[23], one of Chile's major electricity generators, has not moved forward. Despite all of this activity, however, Chile remains without any geothermal energy in production and only very modest plans for future development.

This abundance of opportunity in geothermal energy would seem to be a boon for a country so starved for energy. So, despite the upside of geothermal energy, why has the

[21] Geothermal Energy Association. *Geothermal: International Market Overview Report.* Geothermal Energy Association, 2012. PDF File.
[22] Ministry of Energy, Government of Chile. Geothermal Concession Database. Ministry of Energy, Government of Chile, 2012. PDF File.
[23] "Colbun mulls over 300MW Renewable Energy Projects". SeeNews Renewables. 25 Jun 2010.

development process for geothermal been so slow and laborious? In his book “Collapse”, Jared Diamond lists several reasons why countries may not decide to capitalize on opportunities that could prevent resource scarcity, ease economic hardships, and ensure self-preservation. In other words, Diamond attempts to answer why countries might make choices that seem to directly (and, at times, obviously) lead to suboptimal social and/or economic results. First, he speculates that some societies “may do disastrous things because they failed to anticipate a problem before it arrived, for any of several reasons. One is that they may have no prior experience of such problems, and so may not have been sensitized to the possibility” or, perhaps, “the experience [of dealing with the problem before] happened so long ago as to have been forgotten”. Considering Chile has faced high energy prices and shortages for nearly five years, both the government and the citizens are well aware of the energy problem at hand. Yet, significant policy action has not been taken. Second, Diamond suggests, a society may fail to anticipate a problem due to “reasoning by false analogy”. He continues, “When we are in a unfamiliar situation, we fall back on drawing analogies with old familiar situations”. Again, I doubt this is the case in Chile. Key actors and government leaders have a wealth of international information available from countries that have faced similar types of energy issues. As mentioned before, many energy-scare countries with similar levels of geothermal capacity have pursued development of the resource through a variety of public and private means. Energy scarcity is certainly not unprecedented in modern times. Third, Diamond argues that perhaps societies “fail to perceive” a problem even when it clearly exists. This may arise because the origins of the problem are simply “imperceptible” and/or the problem arises in the form of a “slow trend” which is “concealed by wide up-and-down fluctuations.” Considering the dramatic onset of the increases in energy prices coupled with a large amount of public outcry over the issue, it is again unlikely

that this is the cause. Finally, Diamond posits, that it is perhaps 'rational behavior' that leads to actions that seem so irrational. That is, Diamond writes, "some people may reason correctly that they can advance their own interests by behavior harmful to other people." While this fourth element in Diamond's framework might be part of the issue in Chile – considering the large existing investments in fossil fuel facilities by Chile's largest energy generators – it isn't likely to be the entire reason.

I believe that the nature of Chile's problem could probably be a very valuable fifth pillar of Diamond's framework. In Chile, nearly everyone perceives a problem with energy, but not everyone seems to perceive the nature of the problem (or the solutions to that problem) to be the same. Thus, many groups are attempting to solve similar problems in different and, at times, competing ways. Proposed solutions from the government have been many and varied – with little effort placed behind turning these proposals into legitimate policies. The largest actors in the energy generation industry seem to want to continue on the path of business as usual, investing most of their money in the very technologies that have been the root of the existing energy problems. A majority of the public staunchly supports renewable energy to the point that certain civil organizations have been quite successful in stalling construction of many non-NCRE plants. Finally, the academic community seems to often focus on the technical aspects of energy over the somewhat more pressing political aspects of energy. Thus, the direction Chile will take to achieve greater energy security is cloudy, at best.

In an attempt to better understand how geothermal energy might be developed in such an unclear environment, I felt it was prudent to interview key actors from a variety of backgrounds. I was able to gather many perspectives clearly show where individuals stood on the issue. In

doing so, the aggregate of these perspectives may shed light on where opportunities and challenges might exist for future development of Chile's geothermal resources.

4.0 THE STUDY

In an effort to understand why geothermal development lags behind other resources in Chile, interviews were conducted with more than 30 key actors in the Chilean geothermal sector. Each of these actors works within government, business, academia, and/or civil society. Through these interviews, I have found that many obstacles are present in the Chilean market and nearly all are insufficiently addressed by current policy. Through this series of interviews conducted in July and August of 2012, I have identified and measured many key actors' perceptions about the:

1. Advantages of geothermal energy in the Chilean context.
2. Barriers to the development of geothermal energy in Chile.
3. Potential policy proposals to overcome those barriers to geothermal development in the Chile.

5.0 PURPOSE

The purpose of this study is to understand why geothermal power has not been incorporated into Chile's electricity supply, despite the slow development of other NCRE resources. I focus on geothermal power production via exploitation of high enthalpy resources, as low enthalpy resources are not conducive to generating electricity. I aim to advance and expand the conversation about the role of geothermal resources in Chile's matrix. By more clearly identifying these advantages, barriers, and incentives I can develop policy suggestions that may help to spur development in the sector. At the same time, I can provide a platform from which an expanded discourse about the role of geothermal energy in Chile can grow between actors in industry, government, civil society and academia.

6.0 METHODOLOGY

This study does not attempt to engage in a case comparison between other countries that have developed geothermal energy. I rely mainly on the market study because the Chilean energy market and social context is decidedly unique to other countries that have developed geothermal energy in a significant way. In 1982, Chile was the first country in Latin America to extensively privatize its energy sector. Today, energy generation, transmission, and distribution are still owned and managed by the private sector, with very modest amounts of regulation by government institutions. As such, the government does not engage in significant projects to spur development and dissemination of new technologies – like those used to generate geothermal energy. In every other case of geothermal development, governments have played a crucial role in developing the resource – often with state-owned drilling companies. Considering the role of the state in Chile will likely be secondary to actors in the private sector, the case of geothermal energy in Chile will need to be considered and evaluated, in most circumstances, on a stand-alone basis. This is not to say that experiences in other countries are not valuable references in our discussion of geothermal energy in Chile, but it does suffice to say that a case comparison would likely produce results that would consistently point to extremely heavy state involvement lacking in Chile. To avoid such obvious conclusions, I instead opt to explore geothermal energy in Chile as a unique case and rely on commonalities and differences in the perspectives of key actors *within the Chilean market* to guide my final recommendations.

I created a standardized 58-question survey and interviewed over 30 key stakeholders about the perceived advantages and barriers of geothermal development in Chile. The barriers included in the study were derived, in part, from those identified in a 2012 Bloomberg New Energy Finance report (See Appendix Table 6). [24] Additionally, I asked these stakeholders about a series of incentives used by other nations to diminish the barriers to geothermal development. I grouped these individuals into three categories: Government, Industry, and Academia/Other. The perspective of communities impacted by geothermal development is also included in this study, but not directly through this survey. I present the community perspective as a commentary on the policy recommendations and suggestions receive in the survey. In some cases, this community perspective may align with perspectives expressed by those in government, industry, and/or academia. However, in other instances, there may be important differences that might shade the results derived from the survey and alter final policy recommendations. See Appendix table 7 for organizational affiliation of study participants.

A scale of 1 through 5 (1 being low, 5 being high) was used for each question in the interview to evaluate each individual's personal perception[25] of a given advantage, development barrier, or development incentive. After completing all interviews, I aggregated the results to discern the general perceptions of the collective group about the strength and/or importance of each of the advantages, barriers, or incentives.

The interview also included a series of open questions. These questions allowed key actors to indicate important advantages, barriers, or incentives they felt may have been missing from the survey. Advantages, barriers, and incentives mentioned frequently by actors in the open

[24] Bloomberg New Energy Finance. *Q3 2012 Geothermal Market Outlook.* Bloomberg New Energy Finance, 2012. 1 PDF File.

[25] Note: Interviews captured the opinions of the individuals interviewed and not necessarily the official position of the companies, organizations, or firms with which they are affiliated.

question section of the interview are also considered important in this study and several are included in our conclusion.

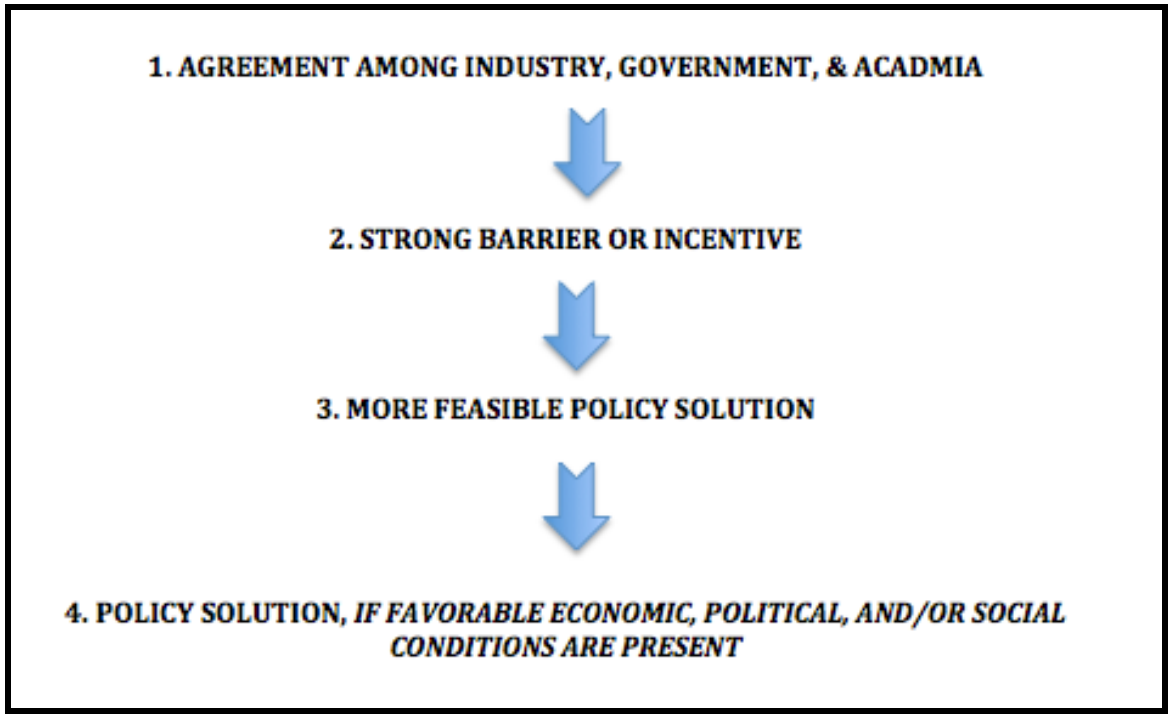
I derived our conclusions about the relative strength or weakness of each respective advantage, barrier, or incentive in the following way:

1. STRONG: Advantages, barriers, and incentives are considered strong if the average response of participants from three categories (Industry, Government, and Academia/Other) is between 4.0 and 5.0. Some advantages, barriers, and incentives may also be considered strong if respondents consistently mentioned them as being strong during the 'open question' section of the interview.
2. MODERATE/WEAK: Advantages, Barriers, and Incentives are considered moderate or weak if the average response of all three categories (Industry, Government, and Academia/Other) is below 4.0.
3. CHALLENGES: Advantages, Barriers, and Incentives are considered 'challenges' if one or two sector(s) finds the importance of the variable to be greater than 4.0 (strong) and one or two other sector(s) gives it an average value of less than 4.0 (moderate/weak). The lack of alignment among the categories of actors for a given issue may represent a challenge to developing more effective geothermal policy.

