and state policies. Further, the objectives of the configuration market include not just clean energy deployment, but the broader virtues of economic efficiency, reliability, and universally available service, along with the incorporation of new, more efficient competitive technologies. This means the existing standards of just and reasonable rates without undue discrimination will be powerful public-interest weapons to prevent regulatory capture's inefficient thumb-on-scale decisions, or to correct them if they occur.

Finally, there is the concern that all of this is too cumbersome, too centralized, and too much like government planning to be trusted to produce efficient outcomes or to really be called a market. Yet surely the existing processes of ad-hoc, legislatively mandated subsidies for favoured technologies, almost exclusively within Balkanized state and utility service territory boundaries, is even further from a market or from the thoughtful incentives needed for the rapid decarbonization of the power system. Any level of insight brought about by broad regional system optimization models and tools would be an improvement. And any additional level of competitive cost information and competitive incentives for efficient risk allocation, development, and operation of a more integrated system would be an even greater improvement. Since the incremental growth path of the configuration market would give us these improvements early on, why not at least get started and see how well we can make it work?

DEVELOPING THE DESIGN OF THE CHILEAN POWER MARKET TO ALLOW FOR EFFICIENT DEPLOYMENT OF RENEWABLES

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The Chilean electric power system is undergoing substantial change, marked by a significant increase in the use of renewable energy. These changes were prompted by the declared intention of the government to respond to the following challenges: the diversification of the country's power-generation sources; the phenomenon of climate change; the desire for energy independence and efficiency; and, in a broad sense, the need to ensure sustainability and security of the national energy matrix. However, since the first market reform in 1982, Chile has not undertaken the significant structural reform of market regulation necessary to address these challenges.

This article outlines the changes that the Chilean electricity market requires to facilitate efficient deployment of high penetration of nonconventional renewables, in particular solar and wind. After outlining the Chilean context and some peculiarities of its market design (which are, however, common to many South American power systems), we present an integrated proposal to improve the resilience and efficiency of the Chilean market design to enable high renewable penetration in the short, medium and longer term.

The Chilean context

The Chilean electricity sector is characterized by the linear shape of the country and its complex mountainous topography. The two main power systems, the northern and central power grids, have recently been connected, creating the National Electric System. Hydropower accounts for 27 per cent of installed capacity; solar photovoltaics and wind resources account for 8 per cent and 6 per cent, respectively; and the rest is shared in roughly equal measure among coal-, natural gas- and fuel oil- fired plants.

Distribution companies act as regulated retailers for captive demand. Most of the economic exchanges are based on long-term contracts between generators and distribution companies or free consumers. The spot market is only open to generators, which use it to settle imbalances between their contract commitments and their actual production. The market is based on audited costs, and no bid is presented by market agents. Even though the system operator provides instructions during the week, and especially the day before real time, these instructions are not binding. The market is cleared ex post – that is, after real-time operation – using the real dispatch to calculate nodal spot prices. Operating reserves are mostly provided by hydropower units, and the original restructuring of the power sector did not consider a real market for ancillary services. The cost of balancing reserves is socialized through demand charges. In addition to a remuneration for energy produced, generators receive a capacity remuneration, through an administratively set capacity price that is included in long-term contracts.

In the last decade, nonconventional renewable energy (NCRE) sources have been promoted through specific amendments to the electricity law. In Chile, the definition of NCRE includes wind, solar, geothermal, biomass, and maritime generation technologies as well as hydraulic technologies that produce less than 20 megawatts. In 2008, Law 20.257 established a 10 per cent NCRE quota by 2024, in the form of a renewable portfolio

standard. This law was complemented in 2013 by Law 20.698, which increased the NCRE quota to 20 per cent by 2025. If the penetration of NCRE does not reach the mandated levels, the Government can implement a call for tenders to cover the deficit. However, in October 2017, NCRE use reached the 20 per cent quota established for 2025; the system operator has projected that by 2030, it will exceed 30 per cent.

The current market design does not seem to be suitable to efficiently integrate these resources; the Government and the generators agreed that an amendment to the current electricity law will be required. To that end, a public regulatory discussion was launched in late 2017 to develop a new Ancillary Services Regulation.

The current ex-post clearing does not make it possible to give a value to flexibility, and thus does not properly reward the agents that provide backup to intermittent renewable generation. As a result, the current market design does not provide adequate signals for further investments capable of providing the flexibility that will be required. Furthermore, from a short-term operational perspective, the current design for the remuneration of ancillary services and the later allocation of these costs does not provide the right incentives for generators to be available in real time.

The next section summarizes the regulatory changes we believe are needed to correct these flaws.

Regulatory proposals

Based on a review of the current design of the Chilean electricity market and a comparison with markets in other countries, regulations can be proposed to help ensure a harmonious integration of renewable technologies.

Binding dispatch

A binding dispatch should be introduced in the day-ahead market, with a price calculated ex ante to remunerate the capacity committed in that depatch, regardless of later modifications to the unit commitment. The binding dispatch provides market agents with an essential tool to hedge their risk in a context where that risk may increase, since dispatch modifications may become more frequent with high NCRE penetrations. Furthermore, a binding dispatch is necessary for efficiently assigning the cost of successive redispatches (and, ultimately, the cost of ancillary services) to the agents who cause them.

