Paper 08GM0224

IEEE POWER ENGINEERING SOCIETY
ENERGY DEVELOPMENT AND POWER GENERATION COMMITTEE

Hydro Developments, Generation Options and the Environment in Latin America

***Luiz Augusto Barroso, Tom Hammons and Hugh Rudnick*[1]**

Working Group on Latin America Electricity Infrastructure

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Track: Utilization of Energy Resources

INTRODUCTION

Latin America has emerged in recent years as one of the most dynamic regions for electricity markets. The region is characterized by high – but uncertain - demand growth rates (over 4-6% annually). The countries have a great diversity in size, installed capacity, power demand, network characteristics (level of meshing and geographical extension) and electricity-gas cross-border interconnections. Because the regional infrastructure is still developing, heavy investments in both generation and transmission investments are required.

The countries of Latin America have plentiful energy resources, including natural gas, oil, coal, biomass, wind, geothermal and other renewable resources, as well as significant hydropower potential. For example, hydropower has always been an abundant resource for the region. It is still a competitive option in Brazil and has had renewed interest in other countries due to recent oil price increases (e.g. Colombia, Peru) or more reliance on local generation (e.g. Chile). Natural gas had a fast penetration in the 90's with many countries (Argentina, Bolivia, Brazil, Peru, Venezuela) promoting natural gas use, especially for power generation. Coal is available in Colombia, Brazil and Chile and has started to have the interest of investors because of the increasing volatility of gas prices and uncertainty in gas cross-border supplies. There have also been incentives for renewables in the region.

However, the most important reserves are highly concentrated in a few countries and often away from major consumption centers. The need to conciliate generation development with the environment has resulted in an environmentally constrained outlook for development of hydropower in the region, which is still a competitive option. In order to overcome this deadlock, countries are developing other resources, such as natural gas, coal and other renewables. These

[1] Document prepared and edited by T J Hammons

technologies have their own advantages but other significant disadvantages (volatility in gas prices, higher cost on coal plants due to emission control, etc). Cogeneration has also been playing a role, mainly in Brazil, where cogeneration from sugarcane biomass has emerged as a competitive generation option.

Various public debates have occurred in recent decades in industrialized economies over the energy supply future. Much greater attention is now being paid to these issues in developing economies. The debates are generally about the comparative economic, environmental and social trade-offs, and public acceptability of the various nuclear, thermal, hydro, and alternative generation options; and increasingly, about the potential role and contribution of demand management options. Other questions are technology and/or country-specific. These types of issues that are increasingly being debated include macroeconomic and consumer affordability dimensions, poverty alleviation impacts, and social, institutional and political implications of centralized versus decentralized energy supply approaches.

The objective of this panel session is to provide a concise outlook of the hydro developments, generation options and the environment in Latin America. Panelists that have been deeply involved in this debate in their countries will discuss topics such as the main trends and issues for different electricity supply options in Latin America considering their social and environment implications, and sustainable development practices.

The Panelists and Titles of their Presentations are:

1. Luiz Augusto Barroso, Tom Hammons and Hugh Rudnick. *Hydro Developments, Generation Options and the Environment in Latin America* (Invited Panel Presentation Summary 08GM0224)
2. Hugh Rudnick and Sebastian Mocarquer, Chile. *Hydro or Coal: Energy and the Environment in Chile (*Invited Panel Presentation Summary 08GM0532)
3. Luiz A. Barroso, Priscila Lino and Bernardo Bezerra. *Cheap and Clean Energy: Can Brazil Get Away with That?* (Invited Panel Presentation Summary 08GM0490)
4. Carlos Rodriguez, Panama. *Panama, Present and Future of Energy Supply*" (Invited Panel Presentation Summary 08GM0488)
5. Jesus Velasquez, Colombia. *The Colombian Electricity Market and its Impact in Hydrothermal Expansion* (Invited Panel Presentation Summary 08GM1518)
6. Ruy Varela, President, SIGLA S A, Buenos Aires, Argentina and Patricio Murphy, External Consultant with SIGLA. *Hydro Developments and Generation Options in Argentina* (Invited Panel Presentation Summary 08GM0631)
7. Gabriel Salazar, Director de Tarifas, Consejo Nacional de Electricidad, Ecuador and Hugh Rudnik, Professor of Electrical Engineering, Pontificia Universidad Catolica de Chile. *Hydro Power Plants in Ecuador: A Technical and Economical Analysis* (Invited Panel Presentation Summary 08GM1543)
8. Daniel Camac Gutierrez, Raul Bastidas Traverso, Maria Castillo Silva and Cesar Butron Fermindez. *Generation Options and the Environment to Assuring the Efficient Development of Hydro Developments in Peru* (Invited Panel Presentation Summary 08GM1450)
9. Invited Discussers.

Each Panelist will speak for approximately 20 minutes. Each presentation will be discussed immediately following the respective presentation. There will be a further opportunity for discussion of the presentations following the final presentation.

The Panel Session has been organized by Luiz Augusto Barroso (Energy Markets Senior Analyst, Mercados de Energia/PSR, Brazil), Hugh Rudnick (Professor, Pontificia Universidad Catolica de Chile, Chile), and Tom Hammons (Chair of International Practices for Energy Development and Power Generation IEEE, University of Glasgow, UK). They will moderate the Panel Session.

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BIOGRAPHIES

Luiz Augusto Barroso, IEEE Senior Member, has a BSc degree in Mathematics, and MSc/PhD degrees in Operations Research from the Federal University of Rio de Janeiro, Brazil. He joined PSR in 1999 where he is now technical director. He has been coordinating several studies and research in the following areas: (i) economic studies; (ii) energy trading, risk management and physical-financial optimization in energy markets; (iii) system planning studies; (iii) electricity-gas integration, (iv) strategic pricing in competitive energy markets and in energy auctions and (v) regulatory assessment to private investors and institutions. Dr. Barroso has been an invited speaker on energy deregulation and power-gas system planning and economics in workshops, courses and talks in Brazil and many countries in Latin America, in USA/Canada, in Europe, and in Oceania.

Thomas James Hammons (Fellow IEEE 1996) received the degree of ACGI from City and Guilds College, London, U.K. and the B.Sc. degree in Engineering (1st Class Honours), and the DIC, and Ph.D. degrees from Imperial College, London University. He is a member of the teaching faculty of the Faculty of Engineering, University of Glasgow, Scotland, U.K. Prior to this he was employed as an Engineer in the Systems Engineering Department of Associated Electrical Industries, Manchester, U. K. He was Professor of Electrical and Computer Engineering at McMaster University, Hamilton, Ontario, Canada in 1978-1979. He was a Visiting Professor at the Silesian Polytechnic University, Poland in 1978, a Visiting Professor at the Czechoslovakian Academy of Sciences, Prague in 1982, 1985 and 1988, and a Visiting Professor at the Polytechnic University of Grenoble, France in 1984. He is the author/co-author of over 350 scientific articles and papers on electrical power engineering. He has lectured extensively in North America, Africa, Asia, and both in Eastern and Western Europe. Dr Hammons is Chair of International Practices for Energy Development and Power Generation of IEEE, and Past Chair of United Kingdom and Republic of Ireland (UKRI) Section IEEE. He received the IEEE Power Engineering Society 2003 Outstanding Large Chapter Award as Chair of the United Kingdom and Republic of Ireland Section Power Engineering Chapter (1994~2003) in 2004; and the IEEE Power Engineering Society Energy Development and Power Generation Award in Recognition of Distinguished Service to the Committee in 1996. He also received two higher honorary

Doctorates in Engineering. He is a Founder Member of the International Universities Power Engineering Conference (UPEC) (Convener 1967). He is currently Permanent Secretary of UPEC. He is a registered European Engineer in the Federation of National Engineering Associations in Europe.

Hugh Rudnick, an IEEE Fellow, graduated as an electrical engineer from the University of Chile, Santiago, Chile. He received the M.Sc. and Ph.D. degrees from the Victoria University of Manchester, Manchester, U.K. Currently he is with the Catholic University of Chile, Santiago, Chile and also with Systep Engineering Consultants, which specializes in power-gas system planning and operations issues. His research activities focus on the economic operation, planning, and regulation of electric power systems. He has been a consultant with utilities and regulators in different countries, the United Nations and the World Bank, mainly on the design of deregulation schemes and transmission and distribution open access tariffs.

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2. Hydro or Coal: Energy and the Environment in Chile

Hugh Rudnick and Sebastian Mocarquer, Chile.

Abstract- Coal and hydro will be the main sources of electric energy in Chile for the near future, given that natural gas from neighboring 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.

1. 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.

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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 Taltal 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**.**

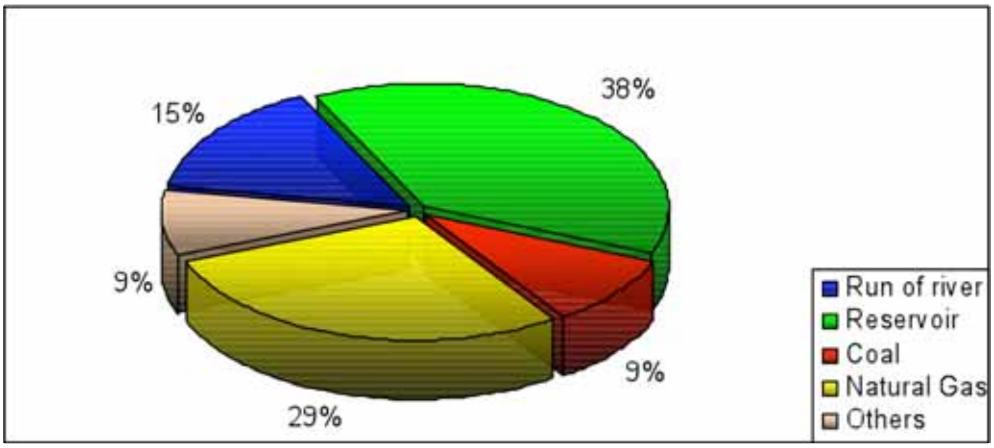

Fig. 1: Installed capacity per generation technology SIC 2007

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 Argentinean 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 Argentinean 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.

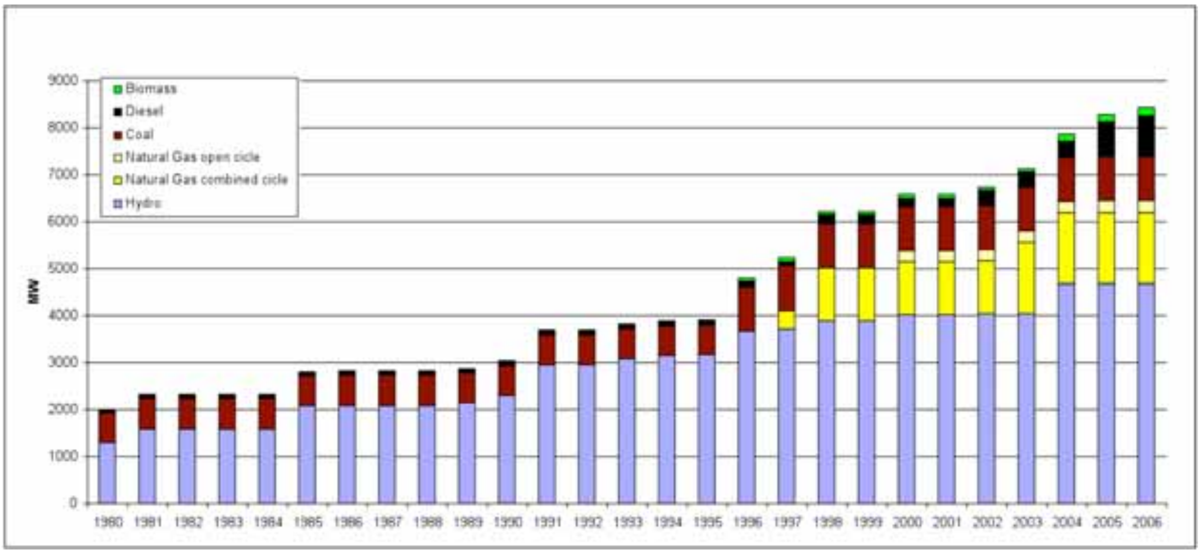

Fig. 2: Evolution of installed capacity per technology in the SIC

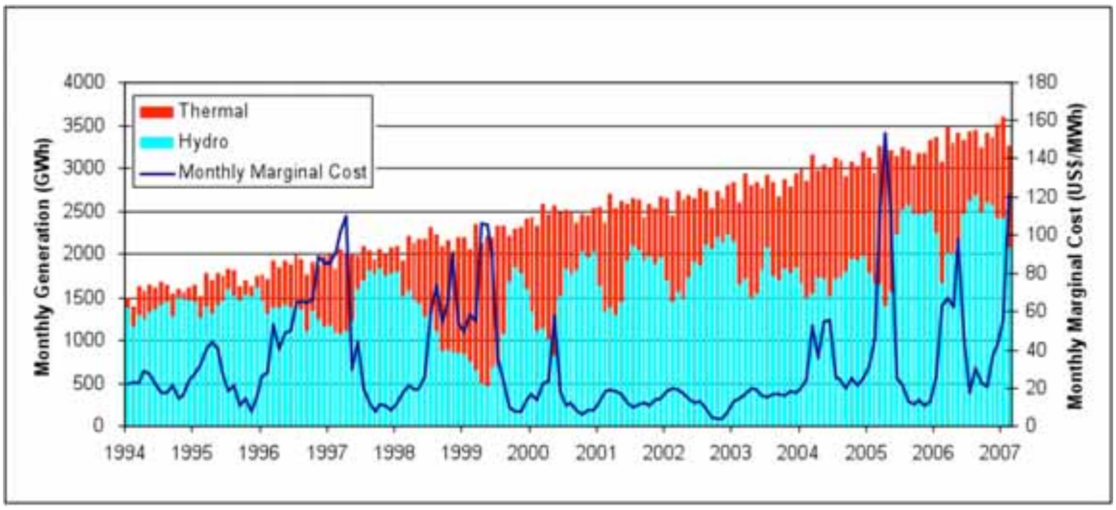

Fig. 3: SIC hydrothermal generation structure/system's marginal cost ratio

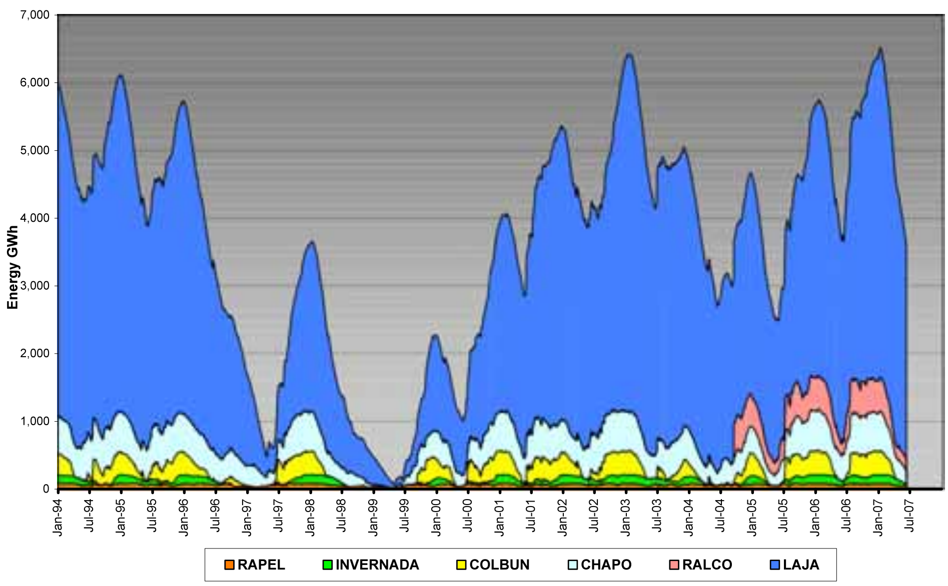

Fig. 4: Hydraulic energy stored at reservoirs in the SIC

2. THE ENVIRONMENTAL ISSUES

Economic efficiency, energy security and environmental sustainability are concerns that must be considered in any energy policy in any given country. These key aspects remain challenged at present in South America. 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 habitants 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.

3. HIDRO DEVELOPMENT

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

Zona	Regíon	Potencia Actual Instalada [MW]	Potencia no Explotada [MW]	Total [MW]	Porcentaje Instalado (%)	Total por zona [MW]
Norte	I, II, III, IV	27,0	232,2	**259,2**	10,4	259,2
Central	RM	298,5	1065,0	**1363,5**	21,9	5805,5
	V	138,3	166,0	**304,3**		
	VI	426,8	936,0	**1362,8**	31,3	
	VII	1328,9	1446,0	**2774,9**	47,9	
Centro Sur	VIII	2287,0	2900,0	**5187,0**	44,1	10355,3
	IX	0,0	N/E	**0,0**		
	X	243,3	4925,0	**5168,3**	4,7	
Austral	XI	17,6	9383,3	**9400,9**	0,2	9626,3
	XII	0,0	225,4	**225,4**	0,0	
TOTAL	**País**	**4767,4**	**21278,9**	**26046,3**	**18,3**	**26046,3**

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.

Table 2: Hydroelectric projects (2007)

Nombre del Proyecto	Empresa Encargada	Tecnología	Potencia Total[MW]	Puesta en Operación
Palmucho	Endesa	Pasada	32	2008
Neltume	Endesa	Pasada	403	2014
Cóndor	Endesa	En Estudio	100	2011
Hornitos	Colbún	Pasada	55	2007-2008
Quilleco	Colbún	Pasada	70	2008-2009
San Pedro	Colbún	Pasada	120	2010
Alfalfal II	AES – Gener	Pasada	250	2013
Las Lajas	AES - Gener	Pasada	250	2014
La Higuera	La Higuera	Pasada	155	2008-2009
La Confluencia	La Higuera	Pasada	145	2009
Damas-Portillo	La Higuera	Pasada	70	2010
Baker I	Hidroaysén	Embalse	680	2012
Pascua II	Hidroaysén	Embalse	940	2014
Pascua I	Hidroaysén	Embalse	450	2016
Baker II	Hidroaysén	Embalse	360	2018
4 Centrales	Pilmaiquén	Pasada	166	No hay Fecha
Ñuble	CGE	Pasada	136	2007-2008

4. 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 that 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.

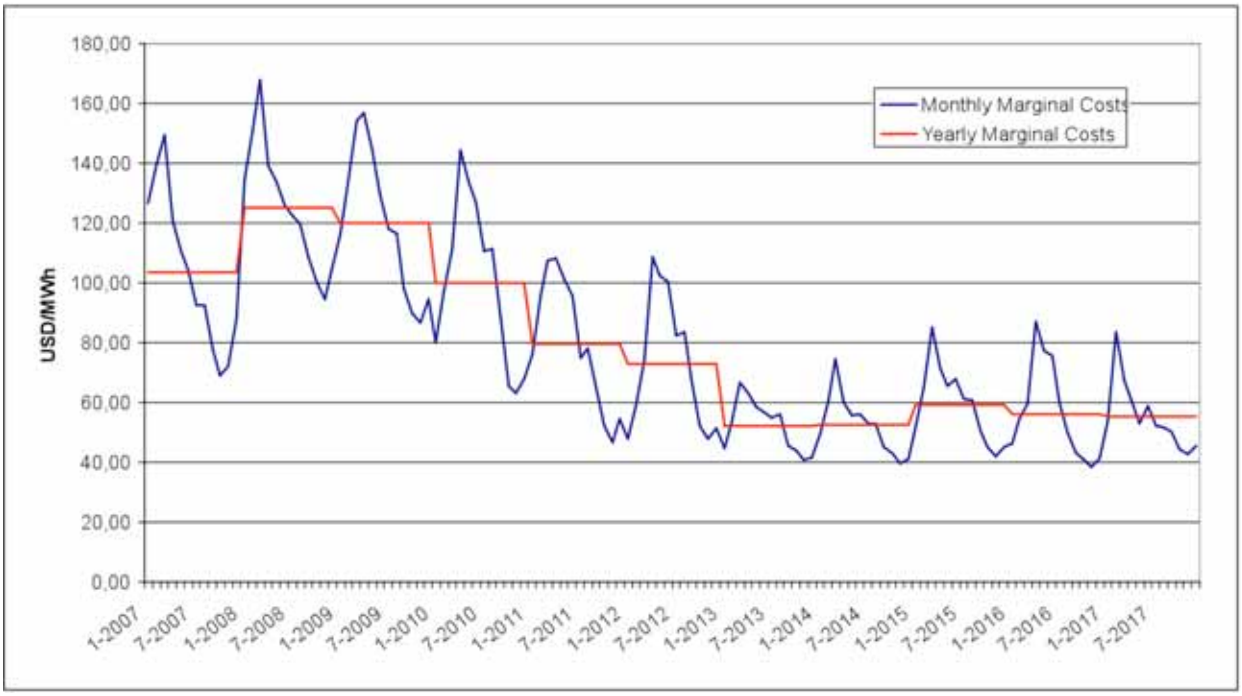

Fig. 5: Expected marginal prices in the SIC

5. 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 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.

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 the government and the Congress already corrected that 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 cannot 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.

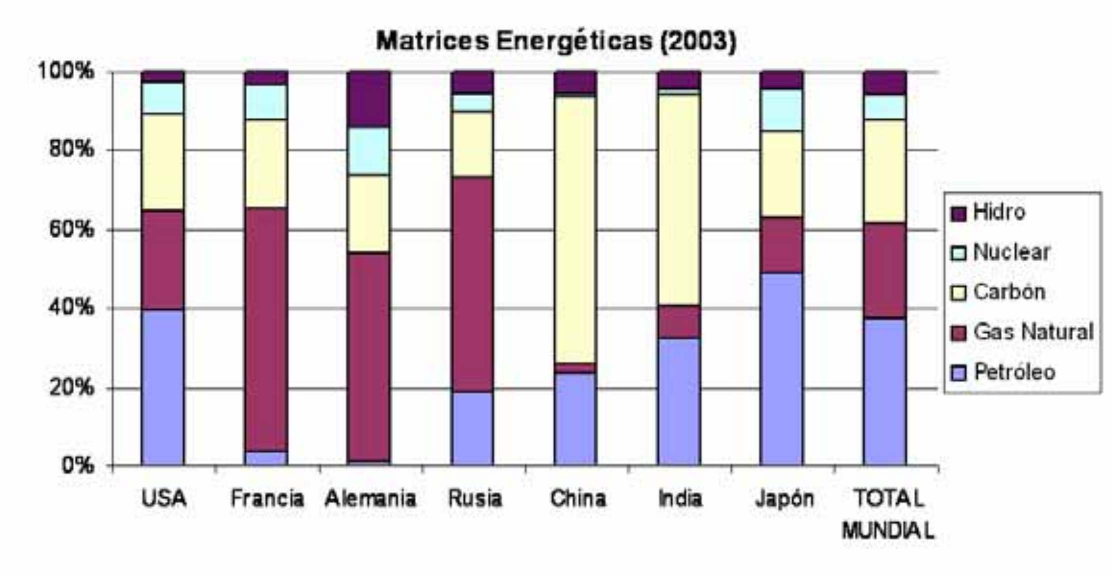

Fig. 6: Energy matrices (2000)

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 private investors must do; that is not the essence of the existing Chilean regulations. But the government should do more 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.

6. CONCLUSIONS

Although the environmental preoccupation is to remain a central issue in the economic development of Chile, there is consensus that the energy supplies 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.

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3. Cheap and Clean Energy: Can Brazil Get Away with That?

Luiz A. Barroso, Priscila Lino, Fernando Porrua, Francisco Ralston and Bernardo Bezerra

Abstract— The objective of this work is to discuss the generation options and challenges to meet an increasing electricity demand in Brazil. Emphasis will be put on the challenge of conciliating generation system expansion and environmental constraints under a cost-effective framework.

Index Terms **--** Power system economics, generation supply options, energy development, environmental issues.

1. INTRODUCTION

The countries of South America have plentiful energy resources, including natural gas, oil, coal, biomass, wind, geothermal and other renewable resources, as well as a significant hydropower potential. Within this framework, Brazil emerges as a good representative of the diversity in the region's generation options. The country has significant hydro resources, gas and coal reserves, potential for wind power development and, more recently, cogeneration using sugarcane waste has emerged as an attractive energy option.

Brazil's electricity consumption is growing at an important pace, with growth rates over 5% that are requiring doubling installed capacity every ten years. This is born from low per capita electricity consumption levels (around 2,000 kilowatt-hours compared to 12,000 in the US and 6,000 in Europe) combined with high economic and population growth. Because predicted annual energy load growth rate runs at 5%, requiring about 3,000 average MW per year and around US$ 4 billion/year of investments in generation, the main challenge for the country is to promote a clean and economically efficient energy growth, using the available generation options.

This work discusses the hydro developments, generation options and the environment in the ongoing Brazil's challenge to effectively meet its electricity demand. It serves as basis for discussions in the panel session "Hydro Developments, Generation Options and the Environment in Latin America", held in the 2008 IEEE PES General Meeting in Pittsburgh, PA, USA.

2. BRAZILIAN POWER SYSTEM AND AVAILABLE RESOURCES

2.1 The Power System

Brazil has an installed capacity of 100 GW (2007), where hydro generation accounts for 85%, for a peak and energy demand near 63 GW and 48 GW respectively. The hydro system is composed of several large reservoirs, capable of multi-year regulation, organized in a complex topology over several basins. Thermal generation includes nuclear, natural gas, coal and diesel plants. In order to couple the development of hydro generation and to benefit from hydrological complementarities, the country became fully interconnected at the bulk power level by an 85,000 km meshed high-voltage transmission network [1].

2.2 The Resources

Figure 1 shows an outlook of the country's available resources for each of its four main regions (South, Southeast/Center-West, North and Northeast). In the same figure we show the tapped hydro potential per region.

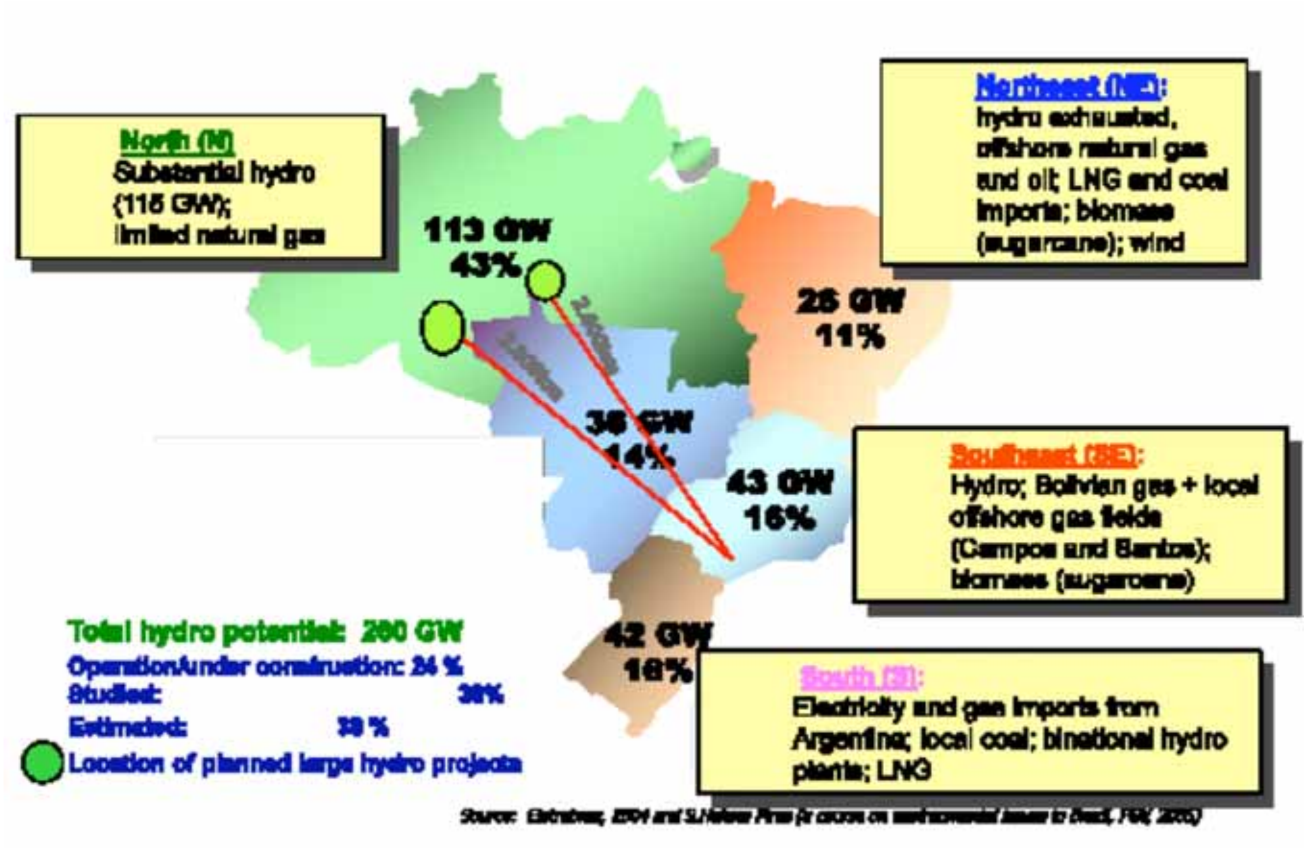

Figure 1 – Overview of generation options per region.

As shown in Fig. 1, the country still has an undeveloped hydro potential of more than 150,000 MW, most of it located in the environmentally sensitive Amazon region, far from load centers and where mega hydro resources such as the Madeira river complex (7,000 MW) and Belo Monte project (5,500 MW) are being considered as expansion options (highlighted in the figure). Less than 30% of its hydropower potential is currently used.

Although in the future the energy matrix composition should become more diversified (including cogeneration, local coal and gas); hydropower is currently still the cheaper expansion option and will drive system's expansion for next years.