Barriers and incentives that are perceived to be strong – that is when all actors are in general agreement – are assumed to be better candidates for policy solutions if political, economic, and/or social conditions are favorable for governing bodies to pass legislation. At the very least, it may give actors an idea of where to begin when considering which barriers or incentive mechanisms to pursue first. For example, if all actors in the survey were in agreement that 'high

initial costs' are a significant barrier, it would make sense that a policy solution for this barrier may be more achievable. Conversely, if actors are in general disagreement about a specific theme, as is the case with the legal framework in my survey, it may signal that policy solutions are less achievable in the near term. Disagreement on a specific theme does not inherently mean that a policy solution is less necessary for that theme – it simply means that the solution may be more difficult to achieve. The line of thought behind this process is represented in the Figure 5 below:

Figure 5: Line of Thought in Creating the Survey



7.0 RESULTS: ADVANTAGES

7.1.1 Strong Advantages

On average, participants across all categories found these advantages to be strong reasons for geothermal development in Chile. See Appendix Table 8 for data.

- **It is an abundant resource in Chile.** *Although estimates for potential output are still unproven, all sectors were in agreement that resources are abundant in Chile.*
- **It is a domestic source of energy and, therefore, improves energy security.**
- **Geothermal energy has a very high capacity factor and, therefore, improves energy security.** *Plants producing electricity from geothermal sources produce a consistent and reliable source of power around the clock. In this manner, geothermal plants function much like their fossil fuel counterparts and serve as a near-perfect, clean substitute. Geothermal energy could power the large mining sector, which currently depends on expensive diesel and LNG plants or environmentally damaging and socially contentious coal plants.*
- **Geothermal technology is mature and has been used in other parts of the world for more than 50 years.**
- **It is versatile resource and can be employed for direct uses (i.e. greenhouses, heating, etc.) as well as electricity generation.** *The development of a robust geothermal sector in*

Chile has implications beyond electricity generation. Home heating and greenhouses are among several other commercial applications of geothermal energy. For example, 87% of households in Iceland use geothermal resources for heating.[26]

- **It has a low environmental impact relative to other energy sources.** *While no energy source has zero impact on the environment, geothermal energy can be produced with lower impact relative to most other energy sources.*
- **Geothermal plants can be built in a 'modular' fashion. Plant capacity can be gradually increased as demand increases.** *Investors and developers do not need to build a large plant in the first phase of exploitation. The plant size may gradually be increased as demand increases.*
- **As an NCRE source of power, geothermal energy can be uses to diminish pollution levels and meet international environmental goals.** *As a new OECD member, Chile has added incentive to participate in international environmental agreements. Meeting international environmental goals may have future economic and political implications.*
- **Some geothermal resources are located near mining operations and can be used by the mining industry.** *The mining industry currently uses about 37% of all electricity in Chile.*[27] *Most of the energy consumed by the mining sector in the northern region of the country is derived from fossil fuels.*[28]

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[26] Bjornsson, Sveinborjn. *Geothermal Development and Research in Iceland.* Iceland National Energy Authority and Ministries of Industry and Commerce. April 2006.
[27] Comisión Nacional de Energia (CNE) and Deutsche Gesellschft für Technische Zusammenarbeit (GTZ), *NCRE in the Electricity Market.* 2009, 29.
[28] Government of Chile. Comisión Asesora Para El Desarollo Elétrico. Government of Chile, 2011. 27. PDF File.

7.1.2 Challenge Advantages

On average, participants were in disagreement about these advantages of geothermal energy in Chile under current policy conditions. See Table 8 for data.

- **Geothermal projects support economic development for nearby communities.** *Globally, geothermal projects have had mixed success in supporting economic opportunities in nearby communities. Research on one geothermal project in Kenya found that many locals saw few direct economic benefits from the geothermal facilities.*[29] *However, this is not always the case. Development plans in New Zealand and the United States, for example, have found ways to address community needs and even make local community members stakeholders in the financial success of the plant.*[30][31] *I will discuss this theme in more detail in the 'Community Barriers' section of this paper.*
- **Development of geothermal energy in Chile will create jobs and promote overall national economic growth.** *Many nations promote NCRE development under the logic that building and maintaining domestic NCRE projects – like geothermal plants – will create jobs and help to develop a future economy powered by a secure, stable, clean energy supply. In our survey, actors in industry were relatively skeptical about the jobs and economic growth geothermal development would create. Those in Government and Academia/Other were slightly more optimistic about the positive economic implications of geothermal development. I might not be surprised to see these mixed results given that*

[29] Mariita, Nicholas. 2002. "The Impact of Large-Scale Renewable Energy Development on the Poor: Environmental and Socio-economic impact of a Geothermal Power Plant on a Poor Rural Community in Kenya." *Energy Policy.* 30: 1119-1128.
[30] The Geothermal Energy Association. *Geothermal Energy in 2010.* The Geothermal Energy Association, 2010. p. 10. PDF File.
[31] "Crónica: Geotermia en Chile, ¿Hay Humo Blanco en Chile?" *24 Horas.* 29 Aug 2008. Web.

the size and scope of geothermal energy is still uncertain in Chile. Without more study and exploration of Chile's resources, it is difficult to conceptualize the size of the economic impact.

- **Based on international experience, geothermal energy is cost competitive per installed KW.** *Some actors were hesitant to cite 'cost competitiveness per installed kilowatt' as an advantage to geothermal energy in Chile. Interestingly, those in government were least likely to find cost competitiveness as an advantage of geothermal energy. Perhaps, this metric can help us better understand the government's relatively weak institutional support of geothermal energy relative to some other sources. This result shouldn't be entirely unexpected. Without a geothermal plant in production, costs for geothermal energy remain relatively vague in the Chilean context, despite analysis by Bloomberg New Energy Finance that suggests competitiveness based on international experience. Unlike in other countries with price supports and/or subsidies, there is more uncertainty around geothermal energy prices in the Chilean market. I believe that more significant government support of geothermal projects and the introduction of some incentive schemes could make 'cost competitiveness' both an advantage and a stronger reason to invest in the sector. I will discuss this in more detail in the 'Financial Barriers' section of this paper.*

8.0 RESULTS: BARRIERS, INCENTIVES AND RECOMMENDATIONS

8.1 FINANCIAL BARRIERS

Despite favorable LCOE for geothermal energy, proving a resource's viability is both expensive and risky – especially, at this time, in Chile. Few investors are willing to assume this risk. Developers require some level of additional government assistance to facilitate project development.

There are extremely high initial costs incurred during exploration period. Deep wells are drilled to determine if resource can produce an economically viable amount of energy. There is no guarantee that exploration will produce a viable resource. The United States Department of Energy reports the average success rate of exploration wells to be roughly 20% to 25%.[32] Due to a set of particularly challenging conditions in Chile (i.e. a shortage of service providers and drilling equipment coupled with remote resources), the costs for geothermal exploration in Chile can be significantly higher than the world average.[33] Geothermal plants use the same drilling rigs as used in natural gas and some other fossil fuel exploration. Considering Chile is not home to these fossil fuel resources, any rigs would need to be imported from Argentina or Peru to Chile for geothermal projects alone. The rigs arrive in 70 to 80 shipping containers. To further

[32] United States Department of Energy. *Geothermal Tomorrow*. United States Department of Energy, 2008. p 20. PDF File.
[33] Espinosa, Carolina. Personal Interview. 26 July 2012.

complicate the situation, these geothermal developers need to compete with large, multi-national fossil fuel energy companies to contract usage of these rigs, often resulting in long delays until equipment is secured. Indeed, many of the respondents indicate that the lack of drilling and service providers was a key concern – indicating that some sort of policy solution is likely necessary (See Appendix Figure 9, Survey Question 21).

According to the IEA, drilling accounts for roughly 20% to 35% of the capital expenditure on an *average* geothermal project outside of Chile.[34] See Table 2 for average industry-wide project costs in $USD (2008) per MW of capacity, which was about $UDS 4 million. In Chile, the costs are about $6 to $7 million per MW produced.[35] Considering some geothermal projects in Chile may be producing at 50MW or even 100MW, it is easy to see how these high initial costs coupled with unusually high drilling expenses in Chile present some serious financial hurdles for developers.

Table 2: Typical Geothermal Power Plant Development Costs (2008)

Development Stage	Approx. Cost (2008 $USD/MW)	Approx. % to TTL Costs
Exploration and Resource Assessment	$400,000	10.0%
Well Field Drilling and Development	$1,000,000	25.0%
Power Plant, Surface Faciliities, and Drilling	$2,000,000	50.0%
Other Development Costs (Fees, Working Capital, and Contingency)	$600,000	15.0%
Total Development	**$4,000,000**	

Source: United States Department of Energy

In addition to the NCRE quota, Chile currently offers a relatively small financial incentive for development of renewables. For NCRE projects in general, the 2005 Invest Chile Project introduced government subsidies during the pre-investment stages (feasibility studies) of NCRE projects through the Corporación de Fomento de la Producción (CORFO), these subsidies

[34] Internatinal Energy Association. *Renewable Energy Essentials: Geothermal*. International Energy Association, 2010. PDF File.
[35] Quote from ENEL GreenPower Chile.

are relatively small (maximum of $USD 60,000, with a limit of 50% of the study cost and 2% of the estimated investment) and do not assist with the potentially much more significant expenses incurred during the drilling phase of the project.[36] Despite this incentive, many of the key actors surveyed, on average, perceived the financial risks of geothermal development to remain quite high (See Appendix Figure 9, Survey Question 13). Because most of actors interviewed (across all sectors) agreed on the importance of this barrier, I can discern that it is likely that both those who have the power to offer the incentives (the government) and those who would like the incentives (the developers) both view financing as an obstacle. Thus, the debate around financing lies not in the strength of the barrier but in how and what can be done to resolve this issue.

Without sufficient incentives, the aforementioned costs of exploration remain too high to spur significant levels of growth in the private market. While the existing incentives for feasibility studies may seem somewhat generous, it is important to consider that Chile has not implemented some of the key financial mechanisms that have been used in an attempt to drive geothermal development across the world in recent years – specifically tax credits and price tariffs – nor has it sought to investigate more creative financing schemes that may help to reduce risk in a geothermal market that is extremely promising.

8.1.1 Tax Credits

Recent geothermal development in the United States has largely been the result of Production Tax Credit (PTC) of 2.2 cents/kWh (2010 $USD).[37] The PTC was introduced as part the 2009

[36] International Energy Agency, *Energy Policy Review.* 2009, 168-169.
[37] Salmon, Peter, and J. Meurice, N. Wobus, F. Stern, and M. Duaime. "Guidebook to Geothermal Finance". National Renewable Energy Laboratory. March 2011.

stimulus package and received support of some prominent politicians.[38] It is not simply the tax incentive alone, but sustained political support of the incentive that has made it a valuable tool for the industry in the past few years – and potentially into the future. Similar tax incentives have been used to expand development of wind energy in the U.S. as well.[39] Chile might consider implementing such a tax incentive to encourage more investment by allowing for a more expedient and, potentially, larger return on said investment. On average, those in industry and those in academia felt tax credits would be a strong incentive in Chile. Notably, those in government, on average, did not feel the tax incentive would be as beneficial (See Appendix Figure 9, Survey Question 15).

