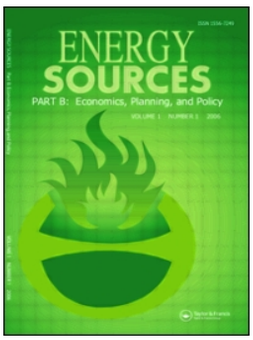

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Chile: Paving the way for sustainable energy planning

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ABSTRACT

Over the last 20 years, economy of Chile grew faster than any other country in South America, thanks to its rigorous economic and political systems and its integration to the global economy. Nonetheless, Chile faces the continuing challenge of finding additional energy supplies to support its economic growth. The country has almost no fossil fuel resources and depends heavily on external sources that accounts for around 60% of its energy needs. However, this may change in the near future, as Chile has started developing its huge potential of sustainable energy sources. This paper examines strategically important energy alternatives for Chile, including energy efficiency (EE) programs, large hydro projects, renewable energy, and nuclear power, focusing on recent developments and remaining challenges. It also gives some recommendations providing alternatives to remove the obstacles.

KEYWORDS

Chile; energy efficiency; energy sources; hydro and renewables

1. Introduction

Chile has sustained economic growth for more than 20 years and is considered to be South America's most stable and prosperous nation. However, Chile's economy ongoing dynamism and the increasing well-being of its people mean a double boost in electricity demand, dragging the country into an inflection point, where the lack of adequate investment in the power sector can jeopardize the future of the country. Estimations show that if Chile's economy continues to grow at its current pace, it is expected that electricity demand will increase from under 65 TWh in 2012 to over 120 TWh by 2025 (CORFO, 2014). One important driver behind the economic growth is the copper industry, making up for around 38% of Chile's electricity demand (Cochilco, 2013). According to the estimations of Chilean Copper Commission (Cochilco), about 50% of further power expansion by 2025 will be used to cover the energy needs of the copper industry. The growth has also brought some undesirable effects, and although Chile is a minor contributor to global CO_2 emissions (0.2%), its upward trend (a 110% increase between years 1990 and 2011) presents huge concerns (World Bank, 2013).

Chile's energy sector is characterized by a strong dependency on fossil fuel imports, making the country vulnerable to price volatility and instability of international markets. Currently, Chile imports around 60% of its primary energy needs in the form of oil, gas, and coal (CNE, 2014). Unlike other countries from the region with high levels of energy self-sufficiency (Colombia (95%), Brazil (90%), and Argentina (80%)), Chile lacks domestic fossil resources (Endesa, 2013). This dependency from external energy sources and growing environmental concerns prompted the Chilean government to reconsider its energy planning policies, focusing on designing an adequate energy matrix to address the energy challenges of the country. Unfortunately, a literature review shows there is almost no empirical evidence on Chile's energy and climate policy. A few recent studies have focused on very specific issues. For example, Mundaca (2013) provides an ex-post assessment of the climate and energy policy developments in Chile as it emerged from a neoliberal economic model, during the period 1971–2007. Coria (2009) examined the environmental and

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energy policy using time series (1997–2005) analyzing the relation to fuel prices and natural gas switching. On the other hand, observations in the context of world countries shows that energy security planning is a complex and dynamic process requiring profound assessments on potential combinations of several risks and hazards, with assessments varying from country to country. For instance, the policy-makers who seek to address the energy challenges in rural India needs to consider air pollution mitigation and energy poverty factors; in Japan they need to meet the difficulty from nuclear power governance; and in many developing countries lacking access to electricity, policy-makers face difficult challenges as they try to improve energy access to their countrymen (Kaygusuz, 2011).

Given the complexities of defining an energy supply model, how should a modern energy matrix for a country like Chile be defined? In simple terms, energy security is defined by the International Energy Agency as available, accessible, acceptable, and affordable supple of energy (IEA, 2014). In the case of Chile, the government has given the guidelines to meet the increasing demand for energy, while reducing the environmental impact of the sector, in two documents: the National Energy Strategy (2012–2030), that focuses on how to make Chile's energy matrix cleaner, more secure, and more cost-effective in the long term (Ministry of Energy, 2012); and the Energy Agenda (2014–2018) that focused on the concrete steps needed to promote such matrix (Ministry of Energy, 2014). As priority areas, both documents outline the promotion of energy efficiency (EE), promotion of renewable energy technologies, and use of traditional energy sources, in particular large hydro sources. In the light of those two documents, this article examines strategically important clean energy alternatives for Chile, focusing on recent developments and remaining challenges.

