A Natural Fit: Electricity-Gas Integration Challenges in Chile and South America

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SOUTH AMERICA IS ONE OF THE MOST DYNAMIC regions for the joint development of natural gas and electricity. Gas is abundant in the region, although unevenly distributed (see Figure 1), with significant new reserves projected in Brazil (in its Pre-Salt basins) and in Argentina (shale gas). Unconventional gas reserves in South America are estimated at 1.430 trillion ft$^3$.

The region's long-term outlook is generally positive, as abundant energy resources offer ample opportunities for the region to sustain its economic growth and electrification; near-universal access to electricity is expected to be achieved by 2030. The region will remain a net oil, gas, and coal exporter. Colombia and Venezuela will benefit from their sizable coal resources, and

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Objectives

► Compare natural gas resources and infrastructure in Brazil and Chile.
► Describe natural gas system interactions with the electricity sector.
► Address the regulatory and system operation changes made to ease the integration of gas-fired plants and future challenges to overcome.

► Hydropower is an expansion option in both countries that has lower production costs and higher capital costs for both the generation projects and the associated electric transmission.
► Local gas-fired thermal generation has lower capital costs for both the generators and electricity network costs, but higher production costs plus the capital cost of the needed gas pipelines or regasification terminals.
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Natural Gas Producers (billion cubic meters – 2011)

Main exporters: Russia, Middle East, Norway, Canada, Algeria, Indonesia

The main natural gas producers: Russia, USA, Canada, Middle East (Qatar, Iran)

Data Source: Natural Gas Information 2012 IAE
Natural Gas Consumers (billion cubic meters – 2011)

Main importers: Japan, Korea, Europe (Italy, Germany, Spain, France, UK), USA

The main natural gas consumers: USA, Russia, Europe (UK, Germany), Iran, China, Japan

Data Source: Natural Gas Information 2012 IAE
Gas reserves

► 45% of the world's gas reserves are "unconventional"…
► …but only 14% of the world supply comes from “unconventional” sources today

GLOBAL GAS RESERVES
Using fracking to access shale gas would vastly increase gas resources in many countries. Russia and the Middle East are not included because their large reserves of easily accessible gas will render shale gas less important there.

Proven gas reserves (trillion cubic metres)
Technically recoverable shale gas resources* (trillion cubic metres)

*Estimates vary greatly
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Current gas markets outlook

- Shale Gas: LNG Exports Plans
- Gas demand squeeze
- In search for new markets
- Japanese nuclear policy unclear
- Growing Gas Demand
- Massive new LNG exports

Source: IHS, 2013, elaboration A. Ansie (2013)
A large potential gas producer

- South America one of most dynamic regions for natural gas and electricity joint development. Gas is abundant, although unevenly distributed.

- Significant new reserves projected in Brazil (pre salt basins) and in Argentina (shale gas).

- Unconventional gas reserves in South America are estimated at 1,430 trillion cubic feet.

- Brazil will become the region’s largest gas producer before 2025.
Gas production, consumption and reserves

**Colombia**
- Production: 11.0 bcm
- Consumption: 8.8 bcm
- Reserves: 170 bcm

**Peru**
- Production: 11.4 bcm
- Consumption: 5.7 bcm
- Reserves: 360 bcm

**Bolivia**
- Production: 15.8 bcm
- Consumption: 2.5 bcm
- Reserves: 281 bcm

**Chile**
- Production: 1.6 bcm
- Consumption: 5.7 bcm
- Reserves: 98 bcm

**Trinidad and Tobago**
- Production: 40.6 bcm
- Consumption: 23.0 bcm
- Reserves: 375 bcm

**Venezuela**
- Production: 20.8 bcm
- Consumption: 22.6 bcm
- Reserves: 5525 bcm

**Brazil**
- Production: 14.6 bcm
- Consumption: 25.1 bcm
- Reserves: 396 bcm

**Argentina**
- Production: 38.8 bcm
- Consumption: 46.1 bcm
- Reserves: 332 bcm

Source: Natural Gas information, 2012, IAE
The golden years of gas in South America

- This presence of abundant gas resources created an active gas industry in some countries...
- …and changed the power matrix of several countries with the penetration of gas-fired generation, which functioned as the “anchors” for a “firm” gas demand, displacing other (more inefficient) technologies
  - Chile, Argentina, Bolivia, Peru

Example: power matrix evolution in Chile (1995 -> 2005)
Poor policies and the role of LNG

- Poor policies for the development of the gas industry adopted in some countries have
  - Created a “gas supply crisis”
  - Interruption of cross border supply → interruption of thermal generation (and later industrial supply)