8.1.2 Price Tariffs

Many other nations attempting to spur geothermal development have found it necessary to implement feed-in tariffs (price guarantees) for geothermal energy. Price tariffs for geothermal energy have recently been implemented in Japan (USD $330/MWh to USD $500/MWh) and Indonesia (USD $110 MW/h to USD $170/MWh), among many others.[40] Tariffs have been received with mixed success around the world. In Chile, a *proposed* NCRE law that calls for 20% of energy to be generated from NCRE sources by 2020 includes such a price tariff. The proposed law features a 12-year tariff that would be set via a tendering system.[41] Passage of the law – and subsequently the implementation of the tariff – would likely help to encourage more

38 Miethling, Benjamin. 2011. "Different but Similar: Geothermal Energy and the Role of Politics in Germany, Iceland, and the United States." Z Energiewirtsch. 35: 292.

39 Barradale, Merrill Jones. 2010. "Impact of uncertainty on renewable energy investment: Wind power and the production tax credit." Energy Policy 38 (2010): 7698-7709.

40 Bloomberg New Energy Finance. *Q3 2012 Geothermal Market Outlook.* Bloomberg New Energy Finance. 2012. 1. PDF File.

41 Leyton, Sebastián. "Chile Considers Bill to Boost Renewable Energy". Renewable Energy World. March 2012. Web.

development. A price guarantee would ensure that projects could promise a more specific estimate of return on investment, thus reducing uncertainty for investors. Moreover, a price guarantee would ensure that price fluctuations in other energy sources (i.e. fossil fuels) would not jeopardize an existing or proposed project's viability. As shale gas imports from the United States look increasingly likely within the next few years, it is important to ensure geothermal development in Chile will not become unhinged by an influx of new fossil fuel energy.[42] On average, those in industry and those in academia felt feed-in tariffs would be a strong incentive in Chile. Again, notably, those in government, on average, did not feel the tariff would be as beneficial (See Appendix Figure 9, Survey Question 16).

8.1.3 Incentives for Off-takers

Another solution may be incentives for the off-takers (i.e. those who purchase the energy). These incentives would largely come in the form of tax incentives provided by the government. That is, large companies – perhaps those in the mining sector – that sign energy contracts with geothermal companies may be able to receive additional benefits in the form of tax relief for making this purchase. In doing so, the companies would have greater incentive to sign power purchase agreements (PPA's) with geothermal developers before projects come online. Thus, it would be easier for geothermal developers to attract investment because it would be certain that there was a buyer for the energy as soon as the plant reached the point of production. This type of incentive might be politically challenging, considering most of the off-takers that would be able to benefit from such tax relief would be consumers that would contract directly with

[42] Ulmer, Alexandra. "Chile GasAtacama Sees Over $4 billion Power Deal with Miners." *Reuters.* 18 Oct 2012. Web.

generation companies for their energy. These consumers are very heavy users of energy (i.e. big industry). The public may be wary of the government providing additional tax relief to large businesses and not the average electricity consumer, who must purchase his or her energy through a distributor. On average, those in industry and those in academia felt tax incentives for off-takers would be a moderately strong incentive in Chile. Again, notably, those in government, on average, did not feel the off-taker tax incentive would be quite as beneficial (See Appendix Figure 9, Survey Question 17).

8.1.4 Recommendation

A most interesting finding in in our review of financial incentives was the fact that most actors in government perceived the barrier of financing and risk to be strong but were often hesitant to support incentives to diminish the barrier. That is, there is a tacit acknowledgement of a barrier but a general reluctance to consider a solution. That said, there is little doubt the government will need to change its tune to a certain degree to help spur greater development in the sector. Based on the survey results, I recommend the introduction of tax incentives for *both* producers and off-takers. In this sense, the government can both push supply and pull demand for geothermal energy. Feed-in Tariffs might also be considered to reinforce these tax incentives, as it would ensure that projects at the point of generation remain profitable in the near term if energy prices were to shift downward. Given Chile's unique political and economic environment, government leaders may need to consider a variety of proven *and unproven* incentives. While the exact mix of financial incentives may take some time to determine, the need for the government to introduce a much more robust set of financial enticements is evident. The introduction of greater

financial incentives represents a clear opportunity for the government to reevaluate its strategy and create the space for more opportunity in geothermal energy.

8.2 MARKET ENTRY BARRIERS

Some geothermal projects are located in remote areas, making access and exploitation difficult.

Because many of the geothermal resources in Chile are located in remote areas far from population centers, grid connection can be both difficult and expensive. To ease complications with transmission and grid connection of NCRE projects, the government offers a 50% subsidy (up to $300,000/year) to reduce costs associated with connecting projects to the grid. Our survey indicates that the current incentives can still be insufficient for geothermal projects and finds that government assistance in both transmission connection and infrastructure development near geothermal sites would be immensely beneficial (See Appendix Figure 9, Survey Question 19).

Without easy access to the market, remote geothermal sites – no matter how large the resource may be – will be more costly, as connecting to the grid and getting equipment and labor to the area will be more difficult. With initial investment costs already high, costs associated with remote exploration/exploitation only increase the financial risk companies must bear.[43]

[43] Armstrong and Lambrides. Organization of American States. *Removing Barriers to Private Sector Development of Geothermal Resources*. Organization of American States, 2005. PDF File.

8.2.1 Recommendation

The government is currently considering a 'Carretera Electrica (Electric Highway)' transmission project that aims to facilitate new transmission infrastructure connected to the main grids.[44] In order to promote production from all viable geothermal resources, the government could carefully consider areas of potential geothermal exploration and exploitation while envisioning the 'Carretera Electrica (Electric Highway)'. In addition, the government could actively ensure that the necessary infrastructure needed for remote exploration and exploitation is in place. By ensuring that remote sources can be effectively exploited, the government will likely reduce some of the risk associated with geothermal projects.

8.3 LEGAL/REGULATORY BARRIERS:

Development companies need to navigate complicated local, provincial, and federal regulations. Additionally, developers often enter costly and lengthy negotiations with landowners for access to the site.

Chile is not unique in the fact that geothermal development companies face a myriad of regional regulations and incentives and, at times, problematic negotiations with landowners near project sites. Similar ordeals play out for developers in many countries – including the United States – where federal regulations and incentives coexist with additional, distinct state policies.[45] However, years of geothermal energy production in the United States have made certain states

[44] Government of Chile. *National Energy Strategy 2012-2030*. Government of Chile, 2012. PDF File.
[45] Salmon, Peter, and J. Meurice, N. Wobus, F. Stern, and M. Duaime. "Guidebook to Geothermal Finance". National Renewable Energy Laboratory. March 2011.

friendlier environments for development – particularly those in the Western half of the country.[46] Developers in Chile do not benefit from the same history of development and/or the same general understanding of the resource by federal, regional, and/or local officials. In Chile, individuals in industry and academia, on average, found the current legal and regulatory framework in Chile to be insufficient and felt the government could improve current legal and regulatory frameworks on both federal and regional levels (See Appendix Figure 9, Survey Question 28). Actors in government generally felt the legal framework was sufficient, suggesting that this is clear disagreement about the efficacy of the existing framework. Policy changes in this area may be particularly difficult to achieve.

A primary concern among development companies is site access. While a geothermal concession confers temporary rights to explore and/or exploit the geothermal resources on a given piece of land, the concession law, as it stands, is generally ineffective in helping companies navigate difficult issues related to the ownership (or perceived ownership) of other resources within the boundaries of the concession. After approval of the concession, companies sometimes deal with legal issues related to access to the site, access to water (a crucial element to geothermal energy production[47]), transmission lines, and indigenous claims to the territory. There is no guarantee that if exploration yields a viable resource there will be a clear or, at least navigable, path to exploitation. I do not mean to say that every geothermal reserve warrants immediate access for exploration or exploitation. Indeed, some sites are environmentally, economically, and/or culturally sensitive areas. Careful consideration of the unique qualities of the site is necessary before any development. That said, the geothermal concessions do not

[46] Miethling, Benjamin. 2011. "Different but Similar: Geothermal Energy and the Role of Politics in Germany, Iceland, and the United States." *Z Energiewirtsch.* 35: 292.
[47] Internatinal Energy Association. *Renewable Energy Essentials: Geothermal.* International Energy Association, 2010. PDF File.

clearly or sufficiently address the broader resource needs of the geothermal company at the start of the project. Equally as important, the concession law does not address the needs of local communities near the project site. The potential legal costs and time delays associated with these issues add to the already high exploration costs and can severely damage public sentiment about geothermal energy development.

8.3.1 Recommendation

Because those in industry and government provided additional comments about the legal framework that went beyond the themes of our survey question, I provide a recommendation that is mostly derived from open discussion with key actors about these themes (See Appendix Figure 10 for Open Question Results). These discussions revealed and clarified other legal obstacles. As such, I recommend that the government review the current geothermal law to examine and reevaluate the following items:

8.3.2 Flexibility of the Concession:

Currently, concessions have a period of two years with an option of renewal for an additional two years. This two-year period may be insufficient for *some* concessions in extreme climates, which cannot be explored/exploited year round. It may also be insufficient if local community concerns require a negotiation or mediation process. Finally, a 2-year period may be insufficient for concessions located in areas that require more lengthy environmental impact studies due to characteristics of the surrounding ecosystem and/or geological context. I do not recommend that a ‘blanket extension’ be added to the period of all concessions. I simply stress that some

concessions may warrant longer windows of time for exploration than others. This will require both a change to the existing law and a more careful review by the Ministry of Energy prior to granting the concession.

The size of the concession is also very inflexible. The law requires that concessions have the shape of a parallelogram, meaning that all sides must be perfectly straight lines.[48] Some concessions, particularly those near international borders, may require a unique shapes so they can fully and effectively exploit resources.

8.3.3 Environmental Impacts Studies:

Environmental impact studies and evaluations are the responsibility of local authorities, which is consistent with the way they are handled in many other countries with geothermal programs. However, many of the participants from industry noted that the studies for geothermal projects often do not follow the same standards from region to region. Therefore, study procedures and results may vary significantly. This lack of uniformity is further complicated by the fact that some of the regional government representatives who evaluate the projects are not experts in geothermal development. The impact studies need to be tailored to geothermal development based on the distinct qualities of geothermal projects and any regional environmental concerns that may be unique to geothermal development. I recommend that the government reevaluate both the standards of these evaluations and the personnel who are responsible for doing these evaluations. To clarify, I do not suggest that all regions adopt the same criteria environmental impact studies. Clearly, different regions, different climates, and different geological conditions

[48] Ley 19657, Sobre Concesiones de Energia Geotermica, Art. 7.

will warrant different environmental considerations. However, a federal overview of regional regulations may provide useful insight into how these impact studies may be made more effective and efficient. Furthermore, the government may be able to remove some of the potentially unnecessary inconsistencies that developers experience across states. A more uniform study with better-informed evaluators will be necessary to facilitate greater levels of future geothermal development and will remove some uncertainty and costs for developers. At present, developers sometimes face serious time delays during the environmental impact study period. These delays, in turn, require a company to stretch its credit – as the future plant is now even farther from production.