2. Sustainable energy alternatives

Chile has abundant untapped sustainable energy resources and the use of these domestic resources in lieu of imported fossil fuels can provide substantial benefits to regions and communities across the country. Systep (2014) and CIGRE (2014) examined traditional hydro sources and other renewable energy technologies and placed them as either cost-competitive or close to being so compared with conventional generation technologies in the Chilean market (see Table 1). Even though levelized cost of energy (LCOE) calculations do not factor in environmental and other externalities (e.g., Renewable Portfolio Standard (RPS), transmission, and back-up generation/system reliability costs) as well as fuel costs variations of conventional generation technologies, it is a simple way to run a first comparison among available technologies. Table 1 provides the estimated national average LCOE for energy alternatives currently available in Chile.

Over the last years, new energy public policies have resulted in an increasing penetration of sustainable energy in the energy matrix. Table 2 details the evolution of traditional hydro and renewable resources, either under operation, construction, under evaluation or already approved by the Environmental Impact Service.

Table 1. LCOE for sustainable energy alternatives in Chile.

Technology	Investment cost[a], USD/kW	Operating cost, USD/MWh	Capacity factor, %	LCOE, USD/MWh
Hydro run of river	2,670–4,000	2.0–5.0	50–60	66.3–112.1
Hydro dams	2,750–3,650	2.0–5.0	55–65	66.1–98.0
Coal	2,400–3,000	37.0–47.0	89	84.6–108.4
LNG	1,000–1,200	74.5–88.0	50–80	100.7–129.9
Solar PV	1,960–2,500	3.0	20–35	73.2–155.4
Solar CSP	7,380–7,841	21.5	70–90	120.9–167.2
Wind	2,000–2,500	7.7	25–40	66.5–123.2
Geothermal[b]	3,480–6,600	–	88–92	65.1–122.5
Diesel	390–860	149.1–223.7	65	178.6–262.4

Sources: CIGRE (2014), Systep (2014), and the authors.
[a]Investment cost includes grid connection costs.
[b]Exploitation cost of geothermal plants has not been included.

Table 2. Sustainable energy capacities in Chile.

Technology	Operating, MW	Under construction, MW	Approved SEIA, MW	Under evaluation SEIA, MW
Large hydro run of river	2,307	80	1,690	1,376
Hydro dams	4,019	0	2,750	0
Small hydro	340	51	290	183
Solar PV	184	441	5,809	4,155
Solar CSP	0	100	760	0
Biomass	461	22	74	66
Biogas	43	0	0	8
Wind	682	154	4,542	2,099
Geothermal	0	0	120	0

Sources: Systep (2014), CER (2014a), and the authors.

2.1. *Development of large hydro potentials*

In the early of 1990s, the contribution of hydropower to the Chile's energy matrix was significantly large, presenting approximately 78% of total electricity production of the country. Over the years, hydropower seemed to lose its advantage over unconventional combined cycle gas sources, particularly when abundant Argentine natural gas entered to the market at a lower price. However, the latest crisis from Argentine supply cuts had changed the Chilean energy matrix completely and forced Chilean government to reconsider development of hydro projects. There are strong evidences that exploiting untapped rich hydro potentials can provide a major impact on the future energy diversification of the country compared with other clean energy alternatives. Unexploited capacity of the hydro resources in Chile was estimated about around of 22,000 MW (Varas et al., 2013). Nevertheless, as of today, Chile uses less than 29% of the exploitable hydro resources in the energy matrix presenting 6,326 MW of total installed capacities (see Table 2). Over the last years, Chile's environmental authorities have approved a capacity of around 4,700 MW proposals for construction of hydroelectric reservoir power plants and run-of-river hydroelectricity plants in the country. Despite the potential benefits, the majority of hydropower projects in the development stage are facing a number of difficulties and challenges, most of the time leading to halts or significant delays. The difficulties are not technical or economic but social and legal. It is only very recently that the Chilean government rejected the perhaps most emblematic hydro project, HidroAysén, what would have been the largest energy project in the country's history (Varas et al., 2013). The project had a total capacity of 2,750 MW and it was expected to generate approximately 28% Chile's annual electricity consumption. It has experienced one of the most widespread protests in recent Chilean history facing about 23 legal charges.

