South American Reform Lessons



Twenty Years of Restructuring and Reform in Argentina, Brazil, and Chile

by Hugh Rudnick, Luiz Augusto Barroso, Carlos Skerk, and Adrián Blanco

SOUTH AMERICA IS FACING IMPORTANT CHALLENGES IN ELECTRICITY SUPPLY to allow for future economic development. Current electricity market designs are being reviewed to avoid supply difficulties and couple the existing outlook of primary energy resources and the investment interest by the private sector. Examples of these developments are the giant Brazil, the economically troubled Argentina, and the pioneer of electricity reform, Chile. While Brazil and Chile progress into a second stage of reforms with public power purchase agreement (PPA) auctions in a private environment, Argentina makes a backward movement to significant state intervention, as in the times previous to reform. With these diverging approaches, their primary challenge is to ensure sufficient capacity and investment to reliably serve their growing economies.

1540-7977/05/\$20.00©2005 IEEE

Economic Growth and Energy Supply

All developing countries require high investments to respond to a continuous increase in electricity demand, directly linked to economic growth. Only South America requires about US\$70 billion of investment in the power sector in the next ten years. Because electricity consumption per capita is relatively small, it is not surprising that while industrialized countries have had an average annual growth of electricity consumption between 1-2%, the Latin American subcontinent has experienced an average growth of over 5% during the last decade. There are 253,000 MW installed in Latin America in 2003, with Brazil dominating with 34%, followed by Mexico with 19.5%, Argentina with 12%, and Venezuela with 8%. Electric systems in the region are often of a radial nature, with weakly meshed networks and only a few incipient international interconnections. Hydro generation is the dominant supply source in the region with a share



figure 1. Sources of electricity generation (2003).



figure 2. Electricity markets in Latin America.

of 52% of the total installed capacity (68% as far as energy generation; see Figure 1) and often with plants within complex cascades over several river basins with diverse hydrological patterns.

A profound transformation took place in the Latin America electricity supply industry organization in the 1990s. Essentially three electricity markets developed in the region: the Central American market, the Andean market, and the Common Market of the Southern Cone (Mercosur); see Figure 2. The one with the largest per capita energy consumption is Mercosur, an integrated market of 230 million people over an area of 12 million km², comprising the countries of Argentina, Chile, and Brazil plus Paraguay, Uruguay, and Bolivia.

Market Reforms in South America

The design of a power market for any country has, as its main objective, inducing a reliable and efficient energy supply, translated into adequate tariffs. Although differing in the degrees and details of implementation, the power sector reform in the South American countries shared a common two-stage process.

The first stage of the power sector reform in the region was based on purely market mechanisms to achieve these goals. In particular, the key driver for decisions were the spot prices in the short-term wholesale energy market, which would then be used to provide the correct economic signal for the entrance of new generation; if there is an imbalance between supply and demand, then these prices should increase and thus create incentives for the construction of new plants. The market risk resulting from the spot price volatility would be managed through purely riskmanagement instruments, such as forward contracts, options, etc. The only nonfinancial instrument would be the capacity fee, whose main objective would be to assure the remuneration of peaking units and reserve generation. With those market mechanisms in place, state-owned utilities were privatized and consumer choice was introduced. Most South American countries reformed their power sectors based on these principles, obviously with differences among the implementation details. The accumulated experience so far has shown many positive aspects, such as a greater efficiency of the private utilities, the positive effect of eligible consumers as a benchmark, and the transparency brought by the regulatory agencies, which provide confidence for investors.

On the other hand, some important difficulties have appeared, in particular with respect to the security of supply. A recent evaluation carried out by the World Bank shows that about 20 countries around the world had energy supply difficulties (power crises, rationings) over the last seven years. Argentina, Brazil, and Chile are among those countries.

A first reason for these supply difficulties is that the economic signal provided by the spot market is too volatile to correctly indicate and stimulate the entrance of new capacity. This is especially true for the countries with a strong hydro-share, where the occurrence of favorable hydro conditions can drive spot prices down, even if there are structural problems with supply. It has also been observed that in hydro systems the spot price increases substantially only when the system is "too close" to a power crisis, when there is no more time to make investments. A second reason is the combination of a strong demand growth with a large volatility in the growth rates ("stop and go" economies that can be heavily affected by international crisis). This makes the generation activity very risky, making the closing of "project finance" for new projects difficult and constraining the entrance of new capacity.