2.3 Regulatory model

As described in [2,3], Brazil relies on a regulatory model based on auctions for long-term energy contracts to meet the regulated market. The key issues of the market are:

Every consumer in the system (regulated or free) must be 100% supplied by an energy contract, i.e., there is an obligation to contract 100% of the load. Contract coverage is verified ex-post, checking the cumulative MWh consumed in the previous year with the MWh contracted in the same period. If the contracted energy is smaller than the consumed energy, the user pays a penalty related to the cost of building new capacity;

Contracts, which are financial instruments, must be covered by 'firm energy certificates' (FEC). The FECs, measured in MWh/year, are tradable. They are issued by the Regulator for each generator in the system (hydro, thermal, wind, cogen, etc), and reflect their sustainable energy production capacity during dry periods;

The joint requirement of 100 % coverage of loads by contracts and 100% coverage of contracts by firm energy certificates links load growth and construction of new capacity. Hence, security of supply is guaranteed;

Free consumers can contract as they please. For regulated users, new capacity procurement is carried out through centralized public auctions[2]. Two public contract auctions are carried out every year for energy delivery 3 and 5 years ahead. It allows investors to obtain project finance and have sufficient time to build new plants. Hence, the new mechanism represents a business opportunity for new investors in the generation business. Long-term energy contracts are offered in each auction. During the supply contract auctions, investors bid for a $/MWh price for an energy contract and this price should allow the investment + operation + return recovery.

Figure 2 presents the overall scheme of the regular existing and new energy auctions, which are offered yearly:

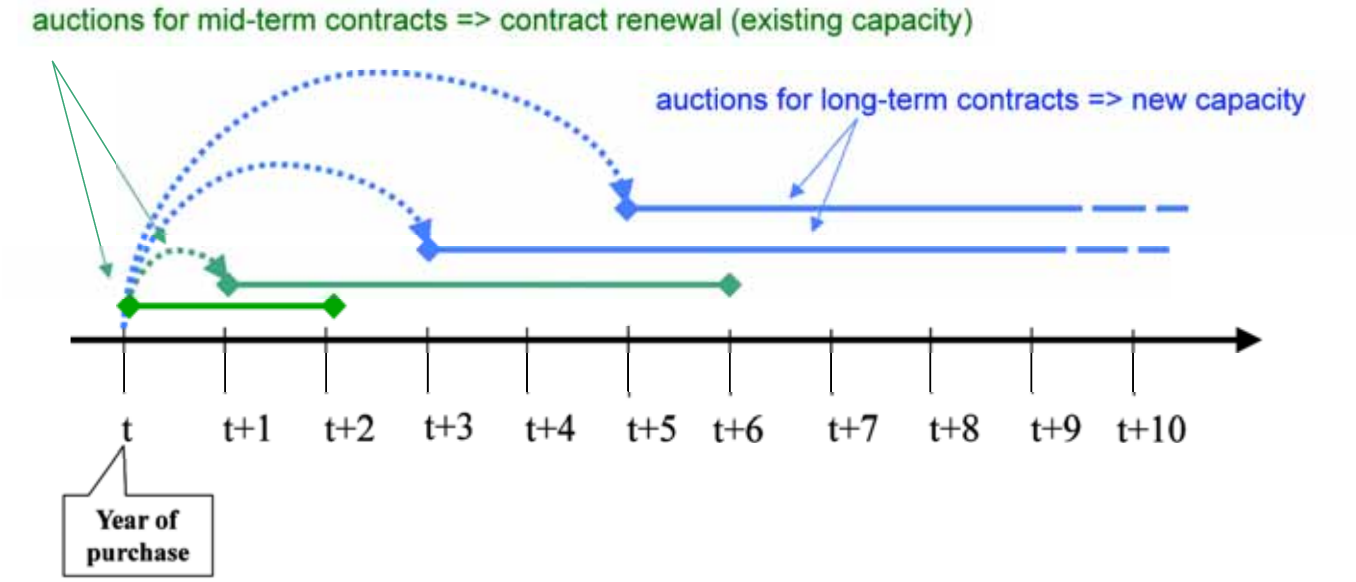

Figure 2 – Overall scheme of energy auctions, source: PSR

More than 30 GW have been contracted since December 2004 (more than US$ 50 billion in contracts).

2.4 Investment needs until 2013

Figure below shows the incremental demand that still needs to be contracted in the country during 2011-2013. We observe that about 6,000 MW (firm energy, not peak) of new capacity still needs to be contracted to match the system needs (these projections, taken from the Brazilian planning study agency – EPE, consider a GDP growth of 4,8% and deduct from each year the energy already contracted in 2006/2007 for delivery in 2011/2012).

[2] There are also auctions for existing energy, intended to renew contracts of existing generators.

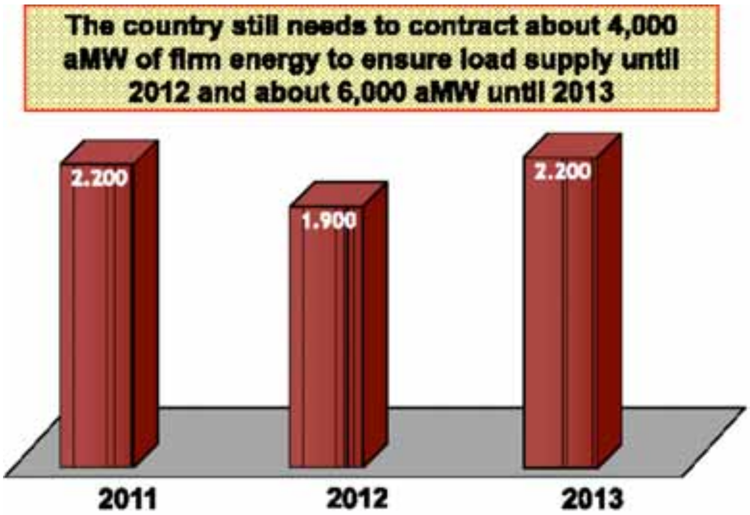

Figure 3 – Investment needs (average MW of firm energy), source: PSR

Let us examine now the generation options for contracting these 6,300 MW of firm energy.

3. STANDARD GENERATION OPTIONS FOR BRAZIL

3.1 Hydropower

The development of hydropower generation in Brazil currently faces some challenges. For 2012 to 2014 there are not much hydroelectric supply options other than large-scale plants in the Amazon, such as the Madeira river complex (7,000 MW) or Belo Monte (11,000 MW). The reason is that the "stock" of projects is depleted and the inventory of drainage basins, now being carried out under EPE coordination, are under way and will be concluded in end-2008, leaving little time for environmental licensing of these plants before offering them in the auctions. Thus, new hydro plants should only be offered at the A-5 auction of 2009, to enter in 2014. The ongoing concentration of hydro supply in large hydroelectric projects has some concerns: (i) these projects have a greater impact in case of delay; (ii) they demand larger investments (few financing agents) and (iii) higher transmission costs.

3.2 Natural gas with local or Bolivian supply

Gas-fired plants were regarded originally as the second largest generation alternative, after hydropower. However, the availability of new natural gas-fired plants is still undefined. These plants would not be competitive if they used supply contracts for local gas or gas imported from Bolivia. As discussed in [4], the reason is that these contracts have "take or pay" and "ship or pay" clauses provided to remunerate the fixed investments in gas production and logistics, which are onerous in a system like the Brazilian one, where thermal plants' dispatch frequency is very low (around 20%) and a mature gas market is not available to allow the reselling of the gas contracts. In addition, problems in local natural gas supply (imbalance between supply and demand, difficulties with Bolivia) and the prospect of a gas price increase (25%, according to recent government statements) have also created important uncertainties.

3.3 Natural gas with LNG supply

LNG, although costlier in unit terms, may be contracted in a flexible manner, which is compatible with standard thermal plants dispatch. In addition and as observed in [4,5], hydro plants serve as a "virtual storage" of the gas, avoiding costs of gas storage. The flexible contracting modality avoids fixed costs and makes these plants more competitive. The concern with regard to LNG is that, in the next years, demand and supply will be substantially out of step, thus increasing the uncertainty on the viability of contracting that fuel.

3.4 Imported Coal

A third alternative for generation, imported coal-burning thermal plants, appeared at the last energy auction (October 2007) offering attractive energy contract prices. An important concern regarding coal is the fact of its being today the technology causing the greatest CO2 emission. Therefore, if the coal were the only option utilized to fulfill the demand of 2011 to 2014, Brazil would be "dirtying" substantially its energy matrix. However, coal has some advantages versus gas, including: a) environmental licensing for coal-fired thermo is relatively easy to get compared with hydro, as it does not require federal approval; b) abundant suppliers, most of which are located in less politically volatile areas and thus, are not subject to political pricing pressures and cartels like oil (i.e., and thus a significant portion of gas, which is often tied to oil prices); c) possibility of flexible supply (only available with LNG) and, c) is a worldwide traded commodity with fairly predictable prices that are less correlated to oil prices versus gas.

3.5 Local coal

The Brazilian coal mining industry is located in the Southern Region of the country. Its relative importance has declined during the last decades but, in the past, it had a greater share of the installed capacity. In the last 20 years, there was practically no expansion in new plants using national coal; the program of coal utilization was reactivated in the last two years. Among the motives why Brazilian coal did not arouse interest, we can mention its low heat value and its high ash content, which imply a higher production cost, requiring a higher specific investment when compared to imported coal. Even so, its competitiveness is assured by its low production cost. For this motive, national coal has been a barrier to the entrance of competitors based on imported coal. However, imported coal took a leap forward because it can be supplied on a flexible basis, while the local coal requires take or pay clauses on the coal contract supply.

3.6 Nuclear power

Currently, Brazil's total nuclear installed capacity is ~2,007MW (~2.4% of the country's total installed capacity but ~3.3% of generation in 2006) comprising the federal owned plants Angra I (657MW) and Angra II (1,350MW).

While the development of nuclear power in Brazil remains highly controversial (mainly as a result of environmental issues related to nuclear fuel waste final disposal), the government's lack of progress in speeding up the environmental licensing for medium and large size hydro has helped fast-track approval for Angra III project. Although Angra III (1,350MW) has not yet cleared all environmental, political, and financial hurdles, its construction is a political decision. The government has already invested ~US$700 million in parts that still cost the company ~US$20 million per year to maintain and the "disposal pools" and other facilities for fuel and other radioactive waste material storage would be located inside the same facilities as Angra I and II.

Brazil is one of only three countries in the world (with the U.S and Russia) that has two unique advantages in developing nuclear power:

Fuel Supply Independence (i.e., Uranium). Brazil currently has proven uranium (U308) reserves of 309,000 tons after having prospected only one-third of its territory (studies ceased ~30 years ago). There are also estimates that Brazil could discover additional reserves of as much as 800,000 tons throughout country. Thus, Brazil would not only be independent in terms of fuel supply, but with further E&P, could also become a natural exporter to countries such as China that are actively developing nuclear power but that have no uranium reserves.

Fuel Enrichment Technology. One of the main hurdles in developing nuclear power is the cost of uranium enrichment. This highly sophisticated process converts the ore from ~0.7% concentration in its natural state to usable “enriched” fuel at 3%-4% concentration for nuclear power plants. Brazil currently processes the yellowcake[3] at its main mine located in the state of Bahia, but the final uranium enrichment is done in Europe. Brazil has proprietary technology for enrichment (developed by the Brazilian navy) that was never employed, given the lack of scale of the Angra I and II plants to justify investments in the fuel-enrichment process. Angra III could represent the break-even point for these investments, which would lead Brazil to an absolute independence of nuclear fuel processing and even possible exports.

4. THE ROLE OF RENEWABLES: CHEAP AND CLEAN?

In face of this, there has been much interest in developing additional supply alternatives that should preferably be "clean" generation sources. The natural candidates would be small hydroelectric plants, wind power plants and biomass-burning plants, especially cogeneration plants using sugar cane bagasse (bioelectricity). Renewables in Brazil have several additional advantages when compared to the standard energy production sources, such as:

Smaller-size projects, which diversifies the risks of construction problems (“portfolio” effects);
Wider range of investors (including local, foreign and hedge funds);
Local resources, such as work power and equipment;
Short construction time, which results in a good attribute for uncertainty about growth of energy demand;
Easier environmental licensing;

Carbon credits: renewable generation qualifies for CER credits under the Clean Development Mechanism of the Kyoto protocol and, thus, provides further incentive for investors in these projects versus most coal, diesel, or gas plants.

Renewables (small hydros, wind power and biomass) were recently granted incentives to contract with regulated consumers that are not eligible to move to the free market. This type of contracting, recently regulated, establishes that regulated consumers demanding over 500 kW (e.g., a supermarket) will receive a 50% rebate from their “wire tariff”, if they contract their energy from alternative sources. Since it is a substantial deduction, these regulated consumers may offer attractive prices to alternative energy in general, above the “ceiling” of the contract auctions.

4.1 Small hydro

Small hydro (hydro plants with capacity less than 30 MW or reservoir area smaller than 3 km^2) is a well-known and mature technology. Today there is about 5,000 MW in projects or inventory, which results in about 3,000 MW of firm energy.

Notwithstanding the smaller size, the economic competiveness of small hydro is comparable to traditional hydro plants because of different taxation rules and easier environmental licensing. The regulation of contracting with incentives increased very much the interest for this type of plant.

Finally, the seasonal production pattern of small hydro is complementary to that of bioelectricity (biomass from sugarcane), which enables them to sell an energy contract that “blends” these two types of energy sources. This will be further explored in this article

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[3] *Yellowcake* is the first stage for fuel processing after the mining of the uranium, done still inside the mine. In this process, the uranium is chemically processed to be transformed into *ammonium diuranate* (i.e., *yellowcake*). This material is then sent to Canada, where it is first converted into UF6 gas. Then it is shipped to Europe, where this gas is enriched from ~0.7% to 3%-4% and sent back to Brazil.

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4.2 Wind power

Brazil has a large potential for wind power. Official estimates [6] points to a potential capacity of 70,000 MW, corresponding to a firm energy of 21,000 MW. The greatest part of this potential is in the Northeast region, followed by the South region. This turns to be an important advantage for wind power, once that Region has few supply options. In addition, wind power avoids great investments in transmission and, in the case of the Northeast, hydro generation complements its production.

Despite this potential for wind power development, this technology faces two major obstacles in Brazil: i) limited know-how; and ii) lack of domestic equipment manufacturers. These points impact directly on its competitiveness. Estimates indicate that remuneration of these plants requires contracts of about 100 USD/MWh, well above prices resulted from the last auctions. However, as there is a "learning curve", it is a matter of time until this technology becomes competitive.

4.3 Sugarcane biomass

The third renewable alternative is bioelectricity. As described in [7], bioelectricity is the cogeneration from sugarcane biomass. The sugar/ethanol sector in Brazil is undergoing an accelerated expansion process. The production process for sugar/ethanol in Brazil uses sugarcane as raw material and its byproduct, the sugarcane biogases, is used as fuel in a cogeneration process that supplies the electricity demand of the whole facility. Because, currently, the biogases have no opportunity cost, this cogen for self-supply is very competitive. Besides that, additional electricity using the same amount of biogases can be produced if more efficient boilers are installed. The cost of this additional generation is only the cost of acquiring more efficient equipment (higher pressure boilers - 65 bar/520^{o}C), which produces more kW per ton of sugarcane. With more efficient boilers being ordered for the new facilities, the cogeneration from sugarcane biomass, has become very competitive in the auctions: their investment cost for energy sales is just the incremental cost of the efficient boiler (the remainder costs are due to the sugar/ethanol business).

Additional gains also apply to this cogen, such as:

(a) *proximity to load centers*: the crop areas are in the Southeast and Northeast regions. The largest crop area is in the state of São Paulo, close to the main load center, implying in reduction in transmission losses and tariffs;
(b) *full complimentarily with hydro resources*: ethanol/electricity production occurs during the crop season, which, in turn, occurs during the dry season of hydro inflows and provides additional economic value for bioelectricity production, because it is produced when energy spot prices are higher and thus are the benefits of spot sales
(c) *shorter construction period*: the cogen from sugarcane biomass takes (on average) 2 years to be built, instead of 5 years for hydro plants. This is important due to uncertainty in load growth (flexibility is valuable because of volatility in load growth);

Hence, a joint initiative of sugarcane producers, cogen associations and equipment manufacturers was launched, with the objectives of increasing the participation of biomass cogen in the energy sector. Instead of subsidized mandatory programs, the bioelectricity initiative relies 100% on private investment and aims at competing with other sources on the same footing. The participation of bioelectricity in the energy supply auctions has been encouraging. Overall, since 2004 sugarcane producers have offered the surplus production of their expansions in the mills (some carried out investments to retrofit their plants and offered the additional energy surplus) at very competitive prices, awarding contracts with bids that displaced "mainstream" technologies such as hydroelectric power or combined cycle natural gas thermal generation on a competitive basis (public auctions) without any subsidies.

However, one of the main obstacles to making bioelectricity viable is their connection the grid. Biomass cogen plants are mostly connected to the 138 kV grid. The electric sector regulation deals differently with the construction of high-voltage and medium-voltage reinforcements. As explained in [1], in the so-called Basic Network, with voltages equal to or above 230 kV, the expansion is centrally planned. The planned circuits are auctioned by minimum tariff criteria, and remunerated by all generators and demands through the Tariff for Use of the Transmission System (TUST). In its turn, planning and construction of sub-transmission system (138 kV and 69 kV) reinforcement is up to distribution utilities; the corresponding cost is transferred to consumers' tariffs in their concession areas. The first difficulty for bioelectricity is that the Basic Network transmission plan, prepared by EPE, was insufficient to convey their power planned to be exported to the Basic Network. For example, in Mato Grosso do Sul and Goiás States planned plants totalize some 3,000 MW, whereas the expansion plan had foreseen only 400 MW. The second difficulty is that investments in 138 kV networks would be substantial, even exceeding in some cases the financial capability of distribution utilities. Finally, transfer of the costs of these 138 kV reinforcements exclusively to local consumers would be inadequate, as the energy would be used by all the demand of the country.

5. ECONOMIC COMPARISON

Figure 4 and Table I show our estimates for the development cost of different generation technologies. We assess the economic competitiveness among the different (Greenfield) generation options considered for system expansion and that will compete in the upcoming *new energy auctions*. Each generation option is represented by a *reference* project, which captures the main characteristics (investment, firm energy, fuel costs, etc) of a typical project belonging to each technology considered for system expansion. The criteria and hypothesis are presented in the table. For each generation technology we calculate its (monomic) energy generation price (USD/MWh of firm energy) subjected to the plant's constructing cost and a given investment rate of return on equity (for example, 13%, in real terms) for the duration of the contract (15 years for thermals and 30 years for hydro). It is important to highlight that the prices estimates developed are reference prices, established for "typical" projects of each technology in order to have a first assessment of competitiveness among generation options. These prices may show a high variability according to the parameters of a specific project, such as investment costs, financing conditions, gas prices, transmission tariffs, tax incentives, etc.

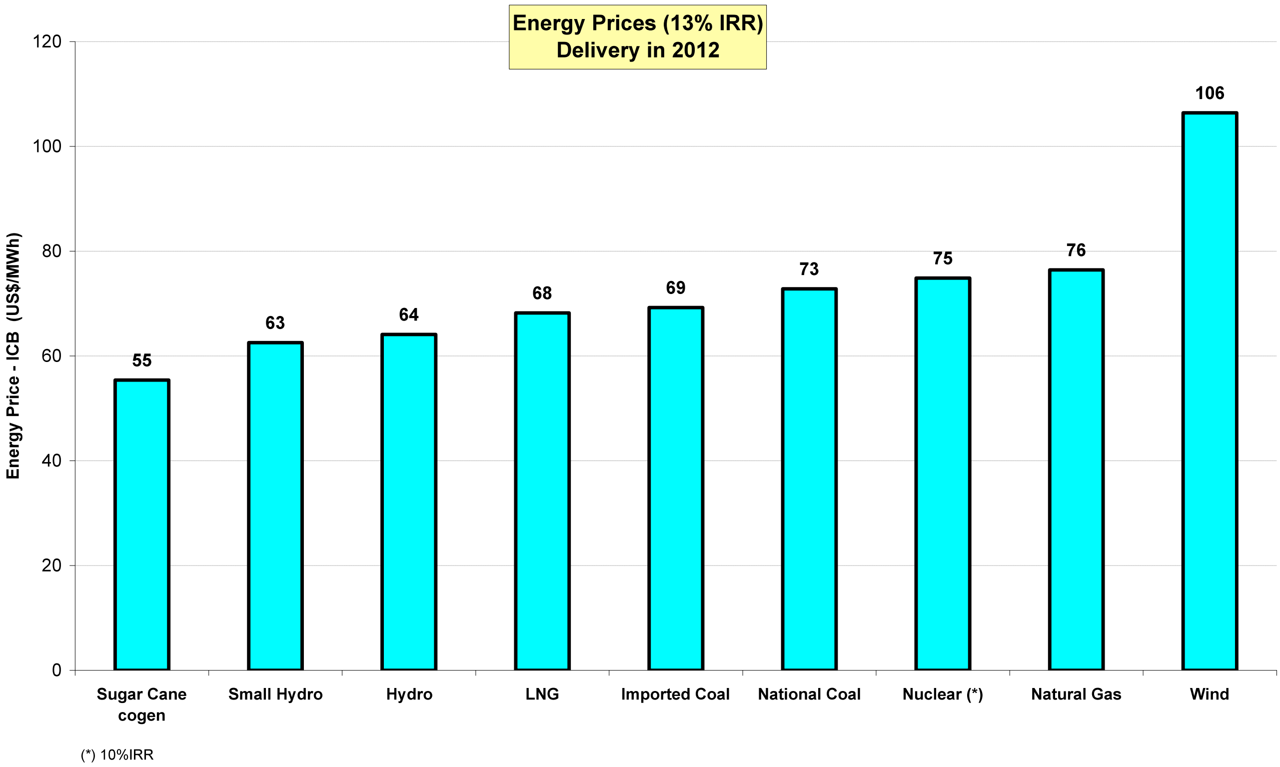

Figure 4 – Energy prices estimates (USD/MWh). Source: PSR

5.1 Assessment

The figures presented show an outstanding economic attractiveness for the cogeneration based on sugarcane biogases (bioelectricity), with prices much lower than the current auction cap (70 USD/MWh) already assuring IRR of 13%. Actually, this competitiveness has created a challenge for the qualification of the sugarcane biomass plants to carbon credits. Ironically, while the theory of Kyoto is to subsidize high-cost/low-emissions technologies with low-cost/high-emission plants (as is the case in most of the world), Brazil's case to qualify for Kyoto credits is challenging because the country's unique "win-win" of having the lowest cost generation technologies also being the most environmentally friendly. LNG and Bolivian natural gas options also present low and competitive estimates for energy prices. CCGT fueled by Bolivian natural gas are expected to present higher prices than LNG because of "take or pay" and "ship or pay" clauses provided to remunerate the fixed investments in gas production and logistics. On the other hand, the conjecture of natural gas shortages in Brazil should lead to a dramatic increase in LNG gas imports and convergence to LNG prices, which are already high and predicted to increase even more for the years to come. Coal-fired power plants are another attractive options. Despite its high emissions and higher investment costs, coal might increasingly replace gas-fired power plants mainly due to its lower fuel costs.

Table I – Economic costs of generation alternatives (1 USD = 1,85 R$)

	Unit	standard hydro	Small Hydro	Local coal	Imported coal	Local/bolivian gas	LNG gas	Sugar cane cogen	Wind power
Capacity	MW	300	30	300	300	300	300	100	100
Investment	USD/kW	1692	2308	1846	1641	769	769	1538	2051
Availability	%	100%	100%	86%	90%	92%	92%	85%	100%
Load factor	%	55%	55%	98.7%	100%	100%	87%	49.6%	35%
Heat rate		-	-	1 ton/MWh	0.4 ton/MWh	7550 BTU/KWh	7550 BTU/KWh	-	-
Fuel cost		-	-	15.4 US$/ton	80 US$/ton	6.5 US$ / MMBTU	10 US$ / MMBTU	-	-
Fixed Costs (includes TUST)	USD/kW.year	31	29	54	58	48	48	48	27
Losses	%	3	3	3	3	3	3	3	3
Variable O&M	USD/MWh	1	1	5	5	2.5	2.5	-	13.5
Take or pay	%	NA	NA	50%	0%	70%	0%	NA	NA
Taxes & charges	USD/MWh	16	5	10	8	4	7	5	8
Equity	%	30%	30%	30%	30%	30%	30%	30%	30%
Financing		Interest rates : TJLP + 2.8% Amortization: 16 years Grace period: 6 months after operational start		Interest rates : 50% TJLP + 2.8% ; 50% Currency Basket + 2.8% Amortization: 14 years Grace period: 6 months after operational start				Interest rates : TJLP + 2.8% Amortization: 14 years Grace period: 6 months after operational start	
Required return (cost of equity + interest expense)	%	13 %	13%	13%	13%	13%	13%	13%	13%
Energy price	USD/MWh	**64**	**63**	**73**	**69**	**76**	**68**	**55**	**107**

6. CONCLUSIONS

Renewable energy has recently emerged as a generation option for many countries in order to provide a clean energy development. Interestingly, Brazil is perhaps the only country where renewable energy from small hydro and biomass is the most competitive among generation options, and that explains why these two options have been the most attractive ones during the past years. Besides that, the enormous delay in the Brazilian environmental licensing process for large hydro projects and the lack of natural gas for thermal plants throughout the country present an exceptional “window of opportunity” in the next years for renewable options, mainly for small hydro and sugarcane fired biogases (biomass) technologies.

Ironically, while the Kyoto protocol is to subsidize high-cost/low-emissions technologies with low-cost/high-emission plants (as is the case in most of the world), Brazil’s case to qualify for Kyoto credits was challenged by the region’s unique “win-win” of having the lowest cost generation technologies also being the most environmentally friendly.

Wind power is apt to be the most competitive in a “second wave”. The reason is because wind power equipment prices are decreasing and bioelectricity prices shall increase due to *cellulose ethanol* technologies, which will make it more attractive to use the biogases for ethanol (fermented sugar) production rather than for electricity generation. Nevertheless, Brazilian government will likely need to offer incentives to facilitate wind power development.

Finally, an interesting issue relates to small hydro and sugarcane biomass: both alternatives suffer from the highly seasonal availability of their resources, which forces producers to discount (or price) the risks faced when selling energy contracts and may ultimately lead to projects being commercially unattractive. However, recognizing the complementarities between these two energy sources may develop interesting trading strategies in the Brazilian hydro-based energy market. On the one hand, energy production of biomass cogeneration plants occurs only during the sugarcane harvest period (from May to November), coinciding with the dry season of the hydro system. On the other hand, small hydro face the hydrological risk during dry periods but can make up for the biomass cogeneration unavailability during the rest of the year. In order to explore this synergy, a portfolio based on these two renewable sources that should be able to mitigate hydrological and fuel unavailability risks and provide a safe and competitive firm energy delivery over a given time horizon can be developed.

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4. Panama, Present and Future of Energy Supply

Carlos Rodriguez, Panama.

***Abstract*:** This article summarizes the electric power sector in Panama since its very beginning in the XIX Century going thru the first private investments until the Panama Government took over in 1961. The nationalized enterprise lasted 37 years until year 1994 when it was privatized once again until the present moment. Now the private enterprise is responsible for generation, transmission and distribution in a horizontal structure.

1. INTRODUCTION

The electric use of electric energy started very early in Panama as well as in many other countries in the Region.

It was only 1884 when the first generating installation was inaugurated in the area known as Casco Viejo in Panama City.

Only two years after T. A. Edison had finished his first Commercial Power plant in Pearl Street, New York.

Of course, the overall capacity of the plant was good in a very limited way, to supply the required energy to a few electric arc lamps in the streets of the more populated area reaching just a few blocks to the wall surrounding the Old Spanish colony.

At that time Panama was still part of Colombia with very low population.

The French Ferdinand de Lesseps was trying to build the Canal. The ocean-to-ocean Railroad had been in operation for about 30 years. Along with the Trans Isthmian Railroad came the first telegraph.

The first telephone had arrived in Panama to be used by the French in the effort to construct the Canal.

Panama obtained its independence from Colombia and it was the United States that continued the construction until it was successfully finished in 1914.

The first generating sets in the territory had been installed by the Railroad Company to furnish lighting for the living quarters of the administrative personnel at the end of 19th century.

[4]As the new effort started there were a few small generating sets distributed in different parts of the railroad for the repair shops and living quarters.

At the end of XIX Century the United Fruit Company also had initiated operations in Panama and brought along improvements including first radiotelegraph for the Great White Fleet.

As the knowledge spread, the first uses of electricity for the industry was also spreading and electric lighting was reaching more families and commercial shops beside street illumination using incandescent lighting.

New generating sets were added to the existing power plants, prime movers included small hydroelectric generating sets for private use in the coffee cultivating farms.

By 1920 additional technology was experimented including use of wood as fuel for the steam generating sets.

Macho de Monte (1937, 700 kW), Dolega (1964, 3000 kW) Caldera (1960, 1000 kW) were installed in this period.

At the end of the fifties most of the provinces in Panama had some form of electrification.

2. SUMMARY OF THE GENERAL SITUATION IN 1957

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area	pob. total	pob. servida	Consumo GWh	nª de clientes	nª de plantas	capacidad en kw
PANAMÁ	312,100	227,259	112.6	43,024	11	24,062
COLÓN	82,014	61,564	18.7	12,950	4	7,200
CHIRIQUÍ	163,900	56,435	14.8	5,229	9	8,250
PROV. CENTRALE S	338,740	57,424	7.8	7,472	27	4,358
BOCAS DEL TORO	27,095	8.191		896	5	1,660
DARIÉN	16,400	6,565		273	6	220
TOTAL:	940,249	417,438		69,844	62	45,750

In 1961 the Government of Panama acquired all the generating companies listed above and organized one operating agency responsible for Generation, Transmission and Distribution. except the Bocas del Toro and Chiriqui provinces and initiated a new program of electrification starting in the area known generally known as the Central Provinces, excluding for the time being, the Canal Zone, Santiago, Chorrera, El Valle de Anton, Arraijan, Chilibre and the Province of Colon.

In 1964 the Cia de Fuerza y Luz installed a new (24 MW) steam generating plant at Bahia ls Minas (BLM I) that required the first 115 kV line from Colon to Panama City.

From 1969 to 1974 the Government Agency installed 3 steam-generating sets of 40 MW each

In Bahia Las Minas (BLM I; II ANDIII). including generation, transmission and distribution systems of the expropriated private companies.

The first hydroelectric power plant was constructed between 1962 and 1967 with an installed capacity of 6,000 kW.

The nationalization of the country remained as a continuous effort during that and the following decade with the Cia. Panameña de Fuerza y Luz (22.7 MW) serving at that moment the main area of Panama City, Colon ((6.6 MW) , Santiago, Chorrera, Arraijan El Valle de Anton, Chepo, Chilibre, Chiriqui (8 MW).

