# Challenges on Integrating Renewables into the Chilean Grid

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*Abstract-* **The Chilean Electricity Law introduced an obligation to power traders, from 2010 to 2014, to certify that at least 5% of the electricity traded comes from renewable sources. From 2015 onwards, the obligation will increase by 0.5% annually until 10% in 2024. Several challenges need to be addressed to permit efficient access for renewable energies. One of these is the natural barrier to entry for new generators, originated in the radial characteristic of the transmission systems. In the past these systems have essentially developed, and adapted economically, to conventional generation and demand. International experience shows that grid operation and expansion needs to be "smarter" for allowing renewable power connection. In Chile, significant challenges have arisen in grid planning and pricing which this paper attempts to address. While new wind farms can be installed in 1.5 years, transmission infrastructure requires 3 to 6 years to be completed. In this framework, extensive construction times of new grid developments, considering community and environmental approval, require a long-term vision, which, in turn, provides regulatory signals in order to minimize bottlenecks for the integration of new generation, particularly renewable. On the pricing side, wind farms push large transmission expansions, but given regulatory arrangements, participate with a small part on transmission toll payments because of the low plant factors of wind generation. In addition, transmission planning under uncertainty, by taking account of different scenarios, and the concept of anticipatory investment becomes critical.**

***Index Terms*— Renewable energy, transmission planning, electricity regulation, wind energy.**

## I. INTRODUCTION

Chile has two main interconnected systems: SING (Northern Interconnected System) and SIC (Central Interconnected System) running along around 2,600 km from north to south. The SIC electricity generation matrix has been traditionally composed by large hydro and thermoelectric power plants, mainly coal fired and natural gas. SING is a 100% thermoelectric system with coal fired, natural gas and diesel plants.

Recent events concerning energy security and low carbon footprint, according to global trends, have brought renewable energy to the center of public debate. In Chile, energy policy is funded on three main principles: security of supply, economic efficiency and social and environmental sustainability.

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Although Chile contributes marginally to world's total greenhouse gas emissions, the population is becoming progressively more aware of the impact of large hydro power plants and fossil fuel fired plants. International non-governmental-organizations (NGO) have been watching and opposing projects of those characteristics driven by private investors in the liberalized energy market, raising the debate between balancing economic growth via energy supply efficiency and security versus sustainability [1].

The Chilean law identifies Non Conventional Renewable Energy (NCRE) as the generation from non conventional sources connected to the grid, such as wind, geothermal, solar, biomass, tidal, cogeneration and small hydro generation up to 20 MW.

In this paper the impact of integrating NCRE to the Chilean grid is analyzed, identifying the main challenges faced by private investors to develop renewable energy projects, transmission grid expansion issues and regulatory signals to be taken into account by the regulator in order to facilitate the NCRE integration and permit a sustainable growth of the Chilean energy market.

## II. EVOLUTION OF THE CHILEAN ELECTRICITY MARKET

Chile was the world pioneer country deregulating and privatizing the electricity industry after the enactment of the Electricity Law in 1982. The electricity market was restructured in generation and distribution companies that were successively privatized at the end of the 1980's. In 1993 the main transmission company was created also under private ownership.

The Chilean electricity market consists of three segments: generation, transmission and distribution. According to the law, the generation segment is defined as a competitive market with freedom to invest, while the transmission and distribution are recognized as monopolistic activities and therefore companies operating in these segments have regulated tariffs. Agents in the generation market compete to supply power to consumers, operating under a short run marginal cost (SRMC) pool-dispatch regime, coordinated by the system operator (namely CDEC). Competition for system development aims on capturing demand growth with the most economic generation plus transmission technology.

The Electricity Law was amended in March 2004 with the introduction of significant changes to the transmission pricing and expansion procedures. Furthermore, in May 2005 the law was again amended to introduce improvements on the energy market regarding long term prices applied to the contracts among generation and distribution companies, introducing energy contract auctions in a pay-as-bid scheme.

