JISEA Joint Institute for Strategic Energy Analysis

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

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NREL NATIONAL RENEWABLE ENERGY LABORATORY · COLORADO SCHOOL OF MINES · Colorado State University · Massachusetts Institute of Technology · STANFORD UNIVERSITY · University of Colorado Boulder

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

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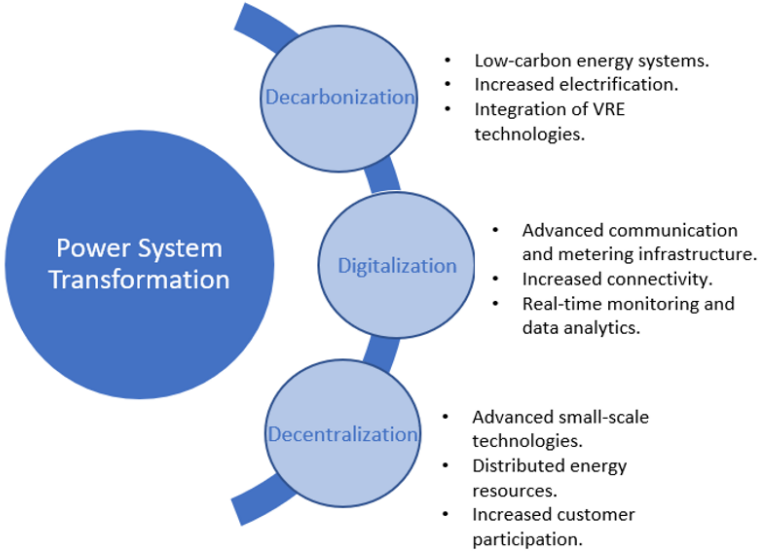
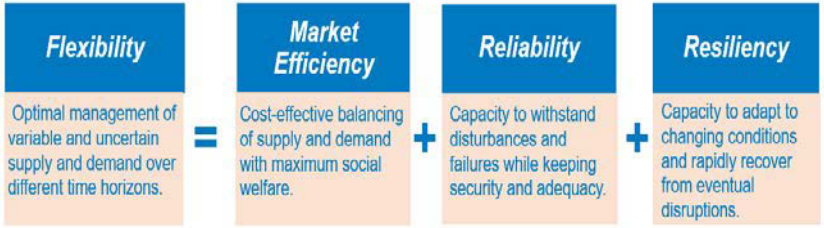
Global Power System Transformation

- 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.

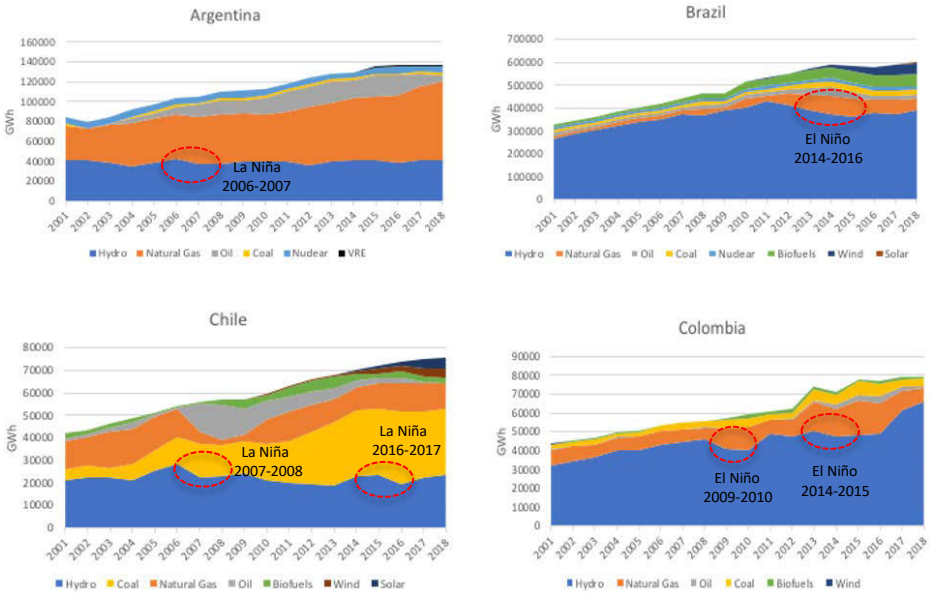
Type	Short-term			Medium-term	Long-term	
Timescale	Subseconds to seconds	Seconds to minutes	Minutes to hours	Hours to days	Days to months	Months to years
Issue to be addressed	System stability (large disturbances)	Quick fluctuations in the balance of supply and demand	Ramps in the balance of supply and demand	Decisions on the number of thermal plants to remain running	Schedule maintenance of power plants / Seasonal availability of some plants	Seasonal and inter-annual balance of generation and demand