Except made of the United Fruit installations in Chiriqui and Bocas del Toro and the main Generating sets of the Canal Commission (Hydro Gatun: 24 MW, Hydro Madden 36 MW and Thermal Miraflores 90 MW.

In 1976 the first important hydroelectric generating plant was finished with an installed capacity of 150 MW in two units at Bayano

Same year, 1976 four generating sets of 7.1 MW were added at San Francisco and sixteen 2.5 MW were installed in different parts of the country.

The first 230 kV line was also finished for this plant serving Panama City.

In 1978 the first of two generating set was installed in the Hydroelectric plant La Estrella

(21 MW) and in 1979 the second (21 MW) was added at La Estrella. Also two hydro units were installed at Los Valles.

In 1979 the 230KV transmission system was finished covering the whole country in including the main power switchyards and distribution sub stations.

In 1982 two 21 MW gas turbines were installed in Panama City, located in the Panama substation.

In 1984 the 300 MW Hydro electric power plant was completed and the double circuits 230 kV lines to Panama City were also finished including Power Switchyards at Chorrera, Divisa, David, Pocri.

In 1992 twenty 1.45 MW generating sets were installed at Bahia las Minas

In 1996 the Government initiated the purchase of backup power from a generating set – Gas Turbine 46 MW (COPESA) privately owned.

Also 96 MW of new power (PANAM) was purchased from a new power plant privately owned.

In 1998 Panama took the most important decision to privatize the whole energy sector resulting in the three new distribution companies (Union Fenosa, Elektra, and Chiriqui); Three generating companies

(Fortuna (300 MW), AES -Bayano (150 MW), Chiriqui (La Estrella 42 MW), Los Valles (48 MW) additional power.

AES as a private enterprise started and finished one new generating station at Esti, with 120 MW.

In 1999 the totality of the Canal Installations were transferred to the Republic of Panama, that is, the Canal proper, and the electric system as a whole, but the main generating stations (Gatun of 24 MW, Madden of 36 MW and Miraflores of 90 MW remained under the administration of the new Canal Authority with the intention of being autonomous and self sufficient from an energy point of view.

The former Canal Zone demand dropped dramatically from about 120 MW to about 50 MW as the Military Bases had also left the Republic of Panama. The excess energy could then be sold to the Panama increasing market, where the Generating system of the Canal Authority operates as an auto generator, that is, one that is authorized to sell excess energy and power to the system.

In 2000 one 54 MW Diesel generating set was added by a private group and started operation as one Merchant Plant for about two years. Later this plant signed supply contracts with local distribution companies.

Current situation in Panama

2005 Gross generation reached 5,877.5 GWh
3,801.4 or 64.68% hydraulic
2,076.1 or 35.32% thermal (bunker, diesel and marine diesel).
ACP (Hydro-Thermal) delivered 630.1 GWh or 10.72%
Net Export to Central America: 51.40 GWh or 0.87%.
2006 Gross Generation reached 5,989.4 GWh
3,579.9 or 59.77% hydraulic
2,409.5 or 40.23% Thermal (bunker, diesel and Marine diesel
ACP (Hydro-Thermal delivered 876.61GWh or 17.57%,
Net export to Central America 49.01 GWh or 0.82%.

3. FUTURE

The future electric development in Panama is based on hydroelectric projects.

According to current investigations, there is a capacity to be developed larger than 2,000 MW in different regions of the Panama geography, in 95 different possible developments.

Current maximum demand is 925 MW.

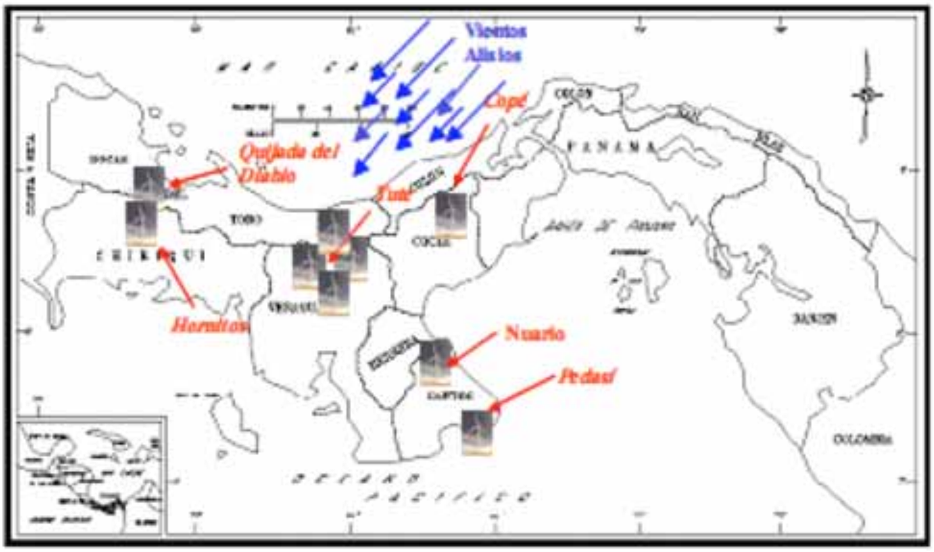
The estimated energy production for this potential is near 12,000 GW-h a year.

At the present rate of growth of 4.5 %, it does not seem to face any difficulties in covering the foreseeable future in Panama.

Thermal Power plants will be necessary as no new projects are in construction. Most likely Combined Cycle projects will be a must as time is very short.

Wind Power Generation is also investigated and licenses have been given for a total capacity of 167 MW. However, not a single project has started, the main difficulties argued are lack of finance, high risk, contracts not feasible with discos.

Air Wind Generation Projects



Nuclear power is out of consideration.

Panama is facing one important difficulty as there is not new power generating installations due mainly to lack of confidence in the Market stability.

The Government of Panama has cancelled an important group of Concessions without apparent justifiable reasons, in addition, the use of subsidies has altered the free market functioning; the rules governing the operation has been changed quite frequently and political appointments to important posts have also been altering the free operation of the market.

Panama National Transmission Network

- o There is a concerted effort in the Central American Region to complete the first phase of the Interconnected System that will allow a power interchange to a maximum of 300 MW from country to country. Transmission lines and power substations have increased the capacity for that purpose. This phase will conclude in 2009. There is a local interchange now, but to a very limited extent of some 50 MW at night.
- o A Central American Regulatory Entity is also in operation and the Organization of Load Dispatch is in operation from a couple of years ago. On the other hand, there is a parallel effort and some agreements have been reached to interconnect the Panama transmission network with the Colombian network.
- o Panama is facing one important difficulty as there is not new power generating installations due mainly to lack of confidence in the Market stability.
- o The Government of Panama has cancelled an important group of Concessions without apparent reasons, in addition, the use of subsidies has altered the free market functioning; the rules governing the operation has been changed quite frequently and political appointments to important posts have also been altering the free operation of the market.
- o This will permit further power interchanges in the future.

4. CONCLUSIONS

There is a concerted effort in the Central American Region to complete the first phase of the Interconnected System that will allow a power interchange to a maximum of 300 MW from country to country. Transmission lines and power substations have increased the capacity for that purpose. This phase will conclude in 2009

There is a local interchange now, but to a very limited extent of some 50 MW at night.

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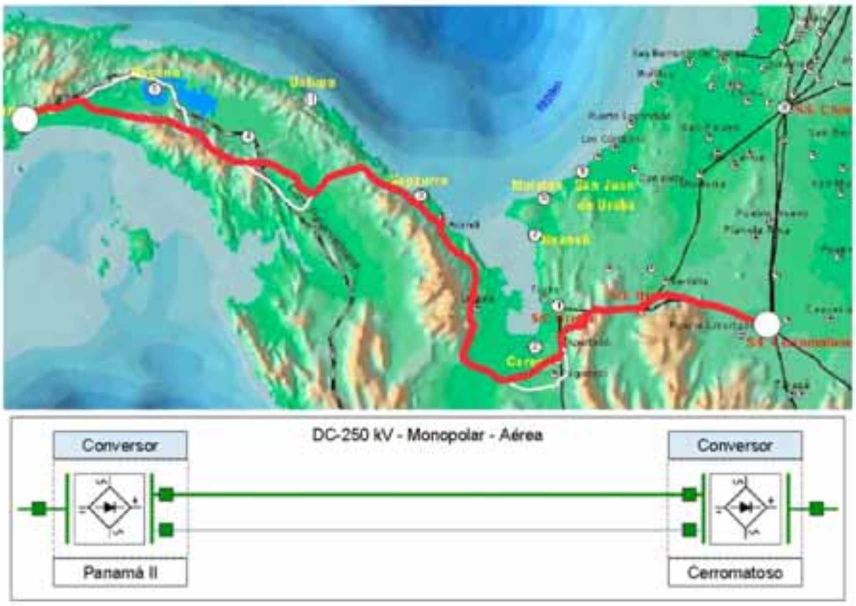
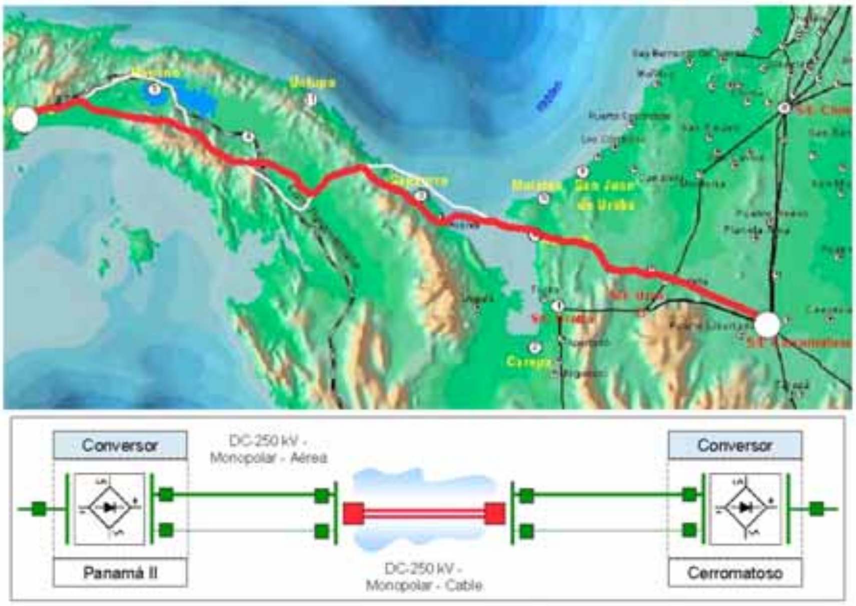
This will permit further power interchanges in the future.

Option N° 1 Intertie
Colombia Panama



Option N° 2

Panama Colombia Intertie



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6. BIOGRAPHY

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1970 - 1988 Head of Engineering Division, Head of Operation, Technical Director,
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5. The Colombian Electricity Market and its Impact in Hydrothermal Expansion

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Abstract. - The creation in Colombia, in 1995, of a competitive market for electric energy corresponded to a change in the control mechanism of society over the electric power sector: previously the control was held by the government using least cost central planning; at present it is done based on the economic principles that govern the markets. Centralized planning and market economy look for the same objective: the minimum cost to satisfy demand of electricity, which is related to the maximization of the social, consumer plus producer, surplus. This is coherent with Article 6 of Law 143 of 1994, which regulates in Colombia the market for generation, transmission, distribution and trading of electricity and establishes: "Efficiency principles force the correct allocation and use of resources so as to guarantee service at the minimum economic cost". Preference for a market economy is based on the belief that it is more efficient due to competition among agents. The regulation of a market cannot define the conditions of optimality. One of its functions is to facilitate, may be to force, that the agents operate near the optimal social point.

Index Terms—Market regulations expansion hydrothermal reliability compensation spot market modeling

1. INTRODUCTION

The evolution of the Colombian power market has been the result of a mixture of concepts; some coming from competitive markets and others from centrally planned systems. Initially, the not-commercialization of the reliability of the electric system implied that these aspects were handled by means of administrative concepts, like "Mínimos Operativos" (Operating Minima) and "Cargo por Capacidad" (Capacity Charge); all of this came as result of the belief that the market was not able to generate appropriate signals and that the administrative procedures were better. The recent creation of a market for reliability ("Cargo por Confiabilidad"), based on auctions of capacity options, is a step towards market solutions for the generation of signals that guarantee system expansion in the long term.

Structural mathematical conditions exist that define relations between the physical world and the economic one, implicit in Duality Theory of Mathematical Programming methodologies. Usually, the primal problem of an optimization model represents the physical system and the dual one the economic system. Mathematically the relation is so narrow that, when the economic interpretation of the physical world does not have rationality, because it allows infinite costs, an economic associated world does not exist. In mathematical terms it is said: when the objective function of the primal model produces an unbounded solution there does not exist a feasible solution in the dual model. Then, the detailed analytical study of the regulation, based in the concepts of Mathematical Programming, allows establishing the influence of the regulation in the tactical and strategic decisions of the agents. Mainly, our research work presents

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relationships between regulation and decisions by agents interested in hydroelectric projects, specifying aspects that facilitate investments and aspects that become barriers for these projects.

At present, the mathematical models fulfill two rolls: i) in centrally planned markets, they are the means to determine “the optimal” decisions and the fair remuneration to the agents; ii) in competitive markets, they are the means of the agents to determine their “optimal” decisions and aids the regulator in establishing optimality conditions of the system for the expansion and the operation, that must translate in appropriate regulations in order to induce optimality in the behavior of market agents.

2. BRIEF DESCRIPTION OF THE COLOMBIAN POWER SYSTEM

Colombia is located in the North West corner of South America. It is interconnected with Ecuador to the south and with Venezuela to the east and to the northeast. An interconnection line is in the last study stages with Panama and Central America, to the North West. The installed capacity in December 2005 was about 13,300 MW, of which 66% was hydro, 27% gas, 5% coal. The remaining 1% corresponds to cogeneration and wind.

Total demand is about 50 TWh, growing at a 4% annual rate. Figure 1 represents the dispatch of different resources under the daily load curve.

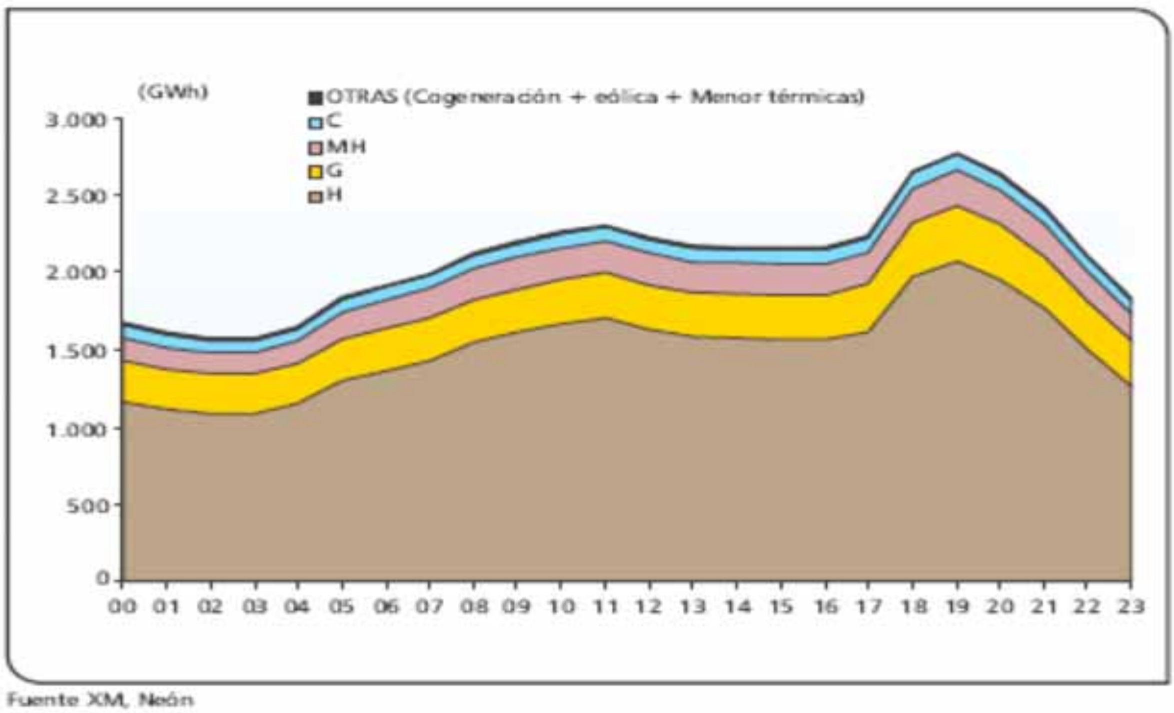

Fig 1. Daily Dispatch of Several Generation Sources

Figure 2 presents the evolution of the national aggregate “reservoir”, in units of energy (GWh). As can be appreciated, there is a strong seasonal effect, with the dry season running from December to April. Furthermore, the aggregate “reservoir” capacity is rather low (about 14,000 GWh), compared to the load. This and the fact that critical hydro inflows are well below average (historical) inflows, as can be appreciated in Figure 3, make the system vulnerable to the presence of droughts originated by the occurrence of El Niño events. For this reason, the government has encouraged increases in the participation of fossil fuel plants in the generation mixture, based on gas and coal, for which there is sufficient local supply (ample in the case of coal).

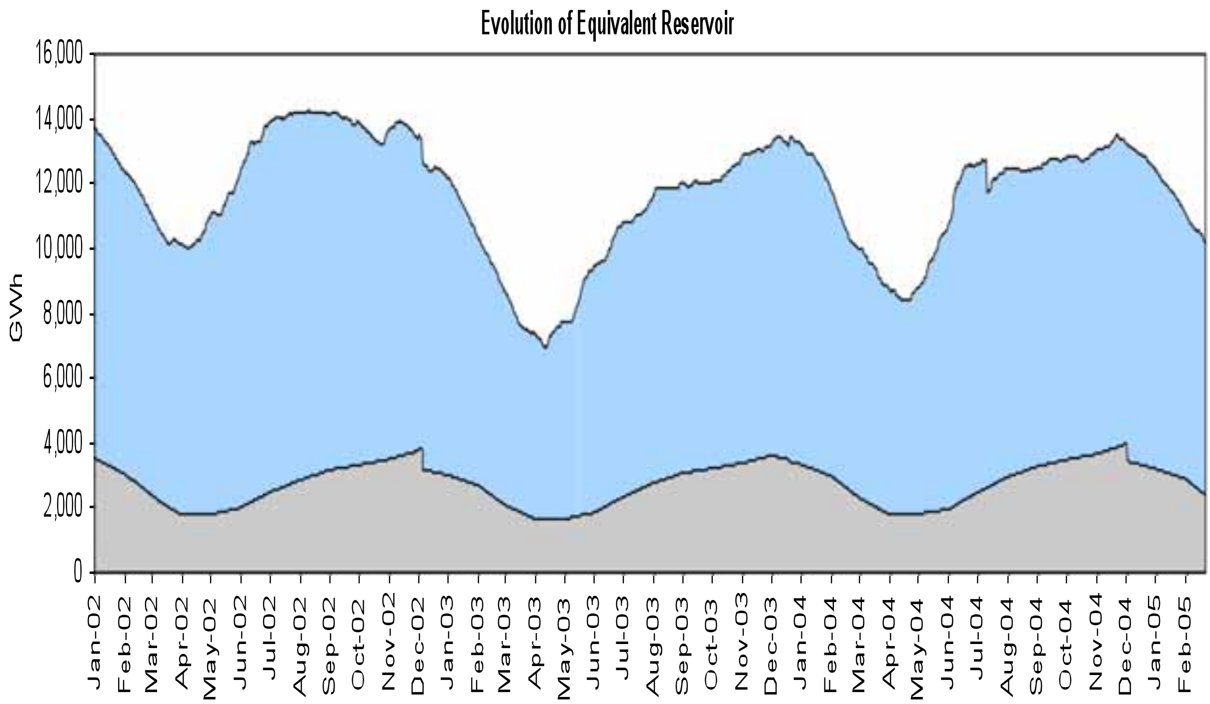

Fig 2. Evolution of the Equivalent Reservoir (2002-2005)

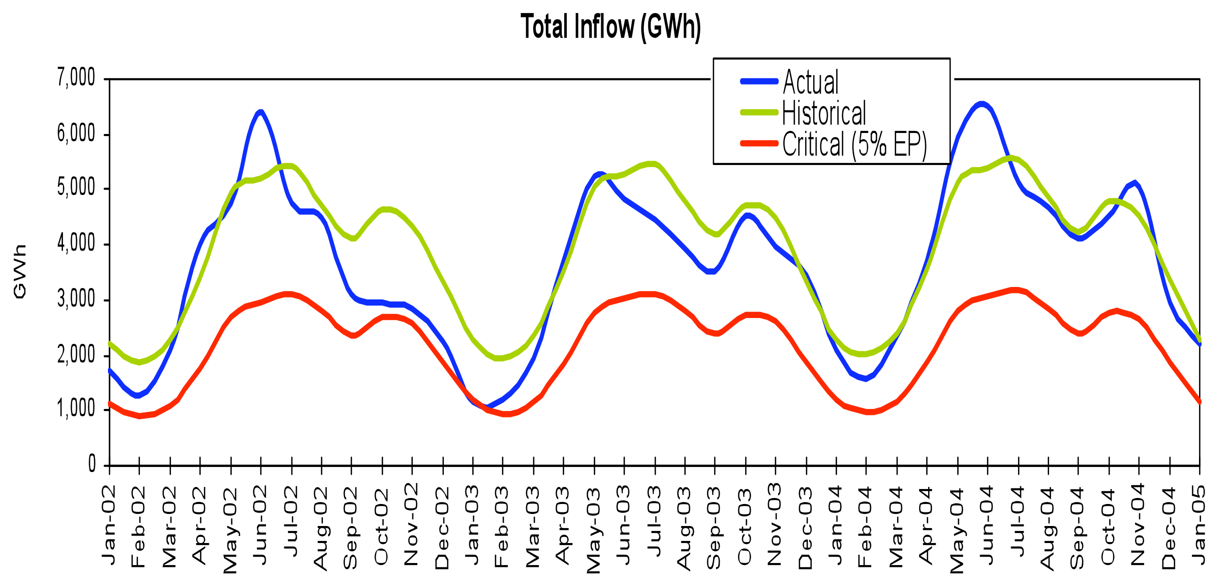

Fig 3 Hydro Inflows: Actual, Historical Average and Critical (2002 – 2005)

The transmission system consists of 11,000 km of 220/230 kV lines, as well as 1,500 km of 500 kV lines. The transformation capacity is 4,500 MVA at 500 kV and 12,700 MVA at 220 kV.

Electric market reforms were implemented in 1994. As a result, the power sector was unbundled into generation, transmission, distribution and commercialization). Table 1 indicates the number of companies in each of these activities.

Table 1 Power Market Companies by Activity	
ACTIVITY	**COMPANIES**
Generation	36
Transmission	11
Distribution	32
Commercialization	67

Total firm energy in 2006 was 60.6 TWh/year, which means a considerable reserve (consumption in 2006 was about 50.8 TWh). Energy surpluses were exported to Ecuador and, to a lesser extent, to Venezuela, through existing interconnection lines of about 300 MW of capacity. An interconnection with similar capacity is planned between Colombia and Panama and, through Panama, with Central American countries.

Transactions in the power market totaled close to 3 billion US dollars in 2006, of which about 18% correspond to the spot market, 19% to the "capacity charge" to be explained in the next section, 57% to bilateral contracts and the remaining 6% to ancillary services, in particular out-of-merit generation and AGC.

3. SYSTEM RELIABILITY ASPECTS OF THE COLOMBIAN ELECTRIC MARKET

During 1992, Colombia experienced the most serious electrical rationing that the country has known. Direct costs were estimated at about three billion US dollars that the Colombian society paid in many ways. Rationing was mainly due to shortages of water resources brought about by an El Niño event. This event precipitated the formation of an electric market (July 1995) and therefore, from its origins, the regulation of the Colombian electrical market does not escape the fears that are derived from a new rationing.

Consequently, the regulation of the market has been determined by the interpretation that was made of the main cause of the rationing: shortage of hydro resources. Then, the efforts have been centered in preserving the resources and replacing them with more expensive resources that are complementary and more reliable. In our view, the economic impact of this interpretation extends to all of the later period during which the interpretation drives the market; this impact has significantly exceeded the direct cost caused by the critical event.

The Colombian Electric Power Market is made up of two main markets: a spot market, called "Bolsa de Energía", and a long term Market based on bilateral not standardized contracts. Later, the regulator added an AGC market in order to pay for system regulation.

Additional to the previous markets, to support the reliability of the system, two indigenous concepts of the Colombian regulation, which have been strongly influenced by the perception of insufficient reliability of the water resource, have been conceived and implemented:

Operating Minima (MOS): Initially, the **MOS** for the reservoirs were introduced in the system of dispatch models of the National Interconnected System (**SIN,** for its Spanish acronym**),** as a means of protecting it from energy rationings. **MOS** corresponded to soft constraints on the minimum level of the reservoirs, for which a subjective penalty factor is introduced in the objective function. It is possible to affirm that the **MOS** are the consequence of the loss of confidence in optimization mathematical models, as the right means to regulate the water resource in critical hydrological conditions. In the author's view, when the mathematical models fulfill optimality conditions, they regulate the hydro resource under all hydrological conditions. Introducing MOS in models that fulfill optimality, increase operation costs since they imply reserves above the optimal levels. In 1995, the regulation took this concept as its own, making **MOS** a part of the electric market and, consequently, basing in them all economic transactions.

Capacity Charge (CxC): the **CxC** was conceived, in general terms, as a regulated income oriented to guarantee the reliability of the system, based on the remuneration of the plants established from the requirements of generation during the summer season estimated by an economic dispatch model with transmission, having as reference a critical hydrologic scenario and a demand projected for the year in reference. Initially the hydrologic scenario was associated to the critical biennium 91-92, later, this scenario was changed to an artificial "hyper dry" hydrologic event.

4. STATISTICAL ANALYSIS OF ELECTRIC MARKET BEHAVIOR

Figure 4 below presents the evolution of (monthly values of) spot and long-term contract prices, as well as the resulting wholesale price, in the 1995–2005 period. Most contracts had two-year duration in this period. It can be seen that contracts did provide a hedge against spot market spikes, originated by occurrence of El Niño events.

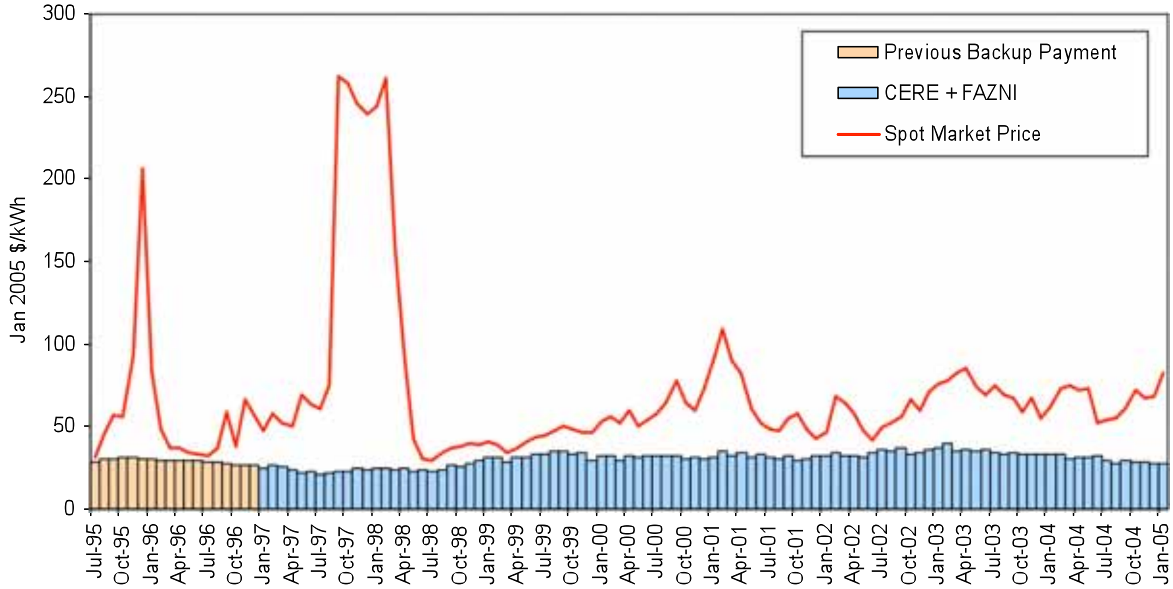

Fig 4. Spot, Long Term Contracts and Wholesale Market Prices

As can be appreciated in Figure 5, historical volatilities of spot prices are an order of magnitude above the ones corresponding to prices of contracts, which emphasize the hedging characteristics of long-term contracts.