New Zealand provides an example of how Chile might add clarity and consistency to this process. In New Zealand, each development field has a unique review panel composed of 3 independent geothermal experts. These experts are often retired geothermal professionals and/or university faculty. The panel meets on several occasions each year to review impact studies to provide recommendations for necessary changes to the current assessments.[49]

Additionally, current regulations stipulate that an environmental impact study is conducted only when a project enters the period of exploitation. This means that developers are only legally obligated to consult with local communities *after* exploration occurs. Damage to the surrounding environment can occur in exploration just as it might occur in exploitation. Communities near projects are generally unaware of any impact these exploration activities might have and suspicions are sometimes raised. As such, I suggest that environmental impact studies might also be considered at the *beginning* of the exploratory phase. It may be very useful to understand the potential nature of any environmental hurdles a project may face before

[49] Arauz Torres, Mariela. *Environmental Monitoring of Geothermal Projects in Nicaragua.* Ministry of Energy and Mines, Government of Nicaragua. 2011, p. 58. Web.

millions are spent during the process of exploration. Early impact studies are practiced in some countries with established geothermal sectors, like Nicaragua and Iceland.[50] Relying on impact studies only late in the project's lifecycle can lead to significant delays due to unanticipated findings. Obviously, the true magnitude of the project's impact will likely not be known until drilling begins. However, there is some added value to assessing the current state of the environment and any gaining an understanding of the more easily discerned environmental concerns for long-term development. At the very least, these early impact studies would provide baseline environmental conditions for the site. Thus, when a plant reaches production, any environmental problems that may arise can be attributed (or not attributed) to the geothermal facility. Perhaps more importantly, communities may be less wary of nearby geothermal endeavors if, to some degree, they better understand the potential environmental impact and are consulted prior to beginning any exploration activities. I realize that earlier impact studies will be an added expense for developers. Therefore, I suggest that the government include the costs of these studies in our proposed resource assessment and ranking initiative. Because the government might cover the costs of these assessments, the information should be public record, allowing communities to understand current conditions.

8.3.4 Investment vs. Development: The Role of the 'Speculator':

Many of those interviewed in industry noted that concessions were often simply granted to the individual or firm that promised the most investment. Many of those in industry felt that the evaluation of a given applicant's technical ability to develop a geothermal project was not being

[50] Arauz Torres, Mariela. *Environmental Monitoring of Geothermal Projects in Nicaragua.* Ministry of Energy and Mines, Government of Nicaragua. 2011. Web.

conducted effectively. While the law currently stipulates that a technical evaluation should take place[51], many developers did not feel that the current evaluation was sufficient. Without the use of such a mechanism, many speculators have entered the bidding processes. These speculators often do not have the capability to develop projects themselves and simply make it more expensive for some legitimate developers to receive concessions. I recommend that government institutions more strongly incorporate a technical and professional evaluation component for the geothermal concession process. It may be necessary to reevaluate the law and describe in greater detail the technical requirements or experience developers must possess to receive a concession.

8.3.5 Incorporation of the Spirit of ILO Convention 169 into Geothermal Law 19.657

On September 15, 2008, the government of Chile ratified the International Labor Organization (ILO) Convention No. 169, The Indigenous and Tribal Peoples Convention of 1989. The purpose of this ILO convention is to recognize the aspirations of indigenous peoples to "exercise control over their own institutions, ways of life and economic development and to maintain and develop their identities, languages, and religions, within the framework of the States in which they live…"[52] By signing this convention, Chile signaled to the world it planned to ensure indigenous communities would be carefully considered in the institutional and legal framework of the country. Yet the government has still not incorporated the spirit of this international agreement into many domestic laws and regulations.

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[51] Ley 19657, Sobre Concesiones de Energia Geotermica, Art. 17.
[52] International Labor Organization. *Preamble, Indigenous and Tribal Peoples Convention, 1989*. International Labor Organization, 2012. Web.

This lack of clarity about indigenous issues and rights in Chile's legal and institutional framework has led to an increased level of uncertainty in all energy development projects, including those in the geothermal sector (See Appendix Table X, Survey Question 42). Some geothermal companies have landed in a quagmire of disputes and debates with community leaders. These debates can lead to costly delays in project development and damaged relationships with local inhabitants. In a 2008 report[53], the U.S. Department of Energy noted, "The cost of time delays is significant, sometimes adding $10 to $20 or more per MWh to the cost of power." Our data suggests that uncertainty about indigenous rights within geothermal concessions causes trepidation among some actors in the sector. This feeling of unease is well founded. In 2008, Geotérmica del Norte, received approval from the regional government to begin exploiting a geothermal resource knows as El Tatio. Despite initial resistance by the indigenous community, the company moved ahead with its plan to drill four deep wells. The company had met all necessary government requirements.[54] However, exploitation of the site was no easy task. After a well failure, the local community became even more vocal in their opposition. The government eventually relented to those opposed to the project.[55] Four years later, the El Tatio project remains in 'standby status' and is still wrapped in controversy.[56]

There is indeed a significant lack of consideration for the indigenous community in the concession-granting process. Concessions are being granted in areas that are important to indigenous groups – particularly areas the government designates as 'natural reserves'. While Chile has signed Convention No. 169, it has not considered this agreement in the geothermal

[53] United States Department of Energy. *Geothermal Tomorrow*. United States Department of Energy, 2008. PDF File.
[54] López, Claudia. *Aprueban explotación en el Tatio*. La Tercera. 4 July 2008. Web. 6 August 2012.
[55] "CDE descartó daño ambiental en 'El Tatio'". *El Mercurio de Antofogasta*. 27 November 2010. Web. 6 August 2012.
[56] Espinosa, Carolina. Personal Interview. 26 July 2012.

concession law or any other institutional framework related to geothermal projects. Article 15 of the convention states:

> In cases in which the State retains the ownership of mineral or sub-surface resources or rights to other resources pertaining to lands, governments shall establish or maintain procedures through which they shall consult these peoples, with a view to ascertaining whether and to what degree their interests would be prejudiced, before undertaking or permitting any programmes for the exploration or exploitation of such resources pertaining to their lands. The peoples concerned shall wherever possible participate in the benefits of such activities, and shall receive fair compensation for any damage which they may sustain as a result of such activities.

While the rights to these subsurface resources in Chile are in private hands, the government does regulate the manner in which these resources are distributed. In accordance with Convention No. 169, I strongly recommend that the government consider a change to domestic policy that supports the goals and ideals of this international agreement. The lack of clarity in regard to indigenous rights within geothermal concessions leads to a sense of uncertainty among some actors in the sector. The government should better understand the claims of indigenous communities in these territories and should then consider these claims when granting concessions. First and foremost, many communities - particularly those in the arid northern regions of the country – are concerned about ground water. Geothermal plants often require significant amounts of water to be pumped from deep reservoirs generate the necessary steam from hot underground reservoirs to turn turbines and generate electricity. Some communities in northern Chile view geothermal development as a threat to their already scarce

water resources.[57] The current law does not contain any provisions that would ensure these communities retain their water supply. As such, local communities in dry regions may be particularly wary of geothermal development. One of Chile's first geothermal projects – in El Tatio – was halted due to community opposition.[58] The company did not execute the wells properly and a blow-out occurred on the site. As a result, a tower of steam and hot water shot into the air for weeks and nearby geysers lost their water supply. A culturally sensitive site was forever changed. While it is commonly believed within the geothermal sector that the El Tatio site was mismanaged and was not developed using best practices within the industry, those outside of the geothermal sector view El Tatio as an example of how geothermal developers can entirely mismanage water resources and destroy sensitive natural sites.

To better comprehend the nature of these claims, the government could be more proactive in consulting indigenous groups prior to granting concessions. This consultation could be part of the pre-exploration environmental impact study I suggested earlier. Following this logic, the government may also be wise to better define areas that would be risky and/or off limits for exploration and exploitation. Some leaders in the renewable sector have suggested that royalty payments may make communities more willing to cooperate. Certainly, additional income would be useful to any community. These payments, however, may simply be viewed as a way of 'buying off' those who might oppose the project. And while there may be some value to these payments, they would not replace lost water supply for communities. When the well is dry, the well is dry. People would need to relocate to survive. Indigenous peoples would be forced to part with a land that is central to their culture. As such, it is likely that particularly dry areas with

[57] Cruz Plaza, Antonio. Energía Geotermica y los Pueblos Atacameños. Offices of the Center for Geothermal Excellence of the Andes at La Universidad de Chile. Santiago, Chile. 4 Apr. 2013. Guest Speaker.
[58] Espinosa, Carolina. Personal Interview. 26 July 2012.

inhabitants should be 'off limits' to geothermal exploration. At present, geothermal projects are forbidden only in national parks. Reserves and other areas of special designation remain open to geothermal development. However, not all areas currently open to development are smart places for development. While it is currently legal to drill in a site like El Tatio, it may also be extremely risky for geothermal companies and traumatic for local communities. The government might reduce some uncertainty and risk that is perceived in the market by mandating greater consideration of indigenous and local community claims and rights in the framework of geothermal concessions and regulation.

8.4 INSTITUTIONAL BARRIERS:

There is a general lack of direction within the government in regard to geothermal resources. Some government institutions out of sync on geothermal issues. There are few geothermal professionals working in government and they are widely scattered.

A lack of direction in existing policy and a lack of general institutional support for geothermal energy sometimes lead to suboptimal regulation. While the government has mandated that NCRE sources comprise 10% of all new energy contracts by 2024[59], it has not put forth no concrete plan for developing these resources. There exists no clear policy for the development of geothermal in Chile, as sufficient tools to spur development remain undefined in the country's plan for the future of energy in Chile.[60] Investors may be wary of supporting

[59] International Energy Agency. *Chile Energy Policy Review*. International Energy Agency, 2009. 167. PDF File.
[60] Espinosa, Carolina. Personal Interview. 26 July 2012.

projects without understanding the government's level of support for geothermal energy. To be clear, no country – with perhaps the exception of early development in the United States in the 1970's – has developed a robust geothermal energy sector without very clear and effective policy and *actions* aimed at advancing and sustaining projects.[61] Our data suggests that those in industry and academia, on average, find this to be a strong barrier for development. Those in government do not feel as strongly (See Appendix Figure 9, Survey Questions 32 and 33). Again, we find disagreement among some of our key actors and see an area where a solution may be less imminent. However, it is important to consider that Chile will be holding presidential elections in 2014. A new administration may give rise to a changed perspective among government actors, potentially making a solution more likely.

Perhaps the most important symptom of the lack of a clear energy policy is manifested in the manner in which geothermal energy regulation is handled by government institutions. While the Ministry of Energy is technically the 'figurehead' department for all energy resources, responsibility for geothermal energy projects, information, and evaluation remains scattered across several government institutions including, but not limited to, The Ministry of Energy, the Center for Renewable Energy, and SERNAGEOMIN (The National Service of Geology and Mining). Moreover, these institutions also have very few people dedicated specifically to managing and advancing geothermal development. The Ministry of Energy, for example, has just one person focused full-time on geothermal energy. Conversely, in 2009, New Zealand had a much larger government support staff for the geothermal sector. The country employed 30 individuals engaged in geological services, 9 individuals in federal government offices, and 6

[61]Miethling, Benjamin. 2011. "Different but Similar: Geothermal Energy and the Role of Politics in Germany, Iceland, and the United States." *Z Energiewirtsch.* 35.

individuals in regional offices.[62] Without a sufficient number of 'subject matter experts' under the roof of a single government entity, the Chilean institutions in place to manage geothermal energy are sometimes not able to do so effectively or efficiently.

8.4.1 Recommendation

Because responses to this incentive were, on average, uniformly strong, I believe it is essential for the government to deliver a plan for development of geothermal energy. However, I also recognize that the government cannot effectively write policy for geothermal development without having a somewhat accurate understanding of the nation's geothermal energy potential. In this aspect, the need for a government-sponsored resource assessment is crucial. The government has completed similar preliminary studies for hydropower resources. Furthermore, the government will need to better clarify plans for energy development as a whole and the role of NCRE within that development. Creating geothermal energy policy without attempting to understand the balance of the energy mix in Chile makes little sense. The future of geothermal energy development cannot be addressed in a vacuum, as the other energy resources with which it competes in the market define its competitiveness.