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

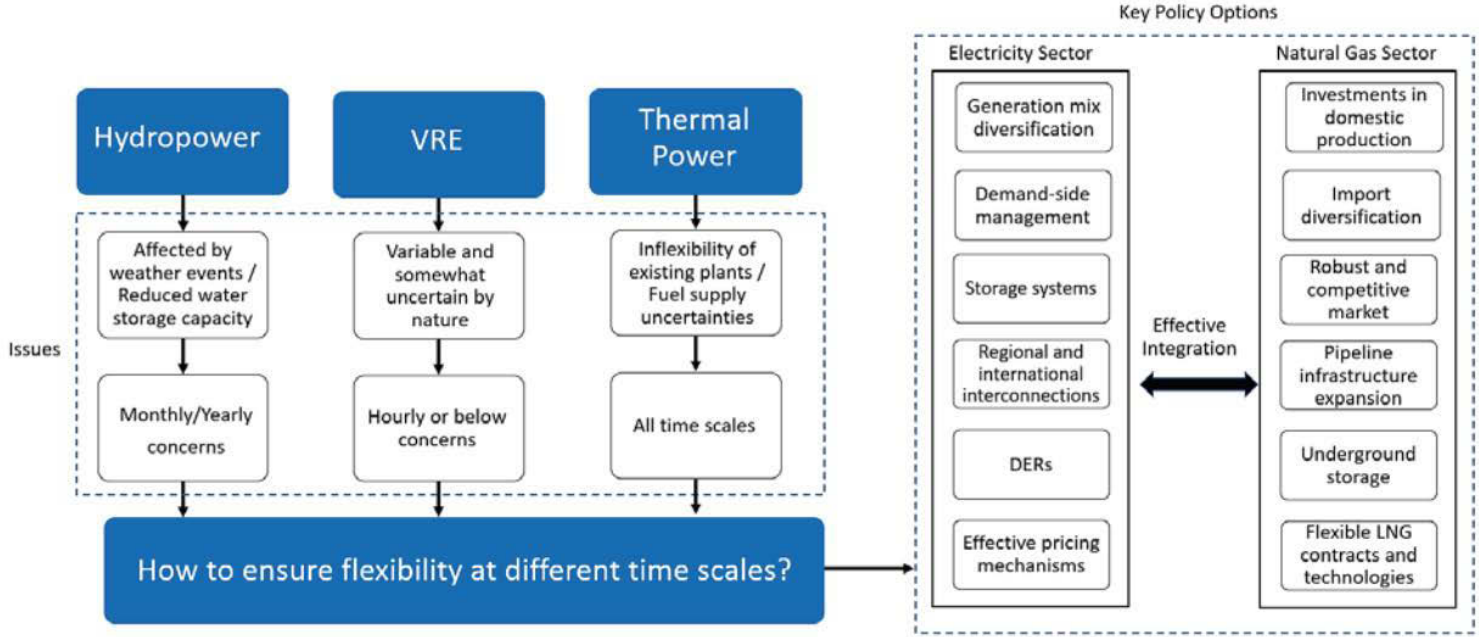
Evolving generation mixes in Argentina, Brazil, Chile, and Colombia:



Source: Data from CAMMESA, CNE, EPE, IEA, and XM.

Need for Flexibility in South American Countries

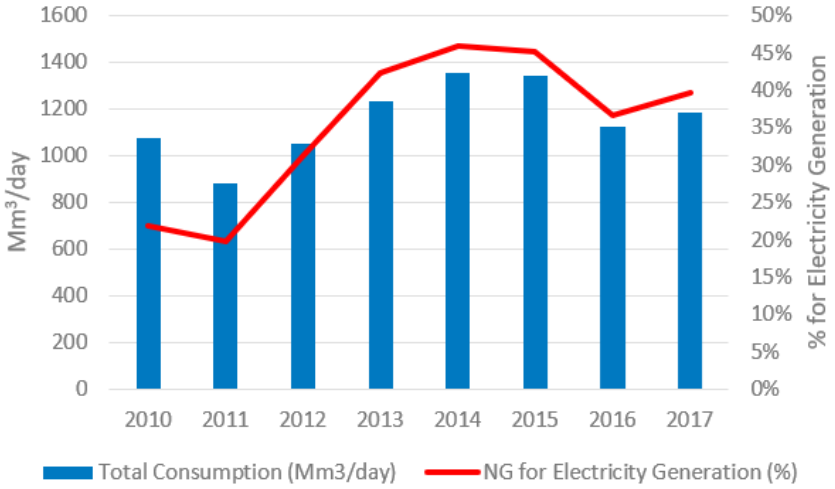
Flexibility issues and options in power systems of key South American countries:



Natural Gas as an Increasingly Important Generation Option

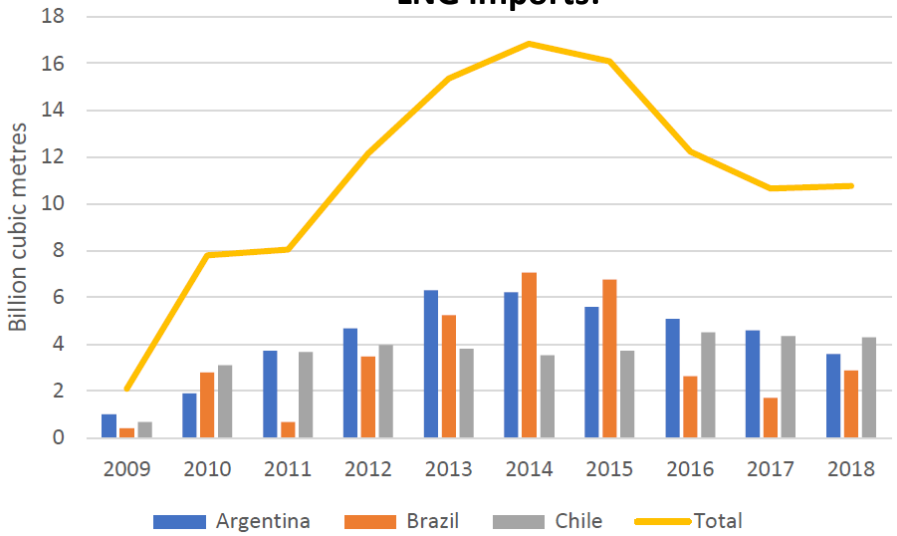
- Increasing natural gas consumption for electricity generation in South America.
- Contract terms for markets in LNG have become more liquid and flexible over the past five years.
- Alternatives to land-based LNG infrastructure have allowed South American countries to enjoy the benefits of short-term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

Total natural gas consumption:



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

LNG imports:



Source: Data from GIIGNL (2019).

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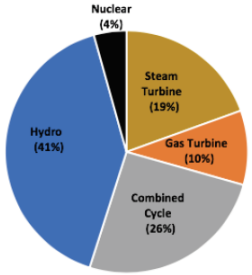
Argentina

Overview:

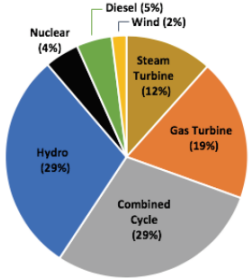
- Most dependent on thermal power generation (about 65% of total installed capacity) among countries analyzed.
- Faces challenges due to aging infrastructure and in directing investments in electricity and gas sectors.
- Energy sector faces strong headwinds due to the shrinking economy, high inflation, and the depreciating peso.
- Decades of market distortions associated with subsidies.

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

23.2 GW (2001)



38.5 GW (2018)



Noroeste (NOA) (GW)

Source	2001	2018
	0.18	0.22
	1.05	3.12
	< 0.01	0.21

Cuyo (CUY) (GW)

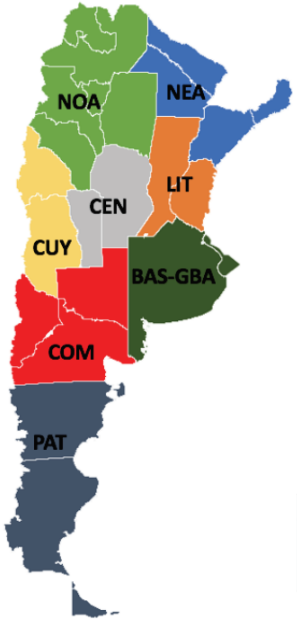
Source	2001	2018
	0.69	1.13
	0.58	0.62
	< 0.01	0.26

Comahue (COM) (GW)

Source	2001	2018
	4.49	4.77
	1.29	2.08
	< 0.01	< 0.01

Patagonia (PAT) (GW)

Source	2001	2018
	0.52	0.56
	0.33	0.57
	< 0.01	0.84



Noreste (NEA) (GW)

Source	2001	2018
	1.71	2.75
	0.15	0.03
	< 0.01	< 0.01

Litoral (LIT) (GW)

Source	2001	2018
	0.95	0.95
	0.28	2.78
	< 0.01	< 0.01

Centro (CEN) (GW)

Source	2001	2018
	0.91	0.91
	1.24	2.30
	< 0.01	0.28

Buenos Aires + Gran Buenos Aires (BAS-GBA) (GW)

Source	2001	2018
	< 0.01	< 0.01
	8.82	16.00
	< 0.01	0.76

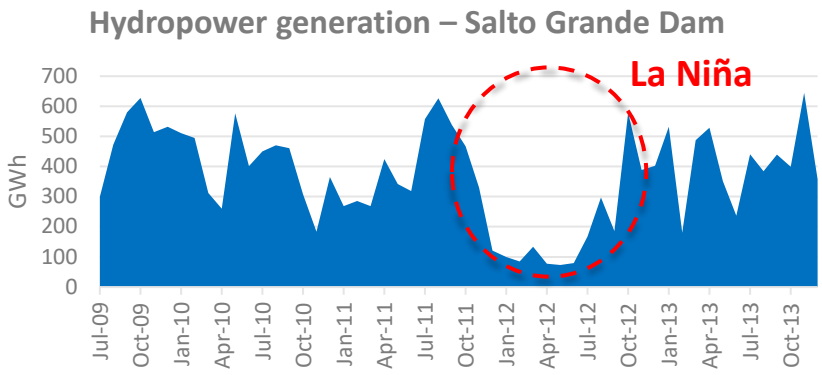
Thermal VRE Hydro

Source: Data from CAMMESA (2018)