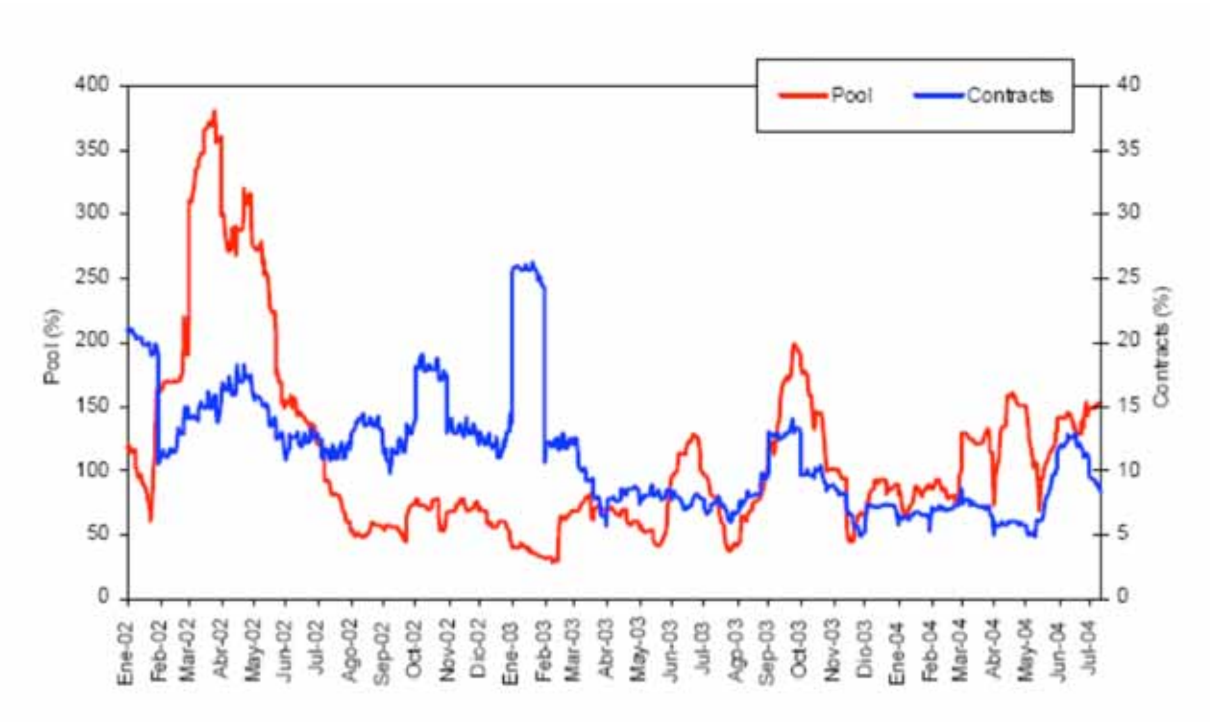

Fig 5 Volatilities of Spot and Contract Prices

Figure 6 is a probabilistic analysis of (monthly values of) spot and contract prices, based on the "survival probability", i.e., **Pr {X > x}**, for non-negative random variables. In comparison with spot prices, contract prices are restricted to a much narrower band. As a consequence, they exclude very high or very low spot prices. On the other hand, contract prices almost always "stochastically dominate"[7] spot prices, which might indicate not enough competition among generators.

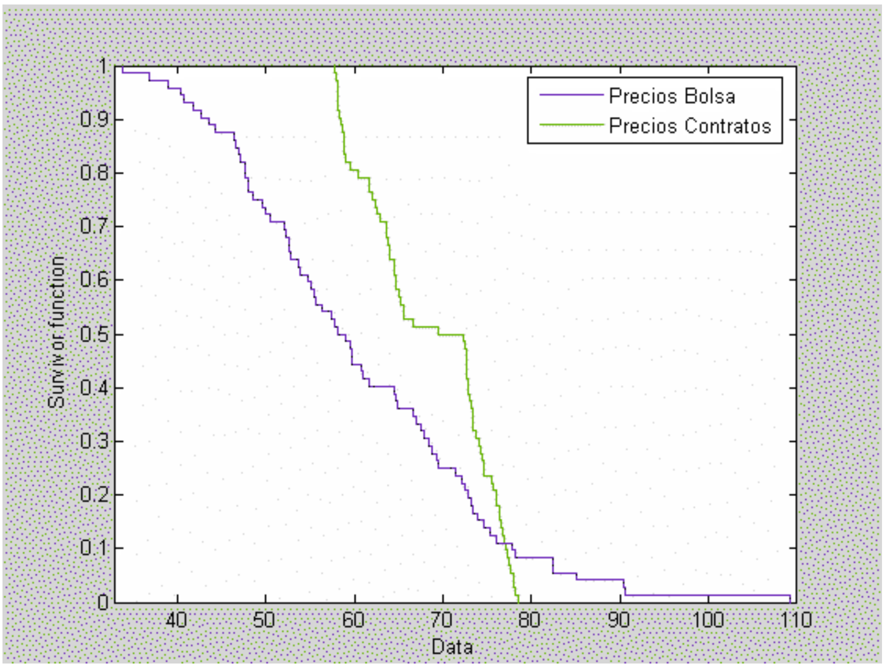

Fig 6. Survival Probabilities of Spot and Contract Prices

[7] A (non negative) random variable X stochastically dominates another (non negative) random variable Y when Pr { X ≥ a} ≥ Pr { Y ≥ a} for any non negative constant a.

On the other hand, Figure 7 seems to indicate that marginal costs (as obtained by a popular minimum cost dispatch program) are not a good predictor of spot prices. Figure 8 indicates that a GBM (Geometric Brownian Motion) would be a better one.

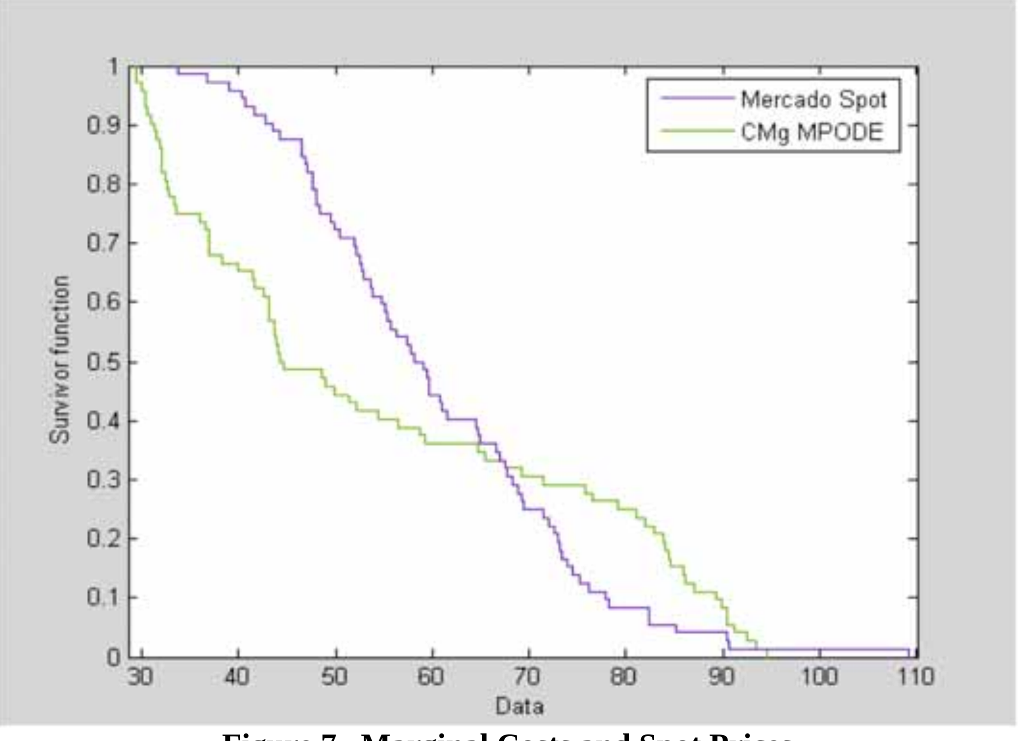

Figure 7 Marginal Costs and Spot Prices

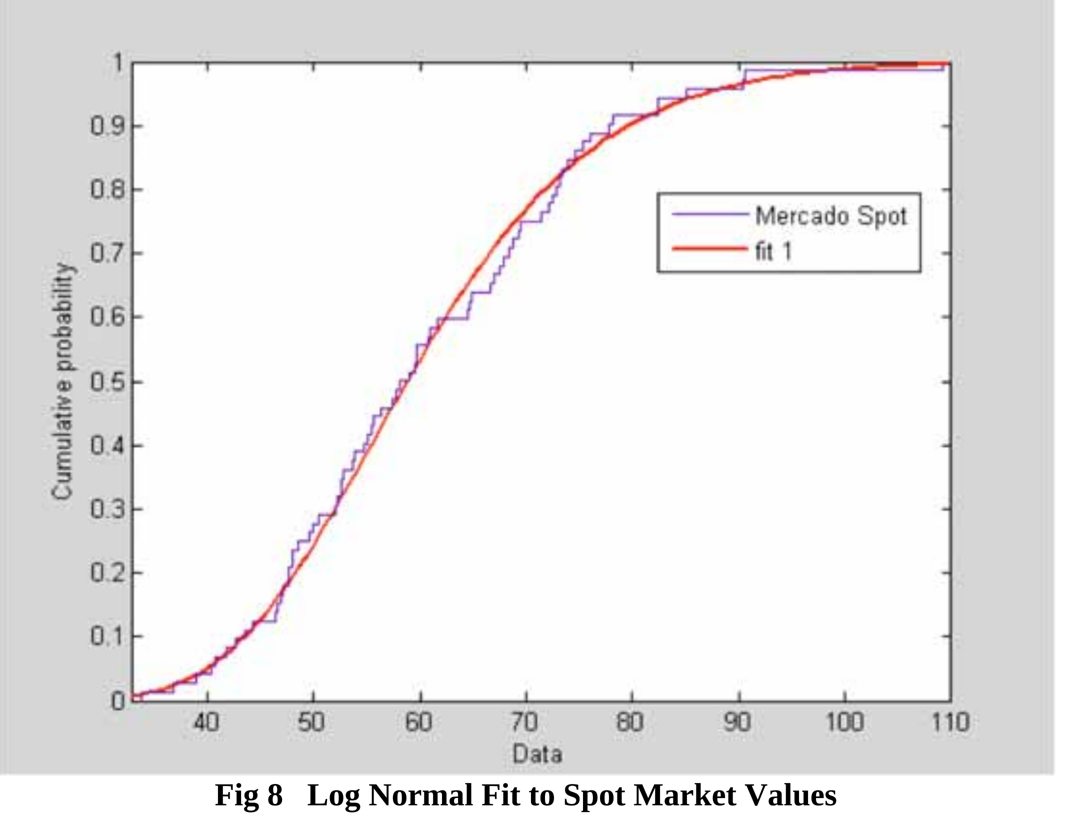

Fig 8 Log Normal Fit to Spot Market Values

5. CAPACITY CHARGE: FACTS AND IMPACTS

The official computer runs made to establish the **CxC** for its four first uses (1997-2000) allowed simulating the operation of the SIN in hydrological conditions similar to the ones that took place during the biennium 91-92. The dispatch model used to manage hydro resources was a version of the **SDP/SA** (Stochastic Dynamic Programming with Successive Approximations [1]) being used to establish the actual operation policies during the rationing in 1992. A formal study of these runs helped in identifying problems in the behavior of the model and its lack of optimality.

As example, the Figure 9 displays the evolution of the contents of some reservoirs for the **CxC** for the period 1998-1999. For its interpretation it is necessary to consider that in Colombia the summer season is associated to a period between December and April.

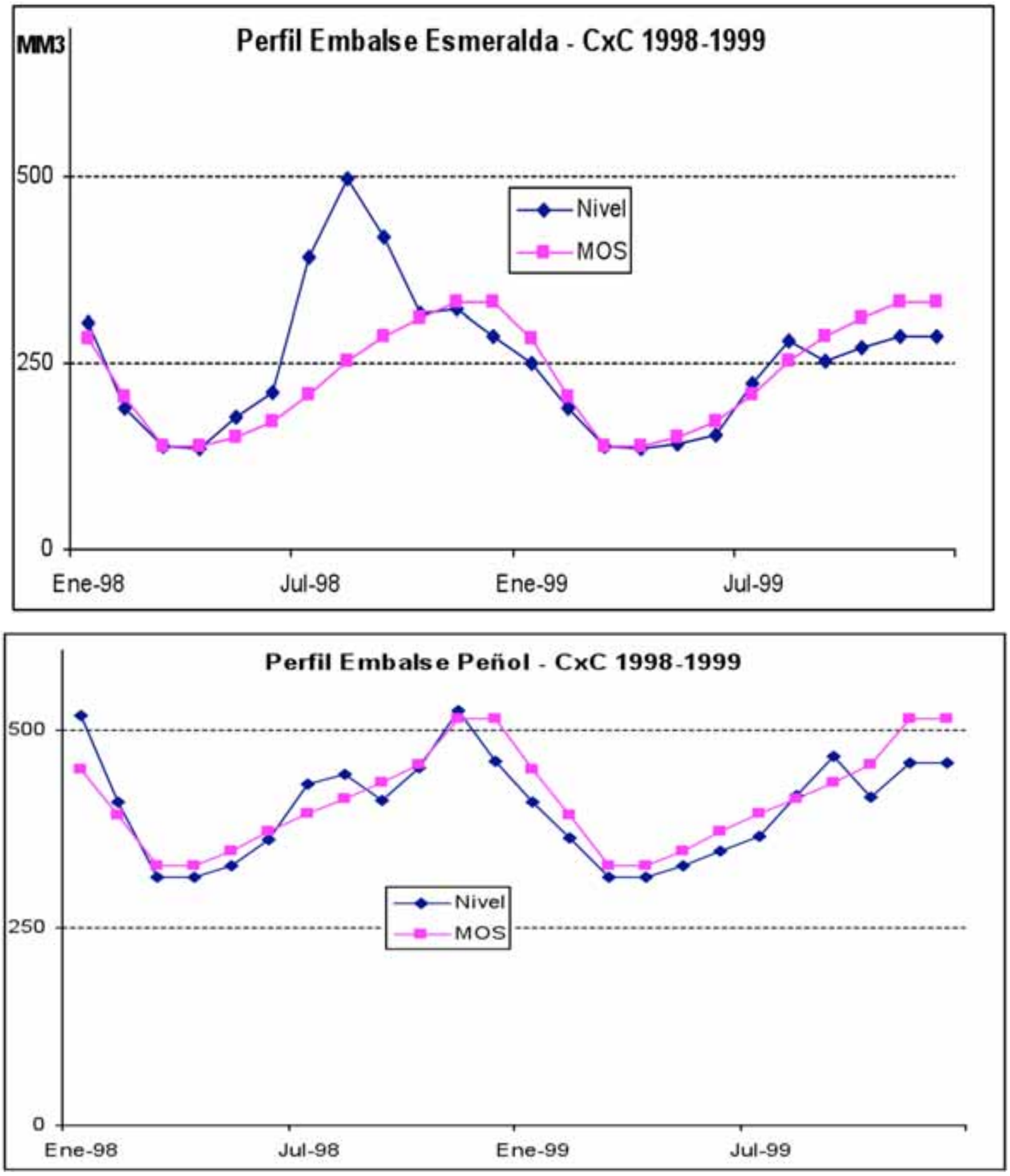

Fig 9 Reservoir profiles for the CxC 1998-1999

The previous graphs allow concluding:

- The **SDP/SA** intensively uses the hydro resource during the previous months until summer 1998-1999 so that it arrives at this period without sufficient water reserves, at the level of MOS.
- In December of 1998 the curve of operative minimums becomes the rule curve for the operation of the reservoirs.
- During the 1999 summer the reservoirs violate the MOS and cause rationing.

It is easy to prove that there are lower operations cost alternatives that avoid rationing. This model therefore does not fulfill optimality conditions.

In 2000, the Regulator modified the established procedure to calculate the **CxC** and replaced the hydrologic scenario 91-92 by the so called SUSIN series [2], corresponding to a biannual series built on the basis of the driest historical monthly inflows for all rivers (i.e., the driest January, followed by the driest February and so on). This artificial series, which almost one probability of being exceeded is not representative since it assumes too extreme drought conditions, as can be seen in Figure 10.

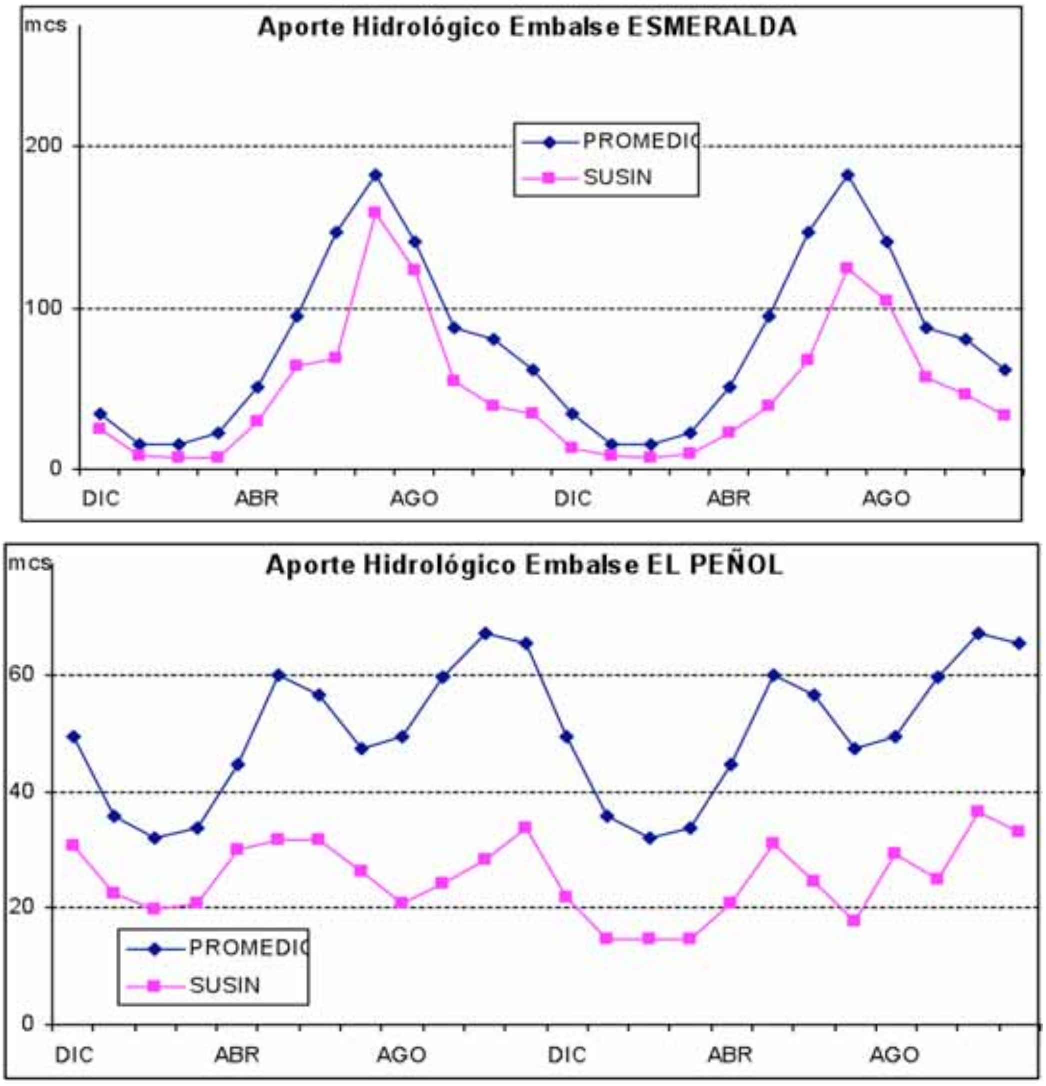

Fig 10 Average and SUSIN Water Inflows

Under the SUSIN condition all the reservoirs receive inflows much smaller than the average, which implies, from the point of view of efficient management, high opportunity costs for the use of the hydro resource in all reservoirs from the beginning of the simulation period.

Figure 11 displays the aggregate hydraulic generation and the thermal one, for the **CxC** 2001-2002.

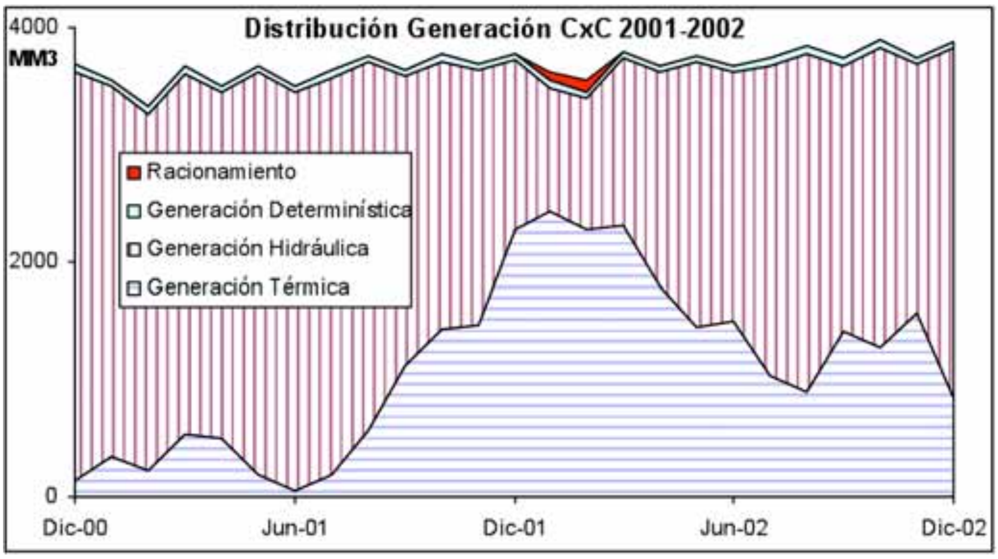

Fig 11 Aggregate Hydraulic-Thermal Generation CxC 2001-2002

Under optimality conditions, in a stochastic optimization model, the use of the thermal resource begins as soon it detects shortage of the water resource, which does not happen here. The model used does not produce signals to correctly regulate the water resource and spends it without precaution; we note that in June 2001 the thermal generation is practically zero. Due to this regulation deficiency, in December 2001 the model required dispatch of all installed thermal generation and, even so, it later incurred in rationing during the summer of 2002. Unintentionally, the SUSIN condition becomes an experimental extreme hydrology that allows easy proof of lack of optimality of the operation of the dispatch model.

The question is: How did this fact impact the market and what socioeconomic effects it produced?

First of all, it must be mentioned that instability was produced in the remuneration of the CxC, mainly for the hydraulic generators, in direct contradiction with the economic principle that was used for its implementation. Figure 12 displays the evolution of the remuneration of some hydroelectric power plants.

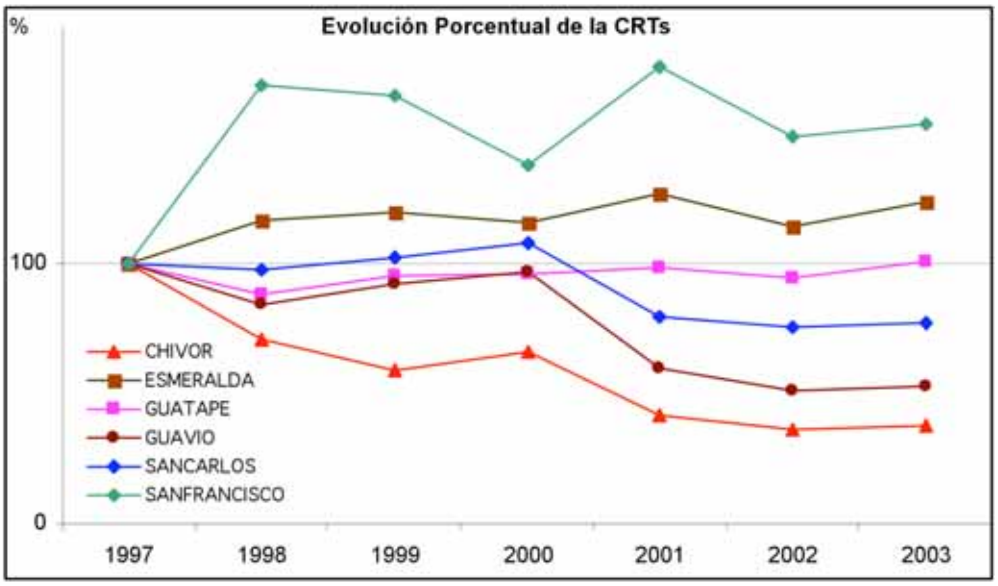

Fig. 12 Evolution of the Total CxC Income of some Hydraulic Power Plants

Of the previous facts we note that run of the river plants (Esmeralda and San Francisco) increased their remuneration whereas hydraulic centrals with water regulation capacity (Chivor and Guavio) diminished their economic value. It is easy to prove that, according to optimality conditions, the value of the relative contribution of the hydraulic power stations must remain constant, and if this value changes, it should do it in the same direction for all power stations.

The previous instability became a wrong signal to the generators that supported their decisions having this behavior as a reference: in a framework that lacks optimality, it is expected that induced decisions also lack optimality. A fact that proves this affirmation is the decision made by one of the agents that we would call HydroGen, in the 1999-2000 period, to declare lower installed capacity and see its CxC revenues to increase as a result. The following table presents for this agent the summary of the allocations of remunerable capacity (**CRT**) for year 1999 and the 2000.

TABLE 2. DETAILS CXC 1999 - 2000

YEAR	HYDROLOGIC SCENARIO	POWER DEMAND (MW)	ANNUAL ENERGY DEMAND (GWH/AÑO)	HYDROGEN				
				INSTALED CAPACITY (MW)	OPERATIVE CAPACITY (MW)	CRT (MW)	UNITARY CXC PAYMENT (USD/MW)	TOTAL INCOME CXC (USD/AÑO)
1999	91-92	7633	46.496	1000	1000	430	27.090	27'090.000
2000	91-92	7150	42.728	1000	750	485	40.740	30'555.000
Variación %	**0**	**-6.28**	**-8.11**	**0**	**-25**	**12.79**	**50.38**	**9.19**

Based on the previous facts, it is possible to conclude that as a result of the reduction of the system's demand, and as reward to the "reduction" of its operational capacity, HydroGen received greater unitary remuneration by available MW in such magnitude that total income was greater than the one corresponding to full capacity. How to justify that a smaller operational capacity implies greater total reliability remuneration? What did the end user receive by this extra remuneration? It is clear that it was not more reserve for its demand.

It is the possible to conclude that if the regulation does not fulfill system optimality conditions, it cannot guarantee decisions by the agents that lead to obtain the optimum social point that maximizes social surplus linked to minimum cost dispatch and, on the contrary, it can induce agents to make economically convenient decisions for them, but inconvenient for the society at large.

6. RELIABILITY CHARGE AND INCOMING AUCTIONS

With a view to correct the distortions described in previous sections and to replace centrally established procedures by market mechanisms, changes were introduced in 2006 to the CxC and MOS calculations. The new compensation was called "Reliability Charge" (**CxCo**). The main ingredients of the Reliability Charge, designed by the Colombian Regulator with the support of Professor P. Cramton, are as follows:

(1) Firm energy of all hydro and thermal plants is estimated a priori, based on algorithms and computer programs developed by CREG, the Regulatory Agency. Firm energy of hydro plants is estimated by maximizing the minimum energy they can provide under a condition of low inflows. Hydro plants can offer energies above this value, with up to 95% probability of exceedence, provided they offer a financial guarantee. Firm energy of thermal units is calculated by de- rating their maximum capacity to account for forced outage rates and fuel (particularly gas) unavailability.

(2) A "Scarcity Price" is established by the Regulator, higher than the highest variable cost of thermal units,

(3) The "Reliability Charge" acts like an option with an exercise price equal to the "Scarcity Price": a generator with a given firm energy allocation, should make this energy available to the spot market at the scarcity price, whenever the value of the spot market is equal or above the scarcity price. Plants can generate above their firm energy commitment, selling this spare energy at the prevailing spot market price.

(4) The unit price ($/kWh) paid for each kWh of firm energy allocated, as well as the firm energy allocated to each generator, are the result of a "descending clock auction" with an elastic demand curve (Figure 13), that takes place three years before the regulator estimates that the firm energy will be required, or when the Regulator so decides. The price obtained as a result of this auction is guaranteed to new investors for a period of up to 20 years, to help them in firming up their cash flow and thus to facilitate project finance. For existing plants, the price is valid only for the following year.

The first auction is scheduled for May 2008, after this paper was submitted. Up to late January 2008, over 90 companies had submitted bidding documents, indicated a strong interest on the part of existing and new investors. We will summarize bidding results in the presentation of this paper.

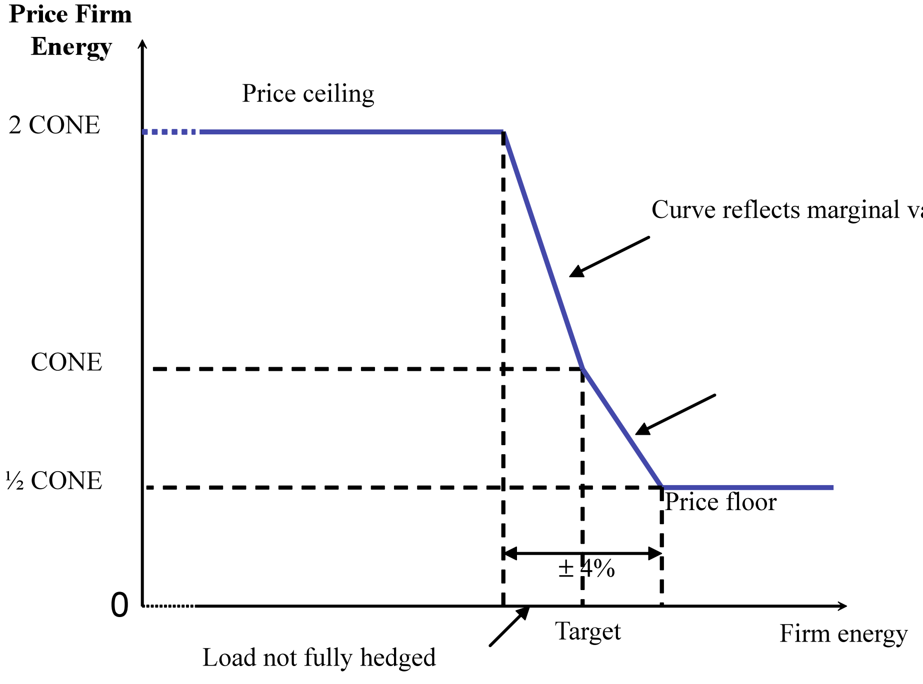

Fig 13. Demand Curve for Firm Energy Auctions

In parallel with the new "Reliability Charge", the regulator is replacing bilateral contracts by short term (up to three years) energy contracts in which all the demand will be auctioned in concurrent auctions for regulated and unregulated clients. In order to reduce risks, these auctions will be rolling, periodic with a certain percentage of the demand being auctioned each time, as indicated in Table 3.

Table 3. Rolling Energy Auctions					
Auction Date	Year	Percent of Demand that is Auctioned			Planning Period in Months
		2010	2011	2012	
Year	Quarter	1 2 3 4	1 2 3 4	1 2 3 4	
2009	1	12.5%	12.5%		14
	2	12.5%	12.5%		11
	3	12.5%	12.5%		8
	4	12.5%	12.5%		5
2010	1		12.5%	12.5%	14
	2		12.5%	12.5%	11
	3		12.5%	12.5%	8
	4		12.5%	12.5%	5

Figure 14 provides the (elastic) demand curve to be used in these auctions. The values included are only indicative. Final figures will be the result of a study to be performed by the Regulator.