The major source of unsolved difficulties comes from the fact that many of the hydroelectric projects have been submitted for approval by SEIA in areas that are legally owned or claimed by indigenous communities of Chile, in particular by the Mapuche community (Prieto and Bauer, 2012). Historically, relations between indigenous communities and Chilean government have been marked by conflict, primarily because of the expansion of industrial projects on lands that are part of the indigenous territory. Unlike neighboring countries in the South America, Chile's constitution lacks legal frameworks and policies concerning rights of indigenous people. Today, common failures in the development of hydroelectric projects in Chile are the lack of adequate consultation with the directly impacted indigenous communities, as required by ILO Convention 169. In addition, absence of compensation mechanisms to the communities, indigenous or not, for the impact of the projects and the lack of basis to ensure that surrounding communities can participate of the benefits of the exploitation of hydro resources, are among the critical reasons of the failure of projects . Another critical factor hindering the development of hydro power projects in Chile is the lack of an impact assessment framework to measure possible environmental and social impacts properly. In practice, project developers design hydroelectric proposals without having to take account of the full range of costs and benefits of a project to the residents of area where it is located (Susskind et al., 2014). The absence of real public participation in analyzing preliminary studies or findings before SEIA submission is identified as a key source of political and legal challenges to hydroelectric

projects. In contrary, the public participation starts once the project developer publishes a project abstract in an official newspaper and it makes impossible for impacted communities to provide meaningful feedback or exercise influence over the project's design or implementation during the short period of time. According to the Citizen Technical Parliamentary Commission, between 2000 and 2011, a total of 222 electricity generation projects entered for the evaluation of SEIA of which 153 (mostly hydraulic) presented this kind of conflict (UNIDO and ICSHP, 2013)

2.2. *Entrance of renewable energy sources (RES)*

Among the alternative sources, Chile is considered to be one of the most attractive countries for the development of RES, thanks to its abundant renewable energy resources, particularly biomass, hydropower, geothermal, solar, wave, and wind that have not been exploited yet. Over 4,000 km of coast exposed to consistent and high Pacific swells boosts wave energy, Southern Chile has significant areas of wind potential, and the Atacama Desert in northern Chile has excellent conditions for solar energy. The estimated potential of renewables in Chile is summarized in Figure 1.

Since 2008, Chilean government has introduced several new regulatory incentives to attract investment in the renewable sector. Since then, accumulated investment in this sector has reached record level of US$ 6.2 billion in 2013 (BNEF, 2013). In 2008, the government took an important step forward by approving RPS scheme that introduced an obligation for companies to generate at least 10% of their electricity from non-conventional renewable energy sources by 2024. In 2013, the Chilean doubled its renewable energy target from the previous goal of 10% by 2024 to 20% by 2025. To achieve the 2020/2025 target, a total of around 6,500 MW of new renewable capacity should enter to the grid in the next 10 years, which means an average of around 650 MW every year.

So far, installed energy capacity from RES has met and even surpassed the defined target. Moreover, renewable installed capacity added 600 MW in the first 7 months of 2014, reaching 1,700 MW from RES (see Table 2). This is equivalent to 8.9% of the total capacity in the whole power system. Wind power leads the RES installed capacity with 682 MW, representing 40% of the share of renewable in the country. The rest of renewable technologies under operation is distributed in 27% biomass (461 MW), 20% small hydro (340 MW), 10% solar (184 MW), and 3% biogas (43 MW).