- ...and fostered the penetration of LNG as an “emergency” new (and expensive) source of supply
A large potential gas producer as an importer

By pipeline:
- Bolivia → Brazil
- Bolivia → Argentina
- Argentina → Chile (inactive)
- Colombia → Venezuela

GNL export terminals:
- Peru GNL: 18 Million m³/day

GNL import terminals:
- Brazil – Pecem: 7 Mm³/day
  - Rio: 20 Mm³/day
  - Bahia (2014): 14 Mm³/day
- Chile – Quintero: 10 Mm³/day
  - Mejillones: 6 Mm³/day
- Argentina – Puerto Escobar: 15 Mm³/day
  - Bahia Blanca: 15 Mm³/day

Source: BP statistical review 2013
Challenges of gas-electricity integration

- Major presence of hydropower creates commercial challenges to integrate the electricity and gas industries.
- Power generation plays a key role in the development of new gas fields, but the absence of a firm gas-to-power demand (subject to hydro variability) is incompatible with the typical take-or-pay characteristics of long term gas contracts.
- Contracting LNG is challenging in dimensioning the required gas volumes.
- Opportunities for natural gas generators to face intermittent renewables have emerged due to its dispatchability and positive environmental attributes.
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Brazil has been drilling for gas for 35 years

► Motivation: 1979 oil shock
  - Increasing depth, distance and cost

► The gas resource potential is significant
  - Very little explored basins
  - 84% of 460 bcm proved reserves are offshore fields
  - Significant unconventional gas reserves (onshore)

► Concession auctions organized by oil-gas regulator grants exploration rights
Pre-salt basins: will drive most of new supply

The developments of these reserves could push Brazil to the top-20 rank of gas producers and top 10 rank of oil producers

- Potential for recoverable oil and natural gas reserves at more than 50 billion barrels of oil equivalent (boe)
Natural gas sector is relatively underdeveloped

- Limited industrial sector demand
- No natural gas use for heating (small residential market)
- Demand for gas-fired electricity production is main driver

Source: ANP, Abegas, MME, ONS
Natural gas sector is relatively underdeveloped

- Modest domestic gas production supplemented by pipeline imports from Bolivia since 1999 and by LNG imports since 2007.
- Natural gas trading carried out chiefly via long-term bilateral contracts.
- Electricity sector more complex than its gas sector in terms of physical assets (lack of robust pipeline network).

Source: Gasnet and ONS
Electricity sector

- Installed capacity 130 GW, yearly consumption 530 TWh, peak demand of 79 GW
- Fully interconnected at the bulk power level by a 100,000-km meshed high-voltage transmission network
- Multiple generation sources: hydro, nuclear, coal, cogeneration from sugarcane bagasse, natural gas (over 12,000 MW) and diesel plants.
- Complex system of hydro plants, comprising several river basins and multiple large reservoirs capable of multi-year storage, accounts for 70% of the country’s installed capacity.
Generation and transmission resources are centrally dispatched by an independent system operator with the aid of stochastic optimization models, with "wetter" basins generating additional energy to compensate for "drier".

- Hydrology is the uncertainty parameter
- Contracts are financial instruments and not considered in the dispatch

Short-run marginal costs are used to set weekly energy spot prices in a wholesale energy market.
Merit-order curve is driven by hydro generation...

Merit-order curve: 2\textsuperscript{nd} week of Feb 2012 (PLD: 37 R$/MWh)

Merit-order curve: 5\textsuperscript{th} week of Nov 2012 (PLD: 300 R$/MWh)
...and translates into volatile spot prices

A capacity mechanism was designed to conciliate generation expansion with spot price volatility: basis of the market model.

Source: CCEE. 1 USD = 2 R$
Not only hydro is cheap

Wind Cheaper Than Natural Gas, Hydro in Brazil Power Auction

Wind is becoming the cheapest source of energy in Brazil, beating natural gas and hydroelectric power.

Developers of 44 wind farms in Brazil agreed to deliver electricity to utilities for an average of 99.58 reais ($61.93) a megawatt-hour in a government-organized auction, the national energy agency Empresa de Pesquisa Energetica said yesterday in a statement. Two gas plants signed contracts for an average of 103.28 reais a megawatt-hour and a hydroelectric project for 102 reais.

The auction marks the first time that wind farms won on price against conventional power plants in a head-to-head contest in Brazil. The price makes it the most cost-effective source of energy in the country.

IDB
Inter-American Development Bank

Figure 9: Wind tariffs under tender systems in selected Latin American markets

Source: Bloomberg New Energy Finance Note: PROINFA tariffs have been adjusted to inflation and represent average tariffs in 2011.
Is natural gas needed in this renewable paradise?