A price should then be calculated for each redispatch or reprogramming of the system carried out in the intraday time horizon, and any difference with respect to the previous programme should be settled at that price. Binding positions, on which imbalances will be calculated, must be updated after each redispatch. Only this series of binding programmes can provide efficient economic signals in the time horizon between the initial dispatch instructions and real-time operations. The potential accuracy of forecasts for renewable power improves as one moves closer to real time operations. At all stages, but especially between the initial despatch and real time operations, it is important to have incentives for accurate forecasts of output from renewable power stations in order to minimize the cost of alternative resources when those renewable stations are not generating as forecasted.

Fixed operational costs

The significant hydro component of generation has usually been able to provide most of the required response in the very short-term; because of this, the current regulation does not explicitly consider remuneration for the thermal plants' fixed operational costs (such as for start-up and shutdown). However, these costs are likely to rise in response to the variability of renewable generation; therefore, a sound methodology for their recovery must be established. The recovery of these costs must be guaranteed to the agents incurring them through the introduction of either an uplift on the spot market price or a fair, discriminatory side-payment. Uplifts to the market price or side-payments must be considered in the calculation of the price of the binding dispatch as well as of any successive redispatch.

An efficient market for reserves

As previously mentioned, there is a consensus that the ancillary services market requires substantial reform. In our view, this should include the following:

- Co-optimize energy and reserves, thus clearing the energy and reserve markets at the same time and with the same algorithm. Those markets can be based on audited costs, as they are in the current design. Co-optimization makes it possible to take advantage of the synergies between these two complementary products and to avoid a bid-based reserve market that would not be consistent with the rest of the Chilean market design. Chile does not have any institutional barrier to co-optimization, since the system operator also operates the market.
- Design reserve products which do not present implicit barriers for the participation of some market participants, including NCRE technologies. The procurement of upward and downward reserves should be separated and pushed as close as possible to real time.
- Avoid as much as possible the socialization of reserve costs.

The latter must be assigned to the agents responsible for them. Costs related to balancing energy (reserve activation) can be assigned according to the imbalances registered between the last binding dispatch and the actual injection of each resource. Costs related to balancing capacity can be assigned either through an enhanced methodology for the calculation of the reserve requirement (fulfilling the cost-causality principle) or by using a moving average of imbalances, calculated for each resource, as a proxy of the responsibility for the incurrence of such costs.

Long-term signals

The Chilean system must guarantee that the future power system will be not only adequate (enough installed capacity) but also flexible enough to cope with renewable intermittency and variability. Proposals have been advanced for introducing specific tenders for flexible capacity, to be launched each time the system operator foresees a lack of flexible resources in the medium term. In order to introduce long-term signals for attracting flexible resources, it would be better to encompass such signals in the current capacity payment, rather than segmenting the market with targeted auctions. This can be achieved either by modifying the methodology for the calculation of firm capacity (considering a term that favours flexible resources) or by introducing a new product, a 'flexible capacity payment', with a specific administratively set price, which would be paid only to resources fulfilling a set of requirements.

Conclusions

At the beginning of this century, Chile – like many South American countries – introduced long-term auctioning mechanisms with the objective of guaranteeing the security of electricity supply. These reforms, which are still in place, did not affect the design of short-term markets for energy and ancillary services. Renewable technologies represent a huge opportunity for the Chilean power sector, but they may significantly alter the current functioning of the electricity market. To make that market more resilient to the expected rapid increase in renewables, it must be reformed to guarantee their efficient integration. First, the new market design must be based on binding dispatches, which fix remuneration and responsibilities of market agents, second, ancillary services must be procured in a market environment, preferably through a co-optimization of energy and reserves. Third, the cost of keeping the system balanced should not be socialized, but rather assigned to agents according to their responsibility for the occurrence of that cost. Finally, the long-term signal conveyed by the capacity payment may need to be modified to attract flexible technologies.

BRAZIL CONSIDERS REFORM OF THE ELECTRICITY SECTOR

Carlos Batlle, Mário Domingos Pires Coelho, Pablo Rodilla and João Tomé Saraiva

When Brazil's electricity market failed to attract enough investments to meet the country's rapid growth in demand, a 2004 law shifted the focus from the short-term market to long-term electricity contracts, as a way to provide investors with hedging tools against the significant volatility of spot prices. Since then, the market design has been based on two obligations: for demand to be 100% covered by long-term contracts, and for the contracts to be 100% covered by firm energy certificates. These long-term contracts have been assigned through a variety of centralized electricity auctions. The regulator can also hold so-called reserve auctions, which are intended as a last-resource mechanism to increase the reserve margin of the entire system, in case it is deemed insufficient. These auctions have been used in recent years to foster the installation of renewable energy technologies.

This combination of auctions and long term contracts attracted the needed investments in generation; but as time progressed, it has showed increasing signs of stress. The government that took office in June 2016 asserted that a number of factors – including previous intervention in resource allocation and prices, inadequate and overly centralized risk allocation that led to judicial disputes, inadequacy of spot market prices as investment drivers, lack of transparency, and subsidized financing via the Brazilian Development Bank – had created the need for an overhaul of the legal framework to enable Brazil to adapt to a more decentralized power system.

In February 2018, the Brazilian Ministry of Mines and Energy, after several months of public consultation, sent the president a proposed Law for the Modernization and Expansion of the Free Market for Electricity. The law has four aims: (1) increasing the granularity of wholesale-market price formation, (2) introducing a mechanism to allow for the internalization of environmental externalities, (3) designing a new capacity product, and (4) widening the scope of the retail market. It complements another, more ambitious proposal to privatize the state-owned utility, Eletrobras, and grant new concessions for its generation plants to operate in the private sector.

The proposed law has not yet been submitted to Congress. However, on