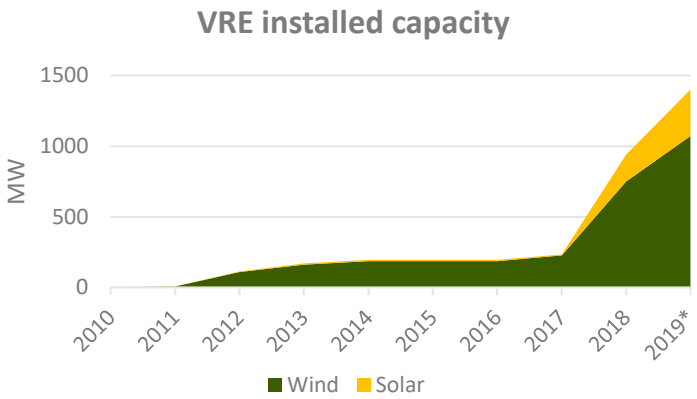
Argentina

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



Source: Data from CAMMESA (2018)



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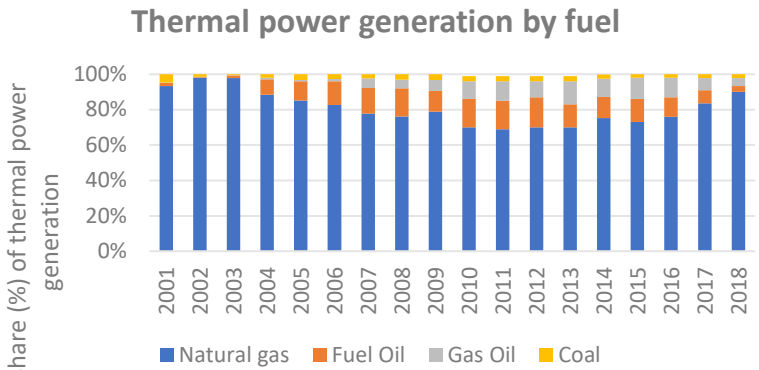
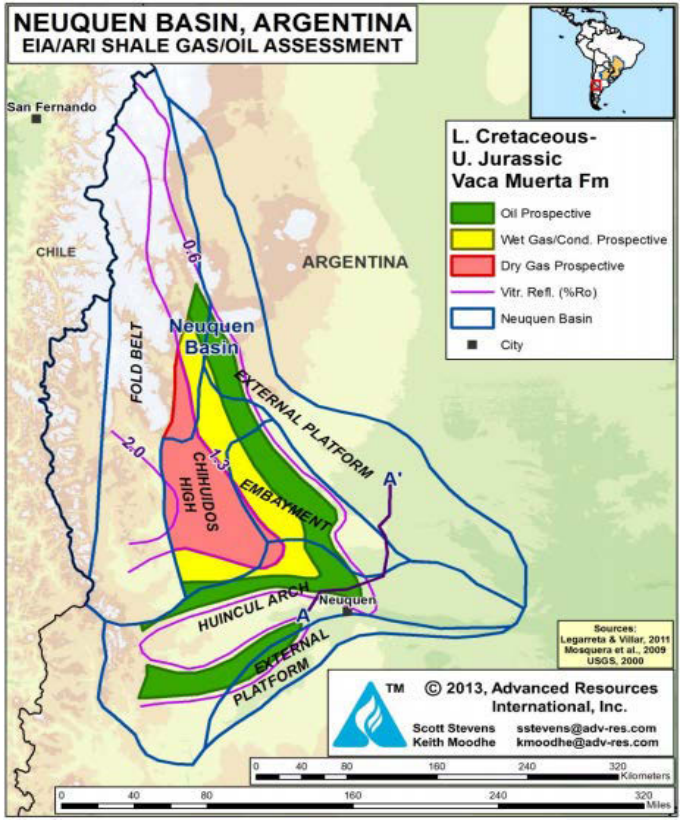


Source: Data from CAMMESA (2018)

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

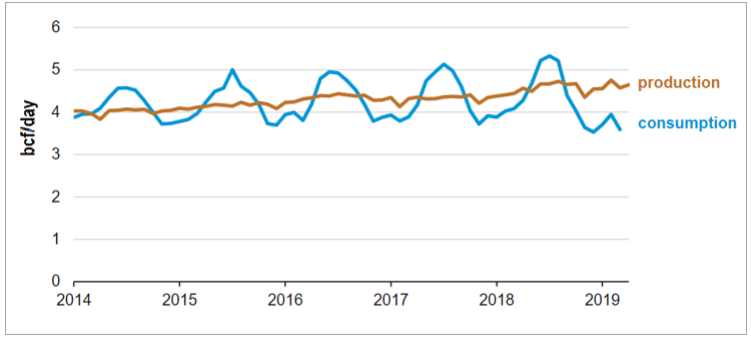
Policy options in the electricity sector:

- 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



Source: U.S. EIA (2019)

Argentina's Energy Plan goals

Sector	Subsector	Goal
Electricity	Renewable Energy	• 20% of the country's electricity consumption from renewable[6] energy sources by 2025.
Natural Gas	Domestic Production	• Double domestic production in 5 years and reach 8.4 Bcf/day.
	Imports	• Stop importing LNG by 2022. • Stop importing pipeline natural gas by 2026.
	Exports	• 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.