Due to these difficulties, many countries in the region have made adjustments in their regulatory frameworks over the last years, aiming to keep the positive aspects of the first stage of their reforms but correcting the issues that have not worked as expected.

The characteristics of this "second stage" include: 1) the key point of the competition is not in the spot market but in the contracts with the demands resulting in the entrance of new capacity (the so-called competition "for the market," instead of "in the market") and 2) the backing of these contracts by physical generation capacity. These changes are being observed in the region (Brazil, Chile, Colombia,

Peru, and Ecuador) and also in other areas, such as in the recent Federal Energy Regulatory Commission/European Union directives in the United States and Europe, where the agents should show mid- to long-term supply coverage to meet future demand. The next sections described how these challenges in electricity supply are being faced by Brazil, Argentina, and Chile.

Brazil: Ensuring Investment Through Public Auctions

Energy Resources

Brazil has an installed capacity of 91 GW (2005), where hydro generation accounts for 85%, for a peak and average demand near 54 GW and 44 GW, respectively. The hydro system is composed of

several large reservoirs, capable of multiyear regulation (up to five years), organized in a complex topology over several basins. Thermal generation includes nuclear, natural gas, coal, and diesel plants. The country is fully interconnected at the bulk power level by an 80,000-km meshed high-voltage transmission network (Figure 3), with voltages ranging from 230–765 kV ac, plus two 600-kV dc links connecting the binational Itaipu power plant (14,000 MW) to the main grid. The main direct international interconnections are the back-to-back links with Argentina (2,200 MW) plus some smaller interconnections with Uruguay (50 MW) and Venezuela (200 MW).

The country still has an undeveloped hydro potential of 145,000 MW, 70% of which is located in the environmentally sensitive Amazon region. In the future, the energy matrix composition should become more diversified, including cogeneration (gas and biomass), local coal, natural gas (both from local production and imported from existing pipelines with Argentina and Bolivia), and renewables (recent regulations provide incentives for wind, biomass, and small hydros).

Market Reform

Following the trend observed in Latin America, Brazil started its power sector reform in 1996. Similarly to many other



figure 3. Brazil's physical system. (Source: ONS, www.ons.org.br.)

The first stage of the power sector reform in the region was based on purely market mechanisms to achieve these goals.

countries, the new rules were designed to encourage competition in generation and retailing, while transmission and distribution remained regulated activities with provisions for open access. Other reform ingredients included the establishment of an independent system operator, a wholesale energy market, and a regulatory agency as well as the privatization of most distribution utilities and of transmission expansion. Political opposition interrupted the privatization of generation companies. About 10,000 MW of new hydro concessions were auctioned off, with a strong participation of private agents. Construction costs and times were reduced by 40%. The reform was then stalled by political difficulties, and in 2001 it was disrupted by a severe energy crisis. During nine consecutive months in 2001 and 2002, rationing was imposed to all classes of consumers in regions corresponding to 80% of consumption, in order to reduce total load by 20%. In 2004, a revised power sector model was launched.

Because system dispatch is cost based, there are no "real" short-term prices, based on the equilibrium between supply and demand bids. Short-run marginal costs, calculated from the Lagrange multipliers of the stochastic dispatch model are used as the clearing prices in the wholesale energy market. Given that the energy production of each generator and the spot price are both determined by a computational model, the market settlement is an accounting procedure (clearing of net difference between the energy produced and the energy volumes registered in financial forward contracts).

Competitive Generation Expansion

Drivers and Constraints

The need for expansion to assure supply adequacy was one of the basic reasons for the power sector reform in Brazil: the gov-

> ernment's resources were not sufficient to fund the investments in new generation capacity that were required to match predicted load growth, which runs at about 4,000 MW per year, requiring around US\$3 billion/year of investments in generation. On the other hand, the country has the combination of a strong growth in the electricity demand but with a high degree of uncertainty on the growth rates (dependent, for example, on the conditions for the sustained economic growth of the country).

