Hydro or Coal: Energy and the Environment in Chile
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Abstract—Coal and hydro will be the main sources of electric energy in Chile for the near future, given that natural gas from neighbouring Argentina is not longer available and LNG price projections leave it only as a backup fuel. The country has limited energy resources, importing more than 73% of its energy. Hydroelectric untapped resources are significant, but they are mostly located in the extreme south of the country, in unpopulated areas of great unspoiled beauty. Non governmental organizations both within the country and from the US are strongly opposing the use of these resources. Renewables, which are only at an early stage, are argued as an alternative, but do not represent a solution with rates of growth of electricity demand over 6% a year. This summary discusses the issues being faced and the environmental dilemma faced by the country, where both coal and hydro produce some kind of impact. The role of the State and the private sector in determining the country’s energy matrix arises as another central discussion.

Index Terms—Power system economics, energy matrix, environmental restrictions, hydroelectric plants, energy policy.

I. INTRODUCTION

The Chilean electric market consists of three segments: generation, transmission and distribution. According to the law, the generation segment is defined as a competitive market, while the transmission and distribution segments are regulated by the State. In the generation market, the different agents compete for supplying power to consumers according to a marginality theory with minimum centralized dispatch cost. Said market competition takes place mainly as regards generation costs; thus, the most economic technologies define the system’s development.

Availability of natural gas from Argentina, which price is much lower than any other thermal technology of the 90s and beginning of the 20s, defined the development of the Chilean market due to its favorable import price. Therefore, participation thereof (since year 1997) gained a significant importance in the Chilean electric market. In addition, the hydrology component of the generation park in the Central Interconnected System (SIC) allowed supplying power at a low cost – approximately US$20/MWh – from year 2000 through year 2004. However, restrictions imposed on import of natural gas from Argentina since 2004 created an unbalance in the Chilean electric market between the generation capacity and the system’s demand. The foregoing led to a boost in the energy price, which at present exceeds US$200/MWh, and to the adoption by the National Congress of a series of measures for promoting proper development of the generating park (Short Law II). In addition, also the diversification of the energetic matrix has been promoted through exploitation of the ERNC (Non-conventional Renewable Energy), which should decrease dependence on traditional sources (Short Law I, Short Law II, ERNC recent bill).

The generation, transmission and distribution companies are geographically distributed across the national territory in four electric systems, which from north to south are the Great North Interconnected System (SING), the Central Interconnected System (SIC), the Aysén System, and lastly the Magallanes System, being the SING and the SIC the most important ones, as together they represent 99% of the installed capacity of the country.

The SING, which is located between the cities of Arica and Antofagasta, has, as of April 2007, an installed capacity of 3,602 MW, most of it corresponding to steam generation plants. The system mainly supplies energy and capacity to large mining and industrial clients that are not subject to a rate regulation system, and represent approximately 90% of the consumption.

The SIC, which is located between Talcah and the Great Island of Chiloé, supplies electricity to over 90% of the country’s inhabitants, and has an installed capacity, as of April 2007, of 8,964 MW. The generating park is of a hydrothermal type, from which 57% is hydraulic, and 43% thermal. Approximately 60% of the capacity generated by this system is for residential consumption, and is subject to a rates regulation system.

The SIC is the most relevant system in the country, and also the best suited for hydroelectric generation, with both large and small plants. Power to the SIC is mainly supplied by plants with hydraulic technology, which take advantage of the properties of the basins and waterfalls of the rivers of southern Chile. The participation of the installed capacity of the reservoir plants stands out in this type of technology. The foregoing is illustrated in Figure 1.

![Fig. 1: Installed capacity per generation technology SIC 2007](image)

The installed capacity in plants with thermal technology represents 47% of the supply; among these, power plants fired with natural gas have the largest participation, representing 29% of the total installed capacity of the SIC. It is worth stressing out that power plants fired with natural gas import the fuel they need for operating from Argentina, through gas pipelines that cross the Andean mountain range. Thus, a
significant part of the generation capacity of the SIC depends on the Argentinian energy market.

Ownership of the plants in the SIC is highly concentrated; there are three large agents in the generation market, which are: Endesa, AES Gener and Colbún.