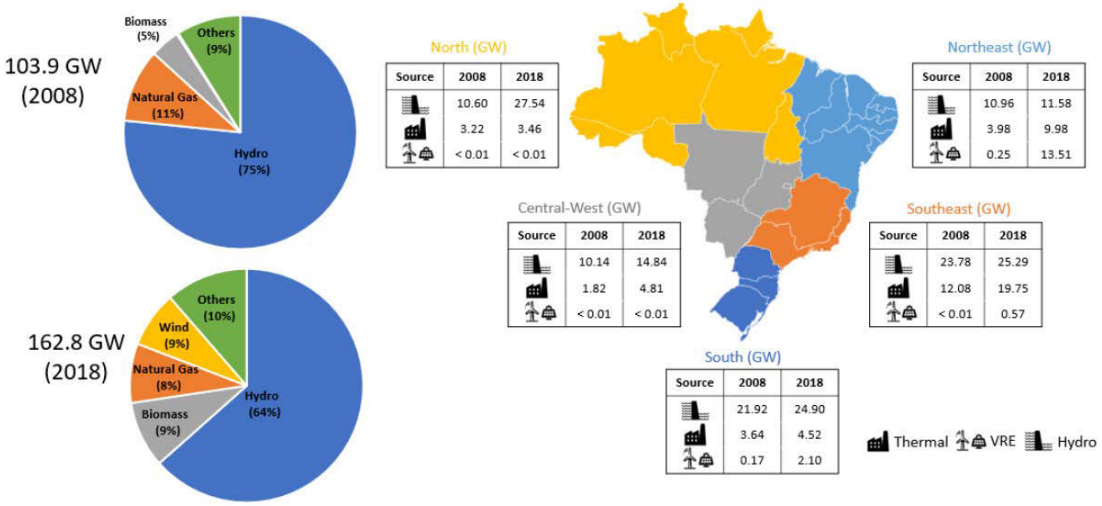
Source: Secretaría de Energía (2018a)

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:

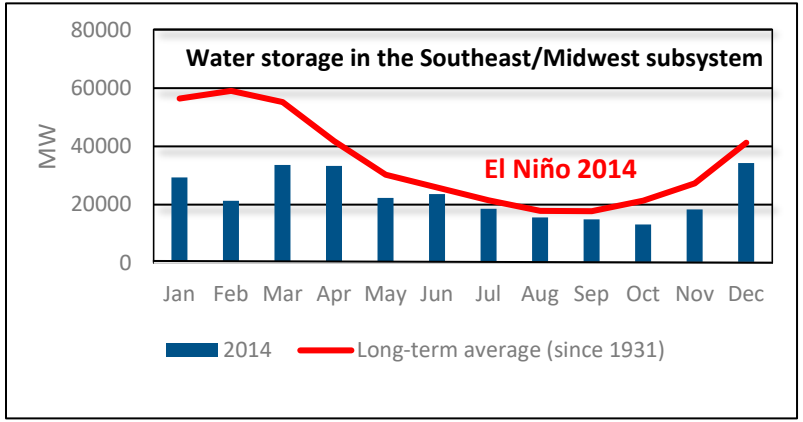


Source: Data from EPE (2019)

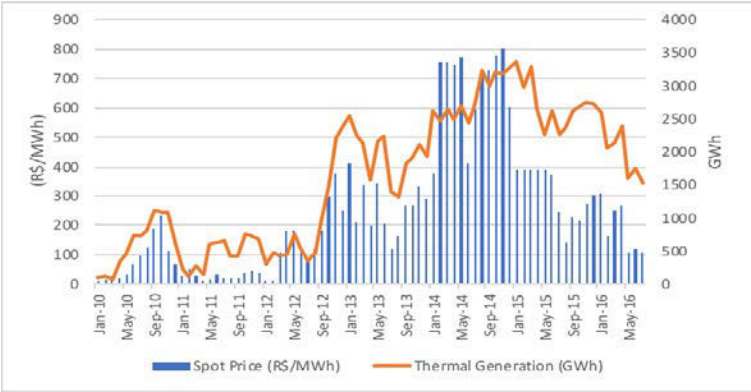
Brazil

Drivers of the need for flexibility:

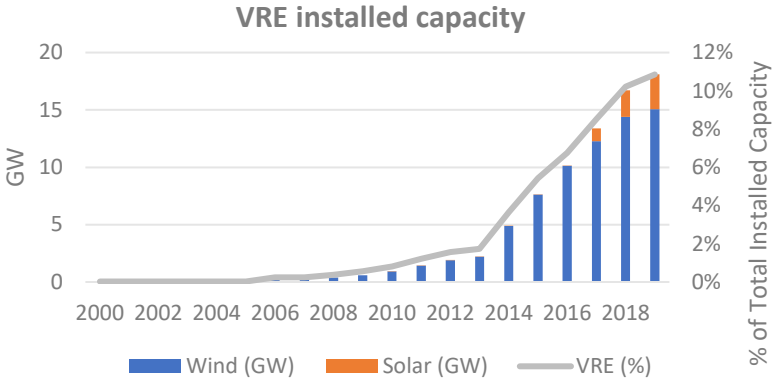
- Prolonged rainfall variability and dispatch of costly thermal power generation.
- Public opposition to hydropower plants and greater adoption of run-of-the-river configurations.
- Growing VRE integration (centralized and distributed).