Electricity demand is expected to continue growing up linked to the Chilean economy growth. Figure 1 presents the SING and SIC load growth (historic and forecast), installed capacity and source, and main geographic and demographic figures. Demand forecast for the period 2010–2020 corresponds to projections of the Chilean energy regulatory body, the National Energy Commission (CNE).

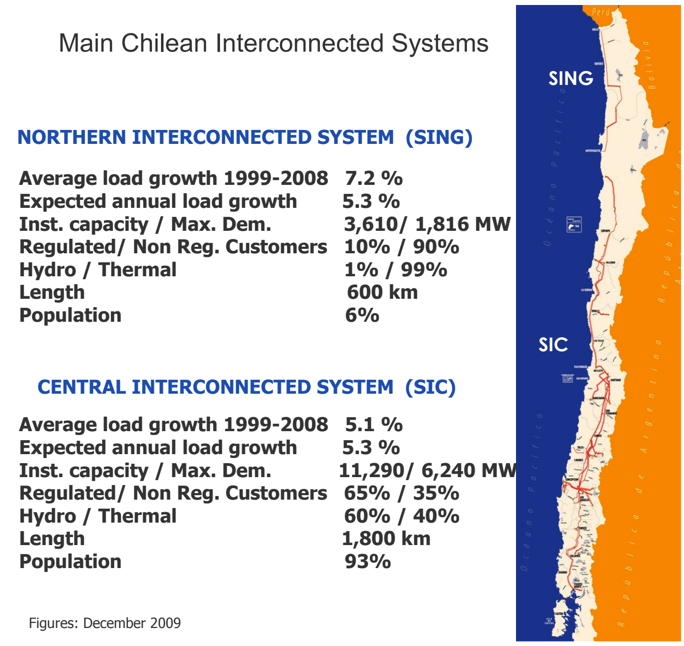


Figure 1: SING and SIC main power system figures.

In 2008, a modification was introduced to the Chilean Electricity Law in order to encourage the entry of non-conventional renewable energy into the electricity market. Thus, from 2010 to 2014, power traders, that withdraw electricity from the system to supply regulated and non-regulated price consumers, must certify monthly that at least 5% of the electricity traded comes from renewable power, either self produced or bought from other generators. From 2015 onwards, the obligation will increase by 0.5% annually until reaching 10% in 2024.

In order to meet the obligations of the NCRE law, significant investment on renewable energy plants is expected over the next years. Table 1 presents the NCRE generation projects presented to the national environmental impact evaluation system. Wind power presents the highest penetration, albeit the energy contribution is low due to the low expected plant factor (around 25% to 30%).

| Generation Projects of NCRE (MW) | | | | | |
|---|---|---|---|---|---|
| | Project Status | Wind Power | Small Hydro | Geothermal | Biomass |
| Presented Projects | Approved | 210 | 100 | 0 | 10 |
| | Under qualifying | 950 | 150 | 0 | 73 |
| Announced Projects | Not yet submitted | 850 | 200 | 100 | 0 |

Table 1: NCRE projects in Chile

Figure 2 shows the expected demand growth and installed capacity of the SIC considering the contribution of NCRE.

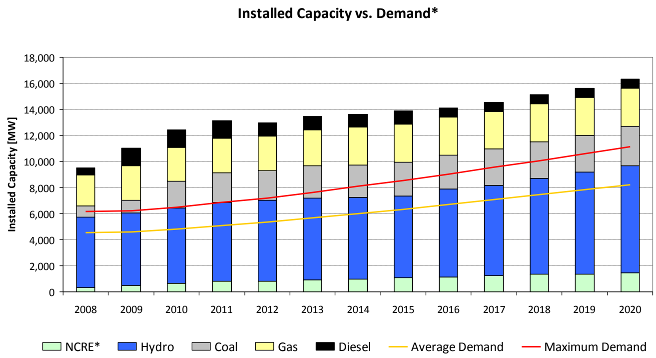


Figure 2: Expected contribution of NCRE to the SIC energy matrix.