> Spot Price Signals Are Inadequate In theory, short-term spot prices should provide the correct economic signal for the entrance of new generation. In the

Brazilian system, however, spot prices do not provide that economic signal, mostly because they are highly volatile: they may be very low for several years and then increase sharply for a few months before going back to the "normal" levels. This pattern is illustrated in Figure 4, which shows the observed short-run marginal costs in the Brazilian Southeast zone from 1993 to 1997. We see in the figure that the system's marginal cost was close to zero in 36 out of the 56 months, and the longest low-price period lasted for almost two years. The reason for this behavior is that predominantly hydro systems are designed to ensure load supply under



Centralized Cost-Based Dispatch

In the Brazilian power system, both generation and transmission resources are centrally dispatched on a least-cost basis by the system operator, i.e., there are no price bids from generators or loads. Hydro plants are dispatched with basis on their expected opportunity costs ("water values"), which are computed by a multistage stochastic optimization model that takes into account a detailed representation of hydro plant operation and inflow uncertainties. Bilateral contracts or other commercial arrangements are not considered in the centralized dispatch.



adverse hydrological conditions, which occur very infrequently. Hence, most of the time there are temporary energy surpluses, which result in very low marginal costs. In turn, if a very dry period occurs, spot prices may increase sharply and even reach the system rationing cost. Due to reservoir storage capacity, these low-cost periods not only occur frequently but usually last for a long time, separated by higher-cost periods caused by droughts.

This situation holds true even when the probability of rationing is high. Figure 5 shows the evolution of marginal costs and stored energy for the southeast zone in Brazil



figure 5. Recent short-run marginal costs, Brazilian Reais(R)/MWh, and storage levels. Exchange rate (March 2004): R= US\$2.71. (Source: CCEE, http://www.ccee.org.br.)

before, during, and after the 2001–2002 supply crisis. Notice that shortly before rationing started (June 2001), prices still did not reflect the scarcity of energy. After the rationing was over (February 2002), prices immediately dropped to values close to US\$6/MWh and have been very low ever since. One of the consequences of this "feast or famine" price characteristic is a difficulty for investors to know the right time to build new plants, arrange for project financing, and start construction, and it increases the risks run by merchant generation.

Mandatory Forward Contracts and Supply Adequacy

A two-step system based on mandatory bilateral contracts has been introduced as an incentive to the entrance of new generation: 1) all loads, captive consumers from distribution companies (DISCOs) and eligible consumers, are required to be 100% covered by PPAs; 2) although supply contracts are financial forward contracts, they must be backed by physical production capacity ("ballast") on the part of the seller, which is the "firm energy" in case of hydro plants.

The rationale of this scheme is to rely on contracts as inducers of system expansion. The need to sign new contracts to cover additional load is the driver for the entrance of new capacity (contracts require physical backing and provide investors with a stable income source that is necessary for financing).

The contract obligation scheme (with physical backing) was coupled with the use of PPAs auctions as the main mechanisms for contracting in a "second stage" of the Brazilian reform, thus forming the backbone to induce supply adequacy and long-run efficiency.

Contracting Obligations Through Public Auctions

In order to stimulate efficient contracting mechanisms for captive consumers, DISCOs (70% of the market) can only contract energy through regulated public auctions. Eligible consumers' contracting can additionally be done through bilateral negotiation. There are two main types of auction: "existing energy" (coverage of the existing load) and "new energy" (construction of new capacity to cover load increase) to couple these with demand uncertainty, these auctions were split in others with particular characteristics. They will be discussed next.

(Re-) Contracting Existing Capacity:

Existing Energy Auction

Existing energy (EE) purchase auctions are carried out yearly. Five- to 15-year PPAs can be offered, to be delivered the following year (contract renewal). The criterion for contracting in auctions is the smallest tariff. DISCOs are responsible for deciding how much energy they wish to contract and contract costs can be passed through to customers up to a reference price. Additionally, an "adjustment" auction (short-term contracts are offered) is carried out up to four times a year for energy delivery within the same year and is intended to "fine tune" the match between contracted supply and load.

Contracting New Capacity: New Energy Auction

The "new energy" (NE) contracts complement the EE contracts in order to cover 100% of the load. Every year, two types of NE auctions are carried out.

- Main auction: offers long-term bilateral contracts for new capacity, which will enter operation in five years' time. The idea is that this contract will allow the investor to obtain the project finance and have enough time to build the plant.
- ✓ Complementary auction: also offers long-term bilateral contracts for new capacity. In this case, however, the plants should enter operation in three years' time. This auction complements the main auction carried out two years earlier because "now" there is less uncertainty about future load growth. This "two-stage" auction process is a strategy for dealing with load growth uncertainty.



figure 6. Argentina: installed power capacity versus peak load. (Source: Mercados Energeticos, based on data published by CAMMESA.)