Although at present the SIC has a generation park with presence of different power generation technologies, 10 years ago supply presented a markedly hydroelectric component, with a participation of 78% in the total installed capacity. In year 1997, an important trade agreement was subscribed between Chile and Argentina, which created a significant Argentinian natural gas supply, which made viable the construction of gas pipelines for supplying gas to residential and industrial clients, and the development of an important electricity generation capacity with combined cycle power plants in the SIC and SING. Figure 2 shows the evolution of the generation capacity in the SIC.

High energy consumption growth, near 6%, worldwide raising fossil fuels prices, strong environmentalist pressure towards reducing greenhouse effect producing gases and promotion of renewable energy production, have been a common challenge in South American energy markets.

While South America contributes little to the world’s total pollutant emissions, societies are increasingly becoming aware of the impact that new hydro power plants or fossil burning thermal generators. Private investors leading key investment decisions in the reformed South American power sectors are facing organized opposition to the building of new plants. Brazil and Chile provide two examples of how countries are trying to reconcile the need for abundant energy supply with environmental constraints.

Pollution control in electricity production in South America, with emissions much lower than those from transport and industry, are essentially driven by a population that is concerned more on their local impact than in the greenhouse effects. Often, local inhabitants and environmentalists join efforts to challenge new coal or gas fired thermal power plants that they argue would be harmful for people and for the economic activity near by the site of the power plants.

The significant hydro potential of the region, a more important area of conflict for electricity supply expansion over recent years has raised with the development of hydro resources. Risks of flooding tropical rainforest, flooding of scarcely populated areas but where there may be an indigenous population and water use conflicts are making life harder for hydro developers.

The Chilean electricity law does not treat two relevant issues from an environmental perspective, investment in new power plants, including plant location and technology, and power plant dispatch. There is full freedom for investment in the electricity sector, with minimal requirements for the installation of hydro plants and transmission lines. Private investors develop projects that, with the tariffs and costs perceived, produce a desired rate of return, while responding to their strategic interests. These interests not always coincide with the social appraisal of fuel costs, investments, return rates, and of course, with environmental considerations.

III. HIDRODEVELOPMENT

The true challenge for Chile is that it must obtain its power diversification and sustainability being inserted in a scheme of competitive market and with limited state intervention. Chile was pioneer in liberalizing the electrical generation segment in 1982, introducing a competitive and private market, where the entrance of new agents depends on the economic signals that the investors gather from the market. Therefore, in Chile the decision as what are the technologies to develop essentially relies in the private capital investment evaluation. The government is solely limited to generate the conditions so that it is possible to reach economic efficiency.

The process of liberalization and deregulation of the electricity market was accompanied by the privatization of the existing state owned electrical companies. Currently, the governments influence in the sector is limited mainly to regulation functions, control, of indicative expansion planning and to the fixation of the electrical tariffs for regulated clients. Objectives as the diversification of the power matrix and the environmental sustainability conform to a secondary level, where the government has limited tools to intervene. The
development of the generation segment has occurred in a frame of a technological neutrality as far as the technologies and fuels used, having all types of energies to compete in similar conditions of quality and price.

Over the past years hydro plants seemed to have lost advantages over fossil fueled plants, particularly when abundant Argentine gas was available at a low price, such as combined cycles, but now have been revisited under the current crisis situation. There are still important unexploited resources in the country (see Table 1); however, these resources are located either in indigenous populated areas, in regions with a high tourist potential or in unexploited natural forest reserves. Some recent examples are the Ralco plant commissioned in 2004 and the Aysen project, which is currently under study.

