White Paper

Chile's Great Renewable Flood

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Shareables

- Renewable generation capacity is expected to keep increasing due to a combination of supportive policies and declining technology prices.
- New transmission projects including the anticipated 2018 SING-SIC interconnection may support increased dispatch of renewable resources across the country.
- Absent anticipated positive demand growth, spot and auction prices may fall as more low-variable cost renewables enter the system.

Executive Summary

Clear policy support and falling technology prices have helped spur a renewable boom in Chile, however regulators must assess the extent to which the market and the electric grid can sustainably support the entry of additional low-cost variable renewable generation. During the August 2016 electricity supply auction, two-thirds of the 12,430 GWh/year were awarded to solar and wind projects. This strong renewable participation caused average contract prices to fall to $46.7/MWh, the lowest level observed in the past decade. Potential changes to future auction contract structures and anticipated transmission system upgrades may provide additional support for renewables. Given the anticipated deluge of renewable capacity, moderate load growth and positive market signals will be crucial for supporting spot and contract pricing.

What Caused the Renewable Boom?

Chile's **geographic location** makes it well suited for renewable generation. The high altitude and dry, cloudless conditions of the Atacama Desert make northern Chile one of the most suitable locations for generating solar power. There is also significant wind, geothermal and tidal potential in Chile. Combined with these natural attributes, Chile's clear regulatory framework, lack of local fossil fuel reserves, and declining renewable technology costs, have resulted in a renewable power boom in Chile.

EXHIBIT 1. SIC + SING CAPACITY MIX (FEBRUARY 2017)

Technology	MW	%
Coal	4,026	18%
Natural Gas	4,875	21%
Diesel	2,824	12%
Other Fossil Fuels	1,091	5%
Biomass/Biogas	382	2%
Hydro (Conventional/ROR)	6,230	27%
Small Hydro (ROR)	443	2%
Solar	1,665	7%
Wind	1,294	6%
Total	**22,830**	100%
Fossil Fuel	**12,816**	**56%**
Renewables	**10,014**	**44%**
ERNC	**3,784**	**17%**

Source: CNE, Capacidad Instalada Generación (March, 2017): https://www.cne.cl/wp-content/uploads/2015/05/Capacidad_Instalada_Generaci%C3%B3n.xlsx
ROR = Run-of-the-River

The **non-conventional renewable energy law** (ERNC[1] Law Nº 20.257) has been a major driver for renewables in the country. It was enacted in 2008 as a means of addressing the fuel supply and power crisis of the mid-2000s, which saw spot energy prices above $200/MWh in 2007. The law aims to diversify Chile's generation mix through the promotion of ERNC resources, such as geothermal, wind, solar, tidal, biomass and small hydroelectric plants (less than 20 MW). The law requires generation companies to demonstrate that a certain percentage of their total energy sales originates from ERNC resources. Generation companies are permitted to meet their ERNC requirement through their own generation or through contracts with third-party ERNC resources. This quota came into effect in 2010, and until 2014, required 5 percent of electricity to come from ERNC resources. Starting in 2015, the obligation increased by 0.5 percent annually so that it reaches 10 percent by 2024. However, an amendment to the ERNC Law (Law Nº 20.698) was approved in October 2013, mandating companies to generate 20 percent of their electricity from ERNC sources by 2025.

[1] In Spanish, Energia Renovable No Convencional (ERNC)

Additionally, during 2014, Chile's National Energy Commission (CNE) modified the auction mechanism to include **energy supply sub-blocks** comprising specific hour segments within the day, in addition to contracts for the traditional around-the-clock supply blocks. The energy sub-blocks commit resources to supply energy only at certain times of the day, allowing intermittent resources to more effectively compete with baseload capacity.The 2013-3 Second Call Auction Process (concluded in December 2014) was the first auction employing the sub-blocks, resulting in increased participation from renewable resources due to a **flexible auction design**.