Yearly pass-through (reference) prices are determined by a weighted average of total amounts and prices of these two auctions.

NE and EE Auction Procedures

Each NE or EE auction is carried out jointly by all DISCOs: each utility declares the energy demand it wishes to contract. The auction announcement then calls for offers that will cover the total demand (sum of all declarations).

For the EE auction, overall, each participant presents an energy price/quantity bid, which are ranked by increasing price until total demand is met. All quantity bids should be "anchored" by physical generation capacity.

For the NE auction, there is initially a "menu" of new generation capacity options (new hydro projects, with pregranted environmental licenses). Investors are encouraged to add other projects, such as thermal plants, international interconnections, etc. Participants are then asked for a fixed remuneration (US\$/year) for each of the projects of their interest. This remuneration is divided by the project's firm energy (MWh/year), which is known from the auction announcement, thus resulting in a US\$/MWh energy price bid of each investor for each project; these are ranked by increasing value until total demand is met.

Contracting Scheme

Since the contracting is carried out "jointly," each winner of a NE or EE auction will sign cross-contracts with each DISCO participating in the auction. The energy amount of each contract is proportional to the utility's declared demand, and the total contracted quantity for each generator matches its

offered quantity (EE auction) or the project's firm energy (NE project).

Also, the EE contracted amount can be reduced at any time to match the distribution utilities' load reduction in case a qualified captive consumer becomes a free consumer. Finally, the EE contracted amount can be reduced, at the utilities' discretion, up to 4% in each year to make up for demand uncertainty. In other words, different from the NE contracts, which can be seen as standard financial forward contracts, the EE contracts are more similar to financial put options.

Example of Auctions

A special EE transition auction was carried out in December 2004. This auction was intended to jumpstart the model and to absorb uncontracted existing energy with a set of eight-year PPA contracts starting in 2005, 2006, and 2007. The auction had 15 generation bidders, totaling 26,000 average MW (avgMW), about

50% of the Brazil's generation market, and 34 buyers (DISCOs). A total of 17,000 avgMW (about 31,000 MW of peak capacity) were negotiated, in a transaction of near US\$27 billion. The size and importance of this auction have transformed it to a key landmark for the Brazilian power sector, calling for the attention of many other electricity sectors worldwide. The cross-contracts awarded will be the same as those of the regular EE auctions that were described previously. Another special EE auction (for energy delivery in 2008–2009) took place in early April and the first NE auctions are scheduled for 2005. Regular auctions will start in 2006.

Argentina: Successful Reform Clogged by Government Intervention

The Energy Market and Resources

Argentina currently has 23,000 MW of installed power

capacity for a peak load near 15,000 MW and an additional 2,200 MW of firm exportations committed to Brazil should be added. Domestic natural gas demand averaged 90 million m^3/day in 2004, while exportations represented near 25 million m^3/day extra. Roughly 50% of the total energy requirements are covered by natural gas.

Although the country was completely energy self-supplied until 2004, the hydrocarbons reserves horizon was significantly reduced in the last years, mainly due to small investment in exploration. Natural gas reserves have now a horizon near 13 years, versus 20 years in 1999. Oil reserves present a similar but smoother trend: the current horizon is near 12 years.

Alternative energy resources to natural gas for power generation include potential hydro developments mainly concentrated in plain rivers, which imply high investment requirements. Use of other energy resources is limited. Historically, coal represented a small proportion of energy balance, while two nuclear power plants totaling 1,000 MW were developed in the 1970s as part of a more comprehensive plan that was later stopped. Finalization of Atucha II, the third nuclear power plant, was repeatedin their concession areas, with the only exception of electricity transmission expansions, for which an innovative scheme based on market participants' decisions was adopted. Production was completely deregulated, allowing the entry of private companies in oil and gas exploration and production as well in electricity generation. Oil sector reform based on a new Hydrocarbons Act also included the privatization of the public company YPF during 1992 (which had the monopoly on upstream activities) and the deregulation of retail fuel prices.