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



Source: Data from CAMMESA (2018)



Source: Data from EPE (2019)

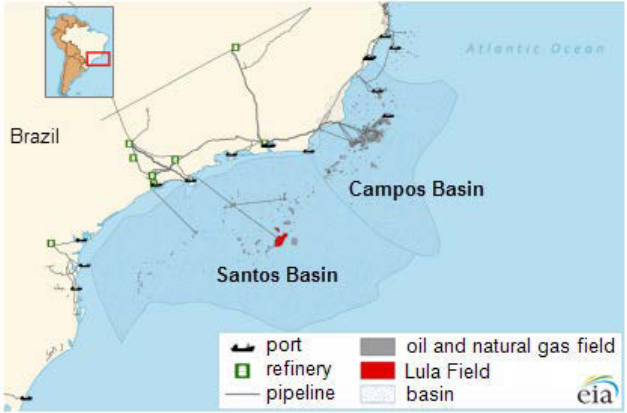
Brazil

Policy options in the electricity sector:

- Generation mix diversification
- Demand side management
- Storage systems and regional interconnections
- Distributed energy resources
- Effective pricing mechanisms

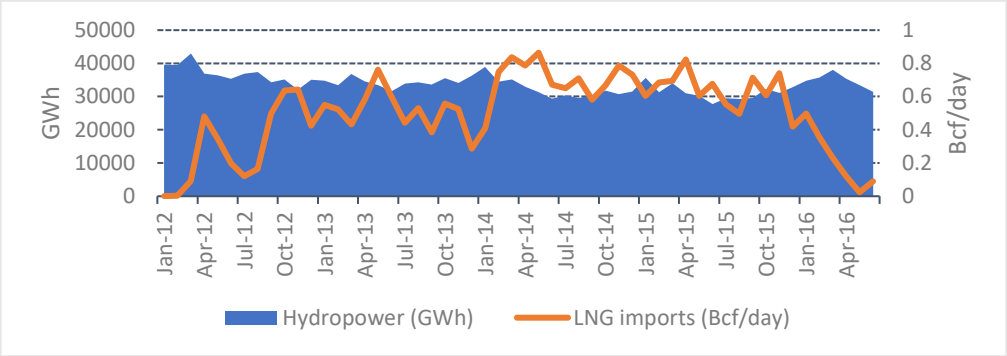
Policy options in the natural gas sector:

- 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

Main Pre-Salt basins



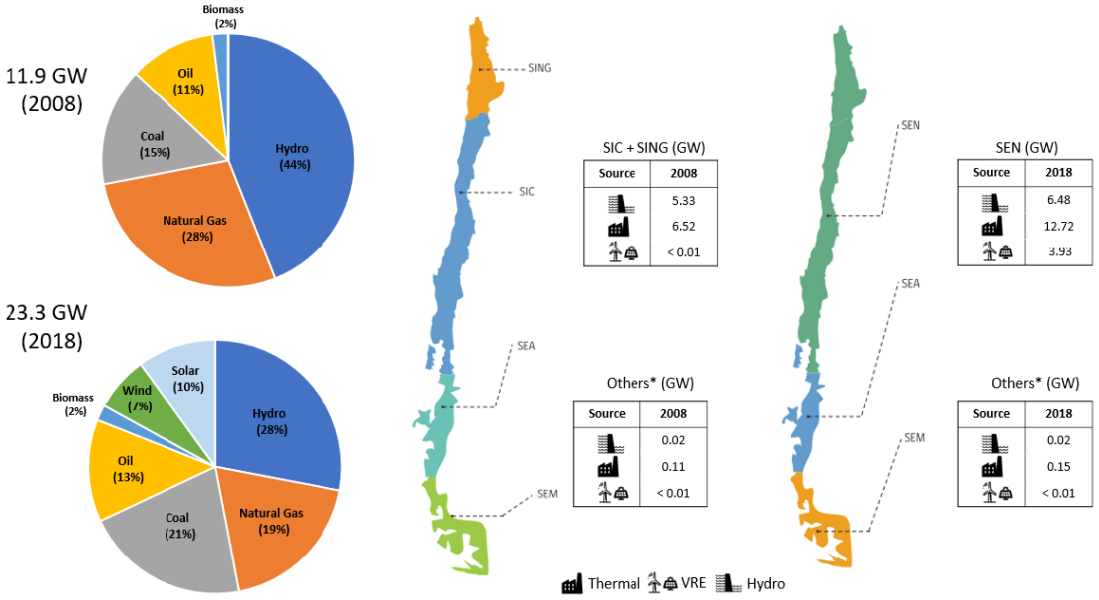
Source: Data from ANP (2019) and EPE (2018)

Chile

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.

