Options for Resilient and Flexible Power Systems in Select South American Economies

JISEA 10th Annual Meeting (Virtual)
April 9, 2020

Josue Campos do Prado, Jeffrey Logan, and Francisco Flores-Espino
Outline

• Global Power System Transformation
  – Need for Flexibility in South American Countries
  – Natural Gas as an Increasingly Important Generation Option
• Country-Specific Analysis
• Summary of Findings
• Conclusions
Outline

• Global Power System Transformation
  – Need for Flexibility in South American Countries
  – Natural Gas as an Increasingly Important Generation Option

• Country-Specific Analysis

• Summary of Findings

• Conclusions
Global Power System Transformation

- Power systems around the globe are changing rapidly due to a confluence of technological, social, meteorological, and economic drivers.
- These changes are highlighting the need for flexibility in energy systems.

- Flexibility addresses different issues that span timescales that range from sub-seconds to years.
Need for Flexibility in South American Countries

- Select South American countries that traditionally relied heavily on large (dammed) hydropower face increasing risk and reliability concerns during El Niño and La Niña hydrological phases.
- They also see rapid growth in VRE sources.
- There is an increasing need to expand emphasis on flexibility and resiliency at different time scales.
- In this study, special attention is placed on the potential role for natural gas to help ensure flexible and resilient power.
- Primary countries of focus:
  - Argentina
  - Brazil
  - Chile
  - Colombia

Source: Data from CAMMESA, CNE, EPE, IEA, and XM.
Need for Flexibility in South American Countries

Flexibility issues and options in power systems of key South American countries:

- Hydropower: Affected by weather events/Reduced water storage capacity, Monthly/Yearly concerns.
- VRE: Variable and somewhat uncertain by nature, Hourly or below concerns.
- Thermal Power: Inflexibility of existing plants/Fuel supply uncertainties, All time scales.

How to ensure flexibility at different time scales?

Key Policy Options:

Electricity Sector:
- Generation mix diversification
- Demand-side management
- Storage systems
- Regional and international interconnections
- DERs
- Effective pricing mechanisms

Natural Gas Sector:
- Investments in domestic production
- Import diversification
- Robust and competitive market
- Pipeline infrastructure expansion
- Underground storage
- Flexible LNG contracts and technologies

Effective Integration
Natural Gas as an Increasingly Important Generation Option

- Increasing natural gas consumption for electricity generation in South America.
- Contract terms for markets in LNG have become more liquid and flexible over the past five years.
- Alternatives to land-based LNG infrastructure have allowed South American countries to enjoy the benefits of short-term natural gas use without the need to invest in permanent land-based infrastructure.

**Total natural gas consumption:**

![Graph showing total natural gas consumption from 2010 to 2017.](chart1)

- Source: Data from IAPG (2019), MME (2019), CNE (2019), and PROMIGAS (2019).

**LNG imports:**

![Graph showing LNG imports from 2009 to 2018.](chart2)

- Source: Data from GIIGNL (2019).
Outline

• Global Power System Transformation
  – Need for Flexibility in South American Countries
  – Natural Gas as an Increasingly Important Generation Option

• Country-Specific Analysis

• Summary of Findings

• Conclusions
Argentina

Overview:

• Most dependent on thermal power generation (about 65% of total installed capacity) among countries analyzed.

• Faces challenges due to aging infrastructure and in directing investments in electricity and gas sectors.

• Energy sector faces strong headwinds due to the shrinking economy, high inflation, and the depreciating peso.

• Decades of market distortions associated with subsidies.

Source: Data from CAMMESA (2018)
Argentina

Drivers of the need for flexibility:

- Rainfall variability (lesser extent than Brazil, Chile, and Colombia)
- Public opposition to hydropower plants
- Growing VRE integration (RenoVar auctions)
- Thermal power inflexibility and fuel supply uncertainties

VRE installed capacity

Thermal power generation by fuel

Source: Data from CAMMESA (2018)
Argentina

The Vaca Muerta shale formation:

- Holds the world’s second-largest shale gas reserves (about 300 Tcf)
- As of July 2019, less than 5% of its acreage has entered the development phase
- Play can accommodate approximately 85,000 wells of which about 1,000 were drilled so far
- Has the potential to supply Argentina’s domestic needs and allow exports by pipeline and LNG
- Main challenges include attracting upstream investments and building necessary infrastructure to move the gas to market