Decreasing investment costs for solar and wind technologies have also encouraged aggressive bidding behavior from optimistic developers. Bids from solar photovoltaic (PV) resources in the August 2016 auction reached $29.1/MWh, the lowest ever recorded for solar projects until a lower bid ($24.2/MWh) was recorded at an Abu Dhabi auction in September 2016. Through these low bids, solar and wind projects outcompeted existing and new thermal generation in the August 2016 auction. The next few years will tell whether the renewable energy developers will be able to profitably deliver the projects under such low contract prices.

EXHIBIT 2. CHILE'S ELECTRIC SYSTEM SNAPSHOT

	SIC	SING
Total Generation, 2016 (GWh)	53,906	19,467
Peak Demand, 2016 (MW)	7,789	2,555
Avg Demand Growth (2016-2036)	3.46%	3.18%
Installed Capacity, Feb 2017 (MW)	17,583	5,768
Marginal Costs, Jan 2017 ($/MWh)	53.2	63.4

Source: CDEC[3], CEN[4], CNE[5], Generadoras de Chile[6], CNE[7]

Will the Boom Continue?

The recurrent approval of policies that support renewables, auction mechanism redesign, transmission infrastructure upgrades and lower investment costs, indicate that the expansion of renewable capacity in Chile is likely to continue. The points below discuss some developments that support this view:

- The 2013 amendment of the ERNC law (described above) suggests continued favorable regulatory support for renewable development. The CNE reports that in December 2016, ERNC sources accounted for 13.5

percent of installed capacity and 15.6 percent of generation in Chile.[2] This rapid penetration of renewables may incentivize the government to further increase the ERNC obligation targets beyond the current level of 20 percent by 2025.

- In recent months, regulators and other stakeholders have contemplated the introduction of seasonal energy supply blocks in Chile's electricity auctions. These seasonal blocks will increase the flexibility of the auction process by committing resources to supply energy for only a few months at a time. This will likely provide upside opportunities for intermittent renewable resources.
- The interconnection of the country's two major grids (SIC - *Sistema Interconectado Central*, and SING - *Sistema Interconectado del Norte Grande*) is scheduled to be completed by January 2018.[3] The SIC-SING interconnection will enable centralized generator dispatch across the country thereby, promoting increased market competition and growth of low variable cost renewable generation. The project is expected to relieve transmission congestion and allow solar power generated in the north and wind power produced in the south to serve load in the high demand regions around Santiago and central Chile.
- Starting in 2018, the implementation of a carbon and pollutant tax policy is expected to increase the variable costs of non-renewable sources. The taxes are applicable to fossil-fueled thermal generators larger than 50 MW. These generators will be required to pay $5/ton of CO2 emitted, in addition to a local pollutant tax (for SO_2, NOx, and particulate matter) dependent on local air quality and the affected population.[4] The possibility exists for these taxes to increase over time, further improving the outlook for renewables.[5]
- Declining renewable technology costs are expected to continue to increase the cost-competitiveness of renewables with fossil-fuel technologies. The investment costs reported by the CNE for a solar ($1,200/kW) and wind ($1,800/kW) power plant are about half the estimated cost of a coal ($3,000/kW) or small-hydro ($3,250/kW) plant.[6] Although the same report estimates the investment cost for a typical combined cycle natural gas power plant at $1,150/kW, gas-fired plants in Chile face significant fuel supply risks and constraints. The gas facilities depend heavily on imported Liquefied Natural Gas (LNG) and Chile's Quintero LNG regasification terminal

[2] CNE, Reporte Mensual Sector Energetico, Jan. 2017

[3] CDEC-SING, Programa de Generación Bruta del SING (2016): www.coordinadorelectrico.cl/resources/docs/coordinador/2016/dic/Anexo-SING-Dic16.xlsx

[4] CEN, Informe Mensual de Operación del SIC (December, 2016): https://sic.coordinadorelectrico.cl/en/informes-y-documentos/fichas/informe-operacion/