The performance of the Argentinean energy sector after reform was largely reported to be successful and was often



figure 7. Argentina: performance on natural gas E&P. (Source: Annual Report on Hydrocarbons Reserves 2003—Energy Secretariat.)

ly discarded because of its higher cost and old technology. Thus, nuclear capacity represents less than 5% of current total installed capacity.

Reforms in the 1990s

At the beginning of the 1990s, Argentina reformed its energy sector as part of a wider economic reform whose main aim was the implementation of a fixed currency exchange rate regime that tied local currency, the peso, to the U.S. dollar at a one-to-one ratio, combined with a free regime of importation and exportation of capital.

The inefficient performance of vertically integrated state-owned utilities during the previous decades led to an integral transformation of the energy sector. This process included the implementation of a completely new regulatory framework established by both the Electricity and the Natural Gas acts, which were passed in 1991 and 1992, respectively. State-owned utilities were vertically and horizontally unbundled and further privatized or given in concessions. Wholesale markets for natural gas and electricity based on private participation were implemented. Transportation and distribution largely remained as regulated monopolies withcited as a model of deregulation. In power generation, Argentina developed one of the most competitive markets worldwide. Wholesale electricity prices decreased from near US 5 cents/kWh in 1992 to US 3 cents/kWh in 1994 and less than US 2.5 cents/kWh in 1997, while domestic consumption grew at an average annual rate of 5.7% between 1992 and 2000, and two private interconnectors of 1,000 MW each were built to export electricity to Brazil. An increase of energy exports also included oil and gas. The country stopped importations of gas from Bolivia in 1994 while it started exportations to Chile and Brazil.

Thus, Argentina became the benchmark for successful deregulation processes worldwide. This rosy situation worsened and decayed under a severe economic crisis that affected all the country's economy sectors at the end of 2001.

The Crisis

After nearly ten years of a fixed currency exchange-rate regime, Argentina faced a severe political and economic crisis at the end of 2001. President De la Rua resigned on 20 December 2001. Within the next ten days it defaulted on its international debts. On 6 January 2002 the congress passed a

Power sector reform has shown many positive aspects, such as a greater efficiency of the private utilities and the transparency brought by the regulatory agencies.

special law that gave "emergency" status to the economy and abolished the fixed currency exchange regime. Since most of the public and private contracts signed during the last decade were at prices and/or tariffs nominated in U.S. dollars, this law established the legal basis for unilateral government intervention on such prices, including tariffs of regulated activities. These actions further motivated foreign investors to litigate against the Argentine government on international institutions like ICSID (the International Centre for Settlement of Investment Disputes) within the World Bank Group.

To meet the economic crisis, the peso was allowed to float. Within the first six months of 2002 it had fallen from parity with the U.S. dollar to 3.6 pesos/US\$1, although several months later it stabilized around 3 pesos/US\$1 with some intervention by the government in order to avoid a higher appreciation of the peso.

Energy Policy After the Crisis

Under the umbrella set by the Emergency Act passed in early 2002, which is still in force, the government made several decisions regarding the energy sector. It aimed to

- minimize the devaluation effects on end users' prices. In practice this meant frozen tariffs in the case of gas and electricity and the implementation of withholding taxes on exports, which reduced the market reference price for oil and gas exporters in order to avoid increasing domestic prices and, at the same time, increase government income.
- guarantee end users' supply, ensuring the coverage of operational costs to existing producers but not fixed costs recovery and promoting new expansions, most of them still in project status.

Frozen tariffs of regulated activities were implemented subject to future renegotiation of concession contracts, which in practice has not happened yet.

Consequently, the devaluation augmented the relative competitiveness of the Argentine economy with respect to the rest of the world. Local industry benefited from the frozen tariffs of gas and electricity and the distorted oilderivatives prices.

An agreement between natural gas producers and the government was signed in 2004. The latter committed to increase regulated tariffs to industrial customers in order to allow a gradual recovery of natural gas prices. Wellhead prices in the Neuquina basin had decreased from US\$1.40/MBtu (million Btu) in 2001 to US\$0.40/MBtu in 2002. The energy sector, with frozen or distorted prices, would undoubtedly contribute to financing the local industry's higher competitiveness in the postcrisis years, in what seems to have been a political decision.