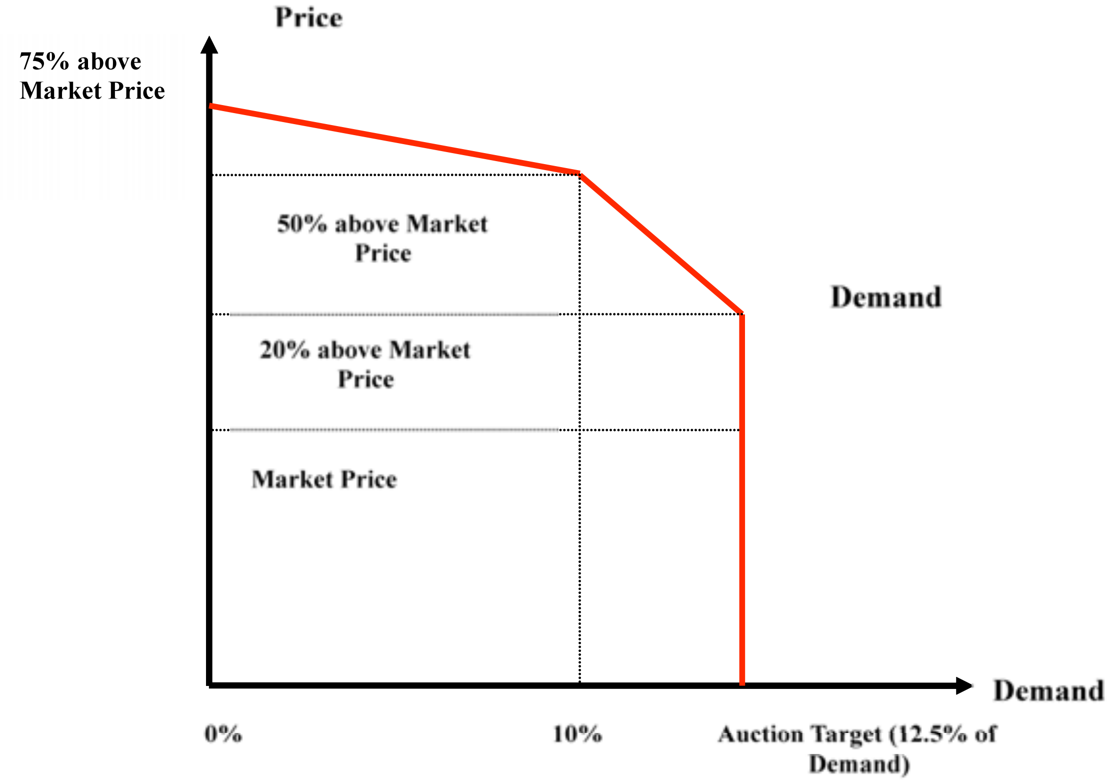

Figure 14 Demand Curve for Energy Auctions

7. CONCLUSIONS

(1) Regulatory decisions made on the basis of administered mechanisms risk being biased by recent events or political considerations and not being optimal, as the design and implementation of the capacity charge compensation proved in Colombia.

(2) The use of correct mathematical models is imperative. In particular, careless introduction of “penalty factors” or arbitrary changes to model parameters (in our case, hydro inflows), to reflect decision makers biases (in this case, water scarcity), can easily lead to undesired results.

(3) Appropriate mechanisms can be devised to stimulate adequate capacity expansion in a hydro dominated power system. Proposed changes include a market-based solution that is to be

implemented in the near future. Even if “the jury is still out” on this proposal, successful experiences in Brazil and Chile with similar solutions and a strong interest on the side of generators to participate in upcoming capacity auctions, allow us to be optimistic in its results, particularly regarding expansion of the Colombian hydro-thermal power system.

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[2] Resolución CREG 111 de 2000

9. BIOGRAPHIES

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6. “Hydro Developments and Generation Options in Argentina"

Ruy Varela, President, SIGLA S A, Buenos Aires, Argentina and Patricio Murphy, External Consultant with SIGLA

***Abstract*—** The paper describes the current situation of energy resources in Argentina focusing on power generation, the main market conditions and short-term forecasts. The paper refers to the projects that have been overtaken by both the government and private investors to expand the installed capacity in the short term enhancing the options based on renewable resources.

***Index Terms*—** Energy Supply; Power Generation; Renewable Energies.

1. INTRODUCTION

Argentina is currently undergoing a state of energy emergency due to the absence of investment in the 2002-2007 period, resulting from the 2001 exchange and financial crisis and the growth of demand driven by the subsequent economic recovery. In fact, reserves of the Argentine Interconnection System (SADI) —around 15% of the maximum load in 2002— have been gradually declining to reach the almost non-existing level of 2% in 2007.

On the other hand, natural gas generation and transport have reached the limit; therefore, thermal generation during the winter season operates on liquid fuels, which, in turn, results in increased imports and a negative impact on the variable costs of generation.

This was the result of the government’s social policy to subsidize consumption of electricity, gas, gasoline and other fuels, which kept energy tariffs for the residential, commercial and small-businesses below their costs. And delays in tariff restructuring and adjustments, in turn, prevent private investment.

Projects to expand the energy supply can be classified in two groups:

a) Activation by the national government of suspended works which have financial resources, and
b) Development of new projects by public and private players.

The forecasted GDP growth of about 5% annually requires the installed capacity to grow by approximately 500 MW per year. With this purpose the national government launched an energy plan in May 2004. The main works are estimated to contribute some 3,750 MW, i.e. an average of 750 MW annually for five years.

On the other hand, there exists in Argentina a framework for promotion of renewable sources of energy defined by the “National Regimen of Wind and Solar Energy” (Régimen Nacional de Energía Eólica y Solar) and the “National Promotion Regimen for the Use of Renewable Sources of Energy for Electric Power Generation” (Régimen de Fomento Nacional para el Uso de Fuentes Renovables de Energía Destinada a la Producción de Energía Eléctrica) aiming to increment the share of renewable energies in the national energy matrix.

2. SUPPLY AND DEMAND

The primary energy matrix in Argentina is heavily dependant on natural gas (49.7%) and oil and its by-products (39%):

PRIMARY ENERGY SUPPLY [kTEP]							
Year:	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Hydro Power	3,100	3,982	3,858	3,638	3,279	3,683	3,816
Nuclear	1,775	2,030	1,716	2, 213	2,379	2,089	2,219
Natural Gas	30,744	29,901	29,894	33,588	35,685	36,359	38,719
Oil	26,731	26,692	25,010	26,098	27,191	26,317	30,414
Coal	779	637,46	538	652	753	949	382
Fuel Wood	656	606	687	806	800	843	843
Bagasse	884	910	676	749	650	710	921
Others (1)	698	597	640	675	679	702	608
TOTAL	**65,367**	**65,355**	**63,019**	**68,420**	**71,416**	**71,652**	**77,922**

(1) Plant waste, wind and solar energy.

SECONDARY ENERGY SUPPLY[kTEP]							
Year:	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Electricity	6,633	6,732	6,537	7,142	7,594	7,273	8,694
Gas through Grids	27,574	26,868	26,276	29,538	30,832	31,892	34,916
Refinery Gas	612	672	803	933	686	702	725
Liquefied Gas	1,701	1,546	1,415	1,595	2,287	1,763	2,944
Grade Gasoline	4,287	3,606	3,665	2,821	3,738	3,710	3,699
Kerosene	1,523	1,356	458	401	507	539	1,265
Diesel Fuel	10,022	9,066	8,614	9,126	11,087	11,543	10,726
Fuel Oil	1,246	1,026	705	666	1,634	1,605	4,984
Coke	1,022	1,003	843	1,012	1,047	1,230	1,248
Non Energy	1,707	2,359	1,921	2,109	2,304	2,419	2,419
Coke-oven Gas	167	164	140	167	189	203	203
Blast Furnace Gas	250	253	250	265	293	298	298
Coal Coke	609	540	562	627	686	689	689
Charcoal	189	196	199	206	218	342	234
TOTAL	**57,540**	**55,388**	**52,387**	**56,608**	**63,102**	**64,208**	**73,045**

SOURCE: Secretariat of Energy

Wind and solar energy share is incipient taking into account the geographical conditions of Argentina, as shown in the table below:

WIND AND SOLAR ENERGY GENERATION				
	WIND		**SOLAR**	
Year	**Energy**	**Energy**	**Energy**	**Energy**
	[MWh]	[kTEP]	[MWh]	[kTEP]
2000	34,758	3	36	0.003
2001	49,361	4	43	0.004
2002	73,405	6	47	0.004
2003	77,649	7	65	0.006
2004	72,446	6	70	0.006
2005	71,606	6	81	0.007

Of the total installed capacity, 57% correspond to thermal generation and 43% to hydropower. Given the river basin characteristics, the mean annual available hydro capacity might be considered around 50% of the installed capacity. On the other hand, the average thermal unavailability amounted to about 24% in 2006.

INSTALLED CAPACITY PER REGION AND TECHNOLOGY YEAR 2007 [MW]								
Region	**Steam**	**Gas**	**Combined Cycle**		**Thermal Subtotal**	**Nuclear**	**Hydro**	**TOTAL**
Cuyo	120	90	374		**584**		857	**1,441**
Comahue		574	741		**1,315**		4,647	**5,962**
Noroeste	261	369	832		**1,462**		220	**1,682**
Centro	200	297	68		**565**	648	918	**2,131**
Litoral	3,857	613	4,287		**8,757**	357	945	**10,059**
Noreste	25	123			**148**		2,040	2,188
Patagonia		194	63		**257**		519	776
SADI	**4,463**	**2,260**	**6,366**		**13,089**	**1005**	**10,145**	**24,239**

Source: CAMMESA

The available capacity associated to the 24,239 MW installed capacity is about 18,500 MW. After the 2001 crisis the maximum load raised from 13,500 MW in 2002 to 18,500 MW in 2007 (37%), and the energy consumption 35%. These figures show the current shortage in installed capacity.

3. GENERATION INVESTMENTS

3.1 Framework

Energy crisis in Argentina shares common factors at a regional and global level, such as:

a) Escalation of oil and by-products prices.
b) Imports of natural gas from Bolivia, the main option to increase supply in the short-term but limited by the need to build a new pipeline (GASNEA) and the doubts as to Bolivia’s capacity to commission the necessary reserves to fulfill the export contract with Argentina (which establishes increasing the current 9 MMm3/day to 27 MMm3/day).
c) The growing LNG trade, the terms and prices to build new terminals and the resulting impact on natural gas price globalization.
d) The environmental issues that restrict the alternatives to build new coal-based thermal power plant and the cost of new “clean carbon” combustion technologies.
e) The consequential “rebirth” of clean energies: hydro, wind and solar power.
f) Appreciation of the nuclear energy alternative.

With the aim to replace private investment, the government designed a public trust system to expand gas pipelines, power transmission systems and power generation plants.

3.2 Federal Government Projects

3.2.1 Yacyretá Hydro Power Plant

Yacyretá is a bi-national hydropower plant (jointly owned with Paraguay) located on the Paraná River, with 20 turbines commissioned between 1994 and 1998. Projects are under way to raise the current dam level —78 m.a.s.l.— to the 83 m.a.s.l. established in the original project, in a period of 4 years. This level rise, which implies re-locations and solutions of environmental issues associated to flood in the areas surrounding the lake, involves an increment in the available capacity from 1,800 to 3,000 MW and from 13.5 TWh/year to 18.5 TWh/year in the current mean generation. At present, a third transmission line is under construction to join this development with the interconnected system.

3.2.2 Atucha II Nuclear Power Plant

The 750 MW Atucha II Nuclear Power Plant is located in Lima, to the north of Buenos Aires Province. There are two existing power plants in Argentina: Embalse (750 MW) and Atucha I (360 MW). Construction of Atucha II started in the 1980s and it was interrupted later on due to financial problems. The current government resumed construction in 2004. The plant will operate on natural or slightly enriched uranium.

3.2.3 FONINVEMEM Power Plants

Two combined cycle power plants of 820 MW each (currently under construction), jointly financed by the Government and private agents in the MEM (through the FONINVEMEM trust) to be installed in the cities of Campana (Buenos Aires Province) and Timbúes (near Rosario, Santa Fe Province). Commissioning is expected by mid-2008 as open cycle, and by mid-2009 as closed cycle. However, natural gas supply will be limited until the GASNEA pipeline is built and Bolivia can increase gas exports to Argentina.

3.2.4 ENARSA Thermal Generation

In order to cope with the supply shortage, the national government launched in middle 2007 a call for bids through the new state owned utility ENARSA. The program consists in the “rapid” acquisition and installation of five open cycle gas turbine plants with a total installed capacity of 1600 MW in different districts in the country.

Some further 500 MW will be incorporated as part of the “Distributed Electric Power Generation Plan” (Plan de Generación de Energía Eléctrica Distribuida) launched in September 2007. This capacity shall be incorporated by beginning of 2008 and shall comprise 10 small GT or diesel power plants and 3 barge floating plants.

3.3 Other Thermal Projects

Provincial governments are jointly developing with the private sector several medium-sized thermal projects, basically aimed to increase energy generation and efficiency of existing steam and/or gas turbine power plants through conversion to combined cycles.

- **Ingentis Project**: a gas-fired combined cycle located in the district of Dolavon in the Province of Chubut which shall generate 450 MW. A wind park with an additional capacity of 100 MW shall also be installed. It is a Greenfield mixed project owned by the private Pampa Holding group, its associates and the Province of Chubut.
- **Pilar Power Plant**: a public project carried out by the Province of Cordoba with the incorporation of 320 MW from GTs to close the combined cycle with the existing STs.
- **Centrales de la Costa Power Plants**: the project comprises the installation of a new 200 MW combined cycle in Mar del Plata and a 50 MW GT in Villa Gesell. This public development by the Province of Buenos Aires was bid for the third time in October 2007.
- **S. M. de Tucumán Power Plant**: a HRSG will be installed to close the combined cycle with the existing GTs, adding 120 MW. Private development by the Argentine group Pluspetrol.
- **Loma de Lata Power Plant**: a HRSG will be installed to close the combined cycle with the existing GTs, adding 190 MW. Private development by the Argentine group Pampa Holding in the province of Neuquén.
- **Güemes Power Plant**: a new 100 MW GT and HRSG to close the combined cycle with the existing STs. Mixed project between the province of Salta and Pampa Holding group.

- **Rio Turbo Power Plant** (Santa Cruz): 240 MW ST fed with coal from the Rio Turbo mine, Santa Cruz Province, using the “fluidized bed of coal” technology.
- **Interconnection of AES Termoandes** (Salta)**: c**ombined cycle of 630 MW, 420 MW of which will be incorporated into the Argentine Interconnected System and 210 MV remain linked to the Chilean Grand North Interconnected System.
- **Genelba Expansion**: the Petrobrás 674 MW combined cycle plant located in Ezeiza, Prov. of Buenos Aires will be expanded in 180 MW by 2009 and in 120 MW more in 2010, summing up 974 MW in total.

4. RENEWABLE ENERGIES

4.1 Regulatory Framework

The renewable energy promotion framework is defined by the National Provisions about Wind and Solar Energy Promotion (Law 25019 from 1998) and by the Regime for National Promotion of the Use of Renewable Sources of Energy for Electricity Production (Law 26190 from 2006) that sets the contribution to renewable energies at 8% to be reached by 2016.

It comprises wind, solar, geothermal, tidal, hydraulic, biomass, landfill gas, gases from purification plants and biogas energies.

The incentives set forth by the abovementioned laws are mainly tax benefits, as detailed below.

4.2 Law 25019/2008

This law promotes research and use of renewable energies through the following benefits:

Benefits	**Description**
Value Added Tax	For capital investments in wind and solar equipment, 15-year deferral and payment in 15-annual installments as from the last year of deferral. Applicable to capital assets, civil works, assemblies and other services.
Tax Stability	Impossibility to increase the project’s tax burden for the first 15 years.
Subsidy	Wind systems will receive 0.01 $/kWh actually generated for the MEM or destined for public services during the first 15 years.

4.3 Law 26190/2006

Law Nº 26190 supplements everything set forth by Law Nº 25019 and promotes power generation from renewable sources and research in technologies to manufacture equipment for that purpose. It extends to all non-fossil renewable sources of energy (geothermal, tidal, hydro, biomass, landfill gases, purification plants gases and biogas energy, except for that regulated by the Biofuels Law [Law Nº 26093] the benefits granted by Law 25019 to wind and solar energies. It established a Renewable Energies Trust.

Benefits	**Description**
Subsidies from the Renewable Energies Trust	0.9 $/kWh for solar energy. 0.015 $/kWh for wind, geothermal, tidal, hydro, biomass, landfill gases, purification plants gases and biogas energy.
Investment Regime	10-year scope as from 2007.
Value Added Tax	It allows advanced return of VAT under the terms of to Law Nº 25924/2004 on the promotion of Capital Investments and Infrastructure Works.
Income Tax	It allows accelerated amortization of Income Tax under the terms of to Law Nº 25924/2004.
Minimum Presumptive Income Tax	Assets shall not be taxed until after the third business year closed after commissioning of the corresponding project.

4.4 Clean Development Mechanism

Argentina has acceded to a set of international initiatives to boost renewable energies, such as the Renewable Energy Coalition resulting from the Johannesburg Summit (2002), Brasilia Platform (2003) and the Bonn Convention on Renewable Energy (2004). It is also a member of the Kyoto Protocol and the Clean Development Mechanism (CDM) where it has presented 19 projects.

According to the reports by the Secretariat of Energy the SADI's CO2 emission factor, as calculated with the ACM002 methodology approved by the CDM Executive Board, ranges between 0.42 and 0.47 ton CO2/MWh.

The governmental policies aim to a more diversified use of the energy matrix. Therefore, there are opportunities for installation of wind power generation as well as for small and medium sized hydro power plants.

4.5 Hydro Power Developments

4.5.1 Small-Scale Hydro

Argentina's hydroelectric potential is partially used, since of the 170,000 GWh/year identified only 38,000 correspond to power plants currently under operation, projected or under construction. The rest are part of a heterogeneous set of studies and projects that still have to be updated.

The approach considered to analyze Argentina's hydropower potential recognizes two groups: small-scale hydro developments up to 15 MW and large hydro developments over 15 MW. This is because the convention adopted classifies small hydroelectric projects considers three different intervals, namely:

- Micro-power plant, 5-50 kW
- Mini-power plant, 50-500 kW
- Small power plant, 500-15000 kW

Installed capacity of small-scale hydro developments interconnected to the SADI amounts to about 180 MW for 62 power plants that generate about 549 GWh/year. These developments are also devoted to other purposes such as irrigation, tourism, flood management and sailing.

There are about 140 new small-scale hydro projects with a total capacity exceeding 305 MW. The national government has prepared a short list of 16 of the "Most Searched Projects" (Proyectos Más Buscados) that provides general information on the project, background, development status rated from "Basic" to "Prefeasibility" depending on the project's progress.

The Secretariat of Energy published the "Study to Improve Understanding and Promotion of Hydro Supply through Small-Scale Hydro Developments" ("Estudio para mejorar el conocimiento y la promoción de Oferta Hidroeléctrica en Pequeños Aprovechamientos") performed within the framework of the Project of Renewable Sources of Energy in Rural Markets (PERMER) with a loan from the World Bank.

This report identifies the small-scale hydro developments up to 30 MW linked or near the electricity networks. A total of 182 projects were spotted, of 116 were surveyed and 20 were classified as the most feasible, representing 46 MW.

The following table includes the most feasible selected projects:

SMALL-SCALE HYDRO PROJECTS
SELECTED BY THE SECRETARIAT OF ENERGY

Project	Province	Level (1)	Capacity (kW)	Mean Annual Energy [Gwh]	Direct Cost ($ million)	Mean Generation Cost ($/MWh)
Los Antiguos	Santa Cruz	ExP	2,100	13.5	51.7	614
San Martín II	Neuquén	INV	3,600	28	10.5	58
Lago Espejo	Neuquén	PRE	4,000	27	22.6	132
Rio Mitre	Santa Cruz	FEA	3,200	22	38.7	274
Río Chico	Santa Cruz	INV	1,000	8.7	10.4	186
Arroyo Cataratas	Neuquén	INV	2,600	14.8	14.1	148
Las Lajitas	Neuquén	INV	500	1.6	0.9	87
San Martín I	Neuquén	INV	300	23	14.7	99
Cholila	Chubut	FEA	900	6.34	13.0	318
Vizcachas I	Santa Cruz	INV	1,000	7	15.5	342
Alto Rio Senguerr	Chubut	INV	4,000	25	47.0	301
Aluminé 3	Neuquén	PRE	10,000	57.5	48.9	136
Andalgalá	Catamarca	INV	840	4	2.4	93
El Sapo	Mendoza	FEA	6,000	46.72	38.8	128
Quemquemtreu	Río Negro	PRE	2,430	4.09	10.5	401

(1) ExP: Executive Project; INV: Inventory; PRE: Prefeasibility; FEA: Feasibility; SCH:

4.5.2 Large Hydro

Although the 10,387 MW installed hydro capacity represents 43% of the total, there is significant though underused hydro electrical potential. About 29 GW correspond to projects already developed for a total of 63 GW identified in 13 basins.

The following are some of the around 300 projects identified by the Secretariat of Energy:

Project	Basin/River	Capacity [MW]
Portezuelo del Viento	Grande	90
Garabí	Uruguay	1,600
Corpus Christi	Paraná	2,800
El Chihuido II	Neuquén	228
El Chihuido I	Neuquén	350
Condor Cliff	Santa Cruz	1,440
La Barrancosa	Santa Cruz	300
Michiuau	Limay	600
Collón Curá	Collón Curá	376
Los Blancos	Tunuyán	324
Portezuelo del Viento	Grande	90

Corpus Chris is a bi-national development on Parana River jointly involving Argentina and Paraguay. It is a hydro power plant located 150 km upstream Yacyretá Power Plant.

Also, in October 2007, the authorities of Brazil and Argentina have signed a draft agreement to assess the feasibility of the Garabí project, which comprises two dams: Santa María and Garabí, including the construction of the corresponding hydro power plants of 800 MW and 3,800 GWh/year each.

Studies assessing Argentine hydro resources not shared with other countries favor projects such as La Leona on Santa Cruz River. Closures in the area of Cóndor Cliff (1,440 MW) and La Barrancosa (750 MW) have been assessed at the pre-feasibility level.

Finally, Los Caracoles power plant (125 MW) is the larger hydro project under construction. Its main purpose is to regulate the flow of the San Juan River, the main hydro resource of the San Juan Province. The plant will be commissioned by the end of 2008/early 2009.

4.6 Wind

The development of wind energy for electric power generation dates back a decade; however, it is growing at a slow pace. Installed capacity —about 28 MW— corresponds to self-generation parks to supply local demand. Large wind farms and parks are to be developed to contribute to the interconnected system, which involves coordinating their location in wind areas near the high-voltage network nodes.

Argentine Patagonia is ideal site for wind energy exploitation because of the speed and regularity of winds. This area is located within the so-called “West winds ring”, with winds that largely exceed the average power of those in Europe, as shown in the Wind Map. In Argentina, there are winds ranging from moderate (4 km/h on average) to near mean 36 km/h annually. Specifically in the Argentina Patagonia, it is worth noting that in addition to the high speed, winds are regular all throughout the year.

There is an extraordinary wing potential in the Patagonian provinces of Tierra del Fuego, Santa Cruz and Chubut; while there already ten wind facilities in the provinces of Río Negro and Neuquén.

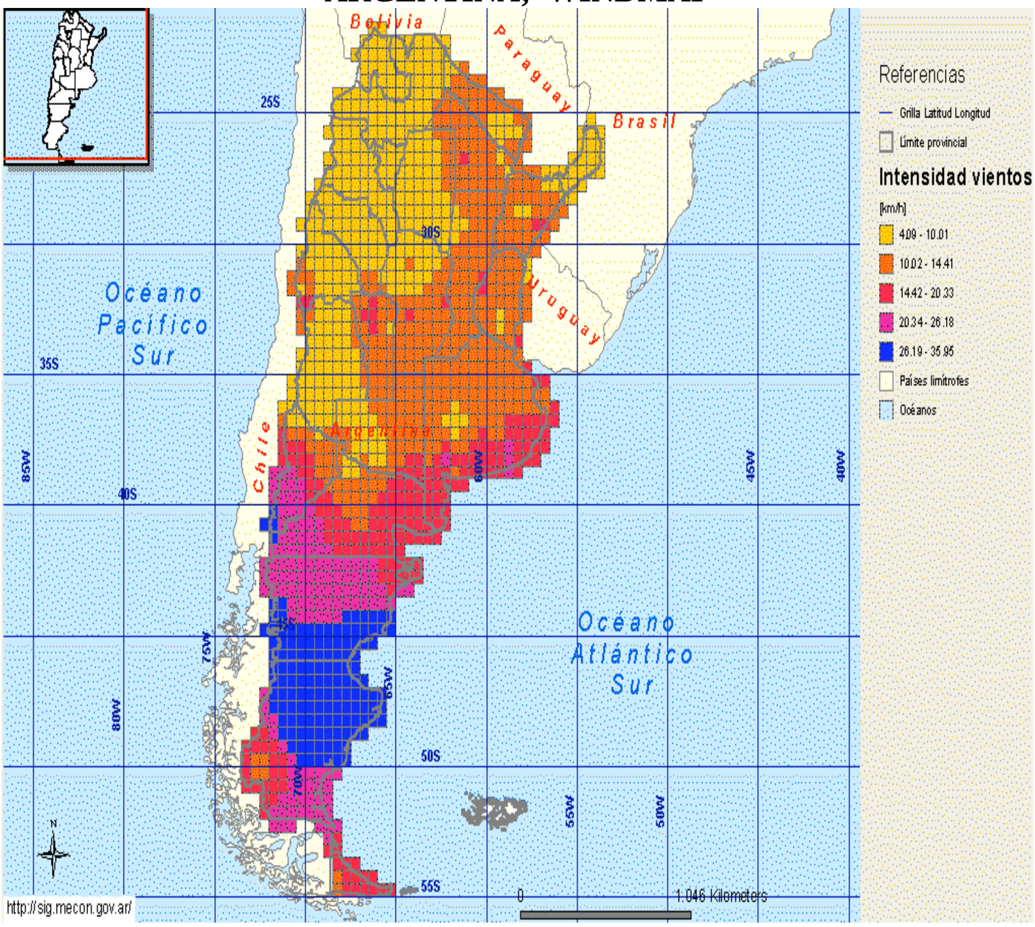
Estimations of the wind potential in Argentina are large and range between 15,000 MW to 35,000 MW depending on the criterion applied. Wind resources on the coast of Buenos Aires Province is comparable, for instance, to that of Germany, the country with the larges wind generation installed capacity.

WIND INSTALLED CAPACITY			
District	**Province**	**Capacity [kW]**	**Year**
Pico Truncado	Santa Cruz	2,400	2001-2005
Comodoro Rivadavia	Chubut	17,060	1994-1997
Rada Tilly	Chubut	400	1996
Tandil	Buenos Aires	800	1995
Punta Alta	Buenos Aires	2,200	1995-1998
Darregueira	Buenos Aires	750	1997
Buratovich	Buenos Aires	1,200	1997
Claromecó	Buenos Aires	750	1998
Cutral – Co	Neuquén	400	1994
General Acha	La Pampa	1,800	2004
TOTAL		**27,760**	

Potencia instalada total: 27.760 kW

Source: Secretariat of Energy

ARGENTINA; WINDMAP



In 2005, the national government launched the "National Wind Energy Strategic Plan". The purpose of such Plan is to develop the wind industry, including the development of a National Wind Map. The initial target is to reach the installation of 300 MW in several wind farms in different areas in the country in a period of three years.

The government has selected the possible sites for the first large wind generation projects. Plan "Vientos de la Patagonia I" (Patagonian Winds I) considers installing near Comodoro Rivadavia (Province of Chubut) a 60 MW wind farm. The remaining projects could be installed in the provinces of Santa Cruz (60 MW), Buenos Aires (around 100 MW), Neuquén and Río Negro, subject to the results of the National Wind Map. ENARSA has been appointed as the Coordinating Unit for every project.

Chubut Province has taken the lead through the implementation of a Strategic Plan in wind generation that comprises a provincial law for subsidies (Law 4,389) and a wind distribution and capacity map.

4.7 Solar

Although Argentina exhibits highly favorable conditions for solar energy exploitation (with large areas with low cloud levels near populated areas), this source is not developed yet, except for very specific small-scale applications.

A solarimetric survey has been carried out over the past years within the framework of PERMER Project with the aim to supply electricity to schools, medical centers, police stations and other consumptions beyond the scope of energy distribution centers.

The project currently involves about 1,800 schools and is being implemented in the provinces of Jujuy, Salta, Tucumán, Santiago del Estero, Chaco, Chubut, Catamarca, Misiones, Río Negro, Neuquén and San Juan, and could be extended to Córdoba, Mendoza, San Luis, Santa Fé and Tierra del Fuego. It is financed with a loan from the World Bank, a donation by the Global Environment Fund, electricity funds and other provincial funds and contributions by beneficiaries and provincial electric distribution concessionaires.

5. OTHER ALTERNATIVES

5.1 Nuclear Energy

Argentina is part of the small number of countries that has nuclear technology, and one of the two, along with Brazil, using nuclear technology in South America. Mean annual consumption of uranium amounts to 130 tons, about 23% of which is slightly enriched.

The government is analyzing the development of new projects by the end of the construction of Atucha II with the technological support of Atomic Energy of Canada Limited (AECL). This approach includes joint technological capacity to export and install nuclear reactors in third countries.

5.2 Coal

Coal reserves in Argentina are not significant; current production of the public mine in Rio Turbio (Santa Cruz Province) is approximately 200,000 ton/year, but given its quality and heating value the country has to resort to imports to supply only one 350 MW power plant and one self-generator.

At present, and in line with the global trend, there is interest in developing other projects, such as a 150 MW co-generation development in the province of Santa Fé supported by food and automotive industries. The project involves the use of coal gasification process, but there is uncertainty regarding the environmental permits for the implementation of such technology in Argentina.