Table 1: Hydroelectric resources in Chile

<table>
<thead>
<tr>
<th>Zone</th>
<th>Region</th>
<th>Potencia Actual Instalada (MW)</th>
<th>Potencia no Explotada (MW)</th>
<th>Total (MW)</th>
<th>Porcentaje Instalado (%)</th>
<th>Total por zona (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norte</td>
<td>1, II, III, IV</td>
<td>27,8</td>
<td>202,2</td>
<td>229,2</td>
<td>90,4</td>
<td>259,2</td>
</tr>
<tr>
<td>Central</td>
<td>I</td>
<td>206,9</td>
<td>1085,0</td>
<td>1291,9</td>
<td>21,9</td>
<td>4055,5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VI</td>
<td>408,6</td>
<td>936,0</td>
<td>1342,6</td>
<td>31,5</td>
<td></td>
</tr>
<tr>
<td>Centro Sur</td>
<td></td>
<td>1393,9</td>
<td>1660,0</td>
<td>2753,9</td>
<td>24,9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VII</td>
<td>2299,0</td>
<td>2600,0</td>
<td>5198,0</td>
<td>44,1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VIII</td>
<td>2686,9</td>
<td>1294,0</td>
<td>3080,9</td>
<td>4030,3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IX</td>
<td>2493,6</td>
<td>4980,0</td>
<td>7473,6</td>
<td>4,7</td>
<td></td>
</tr>
<tr>
<td>Austral</td>
<td>XI</td>
<td>77,6</td>
<td>936,3</td>
<td>1013,9</td>
<td>9,2</td>
<td>9636,3</td>
</tr>
<tr>
<td></td>
<td>XII</td>
<td>453,6</td>
<td>2079,5</td>
<td>2533,1</td>
<td>20,5</td>
<td>223,1</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>4707,4</td>
<td>27379,5</td>
<td>32086,9</td>
<td>18,3</td>
<td>25640,3</td>
</tr>
</tbody>
</table>

Table 2 summarizes the main hydro projects under consideration at present. Opposition to projects in Neltume, San Pedro, Alfalfal II and others has already surfaced. But the greatest discussion is taking place on the construction of the hydroelectric power stations in the rivers Baker and Pascua, located in the extreme south of Chile in the Aysen region. The investor group has announced that the project consists of the construction, from year 2010 until the year 2022, of five hydroelectric power plants with a joint installed capacity of 2,750 MW. In addition, the project involves the construction of a transmission line in DC of 2,000 kilometers to unite the power stations directly to the capital of Chile, Santiago, the largest demand center. The project involves an investment superior to 4,000 million dollars. These power plants will imply the access to energy of clean production in great volumes, energy of a domestic origin that will contribute to reduce the foreign fuel dependency. These projects will also imply, during their construction, an important economic contribution to the zones where they will be located. It is important also to recognize that these power stations will be inserted in zones of great natural beauty, not taken part by the man. Its construction without a doubt will cause alterations to the ecosystems of the zone, were the total flooded surface of 93 square kilometers.

It is clear from the important resources that are being located to fight the construction of the Aysen project, that it has become a strategic objective for environmentalists worldwide, and particularly from the US. An onerous campaign has been orchestrated for this purpose. The discussion is heating up before the required environmental studies are finished. It has also become a source of political fighting with government ministers being questioned for taking one position or the other.

Without doubt the development that finally achieves the Aysen project will be a test of maturity for the Chilean model and the ability of the deregulated electricity markets to satisfy the interests of the country. As never as before Chile will need a long term vision that oversees far beyond the short term particular interests or necessities. The benefits or costs that bring with them for Chile the construction of these hydraulic power plants will remain in time for several generations of Chileans to come.

IV. COAL AND ITS INSERTION

With no natural gas from neighboring countries, with no clear overview on hydro, LNG and coal arise as alternatives. The National Petroleum Company (ENAP), a government company, took the lead in LNG. It was given the task of leading a pool of large natural gas consumers who have aggregated demand, which through an international bid hired British Gas to invest in a regasification terminal located in central Chile, along with the supply of LNG. Nevertheless, the high expected prices of LNG and its volatility anticipate that this one single alternative will have a backup function, more than a source for generation expansion. This project has already been given environmental licensing, which was pursued by the government prior to the international bidding, and construction has already started.

With those restrictions, coal arises as the most economic alternative and coal-fired plants are again been considered in the country as a tool for development. They are been planned equipped with pollution control systems, like circulated fluidized bed or pulverized coal with additional pollution filters, with the added costs of emissions mitigation equipment negatively impacting their economical assessment. Even with those control systems, coal plants will necessarily imply some sort of impact on the environment, so that the issue of plant location has become a puzzle not easy to solve. The need to locate the close to sources of water, the sea in the case of Chile, imposes more restrictions. Few places are available that have no population nearby or that are away from areas with endangered species. Environmental opposition to thermal plants in the central part of Chile is growing in the country, not as strong as the one opposing hydro, but it will be a short time before people dimension the dangers of coal.