Despite improvements in Chilean renewable industry, a serious number of obstacles remain for the implementation of renewable projects on even more significant numbers. When looking at the situation of the market, renewable energy projects with environmental approval reached to 12,000 MW in 2014 (see Table 2). However, only a small portion of projects (1,700 MW) have materialized until today. It seems there are a series of barriers slowing down and even stopping the advancement of renewables. Factors such as a lack of investment in transmission infrastructure, difficulties in building such lines resulting from Chile's geography, and difficulties to connect to existing grid are

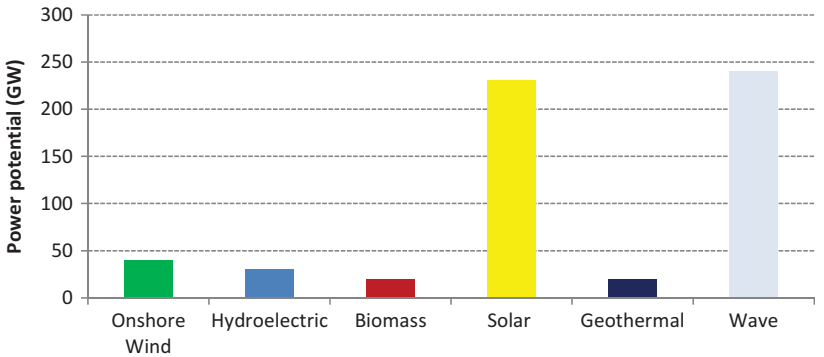

Figure 1. The estimated potential of renewables in Chile. Source: CERb (2014) and the authors.

identified as key impediments for development of renewable projects. Some loopholes in the legislative framework guiding the granting of right-of-ways and the absence of effective project evaluation criteria have often resulted in discretionary decisions. Also, it is possible to identify some other most common barriers stopping advancement of renewables in the country, such as high cost of the initial investment, limited access to financing, opposition from local communities, and the lack of interest from large consumers to sign long-term contracts (PPAs) with intermitted sources.

2.3. *Promotion of energy efficiency (EE) programs*

Another important alternative within energy sustainability is EE. The savings from EE programs in Chile has been estimated between 1,700 and 4,100 MW by 2025, showing that the country has a tremendous potential in this area (Karakosta and Askounis, 2010). EE is considered to be one of the most cost-effective alternatives to reduce costs, to increase energy security of the country, and to achieve emission reductions for a sustained growth. According to the study by the CNE, the long-term benefits of EE strategies far exceed the short-term costs of implementing them in Chile (NRDC, 2014). For example, estimated economic benefits of EE improvements in the country make up around between 12 and 23 billion USD compared with total projected $904 million USD costs of these strategies. This confirms that even under the most pessimistic scenario, adopting EE measures in Chile have huge potential of economic benefits.

Historically, EE had not been a priority of Chilean government, with no permanent state policy. Although there had been several unrelated attempts to promote EE (including the energy conservation and rational use programs), these had a minor effect curving energy consumption. However, the formation of the Energy Efficiency Program (PPEE) (2005–2010) was an important step in this direction. Furthermore, the establishment of the National Energy Efficiency Agency (AChEE) and the Energy Efficiency Division of the Ministry of Energy in 2010 have strengthened the public–private commitment in this area.

The Chilean government redefined its EE strategy approving National Action Plan for Energy Efficiency 2012–2020 (Ministry of Energy, 2012). The action plan is intended to be a guide for the public and private sectors to take the necessary actions to achieve the great potential of EE. It has set the concrete goal of reducing Chile's projected 2020 energy demand by 12% via EE programs, equivalent to reducing over 41,500 Tcal (teracalories) by 2020. This goal includes a reduction of 16% in the industry and mining sectors (accounting for 7 million tons of CO_2), 13% in the commercial and residential sectors (accounting for 600 thousand tons of CO_2), 10% in the transportation sector (accounting for 3.5 million tons of CO_2), and 18% from the construction sector (accounting for 3.3 million tons of CO_2).

Since the beginning of the EE efforts in 2005, Chile has introduced a number of significant EE programs, such as "Light Up with Good Energy," initiative that was launched in 2008 to supply compact fluorescent light bulbs (CFLs) to the 40% most vulnerable population in Chile (CCAP, 2012). Other similar EE initiatives include the National Efficient Lighting Strategy (NELS) that was announced in 2013.