5.3 LNG

The Uruguayan and Argentine governments have started to jointly develop a LNG project, consisting of a terminal and degasifications plant in Montevideo, which in a first stage would be producing 10 MMm^3/day, 50% of which would correspond to Argentina. The intention is to use the Cruz del Sur pipeline (Buenos Aires-Colonia-Montevideo), used to export natural gas from Argentina to Uruguay, in reverse sense to inject the plant's production to the trunk pipeline in the Argentine system.

6. CONCLUSIONS

Optimal utilization of the vast natural resources in Argentina has been historical limited by cyclical policies: the centralized planning of large works lacking a market criterion typical of the 1970s, which ended up with the energy crisis in the 1980s, was replaced by the market model of the 1990s which although successful —the market still operates with the investments carried out in that period— fell pray to the financial crisis and, particularly, to devaluation and pacification. The subsequent policy was characterized by state intervention and the freezing of tariffs, hindering private investment which was replaced by public investment, mainly focusing on the expansion of gas pipelines, electric power transmission systems and thermal generation plants.

Neither the market model from the 1990s nor the current hybrid scheme have encouraged the development of renewable sources of energy for power generation, beyond the good intentions shown through national regulations to promote the use of renewable resources such as wind and solar energies mentioned in Section 4.1. Wind developments, although valuable, are limited (28 MW); the last main hydro power plant was commissioned in 1999 (Pichi Picún Leufú), and with the gas and oil reserves in decline, the imports of liquid fuels for power generation are steadily on the rise.

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8. BIOGRAPHIES

Ruy Varela graduated as Industrial Engineer from the Buenos Aires Institute of Technology (ITBA, 1971) with post-graduate studies in Operations Research from the Catholic University of Argentina (UCA, 1973). He is an expert on energy economics and regulation. His recent background was developed following deregulation and privatization of the power industry in Latin America (1992), where he has managed several restructuring and/or privatization projects on generation, transmission and distribution in which SIGLA was involved. His previous background was on energy planning and economics. In later years his activity has been focused on the tariff revue process of distribution in Brazil and other Latin American countries, such as Guatemala, Nicaragua, Panama, Bolivia, Peru, Uruguay and Venezuela. On the academic side he was the founding professor of “Power System Planning in Deregulated Environment” for the postgraduate course on “Power Market Management” at the ITBA (1996-1998). Ruy Varela is founding partner and current President of both energy consultant firms SIGLA (Argentina, 1977) and SIGLASUL (Brazil, 2002).

Patricio Murphy graduated as Electrical Engineer from the Rosario University (UNR, 1980) with post-graduate studies in Energy Management at the International Labor Organization (ILO) in Italy. He is an expert on energy economics and investment projects. His recent background was developed following background was on energy planning and economics. In later years his activity has been focused on the tariff revue process of distribution in Brazil and other Latin American countries, such as Guatemala, Nicaragua, Panama, Bolivia, Peru, Uruguay and Venezuela. On the academic side he was the founding professor of “Power System Planning in Deregulated Environment” for the postgraduate course on “Power Market Management” at the ITBA (1996-1998). Ruy Varela is founding partner and current President of both energy consultant firms SIGLA (Argentina, 1977) and SIGLASUL (Brazil, 2002).

Patricio Murphy graduated as Electrical Engineer from the Rosario University (UNR, 1980) with post-graduate studies in Energy Management at the International Labor Organization (ILO) in Italy. He is an expert on energy economics and investment projects. His recent background was developed following opportunities for investment in the power industry in Latin America (1992), where he has managed several investment projects on generation in which SIGLA was involved. He worked for CAMMESA, the system operator and wholesale market administrator in Argentina, in dispatching economics and billing, and was commercial director of AES Parana, a dual combined cycle plant in San Nicolas, Argentina. He also joined other AES business activities in Argentina, Chile and Uruguay. Patricio Murphy is an associated of the energy consultant firm SIGLA in Buenos Aires and a member of the IEEE.

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7. Hydro Power Plants in Ecuador: A Technical and Economical Analysis

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Abstract- Private investment in generation plants in Ecuador has been null over the last 10 years due to several political and economical factors. The only important hydro plant over that period, a 250 MW plant, was constructed by the Ecuadorian State. At present, the Ecuadorian State and the Ministry of Electricity are the only ones initiating the construction of new hydro plants of significant capacity for the country. This reveals the failure of the existing competitive market model that has been in place for the last 10 years, particularly in relation to incentive to private investment. Arguments are being raised to return to a centralized mandatory planning scheme, under government direction, where the important hydro investments are made by the State and private investors are left with the thermo projects and small hydro. The presentation will discuss the hydro developments and future prospects.

Index Terms-- Power system expansion, energy matrix, hydroelectric plants, energy policy.

1. INTRODUCTION

Currently the Ecuadorian State is reactivating many important hydro projects such as: Coca Codo Sinclair (1500 MW), Sopladora (500 MW), Mazar (180 MW), Toachi Pilatón (320 MW), Minas La Unión (380 MW). The entrance of these projects will have an important impact in the power matrix of Ecuador, its energy prices and the electricity transactions with neighboring countries.

The panel presentation will provide a technical and economical analysis of the impact of the entrance of the hydro power plants in the operation of the Ecuadorian electrical system. For the analysis, technical tools for expansion planning (OPTGEN) and operation simulation (SDDP) will be used. Results will be analyzed and the main conclusions presented in order to obtain a long-term vision respect to the power matrix and the electrical operation of the Ecuadorian Power System.

2. ECUADORIAN ELECTRIC POWER SYSTEM

Ecuador's area is 256.370 km^2; its population is around thirteen million. It is crossed by the Andes Mountains, this characteristic origins three different natural areas: Coastal Region, that represents one fourth of the country's area and which includes nearly 50% of the population; Highlands, that represents another one fourth of the country's area and which includes less than 50% of the population; and finally, Amazon Region, that represents the rest of the country's area and which includes around 5% of the population. Also, Galapagos Islands are part of the Ecuadorian territory but the electric service is provided by an isolated system.

Since April 1999, the Ecuadorian Wholesale Electricity Market (MEM) started, based on the Ecuadorian Electricity Law (LRSE) leaving a vertically integrated model, regulated by CONELEC (Ecuadorian Electricity Council). Appendix A provides statistical information on the Ecuador electricity market.

By December 2006, MEM was composed by 17-generation agents (8 of them privately owned, 8 State owned and 1 temporally administrated by a government agency), 1 transmission company and 20 distribution

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companies (18 pertaining to the interconnected grid -SNI- and 2 isolated systems). All distribution companies belong to government organizations.

3. GENERATION INFRASTRUCTURE

From 1997 to 2006, the hydroelectric generation to total generation ratio has decreased from 55 % in 1997 to 48% in December 2006, as shown on figure 1. This variation is considered adverse from economical, energetic and environmental points of view.

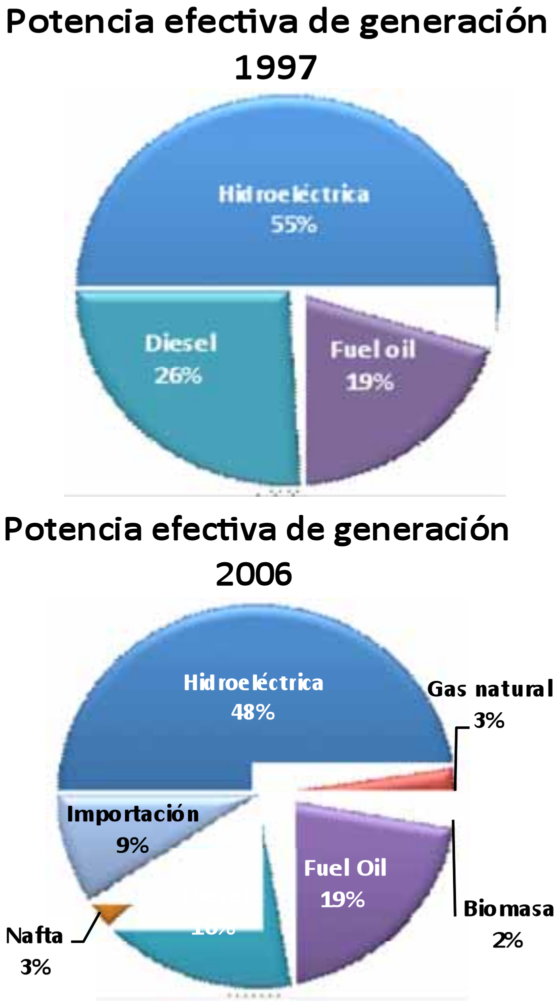

Figure 1. Generation composition comparison years 1997 - 2006

A total of 1183 MW was added between 1997 and 2006. This new capacity comprises:

- Marcel Laniado, hydroelectric plant, 213 MW, 1999.
- Victoria II, naphtha fueled gas turbine, 102 MW, 2000.
- Bajo Alto 1, Natural gas fueled gas turbine, 130 MW, 2000.
- 230 kV tie line with Colombia, 250 MW, 2003.
- Combustion motor power barges, 150 MW, 2006.

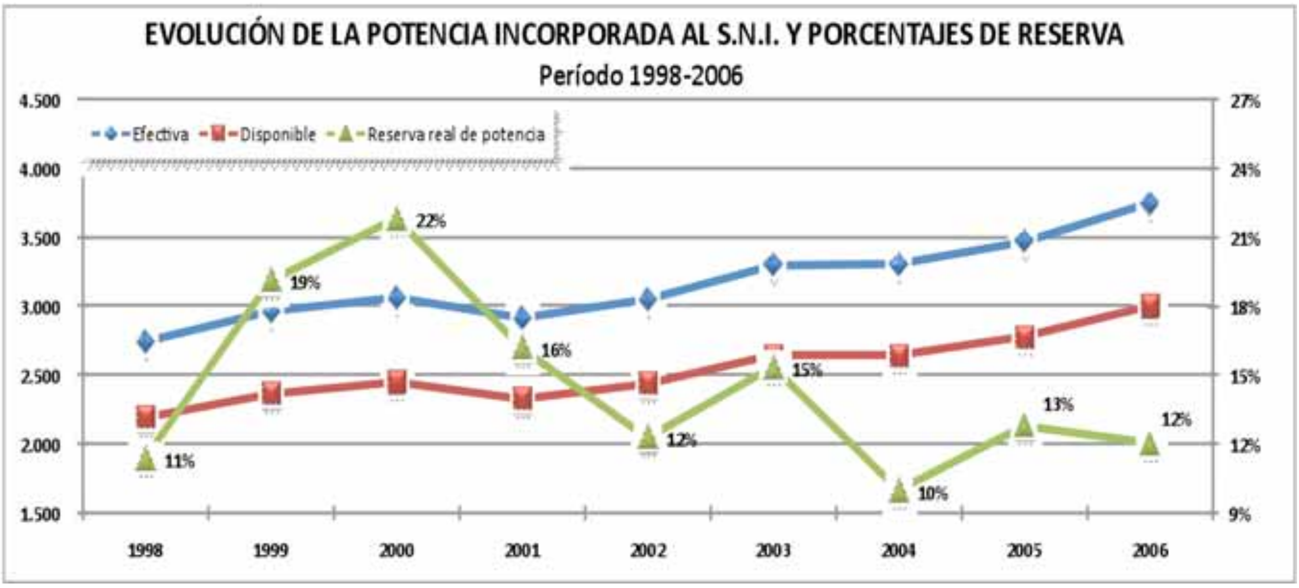

Figure 2. Generation capacity and reserve evolution.

By 2006, gross generation (generation plants and interconnection) was 16,384 GWh, being 43.5 % from hydroelectric plants, 46.9% from thermoelectric plants and 9.6 % from Colombian System. Figure 3 shows the generated energy by type of plant. 85 % of the hydroelectric power capacity is covered by the 4 largest hydro plants: Paute (1,075 MW), Marcel Laniado (213 MW), Agoyán (156 MW) and Pucará (74 MW). It's important to clarify that in the first months of 2007 a new hydroelectric plant began to operate, San Francisco, with a capacity of 230 MW.

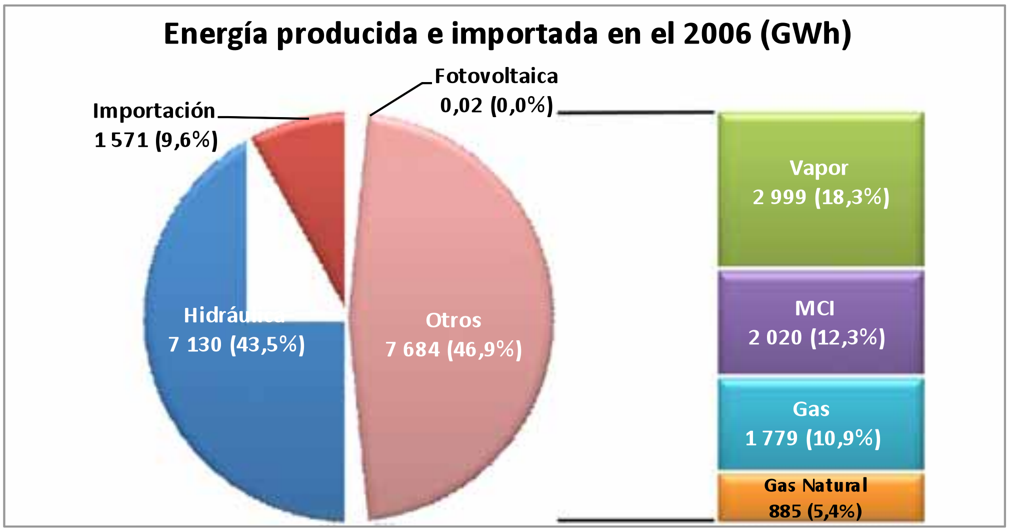

Figure 3. Generated and imported Energy in 2006

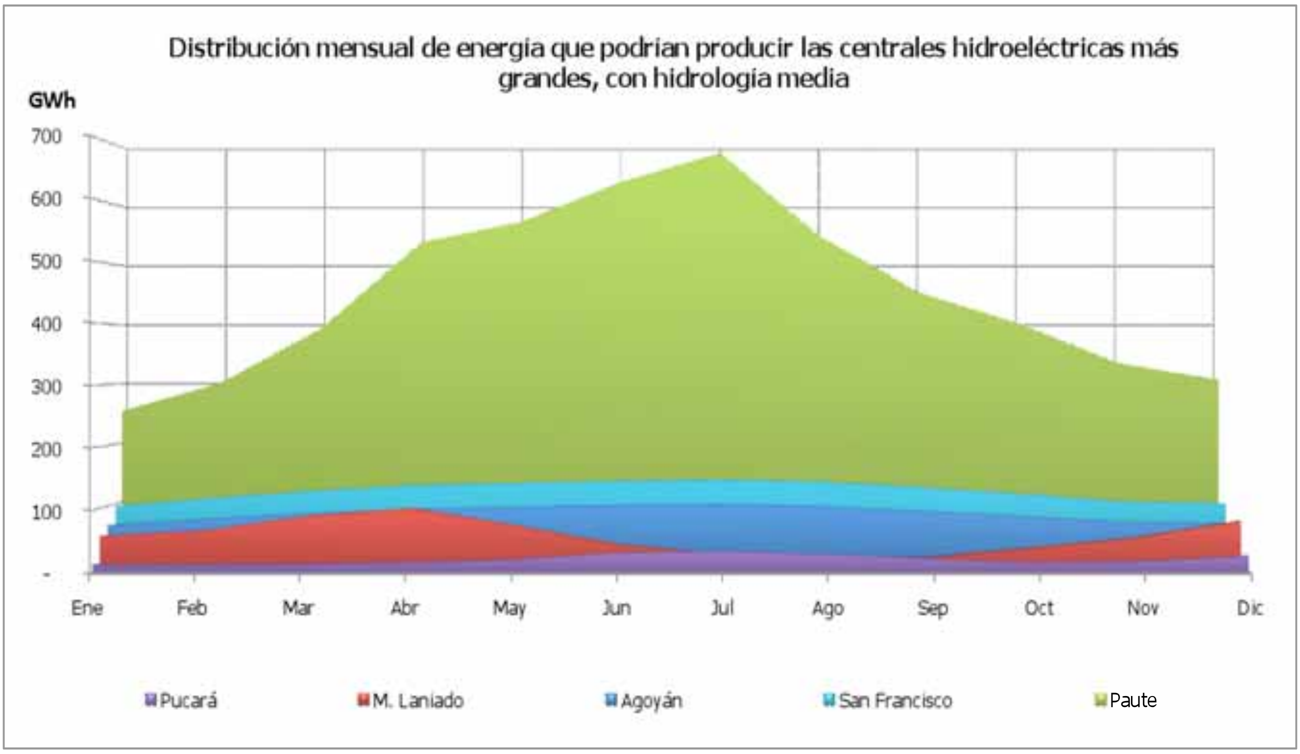

Figure 4. Generation of hydroelectric energy in medium hydrology

4. TECHNICAL AND ECONOMICAL ANALYSIS OF FUTURE HYDRO POWER PLANTS IN ECUADOR

Demand forecasted for the analysis in given in Appendix B.

In 2007, the 5 largest plants cover 88% of hydroelectric power capacity: Paute (1 075 MW), San Francisco (230 MW), Marcel Laniado (213 MW), Agoyán (156 MW) y Pucará (74 MW). Four of them are located in the Amazon watershed and only Marcel Laniado plant is located in the Pacific watershed.

The considered future hydro projects are the following:

1. Mazar. 190 MW plant located upstream of Paute plant. Mazar will be capable of producing approximately 871 GWh per year, and reinforce the energy production of Paute plant, summing up to 6,380 GWh per year both plants. It is considered that Mazar will begin operation by the second semester of 2009. Energy produced by this plant will substitute an estimated of over 100 million gallons of fossil fuels.
2. Sopladora. 320 MW plant located downstream of Paute plant. Sopladora will contribute with approximately 2,700 GWh per year. Its commercial operation is estimated to begin in the first semester of 2011.
3. Toachi Pilatón. This 228 MW plant production will be around 1,120 GWh per year and is considered to begin commercial operation in the second semester of 2012.
4. Coca Codo Sinclair. Considered as a priority project, this 1,500 MW plant is estimated to begin commercial operation in the first semester of 2014. The energy production is estimated to be around 10,370 GWh per year.
5. Minas & La Unión. These two projects, Minas of 300 MW and La Union of 80 MW are estimated to begin operation in the first semester of 2012.

The largest hydroelectric plants lie in the Amazon watershed, where rainy season occurs usually between April and September and the dry season is between October and March opposed to the Pacific watershed. That is why the maintenance of the hydroelectric plants is programmed for dry season and the maintenance of the thermoelectric plants for the rainy season. Figure 5 shows the energy contributions of the new considered hydroelectric projects, and also the energy expected to be produced by existing plants.

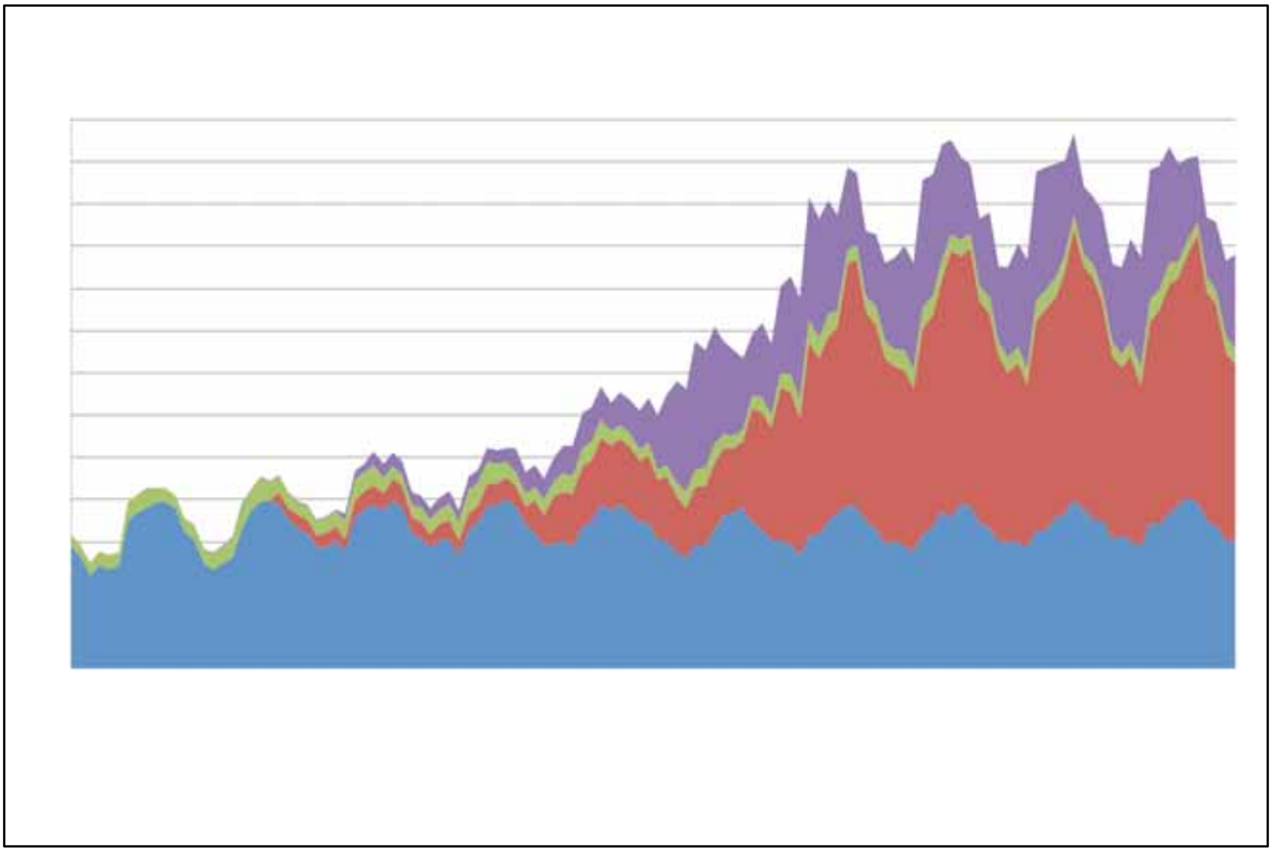

Figure 5. Expected energy production of current and future hydroelectric plants.

In figure 6, energy contributions of hydroelectric projects without considering Coca Codo Sinclair plant are presented. The high contribution of new Pacific watershed projects is appreciated.

In figure 7 the percentage composition of hydroelectric generation considering Amazon watershed and Pacific watershed including future projects is presented. Figure 8 shows the same composition but not including 1500 MW from Coca Codo Sinclar project.

5. ENERGY BALANCE ANALYSIS (BASE CASE AND SENSITIVTIES)

The energy balance considering the actual power plants and the entrance of the new generation projects was evaluated. It is shown in figure 9.

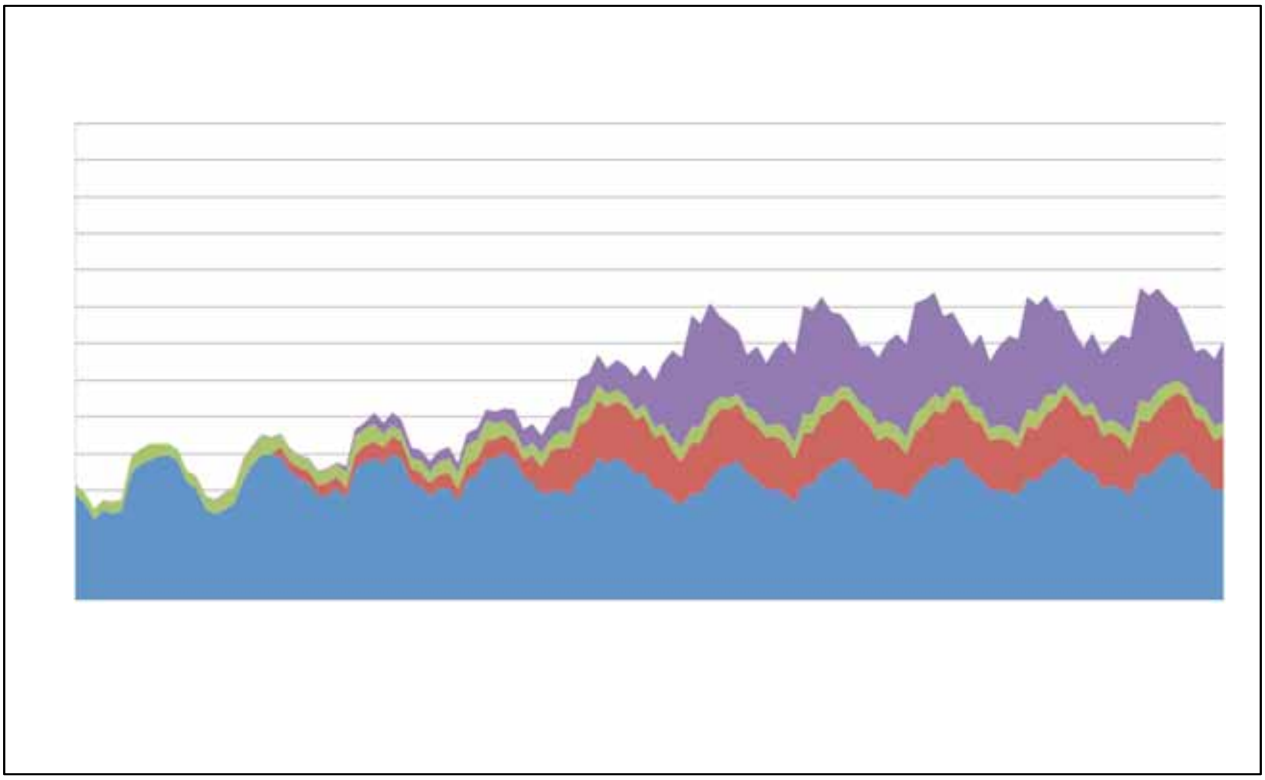

Figure 6. Energy contribution of hydro projects w/o Coca Codo Sinclair

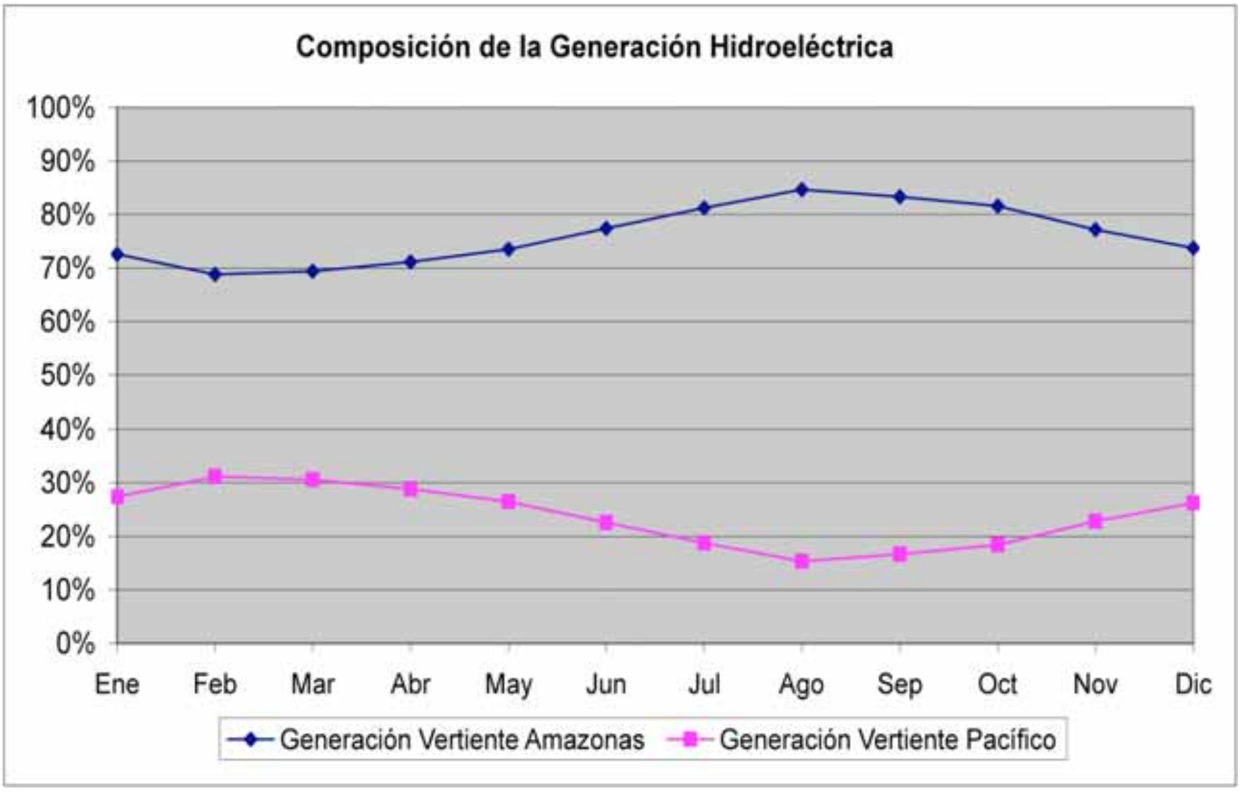

Figure 7. Amazonas watershed vs. Pacific watershed with Coca Codo Sinclair Project