[62] New Zealand Geothermal Association. *Skills Issues in the Geothermal Sector*. New Zealand Geothermal Association, 2009. 29. PDF File.

8.5 EDUCATION AND WORKFORCE BARRIERS:

Many Chilean universities do not support programs specifically designed to develop geothermal professionals. Additionally, few universities actively support geothermal energy research initiatives (See Appendix Figure 9, Survey Questions 38 and 45).

In part, the lack of service providers in Chile can be explained by the lack of geothermal professionals being produced by Chileans higher education system. While much progress has been made in recent years with the development of the Centro de Excelencia en Geotermia de Los Andes (CEGA) at the Universidad de Chile, the academic study of geothermal resources in Chile has still not reached a level of maturity. The academic community often lacks the resources to gather important data and information related to geothermal exploration in Chile. Currently, much of the information collected about Chile's resources lies in the hands of the private firms who fund the exploration. The government does collect some data in a relatively informal manner through the concession granting process, but does not have any formal requirement about the disclosure of all data.[63] Research at the university level is, at this point, somewhat limited by a lack of available information.

Because geothermal fields in Chile exist in a unique geological context, professionals who arrive from other regions may not truly be 'experts' on geothermal exploration and exploitation *in Chile.* A lack of mature academic resources could manifest itself in a slower growth within the sector, as the market sometimes relies on foreign actors to advance projects. Additionally, a lack of geothermal professionals on the domestic level will likely serve to dampen Chile's political responses to geothermal opportunities because fewer domestic voices

[63] Espinosa, Carolina. Personal Interview. 26 July 2012.

within the political system will be calling for greater institutional and legal support of the sector. Perhaps most importantly, a more mature academic nucleus of geothermal study in Chile would produce greater amounts of information, greater numbers of knowledgeable professionals, and new technologies that would assist in reducing risks and, subsequently, the costs associated with geothermal exploration in the Andean context.

8.5.1 Recommendation

The sentiment within many in industry was that the research centers would develop as a response to business demands. Thus, a stronger market for geothermal energy would lead to a greater need for professionals and, subsequently, greater public and private support for research centers like CEGA. In the interim period, however, research centers face many challenges advancing studies and projects. CEGA, the geothermal research center at the Universidad de Chile, has been in existence for less than two years. Therefore, much of the work being done through the center has yet to have significant impact on the geothermal sector in Chile. Furthermore, the state has only made funding for the center available for a *possible* total of 10 years.[64] Other than providing funding, the government generally has little interaction with the center. Limited funding and limited institutional interaction with this center places a constraint on the center's ability to function as a true incubator for innovation and information. I recommend that the government secure long-term funding for the center and to develop a mechanism to facilitate the sharing of information between government institutions and the universities. This relationship would be

[64] Morata, Diego. Personal Interview. 14 Aug. 2012.

especially beneficial should the government engage in its own large study of geothermal resource potential in Chile.

To do their part, the universities can continue to sponsor relevant informational seminars and forums with both regional and international participants. In this way, the universities may continue to broaden the conversation around geothermal development in Chile and increase awareness about global geothermal initiatives and best practices.

8.6 SOCIAL BARRIERS:

Some groups may oppose projects near environmentally or culturally sensitive sites.

In the legal barriers section of this paper we discussed issues related to rights of communities near projects. Aside from these issues, there is also a general misunderstanding of the resource, which may complicate relationships between development companies and nearby communities. Many of the individuals surveyed indicated that the public is generally unaware of what exactly geothermal energy entails. The U.S. Department of Energy regards 'outreach and education' as a key component to government support of the geothermal sector.[65] A 2011 survey[66] of nearly 700 Chileans asked them to choose their preferred energy source(s), allowing for the selection of more than one source. 20% of respondents preferred geothermal as an energy source. In comparison, 61% of respondents selected solar energy, 57% preferred wind, and 39%

[65] The National Renewable Energy Laboratory. *Policymakers' Guidebook for Geothermal Energy Generation*. The National Renewable Energy Laboratory of the U.S. Department of Energy. 2011. 5. PDF File.
[66] Aravena, Claudia, W. George Hutchinson, and Alberto Longo. 2012. "Environmental Pricing of Externalities from Different Sources of Electricity Generation in Chile." *Energy Economics.* 34: 1220.

preferred hydropower. All fossil fuel sources were preferred by less than 20% of respondents, with gas leading conventional sources at 12%. The fact that geothermal lags so far behind its NCRE counterparts (and so close to its fossil fuel counterparts) suggests that the public may be generally unaware of the benefits of geothermal power. See Appendix Figure 11 for full survey results.

8.6.1 Recommendation

The government may consider public awareness campaigns that highlight the economic, social, and environmental impacts of geothermal development. These programs may be specifically targeted to school-aged children so that future generations have a clearer understanding of the nature of the country's energy options. Ultimately, the success of geothermal power in Chile will likely be closely tied to gaining the support of the public, as exploration and exploitation may, at times, occur near communities and other sensitive sites.

9.0 CONCLUSION

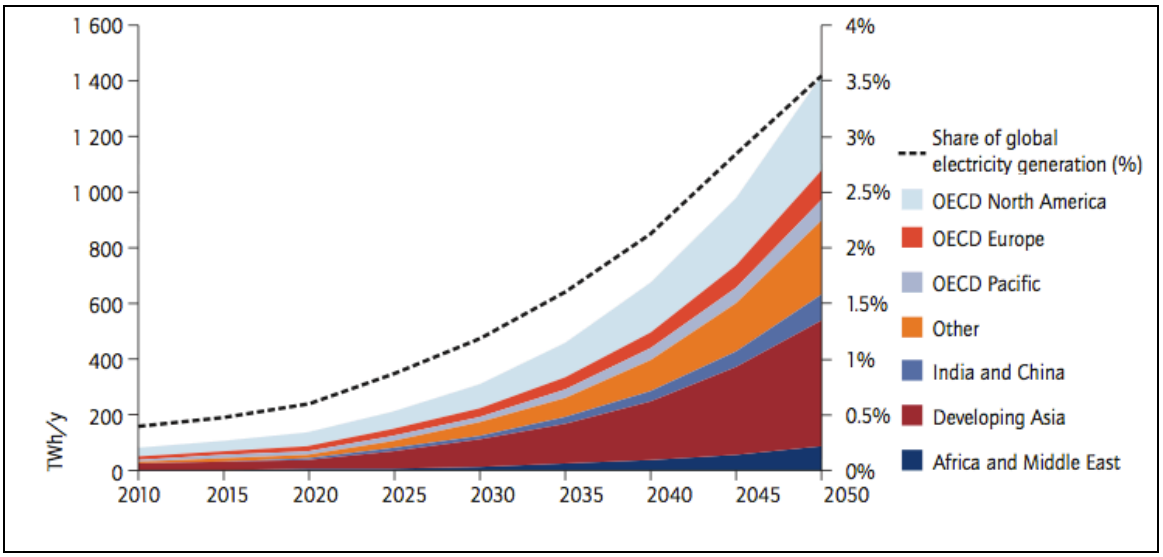
Through this study, I have used data and responses collected during a series of interviews to gain a better understanding of the characteristics, challenges, and opportunities of geothermal energy in the Chilean context. The final set of recommendations is summarized in the table at the end of the document. All actors in the geothermal sector will need to carefully consider barriers and policy changes related to: (1) high initial costs, (2) resource access, (3) a comprehensive legal framework, (4) institutional constraints, (5) social sustainability, (6) information dissemination, and (7) education and training. Agreement among survey respondents was not uniform across these themes. I find that policy solutions are likely to be most achievable for barriers related to financing, institutional constraints, and public awareness. The balance of the barriers – particularly those of the legal variety – may require solutions that are less feasible in the near term. See Figure 9 for final recommendations and feasibility assessments.

In future analysis of geothermal policy in Chile, it may be necessary to include the perspective of 'off-takers – those who buy energy from generation companies – in a market study. Gaining a clear understanding of what might entice them to buy geothermal energy is likely to be a crucial element as geothermal plants come online. While I do make mention of tax incentives for off-takers, there may be other (i.e. non-financial) tools that could entice them to buy from geothermal plants. Additionally, as Chile begins to develop its sector, there might be some value, at that point, in conducting case comparisons between Chile and countries that have

developed the resource with much greater state involvement. As geothermal gains traction around the world, there may be some valuable findings to glean from the Chilean experience.

The Chilean government and other actors in the energy sector will need to determine the value of clean, secure, domestic energy. In a global economy with fluctuating fossil fuel costs, the value of geothermal development is likely to rise. Figure 6 below indicates the International Energy Agency's vision for the growth of geothermal energy around the world. The question today is: will Chile be a part of this projected growth in geothermal energy?

Figure 6: International Energy Agency Roadmap Vision for Geothermal Power Production (TWh/y)



Source: IEA Geothermal Roadmap, 2011

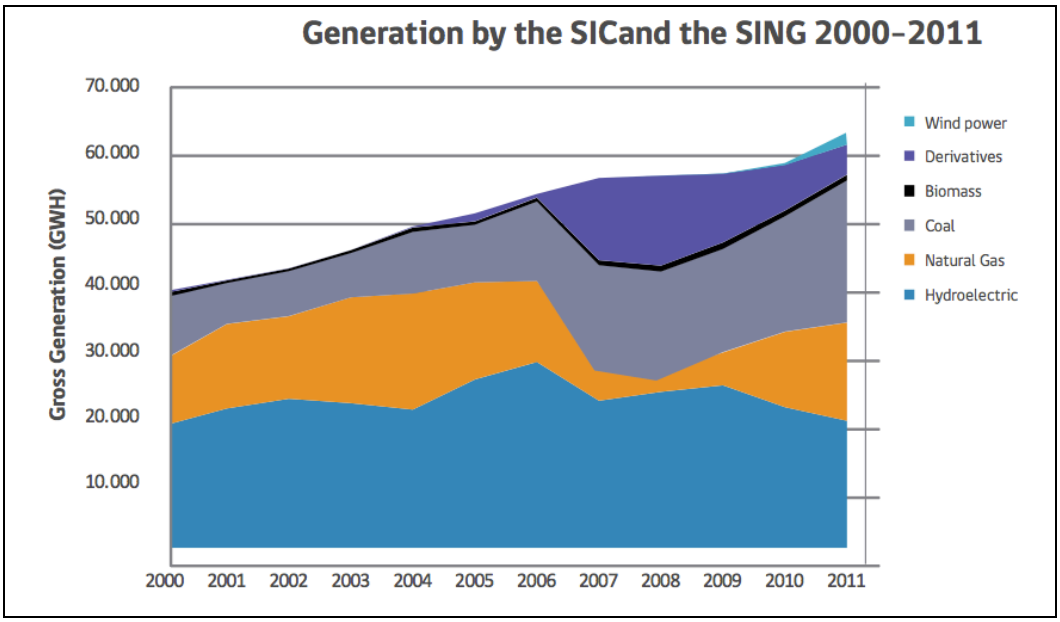
Figure 7: Recommendations and Policy Feasibility