- Capacity additions have been dominated by wind power and run-of-river large hydro, with prices as low as 40 to 50 USD/MWh – with gas-fired generation being generally more expensive.

- However, thermal plants can play two important roles as supporting generation sources:
  - The role of *back-up generation*, especially during extensive periods of low rainfall.
  - The role of *dispatchable* generation that can quickly respond to the system’s renewable intermittent need, with low emissions

- Brazil is integrating 10,000 MW of wind until 2016

- Brazil is integrating large hydro plants with no storage capacity (for environmental reasons, only run of river plants built since 1999)
Feast or famine characteristic of spot prices

Challenge: long periods of abundant hydro production (and near-zero electricity prices) can be followed by water scarcity events in which thermal plants are dispatched baseloaded.

The “feast or famine” characteristic of electricity spot prices implies a very volatile demand for natural gas (at a stable fuel price)
Does the gas producer like this flexibility?

No, the gas producer must:

- Guarantee the fuel supply (there are severe contractual penalties!)
- “Reserve” gas production + transportation capacity for thermal consumption even when thermal plants are not dispatched

Moreover:

- The infrastructure for gas production and transportation is based on fixed costs
- It is not economical to build pipelines with 50% of idle capacity most part of the time
Undesirable behavior

- Infrastructure of gas production and transportation dimensioned for peak consumption hours. Irregular gas demand makes it difficult to recover substantial fixed costs involved.

- To ensure investment costs will be correctly remunerated, mandatory “take or pay” and “ship or pay” clauses are incorporated to gas supply agreements.

- Without a secondary market to resell the natural gas would imply physical must-run generation of natural gas plants, reducing these plants’ flexibility attributes and hence their attractiveness to the power sector.
The integration and disintegration years

► 2000 construction of 3,200 km Bolivia – Brazil pipeline dimensioned to transport 830 Mm3/day

► Power purchase agreements signed with distribution utilities to ensure their commercial feasibility.

► Abundant hydro inflows and reduced consumption implied little need for new gas-fired capacity; hydro generation sufficient to meet 95% of the load.

► Gas diverted to other uses; “overbooking” of gas firm sales resulted in massive dispatch failure in a dry season.

► Three LNG floating storage regasification terminals were built, triggering a new era of gas and electricity integration (total import capacity of 41 million m3 per day).
The emergence of LNG and its integration

- The electricity regulatory framework introduced in 2008 a creative “virtual storage” mechanism, to use already existing hydro reservoirs as energy warehouses, or “energy banks” that can enable intertemporal energy swaps, accommodating the various technologies’ needs.

- Mechanism determines that a thermal plant that is not dispatched by the system operator but that elects to generate anyway (already committed with an LNG cargo) can do so by displacing reservoir hydro plants in the merit order, receiving an “energy credit” that is linked to the amount of water that was stored.

- Taking full advantage of hydro “energy banks” has the potential to greatly improve the system’s efficiency by capturing the benefits of international gas price seasonality and optimizing plant maintenance schedules.
The stochastic dispatch model was changed in 2011 in order to better represent LNG-based generators’ non-anticipatory constraints and shield them from unmanageable uncertainties. In the enhanced model, LNG plants’ dispatch was to be centrally determined by the system operator two months in advance, with no possibility of ex post adjustment – since this lag period was determined to be optimal to minimize gas procurement costs.
Current situation and challenges

- Over the past five years, only two new natural gas plants were contracted in new energy auctions (representing less than 7% of the total planned expansion).

Difficulties:
- Each candidate thermal project in an auction for new capacity is required to obtain commitment that ensures the availability of gas reserves that enable the baseload generation of the thermal plant for 20 years, which is the entire contract duration. This constraint is very costly for the natural gas sector.
- In addition, the electricity sector’s new capacity auctions often impose constraints on operational parameters for candidate thermal plants.
- Selection criterion in the auctions only takes into account the price criterion, which may put thermal plants at a disadvantage (dispatchability not priced).
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Energy sector

- Chile is very energy-dependent, with 73% of its primary energy mix coming from abroad.
- The country has limited coal, oil and gas resources.
- Its hydro reserves in the Andes Mountains provide, along with biomass, the most significant local resources, and much hope has also been placed on future solar energy development in the Atacama Desert, with its abundant solar radiation.
Electricity sector

- The power system grew initially through the development of low-cost hydro resources, coupled with thermoelectric plants based on imported coal, as the most economic backup supply option for dry years (local coal resources were of poor heat and pollutant quality).