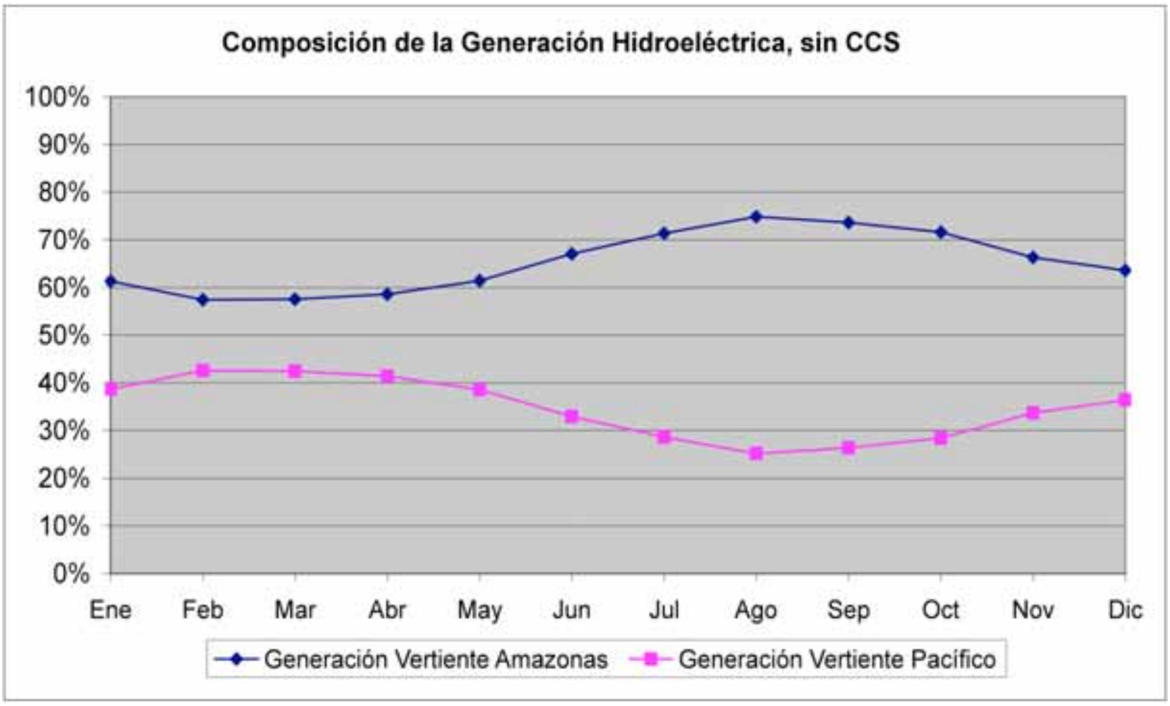

Figure 8. Amazonas watershed vs. Pacific watershed w/o Coca Codo Sinclair Project

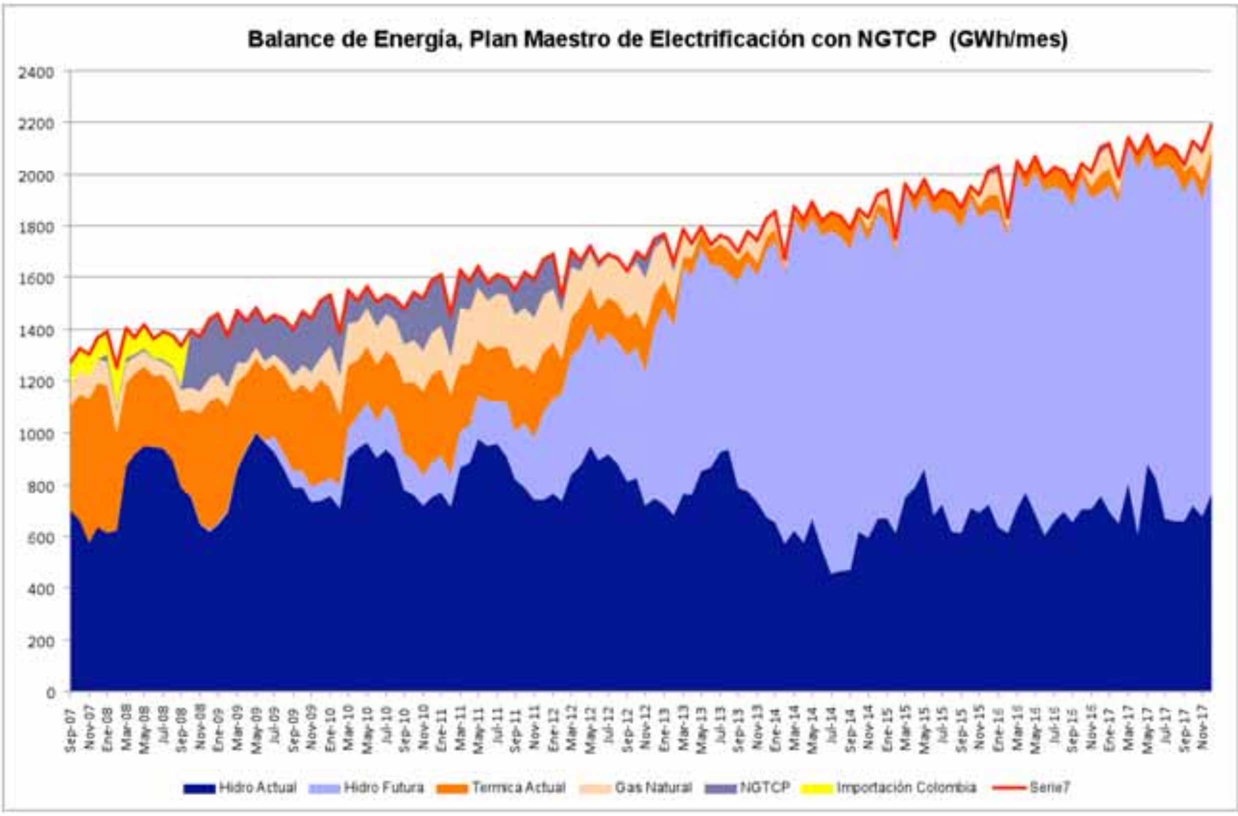

Figure 9: Energy balance considering new projects

An analysis considering a possible 2-year delay on the entrance of Coca Codo Sinclair project was made, the objective was to detect possible energy shortages needed to be covered by additional thermo electric energy. In Figure 10 the resulting energy balance is shown. Additional 300 MW of thermal generation or an equivalent on energy imported from Colombia are needed to cover the possible deficit. Starting 2012, this thermal generation effect begins to decrease, caused by the entrance new hydro projects like Sopladora, and getting to a minimum by 2015, when Coca Codo Sinclair gets fully functional.

The evolution of marginal energy costs for both cases is presented on figure 11. The 2-year delay on the entrance of Coca Cod Sinclair project will cause a significant increase on energy prices due to the thermal energy needed. This delay will cause not only energetic but also economic inconveniences, fossil fuels consumption will increase significantly, on figure 12 the estimated consumption for diesel, fuel oil and bunker if Coca Codo Sinclair project entrance delays for 2 years. An increase of about 150 million gallons is expected, the difference is shown on figure 13. The increase in fuel consumption represents an estimated of $80 million considering today fuel prices to keep constant.

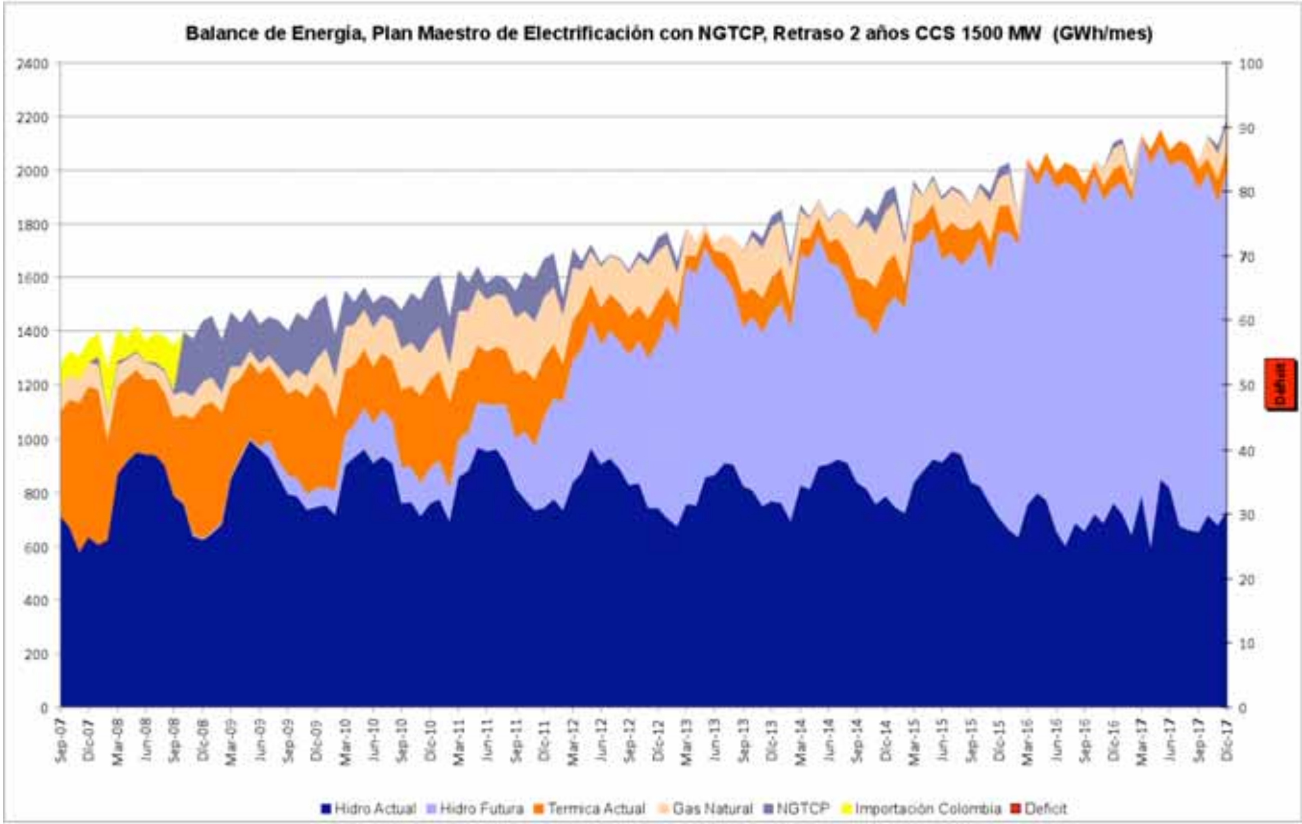

Figure 10. Energy balance with 2-year delay on Coca Codo Sinclair

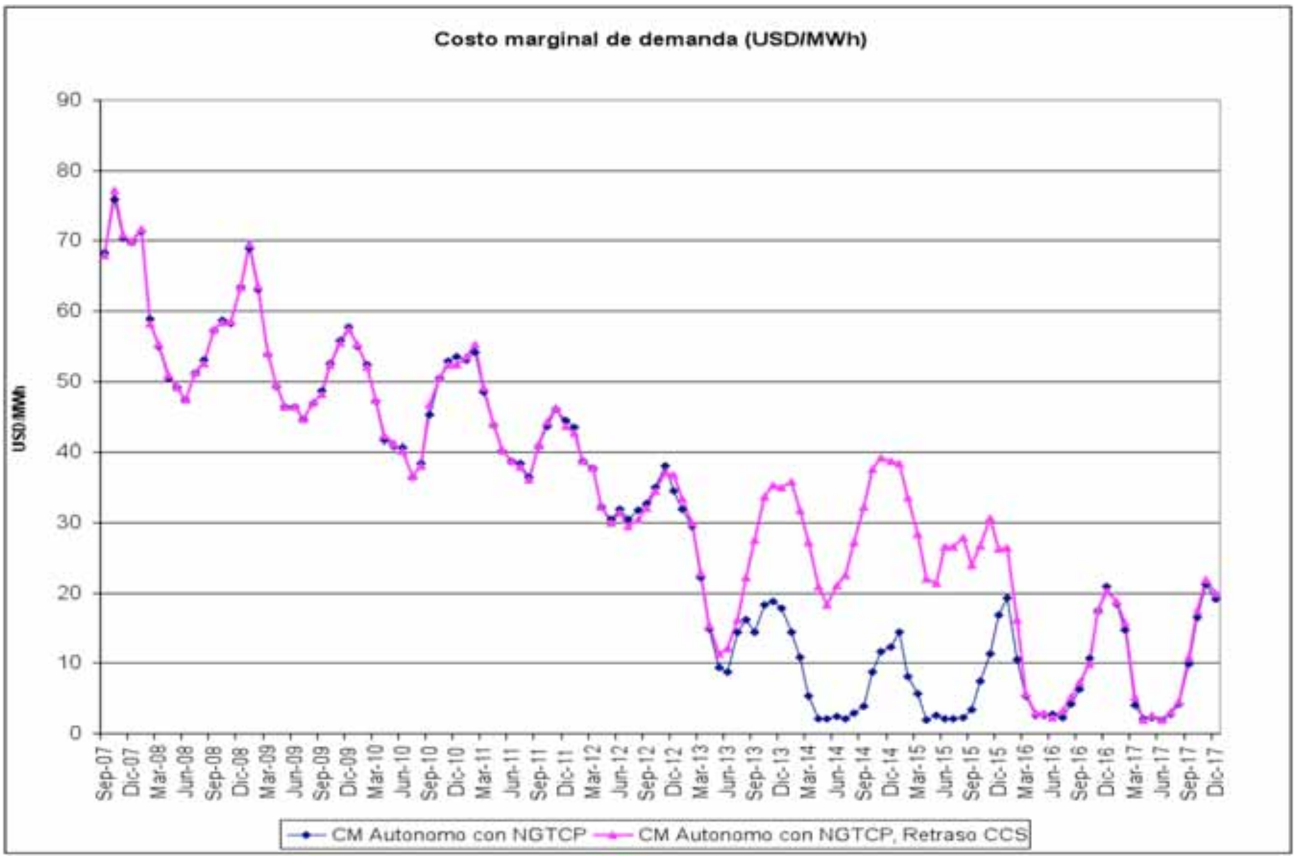

Figure 11. Marginal costs evolution, with and without delay on Coca Codo Sinclair project.

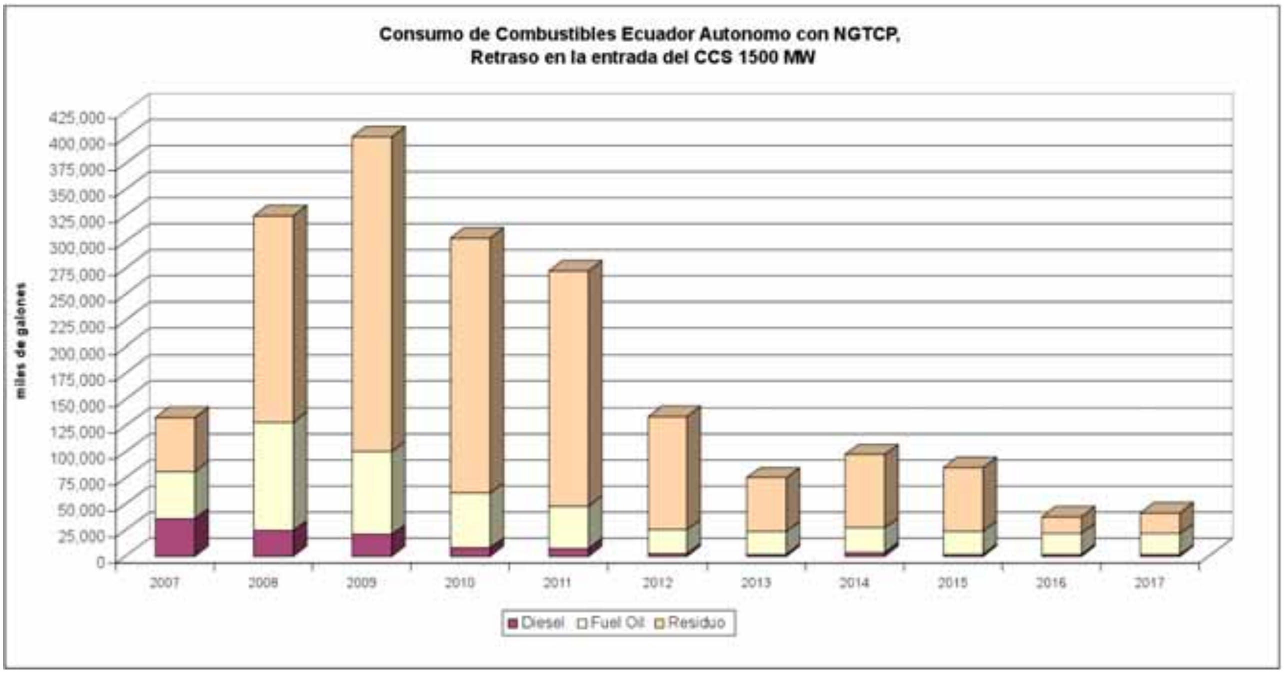

Figure 12. Fuel consumption if Coca Codo Sinclair project delays 2 years.

Figure 13. Fuel consumption difference between base case and Coca Codo Sinclair project delay case.

6. FUTURE EVOLUTION OF COSTS AND ELECTRICITY RATES

The evolution of future average generation costs is analyzed to provide an outlook of how future energy contracts prices will evolve. Average production cost for each generation unit is separated in fixed and variable costs. An 11.2 % discount rate is used.

Resulting average generation costs are shown on figure 14. Their evolution presents a decreasing rate, starting on $ 37.84 per MWh in 2008 to $ 32.24 per MWh in 2017.

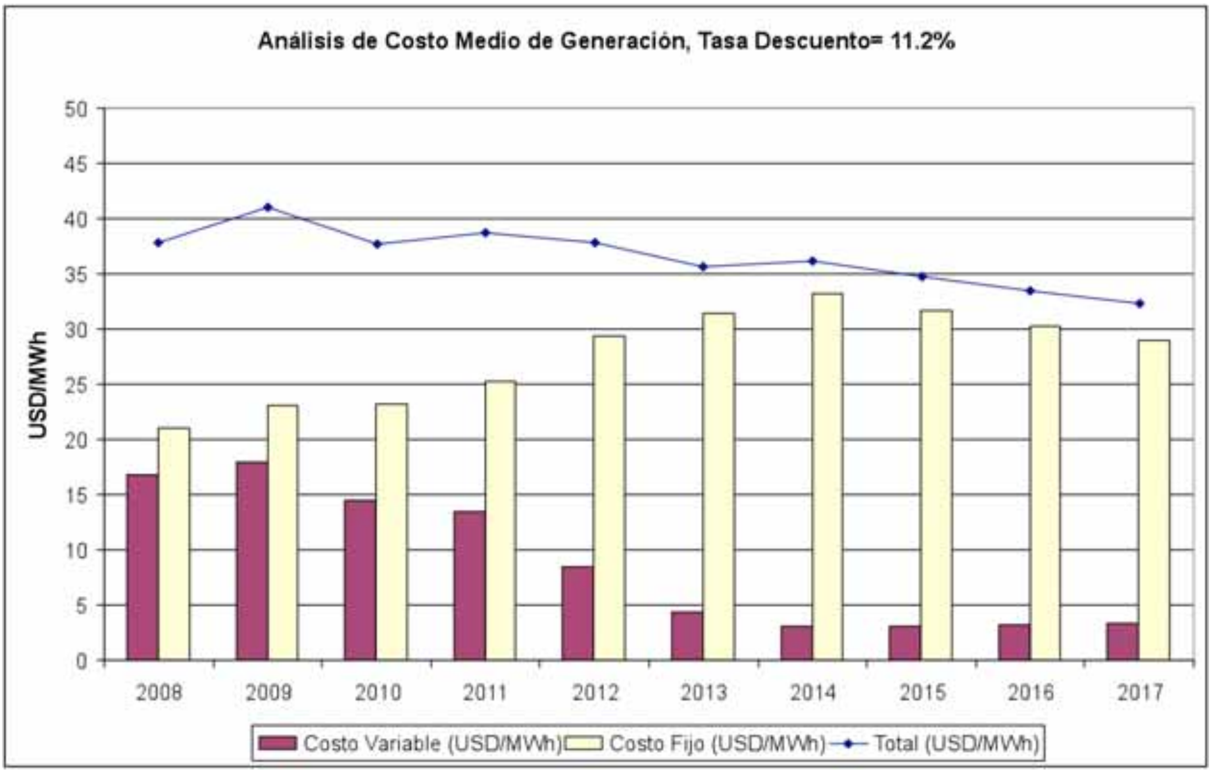

Figure 14. Average generation costs 2008 - 2017

Figure 15 shows the evolution of electrical tariffs in Ecuador, considering average costs in generation, regulated transmission tariff and distribution costs.

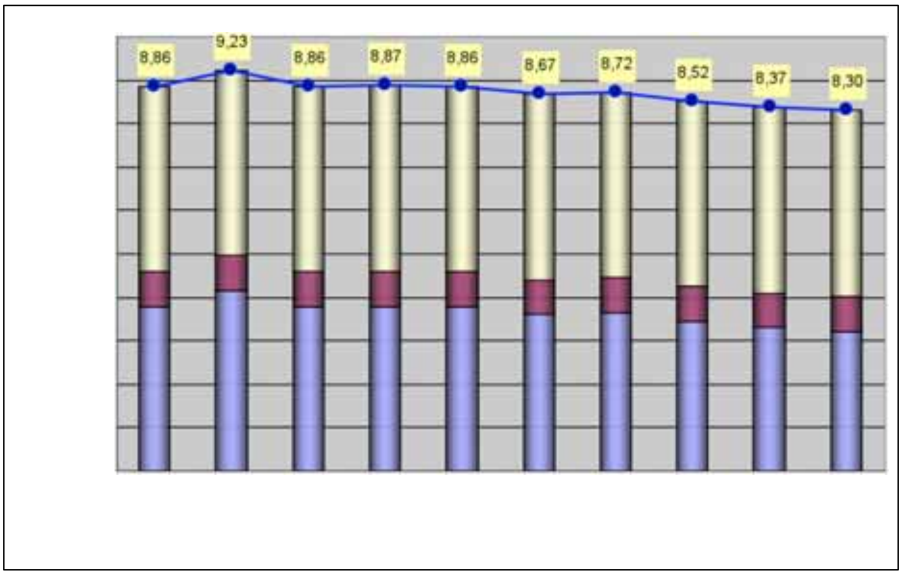

Figure 15. Evolution of tariff

7. CONCLUSIONS

The technical and economical impact of the new hydro power plants in Ecuador is positive. The on time implementation of the projects is fundamental. The Government of Ecuador is assuming the task of the centralized planning of generation with mandatory application. Coca Codo Sinclair is the most important hydro project in the next decade, but it is necessary to start considering new renewable resources for electric generation.

APPENDIX A. - 2006 WHOLESALE ELECTRIC MARKET STATISTICS

In 2006, the maximum power demand at generation buses was 2,641 MW, showing an 8.4 % rise (217 MW) compared to peak demand of 2005. Total traded energy during 2006 accounts 15,085.94 GWh, this includes the following components:

- 6,273.27 GWh (41.6%) in the Spot Market; and,
- 8,812.67 GWh (58.4%) in the Contract Market

Total energy billed sums up $ 927.02 million, detailed as follows:

- $ 604.84 million (65.2%) in the Spot Market; and,
- $ 322.18 million (34.8%) in the Contract Market

The Spot Market bill includes: purchased energy in spot market to accomplish contracts, power, reserves, etc. Also, the power to be compensated in the contract market is cleared off in the spot market. It is important to clarify that the distribution tolls are not considered.

The average energy price in MEM was 6.14 ¢/kWh as a result of the following:

- 9.64 ¢/kWh in the Spot Market; and,
- 3.66 ¢/kWh in the Contract Market

The Transmission Grid transported 14,439.06 GWh with 3.1 % of power losses. The Transmission Company billed $ 103.41 million and the unit price was 0.716 ¢/kWh.

Total MEM income for exported energy during 2006 was $ 49.71 thousand. Total charges for imported energy were $ 124.98 million.

APPENDIX B. - DEMAND PROJECTIONS

Forecasted power and energy demand considering a medium increase scenario is shown, yearly on table 1 and monthly in figure 16.

Table 1. Demand and energy forecast

Year	Non Coincident Maximum Demand (MW)	Maximum Demand (MW)	Energy (GWh)
2008	2 939	2 851	15 748
2009	3 073	2 980	16 563
2010	3 208	3 112	17 398
2011	3 348	3 247	18 254
2012	3 496	3 391	19 164
2013	3 644	3 535	20 071
2014	3 798	3 684	21 009
2015	3 957	3 838	21 984
2016	4 129	4 005	23 006
2017	4 246	4 119	24 168

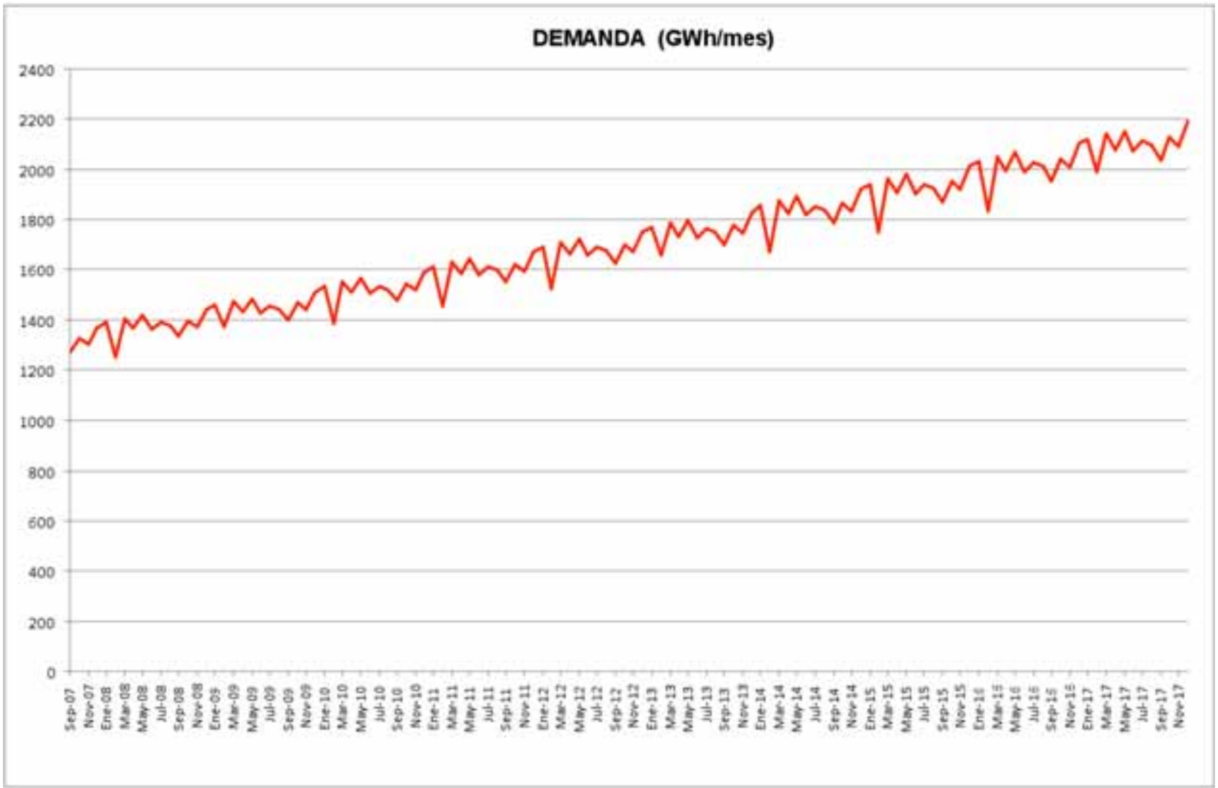

Figure 16. Monthly demand forecast 2007 - 2017

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BIOGRAPHIES

Gabriel Salazar, graduated as Electrical Engineer from Escuela Politécnica Nacional of Quito, Ecuador and Doctorate in Electrical Engineer from Instituto de Energía Eléctrica of San Juan, Argentina. He is presently the Director of Electrical Tariffs in the Electric Regulator of Ecuador. He is professor of the Electrical Sciences Magister program in Escuela Politécnica Nacional of Quito, Ecuador.

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8. Generation Options and the Environment to Assuring the Efficient Development of Hydro Developments in Peru

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Abstract—In this paper a diagnostic of Peru's potential of hydro power generation is made, risks and barriers that interested private investors confront are identified and over the basis of the current regulatory framework and generation market design, some measures are proposed to be taken in consideration in the bids for long term contracts that DistCos will call so they could make feasible in order to develop hydro power projects**.**

Index Terms— Hydro Developments, hydro Concession potential, hydro Authorization, Theoretical Potential.

1. INTRODUCTION

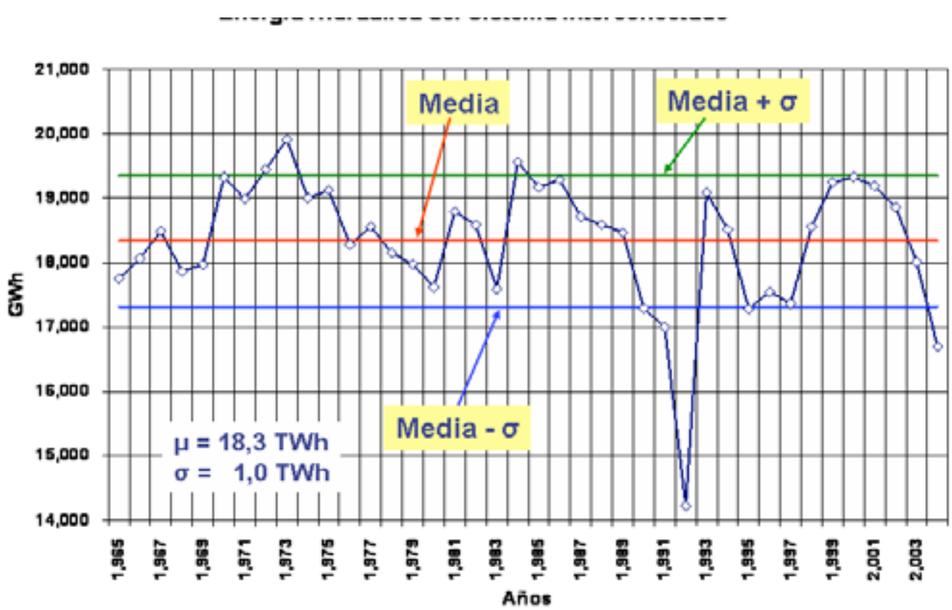
The Peruvian electric market design is based on a clear split between electricity supply with natural monopoly characteristics, for which regulated prices were set (transmission & distribution), and areas in which it was possible to create competitive conditions for freedom of pricing (generation & supply to large clients). The rates are set as the average of short-run marginal cost (SRMC) for small consumers (consumer rates) of DistCos and free prices for free consumers[9] (contestable consumers).

The system operation spot trading function is all managed by an organization essentially of the generators (named System Electric Operation Committee – SEOC). The SEOC calculate the SRMC as a result of economic dispatch.

Peruvian electrical system is mainly hydroelectric. Next picture shows the potential production of present installed hydropower capacity using for the simulations the hydrological series of the last 42 years.