CONCLUSION: TABLE OF RECOMMENDATIONS AND POLICY FEASIBILITY				
Barrier Type	**Barriers**	**Barrier Details**	**Recommendations**	**Policy Solution Feasibility Based on Respondents' Attitudes**
Financial	***All of the Risk Falls on the Investors***	Extremely high costs and risks associated with exploration process. No guarantee of viable resource for exploitation.	The government and industry leaders might cooperate to reduce the amount of risk investors must bear through more a series of financhial mechanisms. A variety of push strategies (increasing the renewable energy quota, tax incentives for project developers and feed-in tariffs) might be considered with a pull strategy (tax incentives for buyers of geothermal power).	**Medium - Agreement on Barrier, Disagreement on Solutions**
Market Entry	***Few Firms Available to Provide Necessary Exploration Equipment/Services***	Only two firms operating in Chile that can provide necessary exploration equipment. Drilling costs remain very high.	1. The government might play a more active role in providing logistical and techical support for the industry. Many international cases of successful geothermal development (Iceland, New Zealand) have relied on the state to play a significant role in identifying and exploring resources. 2. The government might explicitly consider geothermal resources as it plans and proposes an 'electric highway' of transmission lines in the country. The government might also more actively consider infrastructure needs near geothermal sites.	**Medium - Agreement on Barrier, Disagreement on Some Solutions**
	Some Geothermal Resources are in Remote Areas	Some geothermal fields are located in areas that do not have adequate infrastructure and/or access to the electrical grid		
Legal	***Inflexible Concession Requirements***	Length of the concession and dimensions of the concession are relatively inflexible. Some variables that effect the process of exploration are not considered in current stipulations in concession law.	The government might review the current geothermal law to examine and reevaluate the following items: *1. Flexibility of the concession:* Currently, concessions have a period of two years with an option of renewal for an additional two years. This two-year period may be insufficient for certain concessions in extreme climates, those which require more demanding environmental impact studies and those faced with concerns from local communities that require more lengthy negotiation processes. *2. Environmental Impact Studies:* The government might reevaluate both the standards of these evaluations and the personnel who are responsible for doing these studies for geothermal projects. A more uniform study with better-informed evaluators will be necessary to avoid risks associated with this process. Additionally, we suggest that environmental impact studies might also be considered at the beginning of the exploratory phase to better understand the nature of any environmental hurdles a project may face. *3. Prioritizing Investment AND Development:* To avoid granting many concessions to speculators, government institutions might condiser including a much more thorough technical and professional evaluation mechanism in the geothermal concession approval process. Furthermore, it may be necessary to reevaluate the law and describe in greater detail the technical requirements developers must meet to receive a concession. *4. Incorporate ILO Convention 169 into Geothermal Law:* A lack of clarity about indigenous issues and rights in Chile's legal and institutional framework has led to an increased level of uncertainty in the geothermal sector. Some geothermal companies have landed in a quagmire of disputes and debates with indigenous community leaders. The government might reduce some uncertainty and risk that is perceived in the market by mandating greater consideration of indigenous claims and rights in the framework of geothermal concessions and regulation.	**Low - Disagreement on Barrier, Solutions Discussed in Open Question Section Not Consistent Across all Sectors**
	Environmental Impact Studies Are Not Uniform and Create Project Delays	Environmental impact studies are not uniform in nature across various regions and sometimes create significant delays. Those who conduct the studies are often not geothermal experts. Environmental evaluations only occur as a project enters exploitation phase - there is no preliminary study to understand 'baseline' environmental conditions and potential impacts.		
	Lack of Formal Legal Regulation of Rights of Other Actors (i.e. Indigenous Groups)	Geothermal developers have no detailed legal framework to reference when negotiating with indigenous communities.		
	Speculation	Some geothermal concessions in Chile are not developed because they are granted to speculators instead of legitimate developers. Concessions often granted based on a firm's promised investment rather than its ability and capacity to implement a geothermal project.		
Institutional	***Lack of Sufficient Human Resources Dedicated to Geothermal Regulation and Promotion in Government Institutions***	There are few people working on geothermal energy in government institutions. A lack of persons dedicated to geothermal means there are very few geothermal experts in government offices.	1. The government could move as quickly as possible to better define a development plan for geothermal energy. However, it is likely that the government cannot effectively create this plan without having a somewhat accurate understanding of the nation's total geothermal energy potential. More information about geothermal resources will be necessary. 2. To more effectively ensure growth in the sector, regulation of geothermal energy might be condensed into a single government office and supported with a greater number of individuals who are subject matter experts. 3. The government might reevaluate the current concession granting process to find ways to make it more comprehensive by including both technical and environmental evaluations. At the same time, the process will need to be streamlined. Following that logic, sufficient staff and resources will need to be in plae to accomplish this task.	**Medium - Agreement on Barrier, Disagreement on some solutions**
	Lack of Formal National Plan for Geothermal Development	The government has not defined a clear plan for the development and use of geothermal energy in Chile		
Information	***No Central Source of Geothermal Data***	Much data about resources remains in the hands of private companies. Neither the government nor academic institutions have complete access the data. To create a more informed regulatory framework and policy, the government will need to have more complete information.	Under the current system, there is little incentive for private companies to share the information gathered during the exploration phases. However, the success of both the government management of geothermal resources and the advancement of university research centers is dependent upon available, complete, and reliable information. We recommend that the government engage in its own study of geothermal resources. We suggest that the government might work closely with other governments and experienced geothermal energy firms to complete a more accurate and complete study than has been completed in the past. The government will not be able to devise a sufficient plan for geothermal development until it understands, within reason, the size and scope of the resource.	**Low - Disagreement on Barrier, Disagreement on Solutions**
Social	***Public May View Geothermal Exploration/Exploitation as a Threat***	Communities may exhibit a 'not in my back yard' attitude toward geothermal exploration and exploitation. Development may be perceived as a threat to existing economic, environmental, and social conditions.	The governmetn might engage in a public awarness campaign to ensure that citizens understand the benefits and nature of geotehrmal projects. To mitigate concerns in local communities, I recommend that the government require an environmental impact study at the beginning of the exploration process to alleviate some possible fears of nearby communities. As part of this impact study, local communities should be consulted about the project and advised of the potential impacts. Transparency is essential and is fundamental for community cooperation. Furthermore, I recommend that the government provide finanancial and logistiacal support for further consideration of communities needs in the project development process. Most importantly, the government might consider	**High - Agreement on Barrier, Agreement on Solutions**
Education	***No Mature Center of Research***	The Center for Geothermal Excellence of the Andes (CEGA) at the Universidad de Chile is current a center of academic research. However, the center is just 2 years old. There no center with a long history of research which can support the industry.	Actors in industry, government, and universities migth work more closely together to create some sort of framework in which information can be shared with new geothermal research centers based in Chilean universities. Without access to more complete information, these centers will likely be less effective in achieving their missiion of advancing geothermal development in Chile.	**Medium - Agreement on Barrier, Disagreement On Solutions**

APPENDIX A

Figure 1

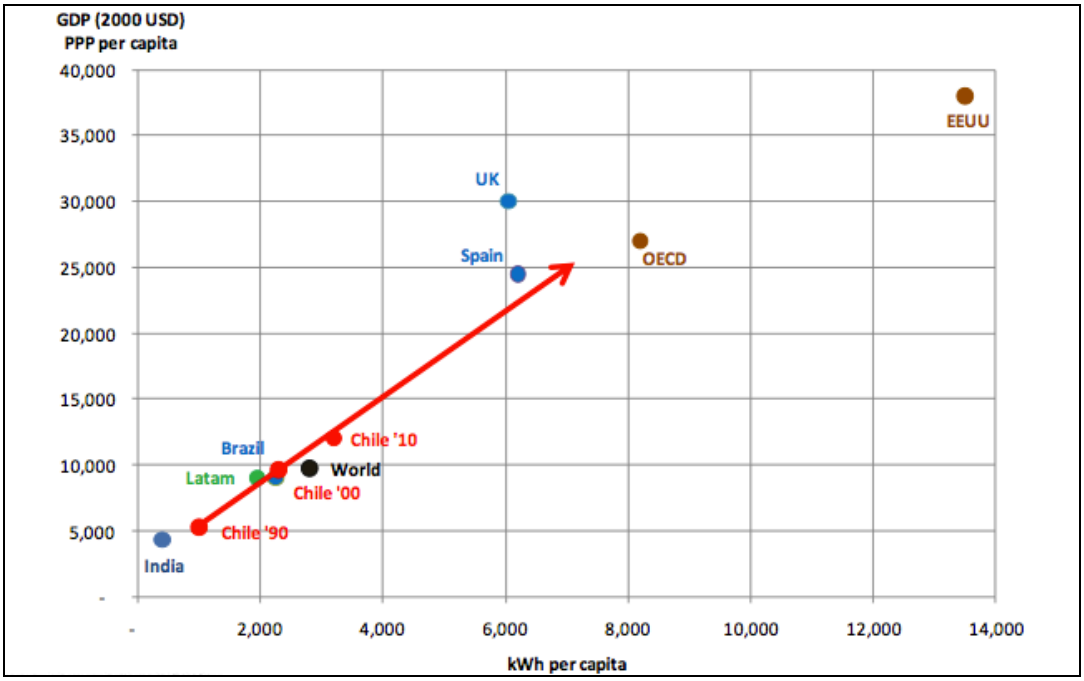
Current Energy Sources, 2011



Source: Government of Chile. National Energy Strategy 2012-2030. Government of Chile, 2012. PDF File.

Figure 2

Trends in Energy Consumption per Capita, 2010



Source: Martinez, Pablo. "GDF Suez in Chile." Austral Offices. Santiago, Chile. 11 Mar. 2013. Invited Speaker.