- Two major interconnected power systems:
  - SING system
    - almost 99.6% thermal (coal and gas) and 0.4% hydraulic
    - installed gross capacity of 4,720 MW with a maximum demand of 2,251 MW (2014)
  - SIC system
    - 41.7% hydroelectric and 56.2% thermoelectric (coal and gas)
    - installed gross capacity of 15,181 MW and a maximum demand of 7,283 MW (2014)
The sweet gas from Argentina

- Argentinean gas seen as an attractive abundant low cost energy alternative.
- Energy gas integration protocol was signed in 1995 between the two countries.
- Heavy investment in several pipelines crossing the Andes, with imports starting in 1997.

- Low-cost gas provided by Argentina (2 US$ dollars per million Btu)
- Traditional hydro and coal-fired technologies became uncompetitive and plans to expand them were halted.
- Thermoelectric generation and the petrochemical industry became the main consumers of natural gas.

- Natural gas became a key part of the Chilean energy mix, contributing 27% of total generation production.
The sour gas from Argentina

- Severe macroeconomic crisis in Argentina in the early 2000’s.
- Escalating gas demand, not necessarily backed by investment in the exploration of new gas fields or in new pipelines, menaced with gas rationing
- Argentinean government did not comply with its international agreements.
- Cuts to the gas transfers to Chile started taking place in 2004.
- Chile was caught unprepared. Government was foreseen the building of seven combined cycle natural gas plants in the next ten years.
- Gas continued to be seen as the major driver of expansion in a market with demand growing around 7% year.
The sour gas from Argentina

Gas curtailments

Spot prices at Alto Jahuel 220 kV busbar
Reaction to the crisis

- The government started looking for regulatory alternatives. Capacity payment regulations were modified to better take into account unreliable gas supply. A gas “drought” concept was introduced, de-rating combined cycle plants that did not have alternative fuel arrangements.

- The government decided to rely on liquefied natural gas as the alternative and defined projects to build the necessary installations to import it from abroad.

- Coal-fired generation and hydro resources in the southern part of Chile resurfaced as alternatives for future development.
Regasification terminals

Two private LNG terminals, GNL Quintero (2009) and GNL Mejillones (2010), supplying the SIC and the SING respectively. Both initiatives were started by the government, requesting state subsidiaries to initiate negotiations with private sector

- GNL Quintero has a regasification plant with a design that permits regasification of up to 20 million m3 per day.
- GNL Mejillones consists of a reception and regasification floating terminal that permits regasification of 5.5 million m3 per day.

- Terminals only supply part of the existing dual-fuel combined cycle plants. Most are burning diesel because they have no natural gas contracts.
- Gas generation, at current international prices, is no competitive.
Supply chain for natural gas to Chile

Production
Shale Gas, Tight Gas
Conventional Gas
4-6 US$/MMBtu

Liquefaction
3 US$/MMBtu

Maritime transport
1-2 US$/MMBtu

Regasification and transport in Chile
1-3 US$/MMBtu

Generator
Total Cost Generator 9-14 US$/MMBtu

Consumption
Levelized cost of energy for coal and natural gas

<table>
<thead>
<tr>
<th></th>
<th>Coal</th>
<th>LNG - Combined Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unitary investment</td>
<td>2,400 - 2,800 US$/kW</td>
<td>1,000 - 1,200 US$/kW</td>
</tr>
<tr>
<td>Capacity factor</td>
<td>85% - 90%</td>
<td>50% - 80%</td>
</tr>
<tr>
<td>Fuel prices</td>
<td>100 - 130 US$/Ton</td>
<td>11.0 - 13.0 US$/MMBtu</td>
</tr>
<tr>
<td>Variable cost</td>
<td>37.0 - 47.5 US$/MWh</td>
<td>74.5 - 88.1 US$/MWh</td>
</tr>
<tr>
<td>Debt-equity rate</td>
<td>70%/30%</td>
<td>70%/30%</td>
</tr>
<tr>
<td>WACC rate (real)</td>
<td>8.43%</td>
<td>8.43%</td>
</tr>
<tr>
<td>Levelized cost</td>
<td>77.2 - 97.3 US$/MWh</td>
<td>89.5 - 112.0 US$/MWh</td>
</tr>
</tbody>
</table>

Levelized cost of energy for coal-fired (circulating fluidized-bed boilers) and natural gas-fired (LNG combined cycle)
Gas contribution to the energy mix - SIC

Source: CDEC-SIC

Generation vs. Spot price (Alto Jahuel 220)
Uncertainties in generation may favor gas

► Chile faces new challenges in its power infrastructure development, as large hydropower and coal-fired power plants are facing strong social rejection due to environmental issues.