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

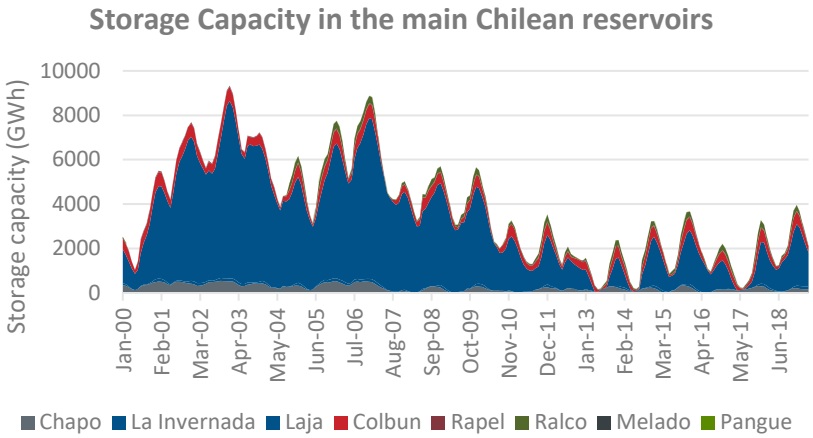


Source: Data from CNE (2019)

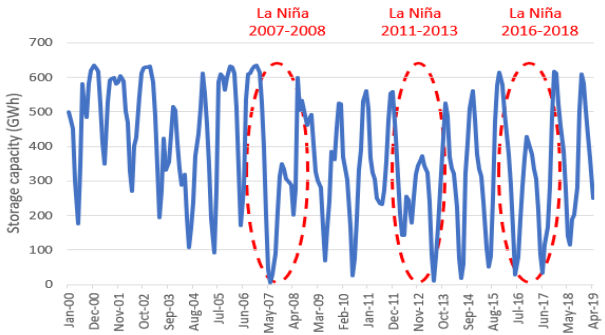
Chile

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



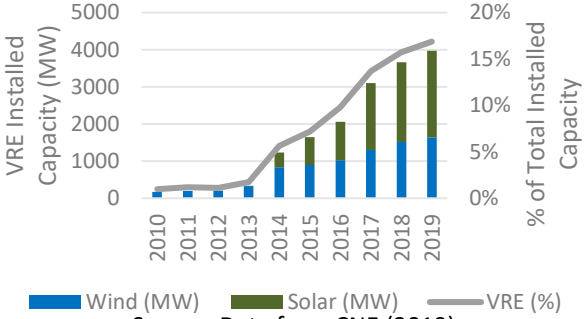
Source: Data from Systep (2019).



Source: Data from CNE (2019).

Hydropower plant	2008	2018
Run-of-the-river	1.9 GW (36%)	6.7 GW (68%)
Impoundment (Large reservoirs)	3.4 GW (64%)	3.2 GW (32%)

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



Source: Data from CNE (2019).

Chile

Policy options in the electricity sector:

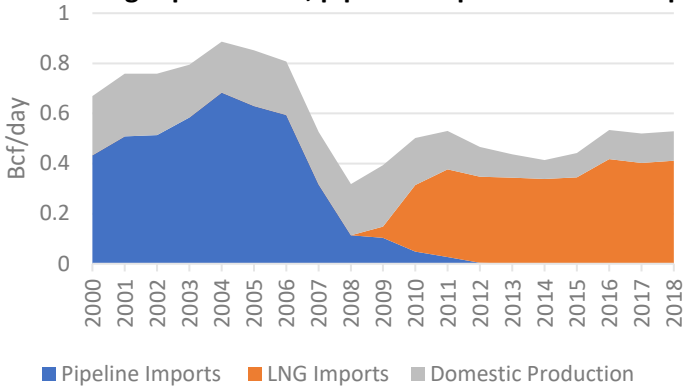
- Generation mix diversification
- Distributed energy resources
- Storage systems and regional interconnections
- Demand side management
- Effective pricing mechanisms

Policy options in the natural gas sector:

- Import diversification
- Flexible LNG contracts and technologies

Source: REVE (2019)

Chilean natural gas production, pipeline imports and LNG imports



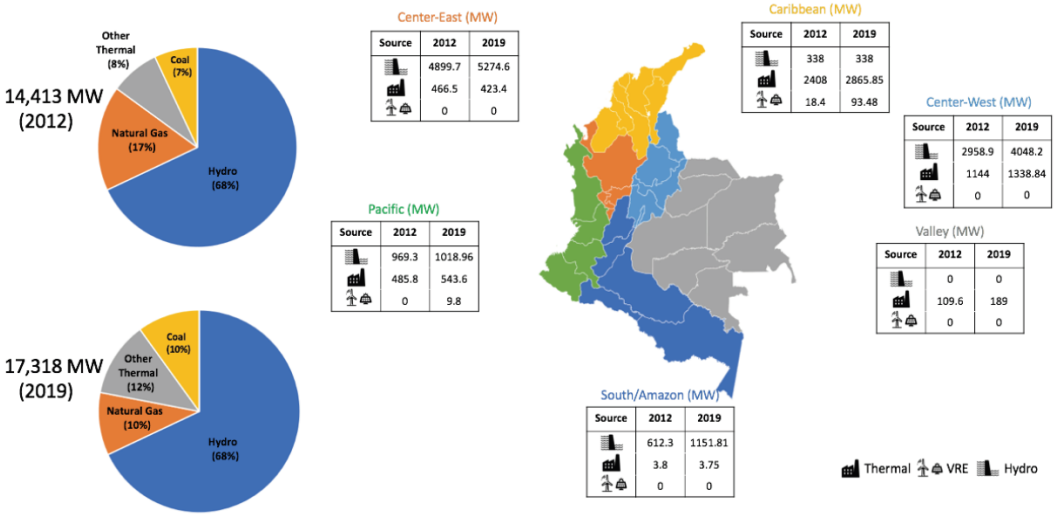
Source: Data from CNE (2019)

Colombia

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.