Even though Chile has made significant efforts to improve EE, the country has not taken a consistent approach toward EE. In particular, some of its announcements and intentions have not been translated into concrete actions. Most of the industrial sector, in particular the industrial and mining sectors, which have significant potential of EE, have not yet incorporated EE it in their operations (NRDC, 2014). In particular, despite the existence of an EE target, the Chilean government has not established a set of concrete actions highlighting short-, middle-, and long-term objectives and sector goals. In addition, current legislation lacks to provide a higher level of coordination and cooperation within and between institutions, agencies, institutes, and other stakeholders. During a short time period, following the creation of the PPEE agency in 2006–2009, EE programs drew significant attention, however the budget for EE showed the decreasing trend, especially from 2009 to 2012, where the annual budget has decreased from USD 34 million to around USD 6 million in 2012 due to the shifting in priorities within the government (CCAP, 2012). At this point, if the budget for EE continues the decreasing trend from the last few years, it looks almost impossible to advance in this field.

2.4. *Study of nuclear energy option*

Among the alternatives to diversify its energy matrix, the use of nuclear energy has been proposed as a reliable source to solve some of the country's energy and emission dilemmas. Although there is no consensus if nuclear power deserves to be considered a clean energy, due to the risks from nuclear waste, it is undeniable that this technology has very low emissions per megawatt-hour, making it an important alternative to lower emissions from power generation. At this time, Chile does not have any nuclear power plants besides two research reactors. However, since 2006, the government committed to an open debate on the prospects of utilizing nuclear energy in the near future. A primary program for a possible Chilean nuclear reactor was presented in 2009, aimed at introducing the first nuclear power plant in Chile around the 2020s (IEA, 2009). However, after the terrible 8.8 earthquake and tsunami in Chile on February 27, 2010, and the Fukushima Daiichi nuclear incident in Japan in 2011, things have turned drastically. Likewise many of countries ongoing fears regarding nuclear technologies in seismic countries such as Chile had a profound impact on local policy-makers, resulting in a complete halt to the process. Still Chilean government is keeping nuclear option open and it can be brought into debate anytime. However, more than even, the government is aware that in a highly seismic country, lacking necessary infrastructure, institutions, and experience in nuclear civil protection, introducing a new complex nuclear power infrastructure from scratch will be a challenging task for the country.

3. Concluding remarks and recommendations

This article is review of clean energy alternatives for Chile. It illustrates recent developments and significant challenges in the promotion of EE programs, development of renewable energy technologies, expansion of traditional energy sources, in particular large hydro sources and study of nuclear energy option. Removing key obstacles to them remains a key concern.

In the case of the hydropower development, it is necessary for Chile to establish clear and transparent policy mechanisms to provide a comprehensive guide for impact assessment and indigenous consultation. The international experience with indigenous communities shows that a key factor in the successful development of a hydro project on indigenous lands lies in the direct consultation and negotiations with these communities. Therefore, it is essential to guarantee direct participation of indigenous people in the decision-making process. Concerning environment and social assessments of proposed projects (SEIA), evaluations should be carried out within a reasonable period of time and carefully taking into consideration the social and environmental impacts. In particular, members of affected communities and the public in general should be given more of a chance to participate throughout the assessment process.

In order to meet the renewable-energy target of 20% by 2025, continuous efforts of Chilean government are needed. It is of utmost importance that the Chilean government should play a key role in establishing additional incentive mechanisms and keep a clear strategy to eliminate barriers that slow or even stop the development of renewable energies in the country. Establishment of a comprehensive national transmission planning process, creation of standard interconnection procedures, regulating open access to transmission networks, strengthening pricing for transmission, are identified as the most urgent measures.

In order to make EE gains a reality, the government needs to take further important actions. These actions include legislation improvements to ensure effective control, development of strategies, commitments for large industry and mining sectors to increase their EE, to promote stable funding, to develop and maintain the EE indicators, and support nationwide educational campaigns.

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