Consequences of the Postcrisis Policy and Later Developments

The energy sector faced, and still faces today, an economic long-run mismatch between what the economy needs from the energy industry and what this industry can offer to the economy under the current "relative prices scenario." In practice, this meant a lack of investments in all energy subsectors since the end of 2001. Consequently, domestic demand growth was gradually absorbing installed capacity, including those investments originally committed to exportations, because the horizon of hydrocarbons reserves was significantly reduced, particularly on natural gas. Figures 6 and 7 illustrate these effects.

These facts were evidenced in April 2004, when the government announced reductions on natural gas exports to Chile in order to avoid curtailments on domestic demand. The consequences of electricity exportations to Brazil are still unknown since exportations contracts roughly have the characteristic of an option for Brazilian demand; while electricity prices in Brazil are lower than the price of Argentine energy, which works as a strike price, interconnectors are not dispatched. Given the fact that the Brazilian power market has had lower prices since 2002, Argentine options have not been significantly exercised. In case they are in the future, similar restrictions to those applied to gas exports to Chile should not be discarded.

But restrictions to exports were not enough to supply the domestic energy demand. In view of this situation, the government restarted permanent importations of natural gas from Bolivia in 2004 as well as occasionally importing electricity from Brazil. In addition, significant quantities of fuel oil and diesel were imported from Venezuela during 2004 in order to ensure full fuel supply for thermal power plants in case natural gas was not available.

In mid-2003, the government jointly with private Argentine companies announced the construction of a new pipeline from Bolivia to Buenos Aires, which would allow an increase of natural gas offered by 20 million m³/day. This project was recently discarded in light of Bolivia's current, severe institutional and political crisis.

Frozen tariffs and distorted prices blocked most of the investment recovery for those companies existing at the time the crisis started. In the particular case of the power market, the measures adopted led to a significant imbalance between what the demand paid and what generators had to receive, which resulted in a significant credit requested from generators. The government proposed to swap such credits with shares of a new company to be created for building and operating a new power plant.

It should be noted that all the described actions, most included in the "Energy Plan 2004–2008" published by the government, were oriented to ensure full supply of future energy demand, reducing the expected average total cost by

allowing special tariffs for them and, simultaneously, avoiding the recovery of "old" investment costs by private investors. More than 4,000 MW of new combined-cycle thermal plants were installed in Argentina between 1997 and 2001. Investors questioned the fact that these plants were considered "old" investments less than five years after they were installed.

The Government as a Leader in Energy Development

A new state-owned company promoted by the government, Energía Argentina Sociedad Anonima (ENARSA), was created in October 2004. The primary initial assets of ENARSA were full exploration and exploitation rights of most oil in offshore areas, but its business scope covers all energy-related activities. It is argued in Argentina that the withdrawal of the government from the energy sector during the 1990s was excessive, and, consequently, a

more significant presence is now required. However, the problem arises that the assumed optimal way to achieve such presence is through a company that, in theory, is able to develop any energy business, but in practice will compete with the private sector under rules that are completely unkown by that sector. In addition the unknown rules could be arbitrarily changed in the future by the government itself.

The government said that ENARSA will allow them to follow what happens in the energy sector "from inside" and, consequently, evaluate whether the private energy companies' behavior is adequate or not. On the other side, many private companies see ENARSA as a tool by which the government may press them to agree to conditions which otherwise would not be accepted. An agreement signed between ENARSA and Petróleos de Venezuela Sociedad Anónima (PDVSA) for acquiring a retail network of gas stations currently owned by the Dutch-British company Shell increased this perception in the private sector, since this is part of a wider strategic agreement between Argentinean and Venezuelan governments on energy matters that gives another dimension to the ENARSA's threat.

Domestic Problems Dominate the Energy Agenda

The energy plan presented by the government just seems to be a palliative for the expected consequences of a lack of investments for about four years, rather than a strategic positioning of the country for possible complex international scenarios. Recent history seems to show a country that, worried by its self-created problems, perhaps has not given adequate importance in the last years to the development of its own energy resources as a strategic positioning of the country



figure 8. Natural gas exports from Argentina to Chile. (Source: Systep Ingeniería y Diseños.)

towards the complex possible international scenarios. This could represent a high cost for the country in the next years, but nothing indicates that this situation can be reversed in the near future.