[5] CNE, Capacidad Instalada Generación (March, 2017): https://www.cne.cl/wp-content/uploads/2015/05/Capacidad_Instalada_Generaci%C3%B3n.xlsx

[6] Generadoras de Chile, Boletín del Mercado Eléctrico, Sector Generación (February, 2017): http://generadoras.cl/media/Boletin_Generacion_Febrero_2017.pdf

capacity is fully contracted such that gas supply for new combined cycle builds is constrained. A potential expansion of Quintero's capacity from 15 million cubic feet per day to 20 million cubic feet per day by 2018 may, however, facilitate additional competition from gas-fired plants.

What Does this Mean for the Electric System?

Today's market participants must consider the impacts of an impending upsurge in renewable generation on the dynamics of Chile's electric system. The likely decline of future auction prices presents a risk for thermal generator revenues as competition from renewable capacity heightens. The expected entry of new renewable capacity[7] may also put downward pressure on spot pricing, posing risks to plants dependent on uncontracted cash flows. Renewable facilities that were financed and constructed based on Chile's notoriously high spot market prices in the mid-2000s may face serious cash flow shortfalls in light of the spot price impacts from the anticipated deluge of renewable energy dispatch. At the same time, the national system operator must assess the impact of increasing renewable penetration on system reliability. In fact, the government of Chile has recently scheduled a stakeholder process to define ancillary services regulation and policies to address the system reliability impacts of the high level of renewable integration.

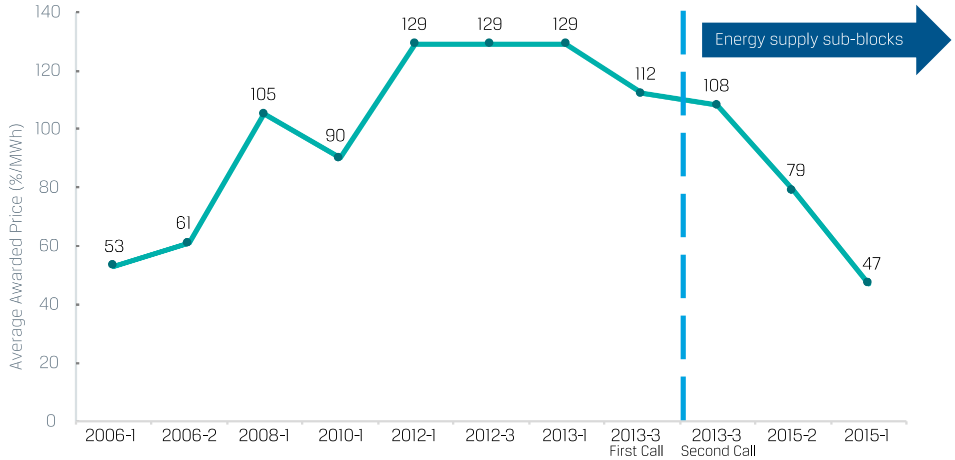
Potential Seasonal Product May Reduce Auction Prices

The potential introduction of seasonal energy supply blocks in Chile's electricity auctions will increase the flexibility of the auction process by committing resources to supply energy for only a few months at a time. Based on outcomes from the introduction of the hour segment sub-blocks in 2014, one can expect this increase in market flexibility to encourage even more renewable participation and weaker pricing. Exhibit 1 below illustrates how prices declined with the introduction of energy sub-blocks in the 2014 auction ($108/MWh), representing the lowest price across the previous four auction processes.

Subsequent auctions have included these sub-blocks resulting in increased renewable participation and further price declines - $79/MWh average price in the 2015-2 auction and $47/MWh in 2015-1 auction held last August 2016. Seasonal supply blocks would provide more opportunities for renewables to compete with thermal generators and further encourage renewable developers and investors to submit low bid prices. Prices in the upcoming auction are expected to remain at current low levels.