Total and regional installed capacity in Colombia in 20012 and 2019:

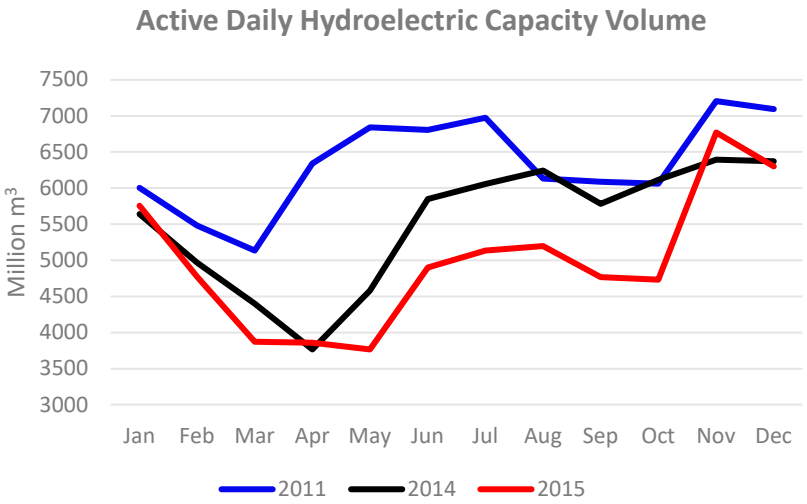


Source: Data from DNP (2017), SIEL (2019), and UPME (2017).

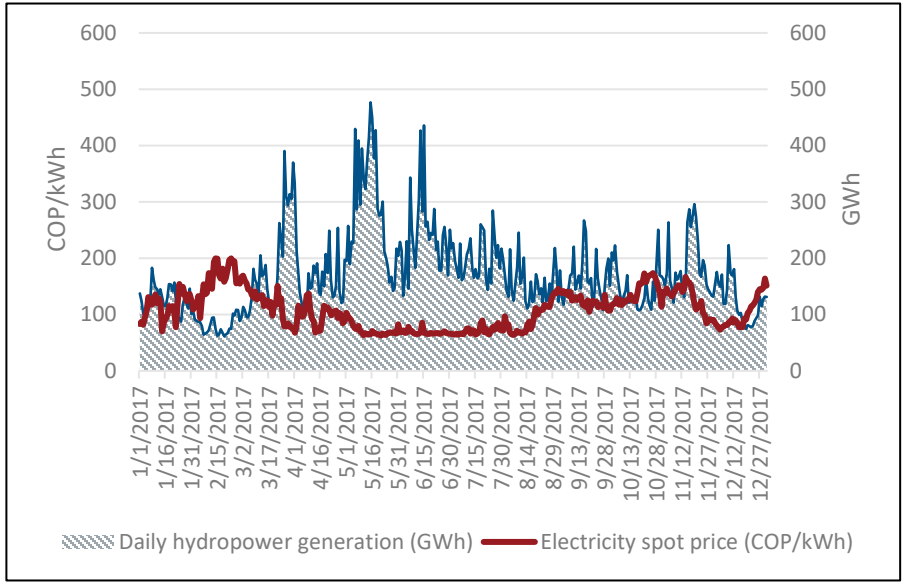
Colombia

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



Source: Data from XM (2019).



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

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Colombian renewables auction closes with 1,298 MW of wind, solar

Policy options in the natural gas sector:

- Investment in domestic production
- Import diversification
- Flexible LNG contracts and technologies

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Project Insights

Colombia's second LNG terminal makes progress

A second LNG terminal in Colombia would boost security of supply, but concerns over financing remain one of several obstacles for the project

By Ed O'Brien
5 SEPTEMBER 2019
Americas / LNG

Summary of Findings

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

		Argentina	Brazil	Chile	Colombia
Flexibility Catalysts	Weather events affecting hydropower	Medium	High	Medium	High
	Increasing adoption of run-of-the-river power plants	Medium	High	Medium-High	High
	Increasing VRE integration	Medium	High	High	Low
	Thermal power generation inflexibility	High	Low	High	High
	Fuel-supply uncertainties	High	Medium	Medium	Medium

Summary of Findings

Barriers and challenges for electricity and natural gas development:

	Issue	Argentina	Brazil	Chile	Colombia
Relative barriers and challenges in the electricity sector	Aging infrastructure	x			
	Transmission capacity limitations	x	x	x	x
	Insufficient revenue for investment	x			
	Public opposition to hydropower plants	x	x	x	x
	Limited international interconnections			x	x
	Lack of market mechanisms to promote greater flexibility	x	x	x	x
	Demand concentration in specific regions	x		x	
Relative barriers and challenges in the natural gas sector	Techno-economic challenges associated with domestic production		x		
	Insufficient long-term domestic reserves			x	
	Lack of underground storage infrastructure	x	x	x	x
	Pipeline capacity limitations	x	x	x	x
	Insufficient revenue for investment	x			

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

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