## III. INTEGRATION OF RENEWABLES INTO THE GRID

Several problems need to be addressed to permit an efficient access for renewable power into the transmission grid. One of these is the natural barrier to entry for new generators, originated in the radial characteristic of the Chilean transmission systems. In the past these were essentially developed and adapted economically to conventional generation and demand [2]. However there are areas, for instance in the north of SIC, where wind power potential is high and transmission grid expansions may be required by capacity constraints, i.e. transfer peak wind injections, although energy contribution is rather small.

In Chile, transmission expansion and pricing was modified in 2004 into a co-operative regulated scheme in order to include the participation of every agent of the electricity market. Since then, significant challenges have arisen in grid planning and pricing [4]. Three transmission segments were defined by the law: trunk, subtransmission and additional systems. Trunk system assets are those essential for competition in the energy market and are integrated by facilities over 220 kV that are economically efficient and necessary to supply the total demand. Subtransmission system assets facilitate access to consumers, with regulated and non regulated prices (clients of capacity equal or higher than 2 MW). Additional transmission systems assets are those exclusively dedicated either to non regulated price consumers or to connect power plants to the system.

On the expansion planning side, every four years there is a long term trunk transmission planning exercise, directed by a multi party committee representing market agents (generators, transmission companies, large consumers and the regulator). It defines a schedule of transmission reinforcements and/or new installations, based on a generation expansion overview provided by the regulator. Then, every year the system operator CDEC must revise this trunk expansion plan according to the current market conditions, particularly demand and effective generation development, with a consultation process including all the involved agents. Then CDEC recommends the corresponding trunk transmission projects to the CNE. Afterwards the CNE has 30 days to release the expansion plan of the trunk system with the projects that must begin construction in the next 12 months.

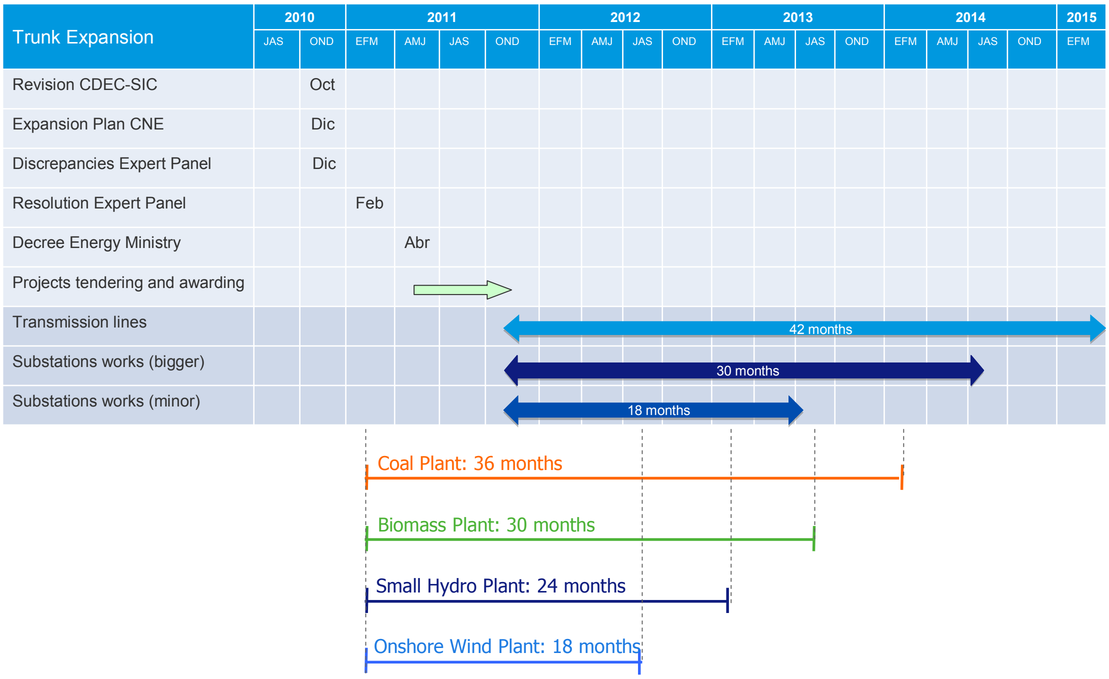


Figure 3: Annual revision of the trunk expansion plan

While new wind farms can be installed in 18 months, needed new transmission lines require at least 42 months to be completed, including rights of way negotiations, environmental impact study and construction.