Source: U.S. EIA (2017)
Argentina

Policy options in the electricity sector:
• Generation mix diversification
• Demand side management
• Storage systems and regional interconnections
• Distributed energy resources
• Effective pricing mechanisms

Policy options in the natural gas sector:
• Investments in domestic production
• Pipeline infrastructure expansion
• Investments in underground storage to mitigate seasonal imbalances
• Robust natural gas market
• Import diversification
• Flexible LNG contracts and technologies

Argentina’s monthly natural gas consumption and production

<table>
<thead>
<tr>
<th>Sector</th>
<th>Subsector</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>Renewable Energy</td>
<td>• 20% of the country’s electricity consumption from renewable energy sources by 2025.</td>
</tr>
<tr>
<td></td>
<td>Domestic Production</td>
<td>• Double domestic production in 5 years and reach 8.4 Bcf/day.</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>Imports</td>
<td>• Stop importing LNG by 2022. • Stop importing pipeline natural gas by 2026.</td>
</tr>
<tr>
<td></td>
<td>Exports</td>
<td>• Exports to Chile (Bcf/day): 1 (by 2022). • Exports to Brazil (Bcf/day): 0.3 (by 2022), 1 (by 2025). • LNG exports (Bcf/day): 40 (by 2023), 120 (by 2025). • Be the world’s fifth largest LNG exporter by 2026.</td>
</tr>
</tbody>
</table>

Source: U.S. EIA (2019)
Source: Secretaría de Energía (2018a)
Brazil

Overview:

• Power sector is growing and diversifying rapidly.
• Continues to be dominated by hydropower, although share of total generation has been in decline since 2011.
• Has sophisticated energy planning capability and has installed more non-hydro renewables than any other South American country over the past decade.
• The country is working to develop its offshore (Pre-Salt) natural gas resources and introduce substantial pricing reforms in both electricity and natural gas sectors.

Total and regional installed capacity in Brazil in 2001 and 2018:

Source: Data from EPE (2019)
Brazil

Drivers of the need for flexibility:

- Prolonged rainfall variability and dispatch of costly thermal power generation.
- Public opposition to hydropower plants and greater adoption of run-of-the-river configurations.
- Growing VRE integration (centralized and distributed).

Source: Data from EPE (2019)

Source: Data from CAMMESA (2018)

Water storage in the Southeast/Midwest subsystem

Source: Data from the Brazilian Ministry of Mining and Energy (MME, 2019).

VRE installed capacity

Source: Data from EPE (2019)
Brazil

Policy options in the electricity sector:
- Generation mix diversification
- Demand side management
- Storage systems and regional interconnections
- Distributed energy resources
- Effective pricing mechanisms

Policy options in the natural gas sector:
- Investments in domestic production
- Offshore pipeline infrastructure expansion
- Investments in underground storage
- Robust natural gas market
- Import diversification
- Flexible LNG contracts and technologies

Source: U.S. EIA

Source: Data from ANP (2019) and EPE (2018)
Overview:

- Has been at the global forefront in introducing market-oriented liberalization and privatization in its energy sector.
- Has relied on coal and petroleum products in electricity generation to make up for the lost gas supply from Argentina in 2004.
- Committed to phase out coal generation by 2040.
- Has enormous wind and solar energy potential but insufficient gas reserves to be developed over the long-term.
- Has a unique geographical and social distribution that pose challenges to its electricity and natural gas transmission planning and operation — flexibility key.
Chile

Drivers of the need for flexibility:

- Prolonged rainfall variability
- Public opposition to hydropower plants and greater adoption of run-of-the-river configurations
- Growing VRE integration and limited transmission infrastructure
- Thermal power inflexibility

![Storage Capacity in the main Chilean reservoirs](image)

Storage Capacity in the main Chilean reservoirs

- Chapo
- La Invernada
- Laja
- Colbun
- Rapel
- Ralco
- Melado
- Pangue

Source: Data from Systep (2019).