As we can see, the hydropower system is able to provide an average of 18,3 TWh. Taking into consideration that the projected energy consumption in 2007 will be 27.3 TWh, it is to be expected that, under these conditions, thermal installed capacity should provide around 9,0 TWh. During drought years, the thermal generation would be of 18 TWh, with high SRMC.

[9] Consumers with demand over 1 MW.



Source and elaboration by OSINERGMIN

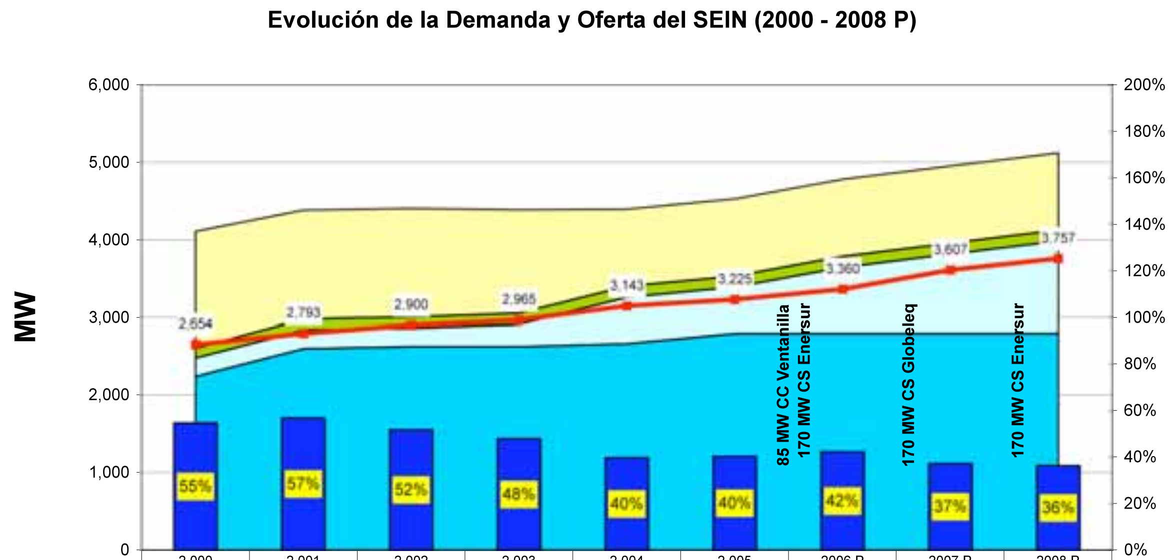
Fig. 1 – Potential Production of Present installed Hydropower Capacity

Having access to the spot market, the generators decide what kind of risks they are going to take: in contracts with DistCos and free consumers, or spot trading. In this model the retailers don’t have any access to the spot markets so they just basically have to buy everything under contract from generators that restricts their flexibility and makes it harder for them to compete effectively with the generators itself.

Currently, DistCos and free consumers in the market can purchase energy only through Full Requirement contracts with generators (contracts for maximum capacity with its associated energy, whatever the load factor would be). According to Peruvian law, the generator cannot contract more energy or capacity than it has as firm energy or firm capacity. The object is to promote enough physical reserve in the system.

The prices contained in the contracts between GenCos and DistCos, for sale to the regulated retailing can not be higher than the rates set by the regulators following an administrative calculation based on a sort of smoothed average of the SRMC projections for 24 month in the future, which requires making projections of supply and demand for similar period.

With regard to investments in hydropower generation, last decade development has been much limited as it is shown in the following picture.



	2,000	2,001	2,002	2,003	2,004	2,005	2006 P	2007 P	2008 P
Petróleo	1,504	1,402	1,399	1,334	997	997	997	997	997
Carbón	125	142	142	141	141	141	141	141	141
Gas Natural	238	238	238	284	592	592	847	1,017	1,187
Hidráulica	2,241	2,600	2,624	2,626	2,663	2,795	2,795	2,795	2,795
Reserva	55%	57%	52%	48%	40%	40%	42%	37%	36%
Demanda	2,654	2,793	2,900	2,965	3,143	3,225	3,360	3,607	3,757

Source and elaboration by OSINERGMIN
Fig. 2 – Evolution of Load and Firm Capacity by Technology

Theoretical hydrological potential

According a study developed by Technical Cooperation between the Government of the Federal Republic of Germany and the Government of Peru [3], the theoretical or raw hydrological potential of a fluvial system or basin is a measure of the total natural resources available for energy production, regardless any change coming from the works that need to be done to use this energy. By this concept, it is considered that any water flow is capable of generating electricity if there is a natural fall and with 100% efficiency, in other words, the linear theoretical hydrological potential for a segment of a river can be determined by the following expression:

$$P = 9{,}81 \times \overline{Q} \times \Delta H$$

Where:

P= linear theoretical hydrological potential $\overline{Q}$= Average water flow in the segment of the river (m^3/seg)
ΔH =Altitude difference between water surfaces at each limit of the river's segment (m)

Finally, the addition of the values of all segments results in the theoretical potential of a river and its tributaries.

For Peru, this amounts is equal to 200 000 MW, as it is resumed in the next exhibit and detailed in the Appendix A.

Basin	Area (km2)	River's length (km)	Linear theoretical potential (MW)	Specific Potential (MW/km)
Pacific	229 060	19 267	29 257	1,52
Titicaca Lake	45 953	4 023	564	0,14
Atlantic	1 023 268	58 065	176 287	3,04
Total	1 298 281	81 355	206 107	2,53

Source: Reference [3]

Fig. 3 –Theoretical Potential

One of the highlights of this information is that total mass of water in Peruvian territory is 2 044 km3 per year, with a yearly average water flow of 64 800 m3 per year. Also, the Atlantic basin represents 85.5% o the total national hydro resources, while the Pacific basin is 14.2% and Titicaca Lake only 0.3%.

Technical Potential

As opposed to the theoretical potential there is the technical useful or practical potential. This a measure of the resources that could be used by means of existing o feasible developments subject to corresponding technical or cost limitations. A particular form of the technical potential is the economic potential that takes into account developments that can be done in short or medium term under the country's economy limitations. An approximate measure oh this potential is in the order of 30% of the theoretical potential in developing countries. A more accurate assessment of this value requires the elaboration of a catalogue of hydro power stations projects that can be build as part of a generation expansion program coherent with load growth.

The criterion used in [3] was to consider in this catalogue all the projects that allowed the exploration of all of the water flows available in a basin. With the aim to identify mutually exclusive projects, optimal development chains were identified. In this way, 328 optimal development chains were identified of a total of 800 projects.

In this sight of view, the technical potential is in the order of 58, 937 MW (corresponding to the average water flow) and a total annual energy of 395 118 GWh and the number of hydropower projects already identified reached 328. In the Table of Appendix B, we show the total of the 328 projects and their location, 51 of these have capacities over 300 MW with a total 31 589 MW which accounts 54% of the total.

Potential Under Exploration

With regard to the Concessions and Authorizations regime, the Electrical Concessions Law states that electrical generation, transmission and distribution could be carried by any person or company, local or foreign, requiring to be entitled by a Concession for: i) Generation that uses hydro or geothermal resources whenever installed capacity is higher than 20 MW, ii) transmission when infrastructure affects public property and/or require imposing right of way;

and, iii) distribution aimed for Public Electricity Service when installed capacity is no more than 500 kW. In the same way, an Authorization title is required form thermal power generation and hydro or geothermal generation when installed capacity is no higher than 500 kW.

Generation, transmission or distribution of electricity that does not require Concession or Authorization titles, can be exercised freely, in compliment with technical standards and dispositions regarding the care of environment and Nation’s Cultural Heritage.

The Ministry of Energy and Mines is who, on behalf of the State, grants a Concession or Authorization Title. In accordance with this, the Ministry has established a Registry of Electrical Concessions.

The Concession for a limitless term enables the use of public property and the right to obtain the imposing of the right of way for construction and operation of power plants and related works, substations and transmission lines as well as distribution grids and substations. Temporal Concessions enables the usage of public property and the right to obtain the imposing of the right of way for the execution of studies for power plants, substations and transmission lines. Authorizations are granted only for limitless term.

The hydro power potential currently under exploration is related to a total of 125 Hydro Power Stations in operation with a total of 3 135 MW of installed capacity which accounts only 5.3% of the technical potential. It should be noted that the 15 bigger plants with capacities over 50 MW add up to 2 662 MW and represent 85% of the total (see Appendix C).

Projects Under Development

Projects for new plants and upgrades for other plants are being developed for the short term (until 2009) reaching a total of 263 MW as shown in the following exhibit.

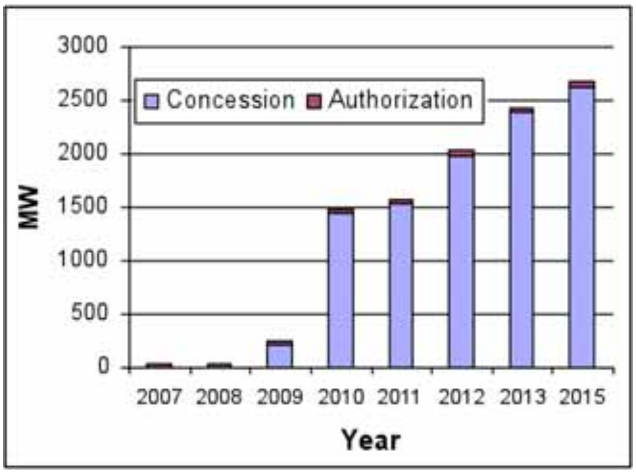
Company	Date	Station	Capacity (MW)
CAHUA	Jun-2007	Upgrade C.H. Pariac - CH 3	0,40
CAHUA	Set-2007	Upgrade C.H. Pariac - CH 2	0,40
EGENOR	Feb-2008	C.H. Carhuaquero G4	9,8
GEPSA	Abr-2008	C.H. La Joya	9,6
EGENOR	Jun-2008	C.H. Carhuaquero 5 (C.H. Caña Brava)	5,5
SINERSA	Jun-2009	C.H. Poechos II	10,0
CAHUA	Jun-2009	Upgrade C.H. Pariac - CH 5 y CH 6	7,7
CELEPSA	Nov-2009	C.H. Platanal	220,0

Source: COES - 2008

Fig. 4 – Hydropower projects under development

Portfolio of Projects

The present Concession’s potential that could be built until year 2015 is 2456 MW, while the present Authorization’s potential reaches 42 MW. The following picture shows evolution of hydropower potential, discriminating those with concessions or authorization.



Source: Ministry of Energy and Mines. Elaboration by the Authors

Fig. 5 – The Peruvian system hydro Concession’s potential

The following exhibit shows the stage of development projects with Concession and Authorization.

IT	Station	Regimen	Type	Capacity (MW)	Year	State
1	CENTAURO I Y III	Concession	Definitive	25	2010	Definite Studies
2	CHEVES	Concession	Definitive	525	2010	Preliminary Study
3	G1 EL PLATANAL	Concession	Definitive	220	2009	Under construction
4	HUANZA	Concession	Definitive	86	2010	Feasibility Studies
5	LA VIRGEN	Concession	Definitive	58	2010	Feasibility Studies
6	MARAÑÓN	Concession	Definitive	96	2011	Feasibility Studies
7	MORRO DE ARICA	Concession	Definitive	50	2010	Feasibility Studies
8	PÍAS 1	Concession	Definitive	11	2012	Pre Feasibility studies
9	PUCARÁ	Concession	Definitive	130	2010	Feasibility Studies
10	QUITARACSA I	Concession	Definitive	112	2010	Feasibility Studies
11	SAN GABÁN I	Concession	Definitive	120	2012	Preliminary Study
12	SANTA RITA	Concession	Definitive	173,5	2010	Feasibility Studies
13	TARUCANI	Concession	Definitive	49	2010	Definite Studies
14	QUIROZ VILCAZÁN	Concession	Temporal	18	2010	Pre studies
15	SAN GABAN III	Concession	Temporal	174	2012	Study
16	SANTA TERESA	Concession	Temporal	109	2013	Pre Feasibility studies
17	LLAMAC 2	Concession	Temporal	71	2012	Pre Feasibility studies
18	LLACLLA 2	Concession	Temporal	71	2012	Pre Feasibility studies
19	COPA	Concession	Temporal	92	2013	Pre Feasibility studies
20	TABLACHACA 2	Concession	Temporal	200	2013	Pre Feasibility studies
21	CHAGLLA	Concession	Temporal	240	2015	Pre Feasibility studies
22	RONCADOR	Authorization	Definitive	3,8	2006	Construction permit granted
23	CAÑA BRAVA	Authorization	Definitive	5,5	2007	Construction permit granted
24	SAN DIEGO	Authorization	Definitive	3,24	2007	Construction permit granted
25	PÁTAPO	Authorization	Definitive	1,02	2006	Construction permit granted
26	LA JOYA	Authorization	Definitive	9,6	2007	Construction permit granted
27	GRATON	Authorization	Definitive	5	2012	Construction permit granted
28	SHALI	Authorization	Definitive	8,8	2009	Stand By
29	CARHUAQUERO IV	Authorization	Definitive	5,5	2007	Stand By

Source: Ministry of Energy and Mines. Elaboration by the Authors

Fig. 6 –Stage of development of projects with Concession and Authorization

On the other hand, recently Peruvian government is supporting the development of hydropower projects not only to supply domestic market but to export to neighboring countries being Brazil the one with bigger load potential amongst them. Specifically, there are 15 projects that add up to 19 285 MW, as is detailed in the following table:

Item	**Project**	**Capacity (MW)**
1	Pongo de Manseriche	7 550
2	Rentema	1 525
3	Paquitzapango	1 379
4	Ina 200	1 355
5	Sumabeni	1 074
6	Urub 320	942
7	La Balsa	915
8	Cumba 4	825
9	Cuquipampa	800
10	Vizcatán	750
11	Tambo-Pto. Prado	620
12	Chadin 2	600
13	Chaglla	444
14	Man 270	286
15	La Guitarra	220
	Total	**19 285**

Source: Ministry of Energy and Mines: Elaboration of Executive Resumes and Study Charts of the hydropower projects with exporting to Brazil potential. Final report November 2007

Fig. 7 –Hydropower projects for exporting to Brazil

Summarizing, Peru has a hydropower potential of 58 937 MW, of which only 3 135 MW are being exploited, 263 MW of new projects are under construction to be completed by 2009. On the other hand, 29 new projects with concession that have good probabilities for being development until 2015 have been identified adding up to 2459 MW as with 15 other projects aimed to exporting electricity mainly to Brazil with a total of 19 285 MW. In the end, there are 33 801 MW of hydropower potential which have not been promoted yet.

Description	**MW**
Technical Potential	58937
Under Exploration	3135
Under Construction (until 2009))	263
Granted Concessions (with probable enter until 2015)	2453
Export projects	19285
Total Potential without promotion	**33801**

Fig. 8 –Peru’s Hydropower Potential Summary

As it shows, Peru has a reasonable potential for the development of hydropower plants. However, under the regulatory frame of the Electrical Concessions Law, no projects have been developed during last decade. This can be explained as it follows: [4]

Investor's perception is that current pricing of electricity creates incentives for thermal generation; since prices do not take in consideration that hydropower generation requires costly, long-term pre-investment studies and very high construction risks.

Hydropower projects have very long timeframes. In some cases, the maturation term could take 10 years to reach the final stages.

Water flow statistical information requires complex and costly studies[10] that private investors are not willing to pay unless the project has high probability of being profitable.

Hydropower projects must confront the cost of long transmission lines that can not be charged to end consumers via regulated transmission mark ups. Financial evaluation of this kind of projects must assume that transmission costs should be charged to generation prices[11].

In recent years, equipment and civil works costs have soared to 50 - 100 % more due to minerals high prices and the development of hydro power projects in other countries that managed to generate adequate incentives for this kind of plants.

Considering the very competitive prices of natural gas for thermal power generation, the benefits obtainable from carbon credits are insufficient to displace the first ones[12].

Long terms, paper work and restrictions imposed by the process of granting concessions, the right of use of natural resources and limited strategies to reduce to a minimum negative externalities associated with the development of hydropower plants create sunken costs that the private investor is not willing to pay

One of the major changes due to the reform recently applied to the electrical sector in Peru is the mechanism of bids called by DistCos under rules approved by the regulator. This mechanism aims to replace the administrative-way of setting prices (Busbar or node Tariffs) with a market oriented competitive process with the outcome of energy prices to be applied in the transactions between GenCos and DistCos.

In this sense, the major advantage of this new mechanism is the elimination of the regulatory risk that GenCos confront, offering great incentives no only to the participation of new agents in the market but also incentives competition between incumbent GenCos.

This bid mechanism is aimed to generate long term supply contracts (up to 10 years) between GenCos and DistCos that also will serve to reduce risk for the GenCos since they will have greater stability and predictability for their revenues.

REFERENCES

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10 River flow regimes, meteorological conditions, sediment drag.

11 Energy and capacity' prices. These prices are calculated on basis of SMRC, fuel costs, investment costs to pay for the peak load unit, respectively.

12 As rule of thumb, for and indifferent decision between a thermal p hydro power plant considering a natural gas cost of 2.00 US$/MMBTU, the investment in a hydro power project should not be higher than 1200 US$/installed kW.

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[4] M Suazo "Comentarios a la Modificación de Diversos Artículos de la Ley de Concesiones Eléctricas 25844" June 2005.
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BIOGRAPHIES

Daniel Cámac Gutiérrez has a BSc in Electrical Engineer from UNCP-Peru and MSc in Electrical Engineer from PUC-Rio. He also maintains an MBA from ESAN-Peru. He is working towards a PhD in Electrical Engineer at PUC-Rio. He joined OSINERGMIN in 2001, where he has been working in setting electrical tariffs, system planning studies and market power analysis in energy markets. Recently, he works in design the bases and rules in order to the bid process.

Raúl Bastidas Traverso has a BSc in Electrical Engineering from UNCP-Peru and complete postgraduate studies in Public Service Regulation Master at PUCP-Peru. He worked in electric transmission sector since 1990. He is working as specialist in OSINERGMIIN since 2003 his main occupation deals with de tariffs setting for electrical transmission utilities, technical analysis. He participated in activities to implement and update the regulatory framework for transmission and generation of electricity activities. He also participated in studies about planning of transmission network expansion.

María Castillo Silva Attorney titled in PUCP, studies of Post title in Energy Law in the same university, graduated in Energy Law in the UPC, with studies of tools of negotiation of Harvard – Boston 1999. She joined the ex- Electric Tariff legal Commission in 1996 and worked in the adviser area. Actually, is the Legal Adviser Department Chief of the GART of OSINERGMIN, responsible executive area that proposes tariffs of energy, applying in legal dispositions of electricity and hydrocarbons sub sectors. One of main functions is advise in legal regulatory and administrative items...

César Butrón Fernández. Has a BSc in Electromechanical Engineer from UNI - Peru and an MSc in Public Infrastructure Regulation from PUCP - Lima. He is the President of the Board of Electroperú, the second largest generator in Peru since 1996, has been member of the board and general manager of various generation, transmission and distribution companies and was involved in the design of the new legal framework for energy bid processes.

APPENDIX A.
THEORETICAL POTENCIAL

Basin	Name	Area	Long.	P.E	P.T.
Pacific	ZARUMILLA	817	129	0,13	10,0
Pacific	TUMBES	2729	236	1,18	180,5
Pacific	CHIRA	11564	1033	0,70	596,0
Pacific	PIURA	10476	720	0,29	209,0
Pacific	CASCAJAL	4147	288	0,07	21,0

Basin	Name	Area	Long.	P.E	P.T.
Pacific	OLMOS	965	91	0,24	22,0
Pacific	MOTUPE	1951	237	0,26	61,0
Pacific	LA LECHE	1578	150	0,71	107,0
Pacific	CHANCAY-LAMBAYEQUE	4906	396	1,34	531,0
Pacific	ZANA	2080	169	0,74	125,0
Pacific	CHAMAN	1248	99	0,19	19,0
Pacific	JEQUETEPEQUE	4257	408	1,70	695,0
Pacific	CHICAMA	4454	451	0,98	443,0
Pacific	MOCHE	2161	304	0,91	278,0
Pacific	VIRU	1967	225	0,67	151,0
Pacific	CHAO	1443	161	0,51	82,0
Pacific	SANTA	12479	1140	4,34	4953,0
Pacific	LACRAMARCA	685	71	0,13	9,0
Pacific	NEPENA	1885	266	0,33	87,0
Pacific	CASMA	3064	305	0,68	207,0
Pacific	CULEBRAS	671	105	0,15	16,0
Pacific	HUAAMEY	2354	191	0,88	169,0
Pacific	FORTALEZA	2342	280	0,41	114,0
Pacific	PATIVILCA	4908	514	3,26	1675,0
Pacific	SUPE	1078	114	0,68	78,0
Pacific	HUAURA	4483	360	2,95	1062,0
Pacific	CHANCAY-HUARAL	3382	243	2,37	576,0
Pacific	CHILLON	2321	211	1,57	332,0
Pacific	RIMAC	3134	298	2,98	887,0
Pacific	LURIN	1600	166	1,06	176,0
Pacific	CHILCA	798	96	0,30	29,0
Pacific	MALA	2522	236	2,23	527,0
Pacific	OMAS	1741	101	0,81	82,0
Pacific	CANETE	5981	563	3,42	1927,0
Pacific	TOPARA	489	60	0,40	24,0
Pacific	SAN JUAN	5333	310	2,50	774,0
Pacific	PISCO	4054	349	2,50	872,0
Pacific	ICA	7366	339	1,35	458,0
Pacific	GRANDE	10522	1129	0,38	424,0
Pacific	ACARI	4082	339	1,95	660,0
Pacific	YAUCA	4589	357	0,83	298,0
Pacific	CHALA	1284	161	0,26	42,0
Pacific	CHAPARRA	1387	141	0,48	67,0
Pacific	ATICO	1425	151	0,21	32,0
Pacific	CARAVELI	2009	196	0,38	75,0
Pacific	OCONA	15908	1430	2,27	3248,0
Pacific	MAJES-CAMANA	17141	1039	2,80	2910,0
Pacific	QUILCA O CHILI	13254	881	1,17	1030,0
Pacific	TAMBO	12697	919	1,64	1508,0
Pacific	OSMORE	3595	321	0,51	164,0
Pacific	LOCUMBA	5316	384	0,25	97,0

Basin	Name	Area	Long.	P.E	P.T.
Pacific	SAMA	4809	278	0,30	83,0
Pacific	CAPLINA	1629	126	0,43	54,0
Atlantic	ALTO MARAÑON	28500	1932	4,47	8636,0
Atlantic	CRISNEJAS	4660	700	0,87	606,0
Atlantic	LLAUCANO	2823	303	2,83	856,0
Atlantic	CHAMAYA	3380	197	3,70	729,0
Atlantic	HUANCABAMBA	3448	301	1,03	310,0
Atlantic	CHOTANO	1694	183	1,83	334,0
Atlantic	CHINCHIPE	7157	375	2,17	499,0
Atlantic	TABACONAS	3792	225	3,95	888,0
Atlantic	CENEPA	7360	434	0,72	313,0
Atlantic	SANTIAGO	33000	2091	2,72	3452,0
Atlantic	MARAÑON MEDIO	24225	1884	3,32	6252,0
Atlantic	MORONA	16070	830	3,11	1753,0
Atlantic	PASTAZA	40997	2692	4,07	1651,0
Atlantic	TIGRE	34120	1914	2,52	4817,0
Atlantic	BAJO MARAÑON	44730	1867	1,46	2731,0
Atlantic	UTCUBAMBA	7507	384	3,21	1232,0
Atlantic	CHIRIACO	4125	247	3,37	832,0
Atlantic	NIEVA	4330	335	0,77	258,0
Atlantic	HUALLAGA SUP	75130	4324	6,10	26362,0
Atlantic	HUALLAGA INF	17433	1158	0,79	917,0
Atlantic	URUBAMBA	52041	3536	3,00	10591,0
Atlantic	VILCANOTA	7272	682	1,85	1265,0
Atlantic	APURIMAC SUP	13538	1522	1,24	1884,0
Atlantic	SANTO TOMAS	3072	372	1,59	593,0
Atlantic	PUNANQUI	793	79	1,25	99,0
Atlantic	VILCABAMBA	2575	227	2,50	568,0
Atlantic	PACHACHACA	5608	427	3,15	1347,0
Atlantic	APURIMAC INF	15357	1057	11,96	12645,0
Atlantic	PAMPAS	23742	1446	3,04	4403,0
Atlantic	MANTARO SUP	9190	917	0,74	683,0
Atlantic	MANTARO MEO	18580	1207	3,70	4469,0
Atlantic	MANTARO INF	6823	555	9,06	5026,0
Atlantic	PACHITEA	26980	1355	4,54	6146,0
Atlantic	AGUAYTIA	11540	652	1,66	1085,0
Atlantic	ENE	7576	451	4,47	2015,0
Atlantic	TAMBO	5171	293	7,26	2127,0
Atlantic	UCAYALI	111928	4667	3,04	14203,0
Atlantic	PERENE	20552	1146	5,90	6760,0
Atlantic	AMAZONAS	57461	3068	1,89	5795,0

Basin	Name	Area	Long.	P.E	P.T.
Atlantic	NAPO	44822	2918	1,08	3142,0
Atlantic	PUTUMAYO	40138	2130	0,35	423,0
Atlantic	YAVARI	59170	1875	3,77	6305,0
Atlantic	PURUS	16900	825	0,33	269,0
Atlantic	MADRE DE DIOS	37600	1005	8,79	8837,0
Atlantic	INAMBARI	17376	1552	6,51	10110,0
Atlantic	TAMBOPATA	14710	470	2,53	1187,0
Atlantic	ACRE	3230	170	0,21	18,0
Atlantic	LAS PIEDRAS	15550	520	1,17	609,0
Atlantic	YURUA	9492	565	0,47	254,5
La. Titicaca	SUCHES	1453	168	0,20	24,0
La. Titicaca	HUANCANE	3557	437	0,15	64,0
La. Titicaca	RAMIS	14444	1426	0,16	228,0
La. Titicaca	COATA	4757	557	0,27	152,0
La. Titicaca	ILLPA	1165	181	0,08	14,0
La. Titicaca	lLAVE	7977	767	0,08	62,0
La. Titicaca	MAURE	1687	227	0,05	12,0
La. Titicaca	ZAPATILLA	474	80	0,02	2,0
La. Titicaca	CCALLACCANE	1299	180	0,03	6,0
La. Titicaca	LAGO TITICACA	9140	0	0,00	0,0
		1 298 281	81 355		206 107,0

Source: Ref. [3]
Legend: captation area in square km
Long. = Total length of the considered rivers
P.E. = Specific Potential (P.T. / Long.)
P.T. = Net Theoretical Potential in Peruvian soil.

APPENDIX B.
TECHNICAL POTENTIAL

Order	Project	Power (MW)	Energy (GWH)
1	ENE40	2 227	18 712
2	MARA570	2 009	16 796
3	INA200	1 355	10 531
4	PAM240	1 329	9 641
5	TAM40	1 287	8 325
6	MARA500	1 181	9 141
7	HUAL210	1 095	6 805
8	URUB320	941	7 243
9	APUR737	905	6 442
10	VNOTA295	850	7 308
11	HUAL190	844	5 993
12	HUAL170	841	7 023
13	HUAL90	801	5 657
14	MARA440	629	4 534
15	APUR720	612	3 808
16	APUR680	612	3 817

Order	Project	Power (MW)	Energy (GWH)
17	TAM60	580	3 749
18	MARA400	570	3 653
19	MAY065	562	3 498
20	PACHA70	539	3 362
21	URUB190	482	3 421
22	MARA460	477	3 370
23	SGAB30	473	2 958
24	PAM180	453	3 698
25	MAN250	434	2 640
26	MAN290	423	2 739
27	APUR810	420	2 613
28	APUR670	419	2 621
29	APUR660	418	2 753
30	INA90	402	2 703
31	URUB90	399	2 456
32	URUB88	399	2 386
33	PER70	396	3 088
34	SGAB10	391	2 088
35	POZ30	390	2 762
36	LUCUM10	368	3 219
37	MAN340	360	2 047
38	PACHA30	356	2 597
39	MAY070	356	2 215
40	HUABA40	354	2 427
41	HUAL120	350	2 166
42	SAMA10	348	2 736
43	SANTA120	345	2 199
44	TAMBO70	342	2 385
45	MARA320	339	2 154
46	MARA350	335	2 293
47	EULA10	331	2 501
48	MAN310	325	1 654
49	APUR765	317	1 968
50	MAN260	315	1 917
51	APUR250	306	1 998
52	OTRAS	27 347	170 313
	TOTAL	**58 937**	**395 118**

Source: Ref. [3]

APPENDIX C
HYDROPOWER POTENTIAL UNDER EXPLORATION

Item	Central Hydroelectric	Location	Power (MW)
Greater than de 50 MW			
1	MANTARO	HUANCAVELICA	798,0
2	HUINCO	LIMA	258,4
3	CAÑON DEL PATO	ANCASH	256,6
4	RESTITUCION	HUANCAVELICA	210,4
5	CHIMAY	JUNÍN	149,0
6	CHARCANI V	AREQUIPA	135,0
7	YUNCAN	PASCO	130,0
8	MATUCANA	LIMA	120,0
9	SAN GABÁN II	PUNO	110,0

Item	**Central Hydroelectric**	**Location**	**Power (MW)**
10	YAUPI	JUNIN y PASCO	108,0
11	MACHUPICCHU	CUSCO	107,2
12	CARHUAQUERO	CAJAMARCA	95,0
13	CALLAHUANCA	LIMA	67,6
14	MOYOPAMPA	LIMA	63,0
15	MALPASO	JUNIN y PASCO	54,4
Greater than 10 MW and less than 50 MW			
1	YANANGO	JUNÍN	40,5
2	CAHUA	LIMA y ANCASH	39,6
3	GALLITO CIEGO	CAJAMARCA	34,0
4	HUAMPANI	LIMA	31,4
5	ARICOTA I	TACNA	23,8
6	HUANCHOR	LIMA	16,2
7	POECHOS I	PIURA	15,4
8	CHARCANI IV	AREQUIPA	14,4
9	CURUMUY	PIURA	12,0
10	PACHACHACA	JUNIN	12,0
11	ARICOTA II	TACNA	11,9
Less than 10 MW			
1	Others	-	221,9
TOTAL Power of Hydropower - 2007			3 135,5

Source: Ref. [4]

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