Figure 3 shows the annual trunk expansion plan revision, comparing construction terms of different generation technologies and typical transmission projects, including substations or lines.

To speed up the release of new transmission capacity to network users, international experience shows that present philosophy of grid operation and expansion needs to be significantly changed towards "smarter" concepts, technologies (special protection schemes, coordinated voltage-control techniques, wide-area monitoring and control systems, advanced dynamic security assessment techniques, and demand-side management) and practices for allowing renewable power to connect in a timely fashion. For example, the massive grid connection of 30 GW of wind power expected in Great Britain by 2020 has triggered a number of procedure reviews, covering various aspects of the technical, commercial, and regulatory framework: transmission access, security and quality of supply standards (SQSS), RPI-X regulation, anticipatory investment proposals, and the transmission network charging scheme. Particularly the review of the deterministic Supply Quality and Security Standards (SQSS), for example, concerning the best usage of N-k criteria, which has been used from 1950 [3].

## IV. IMPACT DERIVED FROM THE INTEGRATION OF RENEWABLES

The integration of NCRE represents a challenge for a power system largely dominated by conventional generation technologies. Particularly wind power in large scale means a big impact on a long radial transmission grid due to the intermittent and unpredictability characteristic of power injections. Operational aspects such as voltage stability control and generation reserves for frequency control will become major issues for the system operator.

Problems also emerge on the transmission pricing side. The existing regulation allocates payments of the transmission lines to generators based on line usage over time. Wind farms may push large transmission expansions which do not coincide with their small proportion on transmission payments because of the low plant factors of wind generation. Therefore, existing generators could potentially see toll payments increases and so will oppose to such expansion projects. This, in turn, can potentially affect the connection decision of wind power projects because of the risk of congestion in the transmission grid.

In order to make decisions in advance to avoid constraints to new NCRE entrance, transmission planning under uncertainty, by taking account of different generation plan scenarios along with an anticipatory investment regime, becomes critical. The main issues that challenge the definition of the transmission expansion plan are related to the new generation power plants to be commissioned under a competitive energy market [5]. The following questions arise:

- What kind of technology will be used in the new generation plants?
- When will the new plants being connected?
- Where are the new plants going to connect to the grid?
- How much capacity is being connected?

Under a deregulated scheme there is freedom to answer all this questions and then the investment decision concerning the expansion of the grid takes the form of an "expansion strategy" instead of an "expansion plan". This strategy must determine the set of transmission projects that allow the best solution to the energy market participants, minimizing the total cost to the users. A system operator that only recommends transmission expansions based on firm commitments from new network users, i.e. full certainty on new generation plants decisions, will be always late and will provoke higher operational costs in the short term and economic losses on NCRE investors.

In this framework, extensive construction times of new grid developments, considering community and environmental approval and rights of way negotiations, require a long-term vision, which, in turn, provides regulatory signals in order to minimize bottlenecks for the integration of new generation, particularly renewable energy. However, in contrast, existing generators exercise market power on new entrants through underinvestment in some transmission corridors, when also trying to minimize toll payments in the short-term. Figure 4 represents the economic evaluation of a new transmission line on a corridor, with two tower options: single circuit line today and another single line in the future, or double circuit today but only one circuit constructed and adding the second circuit cable in the future.