Figure 3

Review of Energy Resources Alternatives in Chile, 2013

		Energy Alternatives									
Goals	Impact Category	Diesel	Coal	Liquified Natural Gas (Conventional)	Nuclear	Large Hydro	Non-Convnetional Renewable Energy: Wind (onshore utility scale)	Small Hydro (Below 40 MW)	Solar (PV utility scale)	Geothermal (Flash and Binary)	Biomass (Wood Pellet)
Economic Efficiency	*Levelized Costs per MWh** *Includes Investment, Fuel Costs, Operations/Management, and Waste Management for entire lifecycle of the project.*	Very High: 346 to 560 USD/MWh	Medium: 73-155 USD/MWh	Medium: 68-111 USE/MWh	Medium: 60-80 USD/MWh	Low: 32-137 USD/MWh	Medium:51-259 USD/MWh	Low: 38-169 USD/MWh	High: 156-242 USD/MWh	Medium: 56-108 USD/MWh	Medium: 35-179 USD/MWh
	Competitive at early 2013 SIC (=$USD 100/MWh) and/or SING (=$USD 150/MWh) Energy Prices		x	x	x	x	x	x		x	x
	Estimated Domestic Resource Capacity Available under current economic and climate conditions	Extremely Low	Medium - could meet 25% of increased incremental capacity needed. 500 Mt proven reserves (Expected extraction of 6Mt per year - equivalent to approx. 2,200MW annually). Reliable foreign suppliers with significant reserves could supplement additional need.	Extremely Low	High - could meet entire needed incremental increase in capacity	High. Government estimates 9,000 MW/yr capacity available. IEA estimates closer to 20,000 MW/yr. Could potentially meet entire needed incremental increase in capacity.	High - could meet entire needed incremental increase in capactiy	Medium	High - could meet entire needed incremental increase in capacity	Medium - could meet some of the incremental increase in capacity. 3,350 MW/yr estimated by ENAP.	Unknown. Currently 5.7 Mt of wood harvested annually in an informal manner for home heating and cooking. Represented roughly 1.6% of TPES in 2009.
	Variability of Supply	Extremely High	Medium (some domestic reserves)	Extremely High - no nearby suppliers. Must rely on expensive Liquified Natural Gas imports from distant suppliers.	None	Medium - Drought conditions have caused significant fluctuations in supply in central Chile but south usually remains consistently wet.	Medium - evaluate capacity for storage	Medium - Drought conditions have caused significant fluctuations in supply in central Chile but south usually remains consistently wet.	Low - evaluate capacity for storage	None	Low in southern Chile, High in central Chile were deforestation has become major issue. Tree plantations an option.
Preservation of the Environment	*Environmental Impacts of Operation*	High	High	Medium: Gas is considered more environmentally friendly than its other fossil fuel counterparts.	Medium - nuclear waste holding facilites needed	Medium	Low - can impact birds and ocean wildlife. Requires large footprint	Low	Low - requires large footprint and includes precious metals that could be mined domestically	Low - Can impact levels of underground water tables if not managed properly	Medium
	Environmental Impacts of Construction	Low	Low	Low	Low	High - large threat to ecosystems and native species' survival	Low	Low	Low	Low	Low
Public Health/Saftey	*Social Impact*	High - air and water pollution possible near plant	High - air and water pollution possible near plant	Medium - Some air and water pollution possible near plant	Medium - cooling pools near nuclear facilities would need to be constructed for spent rods. Long term impacts unknown.	High - may dispace communities and/or wildlife or plantlife needed by communities. May also disrupt river flow needed to sustain local agriculture or tourism businesses.	Low - requires large footprint to gererate sizeable amounts of energy.	Low	Low - requires large footprint to gererate sizeable amounts of energy.	Medium - may have detrimental impact on underground water reservoirs in arid regions.	Low
	Seismic Safety Risk	Low	Low	Low	Medium - thorough seismic impact studies needed. New technologies believed to withstand large siesmic events.	Medium - Strict construction standards necessary to prevent liquification of soil/rock below dam.	Low	Medium - Strict construction standards necessary to prevent liquification of soil/rock below dam.	Low	Low	Low
Political Feasibility	*Likilihood of Successful Adoption*	High - in place.	Low - although the technology is in place, many new plants (i.e. Castilla) have faced	High - in place.	Low - radical change. Public and legislature strongly opposed to nuclear energy in a seismically active region	Medium - large gains possible and technology in place. Majority of public opposes large scale hydro due to environmental impacts.	Medium - radical change but popular among the public. Limited wind energy in production. Costs remain higher than fossil fuels but are increasingly competitive.	High - technology proven in Chile and several plants in production.	Medium - radical change but popular among the public. Limited amount of solar energy in production. Costs remain higher than fossil fuels but are increasingly competitive.	Medium - radical change but popular among the public. No geothermal plants in production. Costs remain somewhat higher than fossil fuels but are increasingly competitive and less expensive than other NCRE Sources.	High - in place.

** Costs based on 2011 Bloomberg New Energy Finance LCOE Analysis. Nuclear costs estimates from 2010 International Energy Agency ranges for the United States.*

Figure 4

Key Geothermal Companies in the Chilean Market, 2013

Key Players in the Market					
Company	Description	Projects	Exploration Concessions	Exploration Concession Requests Waiting for Government Approval	Exploitation Concessions
ENEL	Large Italian energy company. Has majority share in two Chilean firms: Empresa Nacional de Geotermia S.A. and Geotérmica del Norte S.A.	Most developed concessions include: El Tatio, Apacheta, and La Torta. Faced controversy around exploration at El Tatio. Has advance d Apacheta site and plans to hae 40MW in production by 2014.	12	7	3
Mighty River Chile (Formerly GeoGlobal Energy Chile)	Formerly owned by GGE, a geothermal company based in the United States. Now a part of Mighty River, a geothermal company based in New Zealand	GGE's most advanced concession is the San Gregorio concession in Southern Chile. The plant has a planned capacity of 70MW and might be online by 2016. Partnership with energy giant Colbún has not yet proven to be fruitful.	3	7	1
Energia Andina	A chilean geothermal company founded by mining company Antofagasta Minerals (60% share) and the National Petroleum Company (ENAP) (40% share) in 2008. In 2011, Australian firm Origin Energy purchased ENAP's 40% share in the company.	Currently involved in exploration across eight project areas. One of the most advanced projects is Tinguirica A in central Chile.	24	10	0
Alterra Power (Formerly Magma Energy Chile)	A geothermal development company established in 2008 by the Canadian Company Magma Energy Corp. In May 2011, Magma Energy Corp merged with Plutonic Power Corporation to form Alterra Power Corporation. Magma Energy is now a subsidiary of Alterra Power, a company that focuses on renewable energy ventures.	Magma Energy Chile's most advanced project is Mariposa, located in the southern part of the nation.	3	1	0
Hot Rock Limited	Hot Rock is an Australian company which operations in Australia, Chile, and Peru. In ealry 2012, Hot Rock signed a joint venture with Energy Development Corporation (EDC) from the Philippines. The agreement covers two of Hot Rock's projects in Chile and gives EDC a 70 percent interest in each project. EDC will fund significant portions of exploration and develoment.	Holds concession in 7 project areas and is in the process of engaging in exploration drilling.	12	8	0

Source: Government of Chile, Ministry of Energy, and Official Company Websites

Figure 5

Key Energy Companies in the Chilean Market, 2013

Chile: Key Players in Energy Generation (Data as of 2012)												
Company	Total Installed Capacity (MW)	Thermal (Fossil Fuel) Installed Capacity (MW)	Hydro Installed Capacity (MW)	Wind Installed Capacity (MW)	Geothermal Installed Capacity (MW)	Solar Installed Capacity (MW)	Biomass Installed Capacity (MW)	Percentage of Chile's Total Installed Capacity	Description	Energy Generation Mix	Planned Status-Quo Projects	Investment/Activity in Non-Status Quo Areas
Endesa Chile	5,611	2,068	3,465	78	-	-	-	32.2%	Evolved from CORFO initiative in 1940's to 'electrify' Chile. Nationalized in the 1970's and privatized in the 1980's. Chile's largest energy supplier. Endesa, a Spanish compay, owns controlling shares in Endesa Chile. Endesa is, in turn, owned by an Italian firm, ENEL, which operates in 40 countries and has nearly 97,000MW of installed capacity. Endesa Chile has 50 plants in Chile, Colombia, Peru, Argentina, and Brazil.	16 Hydroelectric Plants, 10 Thermoelectric Plants, 2 Wind Plants	2 Thermorelectic plant (Bocamina II 370MW, TBD 740MW), 3 Hydroelectric Plants (Los Cóndores 150MW, Netlume 490 MW, HydroAysén 2,750MW - status uncertain)	
AES Gener	4,064	3,769	271	-	-	-	24	23.3%	Owned by AES Corp., a U.S.-based multinational energy firm. AES Gener has operations in Chile and Colombia.	10 Thermoelectric Plants, 1 Hydroelectric Facility, and 1 Biomass Facility	4 Thermoelectric Plants (Angamos 518MW, Cochrane 532MW, Guacolda 152MW, Los Robles 750MW - suspended since 2009), 1 Hydroelectric Plant (Alto Maipo 531MW)	1 Solar Facility (Solar Los Andes 220MW - in stages)
Colbún S.A.	2,692	1,534	1,158	-	-	-	-	15.4%	Evolved from CORFO's hydropower initiatives in 1980's. Became an independent firm in 1996 and opened to foreign investment in 2010.	15 Hydroelectric Plants, 7 Thermoelectric Plants	2 hydroelectric plants (Angostura, 316MW and San Pedro, 150MW), 1 Thermoelectric Project (Santa Maria II, 350MW)	2 geothermal concessions (have not advanced and will likely NOT advance according to off-record interviews with their project parter, GGE Global), Two wind measurement towers in Maule Region.
GDF Suez	2,177	?	?	48	?	?	?	12.5%	Owned by multinational energy firm International Power, which operates in 30 countires and produces energy mainly through gas and coal. Within Chile, GDF Suez operations as majority stakeholder in the following firms: E-CL, GNL, Solgas, Eolica Monte Redondo		34.4MW Small-Scale Hydro in Construction, two 165MW biomass/mixed fuel plants, two 375MW coal-fired plants	48MW Wind Farm is producing energy, a second 100MW wind farm is being planned for Antofogasta, Several projects exploring energy gemeation with algae and biomass.
Pacific Hydro	500	-	500	-	-	-	-	2.9%	Owned my multinaitonal Australian Energy firm. Chile was home to the company's first investments outside of Oceania, arriving in the region in 2002.	4 Hydroelectric Plants	5 New Hydroelectric facilities in planning - total estimated capacity of up to 500MW.	108MW Wind Farm planned in North Cemtal Chile.

Source: Official Company Websites

Figure 6

Barriers to Geothermal Development, Based on International Experience, 2012

	Barrier Type
1	Proving a resource's viability is both expensive and risky. Few are willing to assume this risk. Developers often require government assistance and government is sometimes not willing to provide it.
2	Insufficient reservoir characterization can lead to unpredictable future levels of resource exploitation. Thus, adding to market uncertainty.
3	Some geothermal projects are located in remote and environmentally sensitive areas, making access and exploitation difficult.
4	Exploration rights do not include land rights. Development companies must navigate complicated local, provincial, and federal regulations. Additionally, developers must negotiate with landowners.
5	Government institutions are not in sync. One institution may issue geothermal permits and other bureaucratic offices enforce regulations that block or delay projects.
6	Environmental groups or other special interest groups sometimes oppose projects near environmentally or culturally sensitive sites.

Source: Bloomberg New Energy Finance. Q3 2012 Geothermal Market Outlook. Bloomberg New Energy Finance, 2012. PDF File.