[7] CNE, Informe Preliminar de Previsión de Demanda 2016-2036 SIC-SING, Fijación de Precios de Nudo 2017 (December, 2016): https://www.cne.cl/wp-content/uploads/2016/12/Informe-Preliminar-de-Previsi%C3%B3n-de-Demanda-2016-2036-SIC-SING.pdf

EXHIBIT 3. EFFECT OF ENERGY SUB-BLOCKS IN CHILE'S ELECTRICITY AUCTIONS



Source: CNE

Transmission Expansion May Soften Price Impacts from Load Growth

Electricity demand across the two major grids in Chile (SIC and SING) is expected to increase at an average rate of 3.3 percent per year over the 2017 to 2036 period.[8] This growth, which represents additional energy requirements of 48.4 TWh in SIC and 16.7 TWh in SING by 2036 compared to 2017 levels, is expected to provide support for spot electricity pricing in Chile. However, when the SIC-SING interconnection enters into commercial operation in 2018, the anticipated increase in renewable energy dispatch from the north and south is expected to lower overall system marginal cost and spot prices, offsetting some of the impact of positive demand growth.

There are also signs of increasing regional integration. For example, in January 2015, the Chilean subsidiary of AES Corporation received permission to export electricity to Argentina using the Andes-Salta 345-kV SING transmission line.[9] AES started exporting power through this line in February 2016, and the permit remains valid as long as the SING does not interconnect to another Chilean electric system with installed capacity larger than 200 MW or for up to 10 years. This clause suggests that the permit will expire once the SIC-SING interconnection is completed. Similarly, Chilean and Peruvian authorities have evaluated a proposed transmission interconnection between countries as favorable. Chile expects to benefit from Peru's low energy costs, excess generation, and proximity. The countries have discussed the construction of a 70 km, 200-kV transmission line with 200 MW capacity to interconnect the SING with Peru by 2021.[10] In addition, a larger 650 km, 500 kV transmission line with 1,000 MW capacity is also being proposed.[11] Market participants will have to consider how the growing regional

[8] CNE, https://www.cne.cl/wp-content/uploads/2016/12/Informe-Preliminar-de-Previsi%C3%B3n-de-Demanda-2016-2036-SIC-SING.pdf

[9] Congreso de Chile, http://www.leychile.cl/Navegar?idNorma=1078638

[10] http://www.revistaei.cl/2016/08/12/engie-evalua-construir-linea-de-220-kv-para-interconexion-chile-peru/

[11] http://www.aminera.com/2016/07/26/electrica-ofrece-chile-peru-construir-linea-650-km-concretar-interconexion/

integration might affect market prices and create energy exchange opportunities in Chile and across the region. The Regional Electricity Market of Central America may be an appropriate case in point here.

While access to demand in neighboring countries like Argentina may present opportunities for renewable and non-renewable generators in Chile, competition from low variable cost generators in neighboring countries like Peru may negatively affect Chilean generator revenues in the long-term. Chile's spot pricing has been one of the highest in the region historically, since they are typically set by plants burning coal and imported LNG. By contrast, hydroelectric plants and plants burning locally produced natural gas are the marginal units during system peak hours in Peru. Under this scenario and assuming interconnection between the two countries, one would expect lower priced energy to flow from Peru, further straining generator revenues in Chile.

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George Katsigiannakis joined ICF in 1997 and is an expert in U.S. electricity markets, with deep understanding of all factors affecting U.S. wholesale electric markets including market design, environmental regulations, fuel markets, transmission, renewables, energy efficiency, and demand side management (DSM). He works in the areas of energy modeling, wholesale market assessments, asset valuations, restructuring, and litigation support, as well as contract evaluation and risk assessments. Mr. Katsigiannakis has a bachelor's degree in Industrial Engineering from Technical University of Crete, Greece, and completed an M.Sc. in Operations Research and Dostoral Coursework in Stochastic Modeling from The George Washington University.

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