In power systems with permanent demand growth, like Chile, the economic evaluation usually arises to the conclusion that the present value of investment is lower for the double circuit option and therefore, that is the expansion decision to be made. However, for generators that will pay the new line, transmission tolls will be higher in the short term due to the higher cost of a double circuit line in comparison with a single circuit line. This paradox has meant several discussions and oppositions from generators to new transmission lines, although for a sustainable development it is essential to minimize the number of new corridors, especially in a narrow country.

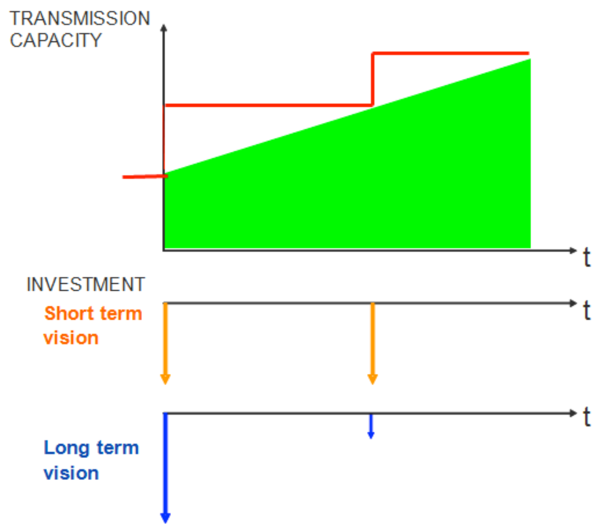


Figure 4: Long and short term vision in transmission expansion

## V. MAIN CHALLENGES

Chile is a developing country where energy consumption growth is strongly correlated with economic growth, in spite of recent efforts to increase energy efficiency. The discussion arises as NGO's propositions aim on more participation of NCRE in the energy matrix. However, the country already has one of the most expensive electricity rates in Latin America and NGO's alternative means a higher cost of electricity compared to conventional generation sources.

One important challenge is the improvement of the annual revision process of the trunk expansion plan by CDEC, which has been an issue to debate because the agents cannot wait for another year to find a transmission solution when they decide to build a new power plant, which is especially important for wind farms due to the fast construction times after obtaining the environmental approval.

Due to the nature of a competitive generation market, projects may change; postpone or new ones can appear in a short period of time, requiring flexible planning methods to decide transmission expansions. The downside of this flexibility is that the solutions achieved could often be considered incremental solutions which follow the generation market but do not represent the most efficient alternatives in the long term. A way forward for this dilemma may be seeking support in the increasing use of new and "smarter" network technology such as special protection schemes, coordinated voltage-control techniques, wide-area monitoring and control systems, advanced dynamic security assessment techniques, and demand-side management. These can actually provide more flexibility by releasing larger network capacity in operational timescales, allowing planners to defer transmission construction and wait for the adequate signals in order to build efficient lines more according to a long-term vision.

## VI. CONCLUSIONS

The transmission regulation in Chile, toll arrangements and expansion procedures included, does not facilitate the introduction of large renewable generation parks into the market. The uncertainties of transmission expansion and the short term view which arises from current regulation affect both generation and transmission long-term investments, jeopardizing in particular the timely entry of renewables.

Running for almost thirty years, Chilean regulation is facing another challenging moment to balance economic efficiency and sustainability. Difficulties to build up new transmission installations require changes on regulatory signals in order to anticipate transmission investment decisions to provide certainty to new entrants, particularly NCRE, that open access is real and congestion will be minimized. NCRE investors require certainties to evaluate and obtain project financing. This is a big issue for a transmission grid that has been developed permanently adapted to generation and demand requirements, with probabilistic security of service criteria where there is no spare capacity.

Another important regulatory signal to be revised relates to the allocation of tolls among users. Currently, transmission payment allocation depends on the expected energy transported, while the effective use that correlates with expansion should address on the users contribution at maximum transportation levels. Subsidies that derive from the current allocation scheme could be used by existing generators to oppose transmission expansions.

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## VIII. BIOGRAPHIES

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