Figure 7

Professional Affiliations of Persons Included in Study

Entity Name	Description	Category
The Ministry of Energy, Government of Chile	Chief government office of energy administration and management.	Government
National Service of Geology and Mining (SERNAGEOMIN), Ministry of Mining, Government of Chile	Chief government office of information for mining and geothermal sectors.	Government
Centre for Renewable Energy (CER), Government of Chile	Chief government office in charge of optimizing use of renewable energy.	Government
GeoGlobal Energy, LLC (Mighty River Chile)	Geothermal development company with multiple exploration concessions and an exploitation concession.	Industry
Energía Andina	Geothermal development company with multiple exploration concessions.	Industry
ENEL Green Power	Geothermal development company with multiple exploration and exploitation concessions.	Industry
Colbún	One of the largest energy generation companies in Chile. Holds 2 geothermal exploration concessions.	Industry
GeoThermHydro	Geothermal development consultant agency.	Industry
Poch	Energy development consultant agency.	Industry
Serviland Minergy	Geothermal development company with multiple pending exploration concessions.	Industry
Magma Energy Corp	Geothermal development company with a few exploration concessions.	Industry
Geohidrologia	Geothermal development consultant agency.	Industry
Economic Commission for Latin America and Caribbean (ECLAC)	One of five regional commissions of the of the United Nations. Purpose is to contribute to the economic development of Latin America	Academia/Other
Center for Energy, Universidad de Chile	Energy development and technology center at Universidad de Chile	Academia/Other
Center for Geothermal Excellence of the Andes (CEGA), Universidad de Chile	Geothermal research center at the Universidad de Chile.	Academia/Other
Consejo de Pueblos Atacameños	Civil Society Organization representing the Atacameño Community in Chile's northern region.	Civil Society

Figure 8

Survey Results – Advantages of Geothermal Development in Chile

Question Number	Advantages	Survey Results: Advantage Strength*			Classification
		I	G	A/O	
1	It has a high capacity factor (consistent, reliable production). As such, it augments energy security.	4.8	5.0	5.0	Strong
2	It is a domestic resource. As such, it augments energy security.	4.4	5.0	5.0	Strong
3	It is an abundant resource in Chile.	4.5	4.8	5.0	Strong
4	It is a versatile resource and can be used for direct uses (greenhouses, heating) as well as electricity generation.	4.4	5.0	4.8	Strong
5	It has a low environmental impact relative to conventional fossil fuel energy sources and non-conventional renewable energy sources.	4.5	5.0	4.3	Strong
6	Geothermal technology is mature and has been used in other parts of the world for over 50 years.	4.4	4.5	4.5	Strong
7	It can be developed in a modular fashion. As such, capacity can be increased to meet growing demand over time without immediate need for the construction of mega-projects.	4.2	4.8	4.3	Strong
8	It is used to meet international goals to diminish pollution. Meeting these goals can facilitate other international business, environmental, and public health agreements/accords	4.4	4.3	4.5	Strong
9	It can be used by the mining industry in the north of Chile because their operations are closer to geothermal resources. The mining industry consumes nearly 30% of all electricity generated in the country.	4.1	4.5	4.5	Strong
10	It supports local economic development.	3.8	4.0	5.0	Challenge
11	It creates jobs and promotes economic growth.	3.6	4.3	4.8	Challenge
12	It is a cost competitive resource per installed KW (based on international experience)	3.6	3.3	4.0	Challenge

**Data Headers: I=Industry, G = Government, A/O = Academia/Other, Avg. = Average of All Groups*

Figure 9

Survey Results – Barriers and Incentives for Geothermal Development in Chile

QUESTION NUMBER	TOPIC	Barrier or Incentive	DESCRIPTION	I	G	A/O	CLASSIFICATION
13	FINANCE	Barrier	All of the risk associated with exploration is assumed by the investors.	4.4	4.1	4.0	Strong
14	FINANCE	Incentive	The government of Chile pays a percentage of the costs of failed wells as and a lower percentage of successful wells. Such policy has been applied in other countries, like the United States and Italy.	4.4	4.1	4.0	Strong
15	FINANCE	Incentive	The government offers tax benefits to electric generation companies that develop geothermal energy projects.	4.2	3.3	4.3	Challenge
16	FINANCE	Incentive	The government assures a feed-in tariff (price guarantee) for geothermal energy which will diminish some of the risk of investment.	4.1	3.3	4.3	Challenge
17	FINANCE	Incentive	The government offers to lower taxes for companies that purchase energy directly from geothermal plants.	3.9	3.3	4.3	Challenge
18	FINANCE	Incentive	The government of Chile creates a carbon tax.	3.6	2.6	4.3	Challenge
19	Market Entry	Barrier	Some geothermal resources are in remote areas - without easy access to transmission lines and/or sufficient infrastructure.	4.5	4.5	4.5	Strong
20	Market Entry	Incentive	The government assures that projects have access to transmission lines and constructs the necessary infrastructure for the development of geothermal resources.	4.6	5.0	4.3	Strong
21	Market Entry	Barrier	Few drilling companies exist in the Chilean market.	4.4	4.8	4.0	Strong
22	Market Entry	Incentive	The government assists in the creation of more accessible drilling technology or helps to attract more drilling companies to the Chilean market.	3.8	4.5	4.3	Challenge
23	Market Entry	Barrier	A few large companies dominate the energy generation market in Chile.	3.6	3.5	4.8	Challenge
24	Market Entry	Incentive	The government helps to promote more competition in the electric generation market in Chile.	3.3	4.3	4.3	Challenge
25	Market Entry	Barrier	Large companies in Chile prefer current energy providers that are known over new NCRE energy producers that may provide energy a similar or lower cost.	2.9	3.5	4.3	Challenge
26	Market Entry	Incentive	The promotion or assurance of the purchase of 100% of energy generated from geothermal resources.	3.7	5.0	4.5	Challenge
27	Market Entry	Incentive	The government offers to lower taxes for companies that purchase energy directly from geothermal plants.	3.9	3.3	4.3	Challenge
28	Legal	Barrier	There is a lack of a clear and comprehensive legal framework to regulate disputes between geothermal developer and other persons who own the rights to other resources within the concession (i.e. indigenous claims, water, etc.).	4.1	2.8	4.3	Challenge
29	Legal	Incentive	The government assists in the creation of a regulatory framework or as a mediator for all of the resource rights that various individuals/groups may have in a geothermal concession.	3.8	3.0	4.5	Challenge

Figure 9 (Continued)

Survey Results – Barriers and Incentives for Geothermal Development in Chile

QUESTION NUBMER	TOPIC	Barrier or Incentive	DESCRIPTION	I	G	A/O	CLASSIFICATION
30	Legal	Barrier	A single geothermal resource can be divided into more than on concession (and, subsequently, between more than one company).	4.4	4.3	4.0	Strong
31	Legal	Incentive	The government grants concessions in a manner that assures that one specific geothermal resource is not divided between more than one company.	4.6	4.4	4.0	Strong
32	Institutional	Barrier	There is no clear energy policy in Chile.	4.4	3.8	4.5	Challenge
33	Institutional	Incentive	The government clearly defines the role of geothermal energy in the future of Chile's energy mix.	4.5	4.8	4.5	Strong
34	Institutional	Barrier	The concession approval process can be lengthy and can create a delay in the progress of the project.	4.4	3.4	4.4	Challenge
35	Institutional	Incentive	The process of granting concessions is expedited.	4.3	3.6	4.3	Challenge
36	Institutional	Barrier	When more than one company solicits a concession, the approval process immediately enters into an open bidding process in which all companies in the market can participate. This can create a delay in the approval process.	3.8	3.3	4.5	Challenge
37	Institutional	Incentive	When more than one company requests a geothermal concession in the same area, only the actor(s) initially interested are considered during the approval process.	3.8	2.8	4.0	Challenge
38	Information	Barrier	There is no detailed, public source of information about geothermal resources in Chile.	3.3	4.6	4.5	Challenge
39	Information	Incentive	The institutions of the government engage in their own project of gathering and publishing relevant information about geothermal resources.	3.5	4.9	4.3	Challenge
40	Information	Incentive	The government requires that companies provide the results of exploration if a concession is abandonded by a company or if a concession for exploitation is granted.	3.1	4.3	4.3	Challenge
41	Information	Incentive	The government of Chile requests the exploration results in exchange for financial assistance from the state (i.e. subsidies for wells).	3.4	3.3	3.8	Moderate/Weak
42	Social	Barrier	Communities near geothermal projects can perceive these projects as a threat to the local community, local economy, and environment.	4.3	4.3	4.8	Strong
43	Social	Incentive	The government expands the regulatory framework to consider the needs and possibilities for development of local communities during the period of exploration and exploitation.	3.8	4.8	4.5	Challenge
44	Social	Incentive	The government can promote (require and/or incentivize) the direct uses of geothermal resources associated with electricity generation, benefitting the local community.	3.8	4.8	4.3	Challenge
45	Education	Barrier	There is no mature geothermal research center in the Andean context.	3.6	4.3	4.8	Challenge
46	Education	Incentive	Generate a mechanism to facilitate detailed information about geothermal resources in Chile to new research centers.	4.1	4.4	4.3	Strong

Figure 10

Survey Results – Open Questions

Category	Barrier		Open Question Resonse	Incentive	Open Question Resonse
Legal	***Inflexible Concession Requirements***	Length of the concession and dimensions of the concession are relatively inflexible. Some variables that effect the process of exploration are not considered in current stipulations in concession law.	***Open Question Response - 8 Mentions***	1.Period of concession should be determined by the unique environmental and/or climate conditions in a concession. Some concessions will require lengthy environmental impact studies, for example. These concessions should be granted for a longer period of time. 2.The shape of the concession should be able to be adjusted according to the needs of the company. Concessions along the border, for example, might require entirely unique dimensions.	***Open Question Response - 8 Mentions***
	Environmental Impact Studies Are Not Uniform and Create Project Delays	Environmental impact studies are not uniform in nature across various regions and sometimes create significant delays. Those who conduct the studies are often not geothermal experts. Environmental evaluations only occur as a project enters exploitation phase - there is no preliminary study to understand 'baseline' environmental conditions and potential impacts.	***Open Question Response - 8 Mentions***	The government might train evaluators so they are better able to evaluate the unique nature of geothermal projects. Furthermore, the government might require impact studies prior to exploration. Earlier impact studies will provide 'baseline' environmental conditions and may help to put local communities at ease about exploration activity.	***Open Question Response - 8 Mentions***
	Lack of Formal Legal Regulation of Rights of Other Actors (i.e. Indigenous Groups).	Geothermal developers have no detailed legal framework to reference when negotiating with indigenous communities.	***"Challenge" Barrier Identified in Survey***	The government needs to incorporate ILO Convention 169 on indigenous rights into domestic geothermal law. A clear understanding of indigenous rights within geothermal concessions may help to reduce uncertainty and, subsequently, the perceived risk of some projects.	***Open Question Response - 4 Mentions***
	Speculation	Some geothermal concessions in Chile are not developed because they are granted to speculators instead of legitimate developers. Concessions often granted based on a firm's promised investment rather than its ability and capacity to implement a geothermal project.	***Open Question Response - 6 Mentions***	In addition to considering promised investment, the Ministry of Energy might more seriously consider technical criteria and a company's geothermal project history when evaluating bidding companies during the geothermal concession granting process.	***Open Question Response - 6 Mentions***
Institutional	***Lack of Sufficient Human Resources Dedicated to Geothermal Regulation and Promotion in Government Institutions***	There are few people working on geothermal energy in government institutions. A lack of persons dedicated to geothermal means there are very few geothermal experts in government offices.	***Open Question Response - 11 Mentions***	Consolidate geothermal management and regulation in one office. Ensure that relevant government agencies are sufficiently staffed with individuals that are knowledgeable about geothermal projects.	***Open Question Response - 11 Mentions***
Social	***Public May View Geothermal Exploration/Exploitation as a Threat***	Communities may exhibit a 'not in my back yard' attitude toward geothermal exploration and exploitation. Development may be perceived as a threat to existing economic, environmental, and social conditions.	***"Strong" Barrier Identified in Survey***	The government should also engage in Environmental Impact Studies at the beginning of the exploration phase rather than just at the beginning of the exploitation phase. This earlier study might include an early consultation process with the community and will serve as an environmental 'baseline' to measure any future environmental impacts the project may have.	***Open - 3 Mentions***
				Also, the government might use a public awareness campaign to effectively demonstrate potential environmental, economic, and social benefits of geothermal energy production.	***Open - 13 Mentions***

Figure 11

Preferred Sources of Electricity Among Sample of Chilean Citizens

Preferred Sources of Electricity for Generation		
1	Solar Power	61%
2	Wind Power	57%
3	Hydropower	39%
4	Geothermal	20%
5	Wave Power	20%
6	Gas	12%
7	Nuclear Power	11%
8	Biomass	8%
9	Oil	5%
10	Coal	4%

Source: Aravena, Claudia, W. George Hutchinson, Alberto Longo. 2011. "Environmental Pricing of Externalities from Different Sources of Electricity Generation in Chile." Energy Policy. 34: 1220.

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