![Hydropower plant capacity](image)

<table>
<thead>
<tr>
<th>Hydropower plant</th>
<th>2008</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run-of-the-river</td>
<td>1.9 GW</td>
<td>6.7 GW</td>
</tr>
<tr>
<td>Impoundment (Large reservoirs)</td>
<td>3.4 GW</td>
<td>3.2 GW</td>
</tr>
</tbody>
</table>

Source: Data from CNE (2019).

![VRE Installed Capacity](image)

VRE Installed Capacity (MW)

- Wind (MW)
- Solar (MW)
- VRE (%)

Source: Data from the Chilean National Energy Commission (CNE, 2019).

![La Niña](image)

La Niña

2007-2008
2011-2013
2016-2018

Source: Data from CNE (2019).
Chile

Policy options in the electricity sector:
• Generation mix diversification
• Distributed energy resources
• Storage systems and regional interconnections
• Demand side management
• Effective pricing mechanisms

Policy options in the natural gas sector:
• Import diversification
• Flexible LNG contracts and technologies

Source: Data from CNE (2019)

Chilean natural gas production, pipeline imports and LNG imports

Source: REVE (2019)
Overview:

- Among the countries in this study, Colombia is the most dependent on hydropower and the most exposed to drought conditions during El Niño years.
- Major exporter of coal, yet that fuel supplies only about 10% of the country’s electricity generation mix.
- Working to rectify market distortions associated with electricity subsidies.
- Natural gas production is in fairly rapid decline while demand continues to grow.
- The only country here that does not have a vibrant market for VRE deployment, but it held its first successful VRE auction in late 2019.

Source: Data from DNP (2017), SIEL (2019), and UPME (2017).
Colombia

Drivers of the need for flexibility:

- Prolonged rainfall variability
- Public opposition to hydropower plants and greater adoption of run-of-the-river configurations
- Declining gas availability

Active Daily Hydroelectric Capacity Volume

Source: Data from XM (2019).

Daily hydropower generation (GWh) and Electricity spot price (COP/kWh)

Source: XM (2019).
Colombia

Policy options in the electricity sector:
• Generation mix diversification
• Distributed energy resources
• Storage systems and regional interconnections
• Demand side management
• Effective pricing mechanisms and reliability market

Policy options in the natural gas sector:
• Investment in domestic production
• Import diversification
• Flexible LNG contracts and technologies
# Summary of Findings

Risks and constraints for more flexible power generation in Select South American countries:

<table>
<thead>
<tr>
<th>Flexibility Catalysts</th>
<th>Argentina</th>
<th>Brazil</th>
<th>Chile</th>
<th>Colombia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather events affecting hydropower</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Increasing adoption of run-of-the-river power plants</td>
<td>Medium</td>
<td>High</td>
<td>Medium-High</td>
<td>High</td>
</tr>
<tr>
<td>Increasing VRE integration</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Thermal power generation inflexibility</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Fuel-supply uncertainties</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
</tbody>
</table>
## Summary of Findings

### Barriers and challenges for electricity and natural gas development:

<table>
<thead>
<tr>
<th>Issue</th>
<th>Argentina</th>
<th>Brazil</th>
<th>Chile</th>
<th>Colombia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aging infrastructure</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmission capacity limitations</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Insufficient revenue for investment</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public opposition to hydropower plants</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Limited international interconnections</td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Lack of market mechanisms to promote greater flexibility</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Demand concentration in specific regions</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Techno-economic challenges associated with domestic production</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insufficient long-term domestic reserves</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Lack of underground storage infrastructure</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Pipeline capacity limitations</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Insufficient revenue for investment</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Synthesis and Conclusions

• All countries except Chile have significant natural gas resources to be developed over the long-term.

• Argentina’s Vaca Muerta formation may be the biggest uncertainty in all of South America’s power sector calculus.

• Imported LNG may be the most expedient short-term option for Brazil, Chile, and Colombia given the recently improved liquidity, and contract terms, of that fuel.

• In addition to the country-specific choices that each jurisdiction faces, the international community can offer a variety of bi- and multi-lateral assistance and cooperation to further enhance flexibility and resilience.

• On a positive note, each of these countries is building from a strong base of renewable hydropower into a diverse portfolio of solar, wind, and natural gas, targeting a clean and resilient power system.
Thank you

The full report from this study is available at:
https://www.nrel.gov/docs/fy20osti/75431.pdf

NREL/PR-6A50-76505