Chile: The Difficulties of Modernizing the Reform Process

The Chilean power sector, which started a deregulation process back in 1982, has been another example in the region of sound sector reforms that have kept private power investment flowing while reducing prices of electricity. The main difficulty in Chile has been to modernize its original, outdated reform. The power sector has experienced several crises over its development that have revealed the weaknesses of its market model. The most recent crisis started when, as indicated before, the Argentinean government started facing problems with its gas supply and in April 2004 decided to reduce gas exports to Chile.

Chile, with 12,000 MW installed capacity in its two main interconnected systems, is a country with limited energy resources other than its hydro reserves in the Andes The energy sector still faces an economic long-run mismatch between what the economy needs from the energy industry and what this industry can offer to the economy.

Mountains. Its own oil only provides less than 10% of the country's needs, while its coal is of poor quality so imported coal must be used for electric generation. Hydroelectric generation has been developed using most of the low-cost resources in the central part of the country; remaining significant reserves are over 2,000 km south of the main load. Argentinean natural gas arose as an attractive, abundant, cheap alternative, and an energy integration protocol was signed in 1995 with the neighboring country. Under that protocol, both governments agreed to establish the necessary regulations to allow freedom of trade, export, import, and transportation of natural gas. Private investors were strongly behind the process and invested heavily in several pipelines that crossed the Andes and defined an energy supply path that would rely heavily on the efficient combined-cycle generation plant technologies. The protocol worked very well, and Chile fully relied on Argentina to provide the necessary energy required to sustain its important economic growth. Gas exports grew steadily through several pipelines (Figure 8). The petrochemical industry and the thermoelectric generation became the main users of natural gas. The arrival of this cheap fuel and the efficient generation technologies meant a significant reduction in the electricity prices in the main interconnected systems.

Looking for Market Alternatives to Face the Crisis

The crisis brought by the reduction of Argentinean gas left Chile with no alternatives. Its neighbor Bolivia has significant natural gas resources, and it is increasing exports to Brazil and Argentina. However, given its long-term border disputes with Chile (Bolivia lost its access to the Pacific in a 19th century war with Chile), it denies the fuel to Chile. Peruvian gas is not yet an alternative, given the distance from the Camisea gas fields to the main consumption centers in Chile.

Chile was not prepared for the surfacing conditions. As a demonstration, the National Energy Commission in its indicative plan of April 2004, projected the building of seven combined-cycle natural gas plants in the next ten years, all fed by pipelines from Argentina. Mainly expansions of existing electric transmission corridors were included in that plan. Major new hydro plants and interconnections with other systems were postponed until 2010 or later, and gas continued to be the major driver of expansion in a market with demand growing around 7% a year. With the crisis developing, the October 2004 indicative plan introduced radical changes to the government view of ener-

gy supply expansion. Only one combined-cycle plant based on Argentinean gas was considered. The government decided to bet on liquefied natural gas (LNG) as the alternative and defined a project to build the necessary installations to import it from abroad (Indonesia, Australia, and Algeria being supply alternatives).

But in the deregulated, privatized Chilean power market, where private capital is the one making investment decisions, there is little space for the government to act, unless changes of laws are introduced. The electricity price scheme relies essentially on market competitive forces, with only part of it, the prices for small consumers (under 500 kW), being regulated by the government. At the end, it is the cost of different generation technologies that will drive development. And the comparison has to be centered on the particular geographic conditions and infrastructure development of the country. In the Chilean investment environment (with the local cost of capital taken into consideration), LNG combined-cycle plants could compete with circulating fluidizedbed boilers fueled by coal.

However, an essential question is troubling investors, what if gas supply from Argentina returns to normal? If a decision is made, for example, to contract LNG, and cheaper natural gas starts reflowing without restrictions from Argentina, it is not clear who will make a loss of unused LNG. High financial exposures may arise depending on decisions made. As indicated, in a deregulated environment, where private investors are the ones that decide expansion, the government is uneasy when faced with an uncertain energy supply that may seriously hurt economic development. The country is returning to high economic growth rates but not enough to solve basic problems such as unemployment and highly unequal income distribution. Therefore, nobody wants energy deficits to shadow economic development.