Unfortunately, those opposing hydro and coal do not offer a practical alternative. Although small run-of-river hydro
plants in the south of the country could contribute economically to supply, they will not respond to the volume of energy being required. Less is the case of wind which is being argued as the solution to future supply, giving as example the important contributions of eolic energy in Germany and Spain, without mentioning the heavy subsidies those countries have given to that development. On another dimension, the path of increasing power efficiency is one that must be pursued, but it will not be a complement to the necessary power generation investments.

Nuclear energy could be a path to consider for the very long term, as the small size of the Chilean interconnected systems makes it unfeasible to connect the large economic nuclear plants that are being built today.

The expected energy crisis of 2008 will surely force the government to define an energy policy, or not defining an energy strategy, or not clarifying which would be the best energy matrix for the country. The government is being blamed for the brown outs that are being projected for mid 2008, and criticized for not having taken adequate preventive measures.

Fig. 5: Expected marginal prices in the SIC

V. THE NEED FOR AN ENERGY POLICY

Under the present crisis, voices arise publicly criticizing the government for not having an energy policy, on not defining an energy matrix, on not clarifying which would be the best energy matrix for the country. The government is being blamed for the brown outs that are being projected for mid 2008, and criticized for not having taken adequate preventive measures.

The authors believe that this criticism is partly unfounded and that the government is taking more blame than deserved. The Chilean energy laws give the market, and the private sector, the decisions on energy investment, particularly in electricity. It is consumers, particularly large industrial and distribution companies, that define the energy they demand and through contracts oblige investors to respond on time and volume to their needs. Thus, they have a main responsibility. The government has no decision on technologies and fuels to be used for generation, on contracts among generation and demand, or on any investment to be made. It is true that regulations may interfere the market, as it did so in relation to prices of contracts between generators and distribution companies, but that was already corrected by the government and the Congress in 2005.

Nevertheless, what the government is to blamed for if for taking a reactive role more that an anticipatory one. It has concentrated on short term tariff regulation, without aiming at achieving a long term overview of the energy sector, without doing a deep thorough independent assessment of energy alternatives for the future. For example, the government, under the law, has the responsibility to determine an indicative plan for expansion generation and transmission of the two main interconnected power systems. It is an administrative duty that is required only for tariff projections, but it could be used as an opportunity to identify which are the social and economic advantages of different avenues for future energy supply. The question of how energy supply expansion and environmental controls will be balanced in a country with the economic characteristics and energy resources of Chile is for example another question that needs an educated answer. The energy matrix of a country can not be copied from others. Figure 6 shows how different are the energy matrices of main developed countries. Each one responds to each countries’ economic characteristics and energy resources. Chile must find its own answer.

![Energy matrices (2003)](image)

The Chilean government has defended itself saying it has defined an energy strategy in relation to security of supply. But the secure supply strategy was more a reaction to the crisis than an anticipated thoughtful policy.

When the government is pressed to take a position on the Aysen project, it has not the global independent analysis to support taking one position or another, and government officials and politicians do so more on intuition than on fact. And that is the case for the Chilean society as a whole. There are no think tanks that have done that analysis and shared it with society, to illuminate the possible paths to follow. It is not required that the government dictates what must be done by private investors; that is not the essence of the existing Chilean regulations. But more should be done by the government than what is being done today. The limit must be defined carefully, and this necessarily has to take place through a sensible discussion among all parties involved, the sooner the better.

The government somehow interfered in the energy sector when ENAP took the LNG initiative. It was done at the sole will of past President Lagos, and no one criticized publicly that decision. Although it may prove as a good long term decision, again it was more an intuitive political decision, rather than one based on a long term overview of the energy sector.

The expected energy crisis of 2008 will surely force the country to respond to the definition of an energy policy, whatever that means for Chile.

VI. CONCLUSIONS

Although the environmental preoccupation is to remain a central issue in the economic development of Chile, there is consensus that the energy supply of the country as a whole must not be neglected, differences arising on what path to follow. Principles for the establishment of a power policy must consider economic efficiency, energy supply security and social and environmental sustainability. The country as a whole must collaborate to better define the role of the government and the private sector in defining the expansion of energy supply.
VII. BIBLIOGRAPHY


VIII. BIOGRAPHIES

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