► Gas challenges arise:
  ▪ First challenge is to contract and bring LNG to supply gas to those plants currently being used suboptimally. Open access to existing terminals as an alternative.
  ▪ Second challenge is to define whether a gas-only path should be defined for system expansion, leaving out coal fired generation entirely, with resultant higher costs.
Colbún, Gener y firmas ERNC miran open season para GNL Quintero

Se ofrece capacidad adicional de regasificación de gas natural licuado para el ingreso de nuevos usuarios al terminal.

Varios interesados recibió la sociedad GNL Chile, que es la encargada de comercializar el terminal de regasificación de Quintero, en el marco del open season que lanzó a mediados de noviembre.

La empresa informó ayer que 19 empresas y consultoras adquirieron las bases del proceso, que considera disponer capacidad de regasificación de gas natural licuado (GNL) por hasta 3,2 millones de metros cúbicos diarios, en contratos de largo plazo.
Essential differences between coal and gas

- Coal can be supplied from a great number of providers in the world and stored at the power plant facility with relatively low cost. Hence, coal supply contracts can have a shorter duration, can be negotiated several times in the lifetime of a power plant, and have flexibility due to the coal storage at the power plant.

- Natural gas integration marries two capital-intensive industries that often use the same type of financing structure. Hence, both industries require long-term gas supply contracts to finance both liquefaction and regasification infrastructure.

- Also, given the geographical location of Chile, all LNG shipments are committed from the supplier with little or no alternative market for the gas. In summary, efficient LNG supply to Chile is based upon long-term supply contracts with important take or pay clauses.

- The possibility of acquiring LNG in the short term spot market exists but at high prices.
The wet/dry challenge for gas supply

► Impossible in a hydrothermal system to contract defined constant and predictable LNG volumes well in advance – usually a requirement to access competitive gas prices.

► Even existing take or pay contracts are difficult to manage, and the Chilean system operators have had to consider zero priced gas at times of “spilling” gas conditions.

► The Government is considering changing the regulation to consider take or pay contracts in a similar condition to hydro reservoirs to minimize dispatch risks.

► Take or pay supplies, although they are essentially rigid contract structures, can have flexibility incorporated to increase or reduce the LNG committed. However, this flexibility comes with a cost, and normally has a long lead-time for the decision-making, that is sometimes too long for hydrothermal systems.
Enap redirecciona GNL fuera de Chile ante expectativa de menor demanda en 2015

El consumo del hidrocarburo por parte del sector eléctrico disminuiría el próximo año por la mejora en la situación hidrológica en el SIC.

Nuevos destinos tendrá el Gas Natural Licuado (GNL) que recibirá la estatal Empresa Nacional del Petróleo (Enap) en 2015, ante las expectativas de una menor demanda a nivel interno.

Según señaló el gerente general de Enap, Marcelo Tokman, la firma salió a vender al mercado internacional parte del GNL que no tenía contratado a firme en Chile, ante la baja en la demanda que se prevé tendrá el hidrocarburo, por menor uso en la industria de generación eléctrica.

“Tenemos todo el gas vendido, pero la demanda y las condiciones hidrológicas para el próximo año indican que no será necesario tenerlo”, dijo Tokman.

Enap tiene contratado con BG una capacidad de 2,3 millones de metros cúbicos de GNL bajo la modalidad take or pay (pago a todo evento) y una vez que entre en operación la ampliación del terminal de Quintero, que elevará la capacidad de regasificación de la planta a 15 millones de metros cúbicos diarios, enap tendrá excedentes, los que ya ha dirigido a mercados internacionales.
Isn´t there gas any closer to Chile?

- Natural gas in Peru and Bolivia
- Abundant shale gas basins in Argentina
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Common elements

► Importance of the power sector as a driver for the development of the natural gas sector.

► Important role of LNG as a “savior” to the countries’ natural gas supply deficit, but better if only temporary.

► The seasonality of Latin America’s natural gas demand tends not to follow international demand patterns, both due to the large participation of hydroelectricity (and the high potential for other renewable sources) in the region’s electricity mix and due to its position in the southern hemisphere.

► The high cost of LNG challenges its use as a baseload fuel.
Challenges to a full electricity and gas integration

► Fully integrating the region to the world LNG network could bring substantial gains.
► A more coherent regional long-term planning and institutional coordination will be necessary.
► Need for:
  ▪ Integrated resource planning of electricity and gas
  ▪ Integrated operations planning of electricity and gas
  ▪ Outstanding issues on the representation of the “gas industry constraints” into the electricity dispatch models

► This challenge will become even more relevant as the development of abundant pre-salt gas fields unfolds in Brazil and shale gas is exploited in Argentina.
Some references


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