Thus, the government has been looking for alternatives. Capacity payment regulations are being modified to better take into account unreliable gas supply. A gas "drought" concept was introduced that derates combined cycle plants that do not have alternative fuel arrangements and, therefore, reduces their capacity payments. A law reform has been proposed to make significant changes in the price system, along the lines of the auctions previously described for Brazil. The proposal sets aside the government regulated price for small consumers (under 500 kW) that is determined every six months and follows the spot price evolution, with all the uncertainty of that evolution. Prices will in the future be

The primary challenge for South American countries is to ensure sufficient capacity and investment to serve reliably their growing economies.

determined essentially by the results of auctions led by DISCOs. Private investors will therefore have 15-year contracts with a fixed price (indexed to inflation) that will make it feasible to invest in alternative technologies, without the phantom of the return of Argentinean gas.

Another measure being considered is to limit by law the dependence on foreign fuels to a certain percentage of national consumption; the idea is that the imports from a particular country shall not exceed a certain value (a similar concept is used in Spain). The idea is not to impact present combined-cycle plants using Argentinean gas, but limit investment in new ones. Critics of this alternative argue it represents a state intervention that will imply higher longterm energy costs for the country as a whole.

Challenges

The primary challenge for South American countries is to ensure sufficient capacity and investment to serve reliably their growing economies. Although they are converging due to the need of a "second stage" of measures to reconcile competition in generation with a guarantee of adequate supply, Brazil, Chile, and Argentina also have their individual energy agendas. Brazil has recognized that the key point of competition is not in the spot market but for the contracts with loads that result in the entrance of new capacity, which in turn has led to the implementation a portfolio of PPA auctions to couple efficient contracting with demand uncertainty. Chile is moving towards these same guidelines, but the recent, unexpected natural gas supply difficulties have introduced the need for new decisions on the energy agenda. Previously known for the success of its reform, Argentina's domestic problem now dominates the energy outlook and may result in a government leadership in energy development. With these diverging approaches, this is how these countries are facing the challenges of electricity supply.

Acknowledgments

The authors gratefully acknowledge the valuable contributions of Mario Pereira, José Rosenblatt, Rafael Kelman and Jorge Trinkenreich from PSR/Mercados de Energia, and Sebastián Mocarquer and Rodrigo Moreno, from Systep Ingeniería y Diseños and appreciate the support from Fondecyt.

For Further Reading

"Latin American Deregulation" [Online]. Available: http://www.ing.puc.cl/power

ECLAC, "Instruments to stimulate investment and guarantee energy security in the Southern Cone countries," (in Spanish), presented at Seminar of the Economic Commission for Latin America and the Caribbean (ECLAC), Santiago, Chile, Oct. 6, 2004.

L. Maurer, M. Pereira, and J. Rosenblatt, "Implementing power rationing in a sensible way: Lessons learned and international best practices," *Energy and Mining Sector Board Discussion Paper, The World Bank Group*, 2004.

H. Rudnick and J.P. Montero, "Second generation electricity reforms in Latin America and the California paradigm," *J. Industry, Competition and Trade 2* (1–2), pp. 159–172, June 2002.

M. Pereira, L.A. Barroso, and J. Rosenblatt, "Supply adequacy in the Brazilian power market," in *Proc. IEEE Power Engineering Society General Meeting*, Denver, 2004.

Biographies

Hugh Rudnick, an IEEE Fellow, graduated as an electrical engineer from the University of Chile, Santiago. He received the M.Sc. and Ph.D. degrees from the Victoria University of Manchester, Manchester, UK. Currently, he is a professor at Catholic University of Chile and a director of Systep Engineering Consultants. His research activities focus on the economic operation, planning, and regulation of electric power systems.

Luiz Augusto Barroso has a B.Sc. in mathematics, a M.Sc. in OR, and is finishing his Ph.D. in optimization at COPPE/UFRJ, Brazil. He is a senior analyst in PSR/Mercados, where he has been working and researching on power systems economics, planning and operation, focusing on hydrothermal system. He has been a speaker on those subjects in Latin America, Europe, the United States, and Canada.

Carlos Skerk graduated as an electrical engineer from the University of Buenos Aires, Argentina. He joined Mercados Energeticos in 1995, where he has been working on power market analysis, development of transmission and generation business in Latin America, Africa and Europe, and power market regulation. He has been speaker on power market regulation issues in Africa and Latin America.

Adrián Blanco graduated as an electrical engineer from the University of Buenos Aires, Argentina. He joined Mercados Energeticos in 2001, where he has been working on natural gas market analysis and tariff calculation for regulated activities in several countries of Latin America.